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STEAM POWER PLANT PIPING SYTEMS

THEIR DESIGN, INSTALLATION, AND MAINTENANCE

BY

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Dedicated to

My Most Esteemed Friend and Former Associate

J. F. RANDALL, M.E.

who by his tolerance enabled me
to engage in
Power Station Design and Constructing.

PREFACE

This publication treats only such parts of the power plant system as are directly related to piping. The design of boilers and engines has not been touched upon, but their operation has been covered. All auxiliary apparatus in the pipe circuit between the boiler and the engine and in the various piping systems for steam, oil, air, etc., have been treated and their general design discussed.

It was not the intention of the author to compile existing information and make a handy reference book, but rather to give a detailed and consecutive treatment of the entire subject of piping as applied to power stations, taking up the design, installation, and operation.

A better method of contracting this line of work has been fully discussed, one which will entail less expense both to the designer and to the contractor, and at the same time insure a higher grade of pipe work.

A system of reasoning and analyzing has been followed that alone in itself is very instructive.

The illustrations are all made from original sketches prepared especially for this work. The text embodies the personal experience of the author and is written entirely from the author's own point of view; therefore it is very probable that many will disagree with the methods of handling certain problems. The author will be grateful to all who disagree with him if they will freely offer suggestions and criticism which may be used in future editions.

W. L. M.

Chicago, Ill.

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STEAM POWER PLANT PIPING SYSTEMS.

CHAPTER I.

INTRODUCTION.

THE first chapter of this work is devoted to the origin and results of improper piping, and also explains the necessity of better piping systems and suggests methods of securing better pipe work and piping systems by employing different methods in engineering offices. The chief requisite in pipe work engineering is so to design as to permit repairs of disabled lines without interfering with the regular service of the plant. There are but few requirements to insure continuous operation, but these few must be very carefully considered and well safe-guarded, for no matter how careful the station attendant may be he cannot foresee every possible difficulty. It is only by experience with trouble that we learn to avoid it, and it is absurd to assume that any man has experienced every difficulty and mishap that is possible in a steam plant so that by careful inspection he could avert any such difficulty that might arise.

Moreover, a plant should not be laid out with a system that necessitates repairs after the plant is shut down, say between 1 A. M. and 5 A. M., for it is not reasonable to expect an operating man to take much interest in his station work if he must work night and day to keep the plant in good order. If a plant is to be well kept up it must be so designed that repairs can be made whenever the chief can find spare help to do the work; this may happen at 10 A. M. one day and possibly 3 P. M. the next day. Repairs that can be made only at certain hours cause such disturbance in the general organization of the men that it takes a day or two before matters fall back into their regular routine again. This disturbance of regular duties means increased expense and it discourages the men, and after a time the station will show conspicuously that it is run down. The first to receive the blame for this is the operator, whereas in reality it should fall upon the designer. Any station manager who has found it necessary to make repeated changes in station operators, who has paid fair salaries and who has failed to obtain satisfactory results, can blame the entire difficulty to faulty design. A station operator very naturally objects to leaving his home at 1 o'clock in the morning to make some slight repair in order to keep his station in a neat condition. His incentive when he makes night repairs arises from fear, not pride; fear of a mishap that may affect the sum he receives in his pay envelope. What a strong contrast is exhibited between a neat, well kept plant and a dirty, dilapidated looking one! If we visit the former we are informed by the chief sitting at his desk, possibly studying his station records, that everything is running beautifully, and upon making a trip through the plant we may note that an intelligent looking assistant is making some joints on a steam line, and in the boiler room the fireman is placing packing in one of the reserve pumps. The general appearance of these men is neat and they are attending cheerfully to their work.

In the dilapidated station we find steam blowing everywhere and a dirty looking, tired out man getting up from an old box just long enough to fill the oil cups or throw some coal into the furnace and then sitting down again. Off in a corner we find the chief taking a nap, for he says, "I was up most of the night trying to make a joint in that old steam line." When asked how things are running, he will say, "The old station is going to pieces; we have all kinds of trouble."

In the first case the men are all working; they appear intelligent and cheerful, and everything is running smoothly. In the other case no one seems to be working, the men take no interest in their work and the station has become dilapidated. The fault lies in the design of the station. Conscientious, capable men are in demand and they select their positions. None of them wants to come back nights and work on a dirty, hot job. The result is that good men cannot be obtained for poorly designed plants, and consequently such plants run down for the lack of intelligent care by men who take an interest in their work. The first cost of making ample provisions for all contingencies will amount to so many dollars and will readily be appreciated by the purchaser. But why, if an engineer is familiar with station operation, does he allow the purchaser to see only the initial cost? If he cannot succeed in persuading the purchaser to abandon a design which would necessitate night repairs, it would be better for the engineer not to be identified with the undertaking. When an engineer loses control of an undertaking and is constrained to accept details which he knows are wrong, it is far better for him and for his reputation as a designer to go on record as opposing the design and to relinquish all connection with the work. Instead of being known as the engineer who designed the monstrosity, he had better be known as the engineer who refused to do so.

Unfortunately, the cause of the greater part of inferior station pipe work can be traced directly to the engineers themselves. There is no other portion of station work that affords the engineer a similar opportunity of showing his knowledge of station requirement, none that requires as much time properly to design, and none that is more certain to develop the station into a run-down, expensive plant to operate, or the reverse. The piping and piping system and the electrical wiring are the only features in power station design that really require extensive engineering knowledge. The machines required are designed by their builders for given capacities, and if the piping and piping system are not properly cared for by the engineer he fails to do that work which is purely his. In other words, the engineer is either incapable or else he is conducting his engineering office on a purely commercial basis and puts as little time and care into the project as is possible. A system of paying for engineering knowledge according to the amount of money a man can spend is certainly far from an equitable basis. The engineer must then make some show for his money. He will possibly resort to a display of inexpensive drawings and allow the builders to furnish the decorative features of the plant. The piping drawings may be prepared "so as to let the contract in two weeks," and they are generally turned over to an unskilled draftsman. The percentage system is wrong; but it is in vogue and will unquestionably remain in vogue for some time. But some better method of designing pipe work is badly needed, and already steps in the right direction are being taken, for we can find men in the large piping establishments who are now making a special study of piping details and who design new details which take the place of those furnished by the engineers. The shop drawings have dimensions center to face, flange, templates, etc., all of which are standard in each particular shop.

As it is necessary for fitters to make these details, this fact suggests a method of letting contracts for pipe work. The method is one that would enable engineers to let contracts for piping with the least possible expenditure of labor, although it entails more time for drafting on the part of the fitter; but the saving effected in pipe-work detail determined by the fitter rather than by the engineer will more than compensate for the extra cost of drafting. Each shop knows best that style of work for which it is best fitted, and what it can construct most economically, and by allowing the fitters to take advantage of these economies they can make lower estimates for the completed work even though they are compelled to furnish detail drawings. The details will be subject to the approval of the engineer in the same way as with structural details. The engineer should ask the fitters to furnish all pipe supports and special features, such as steam gages, safety valves, etc., as well as pipe covering, as the engineer would not have any details to show these.

The engineer should specify either the make or the style of the valves, fittings, pipe, etc., for each system. He should also furnish drawings showing the location of the boilers, engines, pumps, etc., and well-developed and complete station diagrams, as will be shown in a future chapter. The pumps should be located to conform to the diagram of station piping as far as possible. In short, the engineer would develop the entire piping system, determine sizes and number of parts, but allow the pipe contractor to determine the exact location of lines and branches, as well as the supports; a class of work that very few engineers are sufficiently posted on or wish to take the time to do well. Instead of the engineer laying out pipe details that will be redesigned by the fitter, he will save expense both to himself and to his client by confining his efforts to designing the station system and to obtaining bids from those fitters who are known to have piping engineers who can properly detail piping.

The result of this method of handling the complex problems involved in pipe work will be that the engineer will give his entire time and study to the station system, a class of work for which he is best suited, and the piping contractor will use more time and skill in planning the different lines and details than the engineer will be able or willing to devote to it. The work when completed would cost less money and would be more creditable to all concerned than if all the details devolved upon the engineer. The pipe contractor of to-day is no longer the petty contractor of former years. His contract runs into large figures and he employs the highest skilled labor to expedite his work. His erecting labor is very high-priced and he can readily save the expense of a capable piping engineer by simplifying his field work, though in many cases it would slightly increase the cost of shop work, on account of the practical details that a purely office man never learns. Structural iron shops have employed this method of redesigning work to such an extent that power station engineers do not even attempt to detail steel work, but give general requirements to steel contractors and allow them to make their details after receiving the contract, and then submit them to the engineer for his approval. In the case of an extremely large undertaking an engineer will sometimes engage a structural engineer to design and detail the work, but will keep him only while he has a large amount of such work on hand. He cannot afford to retain a specialist after the work is designed and the specialist cannot afford to undertake such temporary work. The result is that the specialists of ability are found with the manufacturers, not with the engineers.

The power station engineer is virtually the assembly engineer and his training has been that of an examiner and a judge. He is not a specialist in any line of manufacture and when he undertakes such work it is very much in the nature of an experiment. Some years ago the engineers designed the boilers, not because they were specially fitted for this work, but because the boiler business had not developed to such an extent that the manufacturers required skilled boiler designers in their employ. But this is no longer the case. Manufacturers now employ engineers who make a specialty of boiler designing and the power station engineers make no attempt to design boilers. The same will be the case with pipe work and it will undoubtedly be but a short time before piping details will be developed by the manufacturer and not by the power station engineer. Not until then will we find good serviceable pipe work installed in the various plants under construction.

The introduction of piping system diagrams, and the letting of contracts based upon them, will be the first move toward developing this method. It will then devolve upon the piping contractor to design the details and he will no longer be able to evade the responsibility of bad pipe work design. His reputation will then depend upon his design as well as upon his workmanship. To protect himself he will be compelled to design his work more thoroughly than it could or would be done by the power station engineer. As previously stated the practice of relegating the details of pipe work to the fitter is in no way detrimental to the engineer or to the purchaser. The engineer could then devote his time to the system, which is generally overlooked; the fitter would lay out a neater and more reliable job and one costing less money to construct; when completed there would be more to show for the labor expended than by the present method of indifferent, incompetent or hasty work laid out by the power station engineer. Instead of making a study of how to connect flanges to pipe, the engineer should devote his thought and study to systems, as for the system alone will he be held responsible. The contractor will assume the responsibility of how to attach flanges to pipe and it will have to be done his way if he does assume the responsibility. An engineer must not expect to hold a contractor responsible for his own notions in regard to certain details. If a contractor is to be held responsible for results he must be permitted to use such details as he knows will accomplish what is demanded of him.

In inviting bids it is not necessary to state what details the manufacturer shall use, but it is advisable to ask him to state the details he proposes to furnish. This can be clearly outlined in specifications, using a loose data sheet for the bidder to fill in, covering such information as the engineer wishes to obtain. If such a system required additional labor on the part of the engineer, or cost more money, or was less effective, the engineer would undoubtedly continue to design his own pipe details. But since the engineer and his clients have much to gain and virtually nothing to lose through the method here outlined, it should not require much argument to prove the desirability of this method becoming common practice.

CHAPTER II.

PIPING DIAGRAMS.

THE laying out of piping diagrams is the first move necessary in determining the equipment required for a power station. To determine sizes of machinery, boilers, etc., before the pipe system is laid out is wholly wrong, as by so doing there can be no defined system, but merely the connecting of a hole in a boiler with a hole in an engine. Almost any novice is able to say, "We shall want so many units of a certain size and so many other units of another size." But why should we expect systematic results from a mere guess? When the question arises how to determine the machinery for a plant, shall we find a well conceived system laid out to determine it? Unfortunately for all concerned the almost universal method is to order the machinery by rule of thumb, and then turn the piping work over to almost anybody in the office that can make the drawings, and never even stop to think about what system is to be used. In fact, if the question be asked in nine out of every ten engineering offices, what their system is of connecting up the apparatus, they would most certainly hesitate before endeavoring to make an answer. When referring to piping we invariably hear the expression, "boilers connected up so and so," and the same with other apparatus. The thought is wrong, and not until "piping" is recognized as the system of the station and given first consideration, will we find better or more reliable installations.

The diagrams illustrated indicate a form of drawing which is quick to make and readily understood. The relative location of apparatus may be different from the diagram, but the connections, etc., would be brought to the same relative point as shown. The diagram should be the first drawing made of the station, and after determining the system the proper number and size of units can be established. The diagram of all station piping should be framed and placed in a conspicuous place, so station attendants will become familiar with the system. Any changes made in piping should be also shown on these diagrams. It matters not how crude the piping system may be in a plant, a diagram should be in plain view showing it clearly.

A simple method of laying out a diagram is to make detached free-hand sketches of each line, such as main steam line, main exhaust, blow-off, etc., and after carefully considering all the lines a complete diagram can be more readily laid out. A scale drawing is neither desirable nor practicable. While laying out the diagram it is also policy to lay out sketches of various details to be retained as references. These various references determine many of the details that require decision before writing specifications for apparatus. Some of the connections shown on the diagrams may appeal to the reader as being rather unusual; the fact that they appear so is the desired demonstration of the value of the diagram. A full comprehension of the entire problem is possible at a very early stage, by making a diagram at the beginning of the work. Dimensions of apparatus, as well as pipe lines, can be determined in the early stages of the work, avoiding the difficulties occasioned by altering specifications after the work is let. It matters not how small the undertaking may be, the diagram will save time in many ways. If it be at all possible, all lines should be on the one diagram. A very practical method is to use a heavy paper that will stand considerable erasing, and lay out the different lines, machines, etc., free-hand, making the diagram on a large sheet — say 24 × 36 in. — so that plenty of room will be afforded for notes, dimensions, etc. Whenever any changes are found necessary in placing orders for apparatus, the diagram should be changed and brought up to date.

This paper drawing is virtually a study, and after details are made and the machinery, piping, etc., have been contracted for, a smaller and neater diagram should be made from it, one suitable for permanent station use. The prints furnished the station would be better if they were white prints so as to permit marking changes on them in case changes are made in the station system. The exhibition of diagrams is not customary, but if they were prepared and put on exhibition, many designing engineers would actually be ashamed of the conglomeration of pipe work that they had designed without employing even the slightest semblance of system.

It is but just that the purchaser should know what his general station system is to be, and he should demand a diagram and learn what he is receiving. If the system is not provided for at the very inception of the work there is but little chance to provide a system after the machinery has been ordered. The old saying "any system is better than no system," holds in station design and the conditions of service will have to determine which system is to be employed. The most complete and perfect system is required for stations that are continuously in service, requiring a large portion of their equipment to be in operation at all times. This system is shown in Fig. 1, and is virtually composed of numerous stations, each complete in itself, and means for connecting them into a collective plant when desired. This is the only system that will permit repairs or shutdown of any portion of the plant and at the same time permit full operation of the major portion of it. The connecting mains are merely conveniences, and whenever desired can be entirely shut off from the operating machines, allowing each sectional part of the plant to be operated independently of the remainder. For instance, if the steam header be shut off and out of use, the four or more units would be separately operated and would have different steam pressures. The steam from one group of boilers would then be used in its companion engine only. This system is somewhat expensive, requires more room for lines than a less complete system and necessitates the arrangement of machines in station groups; in fact, the grouping of the related machines is necessary for virtually all systems, rather than the grouping of similar machines. For example, if a plant is laid out with engines in one group and then a group of pumps, then a group of economizers and then a group of boilers, we can rest assured that but little system in pipe work can be employed.

As stated before, in order to establish a system in station design it must be done before any machinery is ordered. There are various systems to employ in station designing, each suitable for a particular line of service. The more flexible system is likewise the more expensive to construct and maintain; it requires a much more intelligent operator and necessitates many cross connections that frequently bring in difficulties in regard to expansion and contraction. This, however, must be given proper consideration and determined by competent pipe work engineers, as it is often the case that the cross connections occasion more difficulties and shutdowns than would the machine for which cross connections have been provided.

Fig. 2 shows a divided station, necessitating the use of certain sections of mains in order to operate the plant. With this system, a

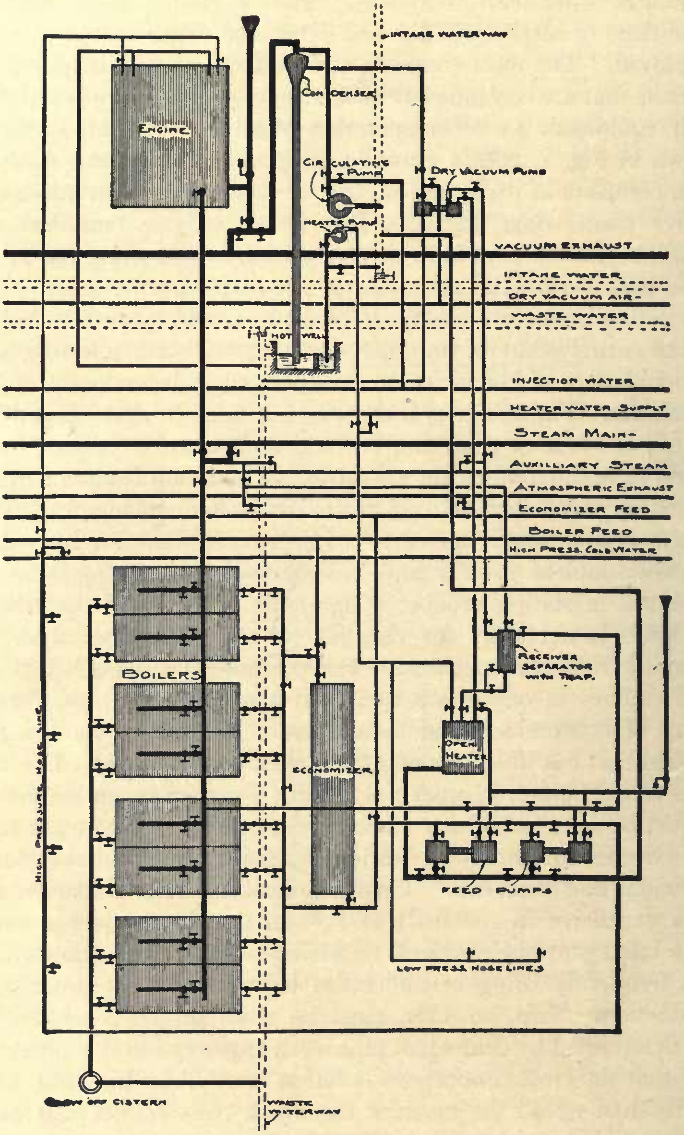

FIG. 1. Diagram of Unit System Plant.

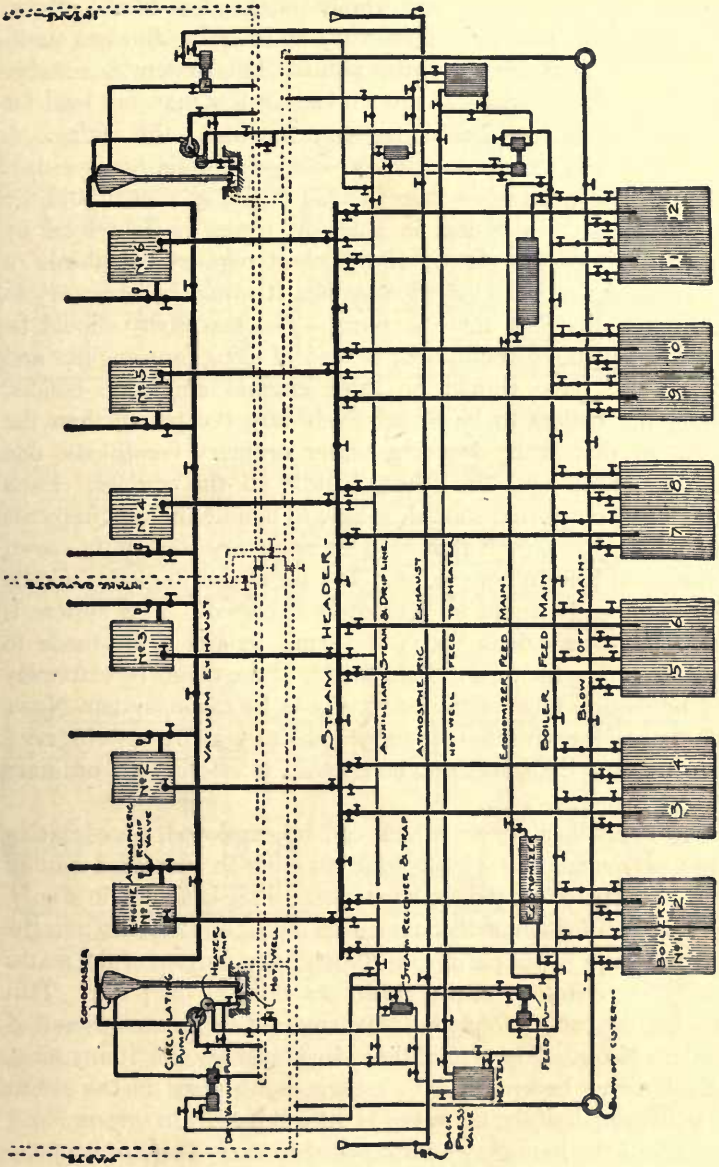

FIG. 2. Diagram of Six Division Plant.

station of, say six units, may be divided into three distinct parts, each operative throughout and wholly independent of the others. This system costs much less than No. 1 and requires but two auxiliaries of each kind for the entire plant. This system is suitable only for such installations as are worked on less than full load for sufficient time to make any necessary repairs to the mains. A plant that has half of its installation idle, say for six hours a day, can be divided into two sections instead of six, as shown, and the necessary repairs to mains be made at times of light load by using one-half of the plant. If the plant requires two-thirds of its installation for its lightest loads, then it would be necessary to divide the station into three sections. The machinery should be ordered to suit these conditions; instead of using four engines and eight boilers, there should be three engines and nine boilers, allowing the boilers to be of relatively larger capacity than the engines, so that while working under ordinary conditions, one boiler can be off and the others handle all the engines. Each heater, feed pump, etc., should be able to handle the requirements of the entire plant, even though it be necessary to slightly crowd it if the plant is in full operation. In case of shutting off a middle section both ends would be separately operated. This system is suitable for installations that will permit repairs to be made to the mains during the time of light load. If the mains be extremely heavy or require much time for repairs to be made, system No. 1 is imperative, for with that system the mains may be out of service for weeks at a time and not necessarily interfere with ordinary service.

There is another system which can be employed, necessitating the use of much more piping and resulting in increased cost of installation, operation and maintenance. This is shown in Fig. 3. Property conditions may demand such a layout. This system is the loop system and it will permit shutting off any portion of the mains and only necessitates shutting down one-third of the plant. This system requires about four times the length of steam main required for system No. 1. The size of the mains must also be, if anything, slightly larger. In system No. 1 there is no point in the steam main where one-half the output of plant will pass. In system No. 3 either side of the loop may be compelled to carry two-thirds of the output of station in case a portion of the main is shut down. This system has many objections, but it is far preferable to a double main system as shown in Fig. 4. The double main system necessitates tying from each piece of apparatus to two different mains, and, due to the fact that one main would be expanded and the other contracted, severe strains are thrown on joints unless both mains

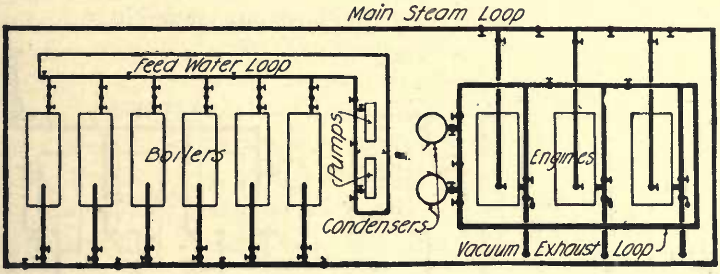

FIG. 3. Diagram of Loop System Plant.

be kept a sufficient distance away from their connections. Each main would of necessity be compelled to carry not less than two-thirds the output of the plant, if arranged as in Fig. 4.

Fig. 5 shows such a crude method of piping a plant that it is hardly worthy of being called a system. In case of repairs to the

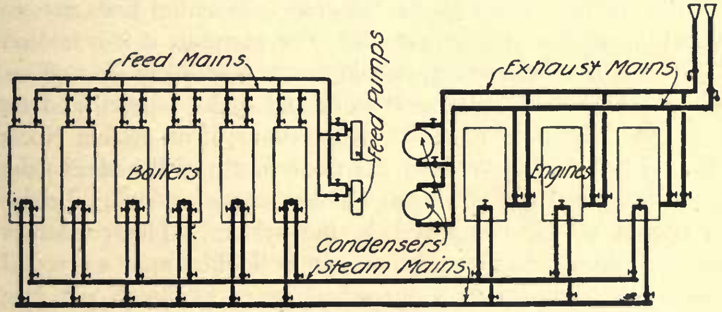

FIG. 4. Diagram of Double Main System Plant.

mains the plant must be completely shut down while they are being made. Generally, difficulties can be anticipated in a failing line, and repairs arranged before a shutdown becomes necessary. If it is imperative that there be no shutdowns during the regular run, the connections as shown in Fig. 5 should not be considered. To avoid this system and at the same time not be compelled to make a big investment in piping, the plant should be laid out so system No. 2 may be used, this system giving by far the greatest protection for the least money. Unfortunately, we will find system No. 5 partially used in the same stations that are using some of the other systems. There is no reasonable excuse for laying out main steam lines according to systems No. 2, 3 or 4 and connecting up boiler feeds or other vital lines on system No. 5.

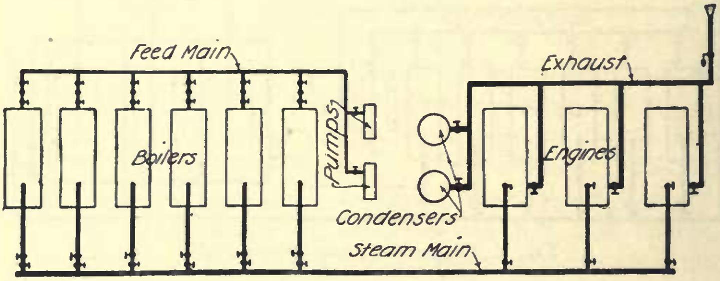

FIG. 5. Diagram of Systemless Plant.

A piping layout cannot be called a systematic arrangement if it lacks consistency. It is purely a waste of money to guard heavy steam and exhaust mains against almost any contingency and then use System No. 5 to supply engines with oil, etc. The station is not correctly laid out if all the absolutely essential lines are not laid out on same or a similar basis. For example, if it is laid out on system No. 2 the operator should find it possible to shut off any piece of piping or underground work and make repairs, and not shut down more than one-sixth of the plant; if on system No. 3, he should not shut down more than one-fourth of the plant using four units. Feed mains, blow-off lines, pump suctions, oil drips, etc., should all be comprised in the system. The condenser, heater and economizer connections can be looked upon as secondaries and the connections to them may be on system No. 2, even though the main lines are on system No. 1.

The object of station system is to insure continuous operation. The condenser, heater and economizer are not absolutely essential, and the same amount of refinement is not necessary with these devices, which are virtually station economies, not operating necessities. However, their importance must not be underestimated, and fair protection should be given them by the systems according to which they are connected. To operate without these auxiliaries is possible, but very undesirable. One condenser doing the work of two and giving but 10 or 15 inches vacuum is far preferable to exhausting to the atmosphere with the attendant engine difficulties. One heater doing the work of two and delivering water to the boilers at but 125° F. is far preferable to feeding cold water. These considerations are covered by system No. 2. The condensers, heaters, economizers and pumps would be suitable for four units and capable of supplying all six under reduced economy. This enables repairs at any time of any auxiliary without interfering with the operation of the plant. The main steam header and feed mains are divided into six sections, permitting the use of five-sixths of the entire plant at all times.

In formulating the plans for a station it is well to bear in mind the path of flow of steam and exhaust. The boiler can be considered the starting point of the loop and the engine the terminal. The pumps, heaters, condensers and pipe lines lie between. To simplify the piping plans it is very essential that the auxiliaries be located in close proximity to the main units. The diagrams show them at considerable distances apart, but this is merely to make the system readily understood and to leave ample room to make alterations on the diagram if found necessary.

In addition to the plan diagrams, there should be an elevation diagram, laid out to scale for elevation only, as shown in Fig. 6. This elevation diagram is a portion of the station system and should be determined if piping is to be figured on from the diagrams and building drawings. It shows the various elevations of lines, lifts of pumps, drains for steam, exhaust and oil lines and other points that must not be lost sight of in the designing of pipe details. For example, it shows that auxiliary exhaust main must not be lowered very much or it will not drain to the heater. It also shows how much fall is given the pump suction from the heater and other details that should be considered and laid out by the engineer in order to locate the apparatus correctly. It is not necessary to show all the boilers or branches, but simply the lines that must be located in some fixed relation to each other. The location of lines should be left to the detailer and only interferences should be shown or noted.

Diagrams prepared as here shown are excellent means of studying station work. The different lines can be separately laid out and they make good studies. Take, for example, Fig. 7. This diagram shows a boiler feed system, which is a loop system as regards

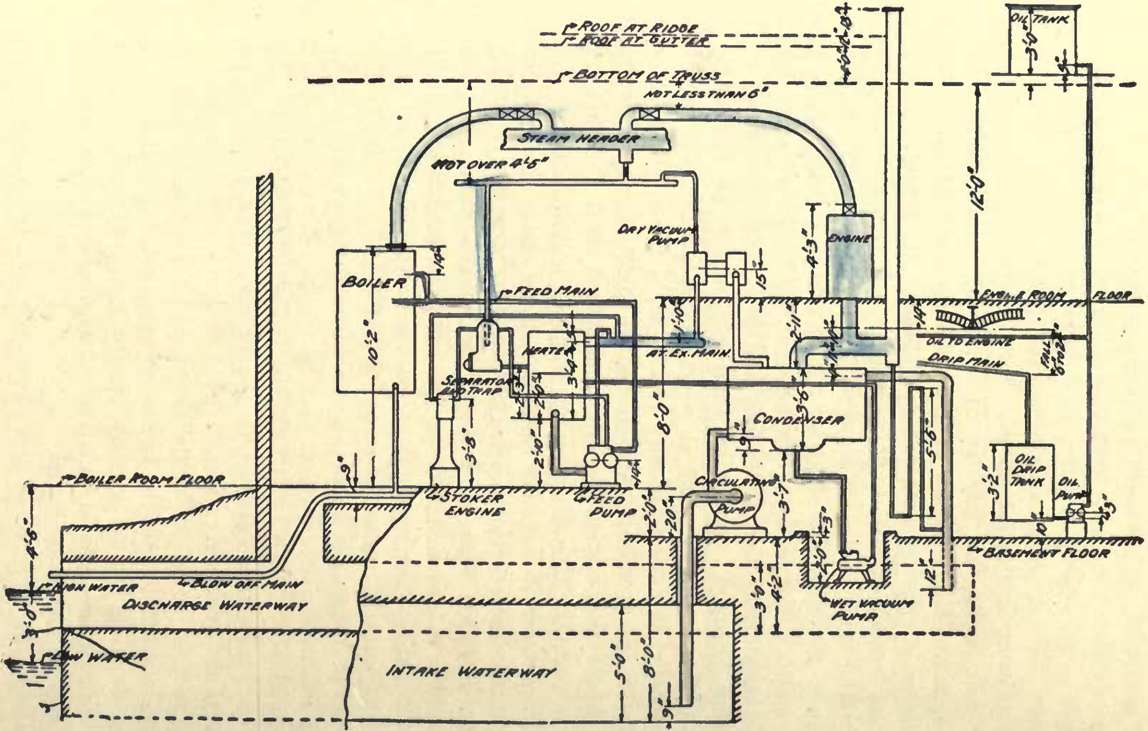

FIG. 6. Diagram Elevation of Plant.

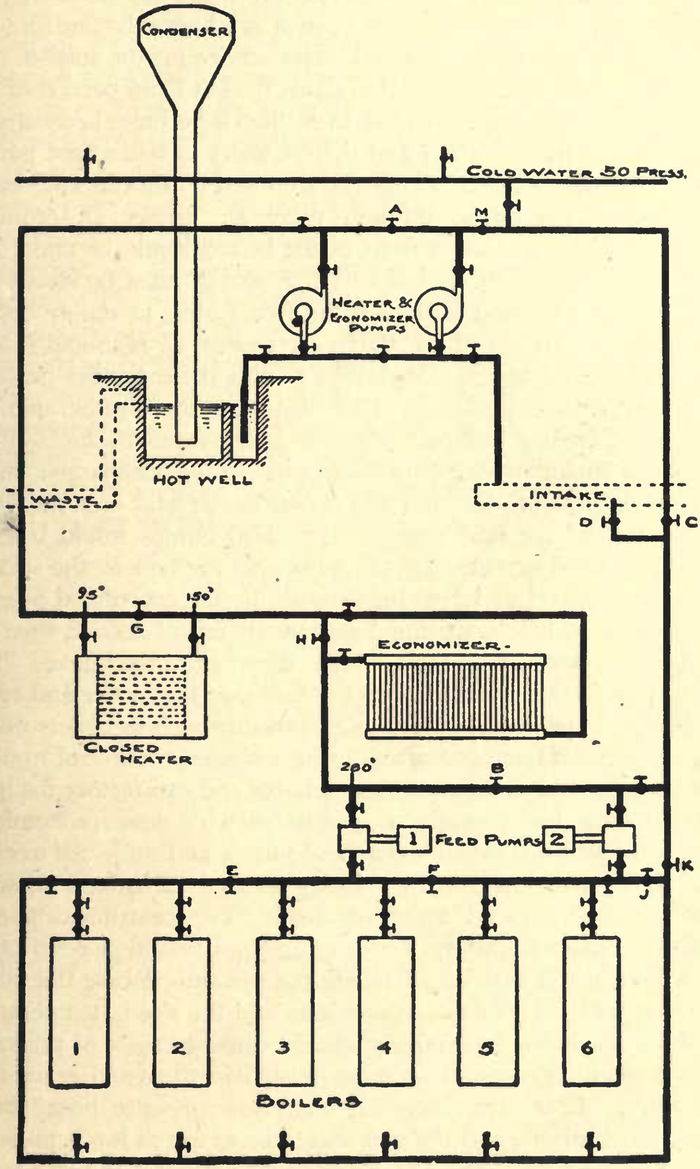

FIG. 7. Diagram Study.

boiler feeding, but in actual service the loops are divided, part being used for a secondary service, such as a hydraulic line for tube cleaning or low pressure general water service for the station. In case it becomes necessary to shut down the left hand portion of the regular feed line, from valves *A* to *B*, then it becomes necessary to use the right hand portion and deliver water to No. 2 feed pump. If found desirable, valve *C* may be shut and pump can take water direct from the intake through valve *D*. Under all ordinary conditions the hose line in front of the boilers would be under low pressure, about 50 lb., but if valves *E* and *F* must be closed the hose line may be used as part of the feed system to supply boilers No. 1 and 2. In case of fire, the by-pass valves *G*, *H*, *S* and *K* may be opened and *L* and *M* closed, thus putting the entire low pressure system under high pressure. This diagram shows a rather unusual method of feeding boilers. Water is taken from the hot well by means of motor driven centrifugal pumps and discharged under say 50 lb. pressure through the closed heater and economizer to the suction of the feed pumps. The feed pumps would be controlled by hand or automatically to supply the boilers, the suction being maintained under 50 lb. pressure by the centrifugal pumps. If at any time both centrifugal pumps are out of service, then the feed pumps would take their suction direct from the intake. The advantage of this system lies in the fact that the heater and economizers are never subjected to high pressure such as boilers would be. Instead of the economizers being a constant source of trouble, they will operate in their old-time reliable and satisfactory manner, on extremely low pressure as compared with those economizers which are placed between boilers and pumps and subjected to careless abuse of firemen, such as closing all feed valves and allowing feed pumps to pound away on them. The centrifugal pumps would maintain a uniform pressure and not require a relief other than a small one that would relieve the pressure in case the valves are shut both sides of the economizers and the rise in temperature of the water in the economizers should cause increase of pressure. The pressure in economizers must be sufficient to avoid generation of steam. There are, however, many low pressure installations using economizers, and the aim should be to use as low a pressure as is found practicable. It would also be advisable to place economizers sufficiently above the feed pumps to permit the suction to flow by gravity to the pumps.

The chief object in showing this unusual system is to call to the attention of the reader how readily the complex problems of station design can be laid out and made perfectly clear without resorting to scale drawings. No station work can be laid out even in a preliminary way until the system of connecting up is determined. It is very much to be regretted that the periodicals show general views of the new power plants and fail to show the system that determined the arrangement of the plant. Not only should the piping system be shown, but smoke flues, stacks, coal and ash systems. The object to attain is the use of as little machinery and piping as possible, and at the same time to permit shutting down any portion of the different apparatus and piping without interfering with the service for which the station is intended. To accomplish this, it is necessary to lay out the system first, then build the plant around it. Each of the various details must be separately considered and a careful determination made of its suitability for the purpose for which it is intended.

CHAPTER III.

PIPING SYSTEMS.

In this chapter we consider the different systems of connecting up machinery and the various systems are separately shown by diagrams, this method being the most convenient one for studying and determining the requirements for each class of service. The form in which these different systems are shown would ordinarily be the form used for "studies" previous to laying out the complete station diagram. The separate diagrams would be somewhat more distinct than a general diagram of all the lines, but the former would not serve to call to the attention of the pipe work designer and erector such other lines as come in close proximity, and for which provision must be made. The general diagram of all the lines on the same sheet, each in approximately its correct position, acts as a constant reminder and greatly reduces the labor of laying out lines as well as the possibility of overlooking some of them. This is the kind of drawing that should be furnished to the piping contractor, showing the desired results but permitting him to lay out the details so as to accomplish these results in the simplest and most economical manner.

In case the contractor should fail to provide for any lines shown on this diagram he would necessarily be obliged to make changes so that the work would conform to the diagram, and as such changes would be due to an oversight on his part he could make no charge for them. The common practice, however, is to detail a portion of the work, leaving the uncertain and indefinite features to be covered by some general clause in the contract which protects neither the purchaser nor the contractor, but which merely leaves a loop hole for the engineer to shift the responsibility upon the purchaser or the contractor. Contractors, however, can protect themselves by adding the following clause to all quotations:

"This proposal covers only such materials as are definitely shown or listed on drawings or in specifications."

Contractors are not at the mercy of engineers when it comes to making bids. When an engineer has certain work to do he is compelled to place an order for it. If he cannot place the order on his own terms he must accept the contractor's terms. If he ignores all of the contractors who use this clause in their bids they can notify the purchaser to this effect, and as the purchaser is invariably a business man, he will readily appreciate the fairness of such a clause. The result would be that the engineer would be careful to make a study of the requirements instead of spending his time in the study of pipe work details. He would lay out a diagram of every line and system required, make the contractor familiar with the situation and make him responsible for the design, details, location and the support of all lines. The contractor would look after his clearances and would take nothing for granted as he would have to do if the engineer furnished the working drawings.

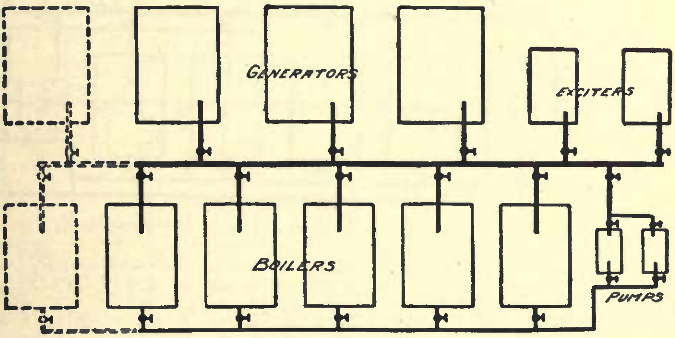

FIG. 8. System, Steam and Feed, One Division Plant.

The various systems are described in a general way and later on the parts of each system are considered in detail. Fig. 8 shows the plan of a station having three generators and five boilers at one end of the station and the exciters and pumps at the other end. The dotted lines indicate future extensions. This plan will not appeal to the reader as unusual for he probably has in mind several stations similarly arranged. Generally it may be assumed that the piping and machinery should be laid out as shown, but instead of using the piping arrangement given in Fig. 8 it may be desirable to employ some system; that is, some arrangement that will provide for continuous operation of the plant and by means of which at least two-thirds of the plant may remain in operation during the time that repairs are being made. Fig. 9 shows the pipe work of this station redesigned so as to conform to such a system. It may be noted that two generators out of the three, three boilers out of the five, also one feed pump and one exciter engine can be used at any time, thus permitting the shutting down of any portion of the steam main which may need repairs. The value of laying out a diagram before ordering the machinery shows itself clearly when considering whether a better system could be laid out. Fig. 10 shows a better balanced system in which there are no double lines of piping, and this arrangement allows the use of two boilers for each of the two engines in case repairs are being made.

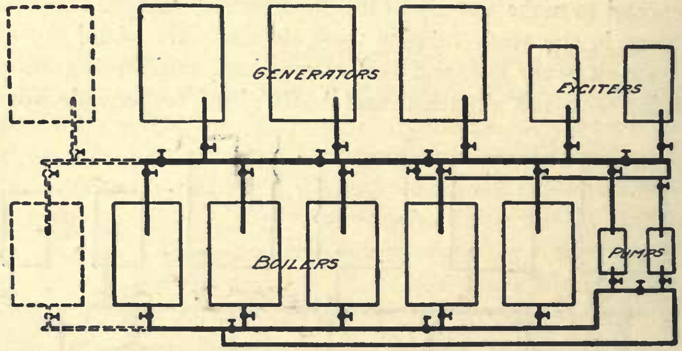

Fig. 9. System, Fig. 8 Modified to Multiple Division Plant.

To lay out a station system requires full consideration of a great many details besides piping, but these details must be considered as only a part of the system and nothing pertaining to the station should be ordered, or even considered as final, until all of the details of the system have been thoroughly digested and determined. It is very easy to refer to the diagram in Fig. 8 and say that it should have been arranged as in Fig. 10, although the conditions may have been such that the arrangement shown in Fig. 9 might be the best solution with possibly a change in the number of boiler units. No plan or system can be styled *a priori* the "best," for that one is the best in each case which best complies with all of the conditions. Nevertheless a fixed plan for securing the most satisfactory results can be followed and no matter what the surrounding conditions are, some system can be employed.

The fundamental requirements of station systems are reliability, accessibility and durability. The requirements of the station must be first determined and some system adopted that will meet these requirements. If the requirements are that the station should run as many hours a day as is convenient for the station operators, the system for such a condition needs practically no valves, no reserve capacity nor any emergency provisions. However, this class of station work does not come into the hands of an engineer to lay out. He is engaged to design stations that will never require a shutdown of the entire system. It is the conditions of service that must determine the system. If the service is twenty hours a day the station should be laid out with this in view. If it must run twenty-four hours a day, running for eight hours at half load only, then the system should provide for repairs being made and at the same time maintaining the capacity.

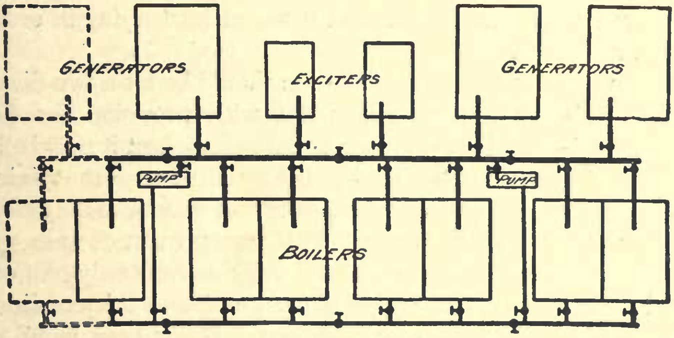

FIG. 10. Sample System; Steam and Water, 3 to 4 Division Plant.

The method of determining the most suitable size of units for a station will not be considered in detail as the question is quite foreign to piping and piping systems except in so far as the number of units is concerned; if the station is required to generate at all times two-thirds of its total capacity the plant should not have less than three units all of the same size. No unit should be so large that the station cannot be operated without it by overloading the other machinery to the permissible limit. The practical advantages in having units of the same size and pattern are too great to be abandoned on account of the petty economies that may be secured under certain conditions by using one large unit. As an illustration of this the following case of a breakdown is instructive. Three units were installed, all of the same kind, size and pattern. One unit was out of service, the crank pin boxes having been removed for rebabbitting, fitting, etc. Two engines were required to carry the load, and while this engine was out of service, a valve eccentric rod broke, which necessitated running one engine with almost a double load. The valve rod was immediately taken from the engine out of service and fitted to the engine that broke down, so that in a short time the latter was in service again. The single engine could not have carried this overload except for a very short time, and having all the engines of the same pattern avoided a shutdown. If the engines had not been all similar the plant would have had to be shut down at least a day in order to finish the repairs.

In any case the original installation should be for a two-division, three-division or four-division plant with provision for future divisions. If the plant is to be a two-division plant it may be built with two units, each of a capacity slightly larger than the minimum load conditions demand, and the future unit may be made twice the capacity of these smaller units. This arrangement of units would be permissible in a plant which ordinarily delivers only half of the power called for on Sundays, holidays, etc., and this condition is quite an unusual one in power stations. It has been found ordinarily that a three-division plant is more suitable for permitting repairs to be made and also requires less investment for reserve capacity. If the plant is to be a three-division plant, the boilers should be in three divisions, say six, nine or twelve in number. The auxiliaries should be in pairs, not necessarily together, but each sufficient for the entire plant, and they should be connected to the different divisions so that when one division is out of service the other auxiliary will be on an operating division.

In order to more fully explain the features to be determined by diagrams as well as the laying out of the diagram the requirement of a sample station will be considered and the method of selecting machinery, etc., followed up. It will also be shown that by this method can be determined much of the station layout and the auxiliaries required at the same time the piping system is developed.

Let it be assumed that the station will now require three units for an output of two-thirds of the total capacity of the units and later will require an additional unit such as shown in the diagram Fig. 10. There is but one solution of the problem under these conditions, and that is that the station shall ultimately be a four-unit plant for output of three-quarters of the total capacity of the units. The boilers must be arranged in three units so as to allow one to be out of condition for cleaning and repairs. Boiler cleaning must not be considered a contingency but a requirement that is certainly unavoidable.

Assuming the engines to be of 2,000 hp. each, then two 500-hp. boilers would be required for each engine, but by assuming three engines of 2,000 hp. each or a total of 6,000 hp., there would be 3,000 hp. in boilers to be divided into five units, so as to allow one boiler to be out of service. This would give five 600-hp. boilers. If the fourth engine unit is likely to be ordered before the three units are called upon to carry full load for a large part of the time it would be safe to estimate on 8,000 hp. of engines or 4,000 hp. of boilers or seven boilers, each of 555 hp., which is a somewhat better arrangement for the four-unit plant.

When it comes to determining auxiliaries there should be considered only that future unit for which space has been provided in the building. More than this is useless speculation, and further, such apparatus as would be provided to-day, it is possible that no one would think of using in the future when it came to be required. The present installation may include one of the two condensers for the completed plant, in which case it would be advisable to provide a 5,000-hp. condenser which would be larger than required for two units, but somewhat small for the three units. A loss in vacuum would be so infrequent that its effect on the station economy would be imperceptible. If the fourth unit is to be installed at an early date it would then be more economical to put in two condensers at the time the three units were installed. These are points that the engineer must determine, and he may decide that he would not wish the plant to run non-condensing even during the short time required to make a repair. As this would be the case if one condenser were installed, it is assumed that two are wanted.

The atmospheric exhausts must be so designed that a repair to one must not interfere with the others, as the atmospheric exhaust is one of the vital lines of the plant and must be as well safeguarded as the steam header. Assume that the condensers will be of the elevated jet type, with electrically driven centrifugal circulating pumps. Economizers will be installed, and as no steam will

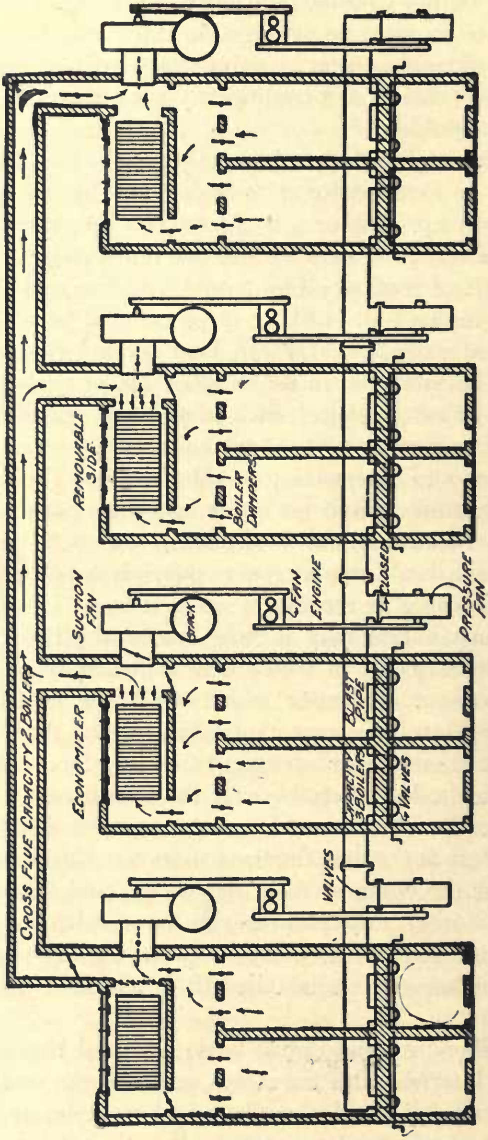

FIG. 11. Sample System; Smoke and Air Flues, 3 to 4 Division Plant.

be required to heat the feed water, the installation can be simplified by using motor driven circulating pumps instead of engine driven. In case the lift be slight, engine driven circulating pumps may be used and the exhaust carried to the heater, but the engines ordinarily used for this service are so uneconomical in steam consumption that together with the other auxiliaries they would deliver more exhaust steam than the heater could condense. The difference in economy between engines exhausting part of their steam to the atmosphere and electrically driven pumps is so slight that the better practice is to adopt that which requires the least labor to operate, which is unquestionably the motor drive. One, two, three or four circulating pumps can be used for the two condensers and only such as are required to deliver the necessary cooling water be operated. It may be assumed for the present that three circulating pumps will be used, each sufficient for one condenser, although when the circulating water is extremely hot all three pumps may be required for the two condensers.

The requirements to be met by the dry vacuum pump are so variable, due to changes in the temperature of the water, amount of vegetable matter it contains and the air leaks in the pipe line, that it may be necessary to run the air pump at a very high speed some days, and possibly it can be run very slowly a week later. Any motor drive is very unsatisfactory for the air pump, so it will be considered that this will be of the steam driven fly-wheel type. It is possible to vary the speed of the dry vacuum pump over a wide range, and as it is important to minimize the labor for attendance, one dry vacuum pump for both condensers will be chosen.

In regard to the boilers, they will be taken to be of the water tube type set two in each battery, and in order to include more piping details in the plan it will be assumed that underfeed stokers are to be used and also induced fan draft. As previously stated, economizers will also be used.

In order to make the station operation secure against all contingencies it may be arranged to have each battery of boilers distinct by itself. Each battery will have its own economizer, its own by-pass flue, stack and fan engine, the same engine driving both the blast fan and stack fan with a cutting in arrangement both for the air blast and the main flue, as shown in Fig. 11. By speeding up these engines two of them should have sufficient capacity for three batteries of boilers. After a careful consideration it

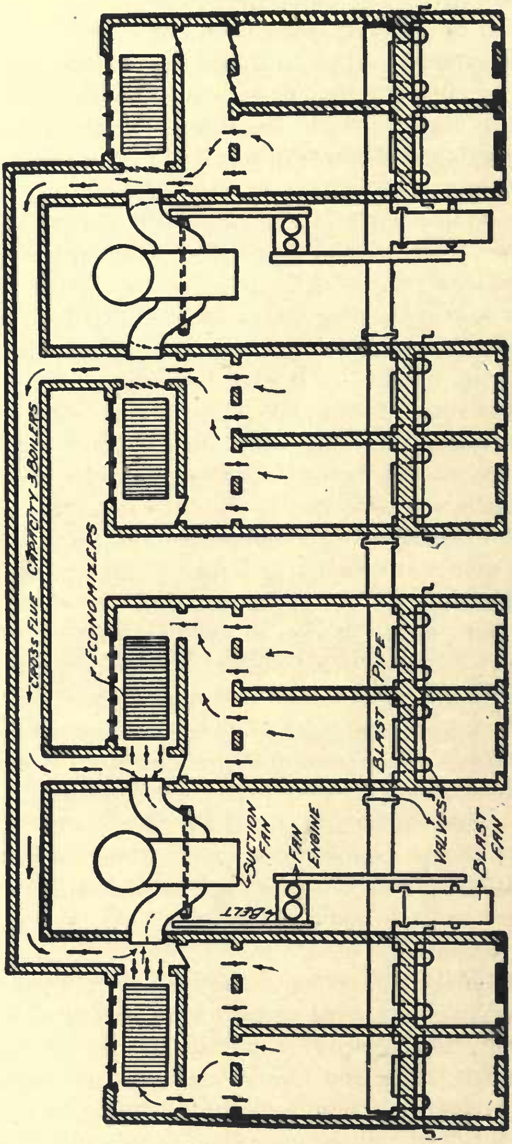

FIG. 12. Sample System; Smoke and Air Flues, 3 to 4 Division Plant (Modified Form).

may be decided to use the plan shown in Fig. 12, making the fan engines capable of taking care of three batteries of boilers each by speeding them up. This would make somewhat less machinery to care for and would allow either fan engine to be shut down and would make it possible to run all of the present installation or three-quarters of the future installation. This would necessitate the use of a second fan engine and stack in order to insure continuous operation of the present three-unit installation.

By placing economizers in separate groups as shown it becomes a very simple operation to clean them, as this can be done when the battery of boilers is out of use and after the brickwork has cooled down. It is wholly useless to invest money in economizers and not to make most liberal provision for cleaning them. They are sometimes allowed to fill up with deposits inside and outside so that they will not raise the temperature of the water more than 20 to 30 degrees, while if they are cleaned both inside and out they can, as proved in practice, raise the temperature of the water from 50 to 270 degrees, a total of 220 degrees. In order to cool the economizers sufficiently to permit careful and thorough cleaning no gases should be allowed to pass on the outside of any of the economizer walls while the cooling and cleaning is in progress. It may occur to the engineer that he can save in space and in first cost of installation by placing the main flue to the stack between the boiler and building wall and place the economizer on top of this, boxed in so to speak, without any possible chance to cool them off. Where else in the plant can he save from 10 to 15 per cent in the cost of fuel by doing better engineering? The saving in this detail alone will in five years pay the entire cost for engineering of the power station. The cross connecting flue can be of light iron and left uncovered, as it is required only in cases of emergency, when one of the fan engines is out of service. The radiation of heat would be confined to the fan casing and the stack. There are many interesting details in connection with the boiler and economizer settings, smoke flues, air pipes, etc., but as they are somewhat foreign to the piping system these details will not be further discussed.

Assume that the arrangement shown in Fig. 12 has been adopted for the station in question. There are the two fan engines to provide for and the piping system and also the stoker rams. The next question that arises is, What shall be done for boiler feed pumps? Electrically driven feed pumps are not satisfactory except when the motors can be run within a very limited range of speed. If the station were very large four electrically driven pumps together with a steam pump could be used, the latter being used with any or all of the electrically driven pumps to take care of any demand less than the capacity of one motor driven pump; one of the electrically driven pumps could be shut down when the slowing down of the steam pump still gave more water than was required. For a plant of the size in question, however, the additional maintenance of using electrically driven feed pumps is not justified. There is also needed a line of pipe to which the water tube cleaner turbine may be attached, and this must be supplied from some other than the feed pump. This is imperative, for water must not be drawn from the feed main for any purpose whatever except to feed such boilers as are under pressure. This requirement must never be lost sight of in laying out a station system having an economizer or closed live steam heater between the pumps and the boilers. Not only should all other service be kept off the feed main, but the latter should at all times be under full pressure. The moment that a hose line or a connection into an empty boiler is opened from the feed line the pressure immediately drops in proportion to the size of the opening, possibly 10 or 15 lb. The temperature of the water in a live steam heater or an economizer is sufficiently high to generate steam when the pressure is lowered, and this causes a serious water hammer in the economizer, heater or pipe lines. For the same reason the blow-off from an economizer should be handled according to an established method which will be mentioned later. Broken economizer sections and leaky joints are often the results of mistreatment.

In arranging for feed pumps two will be required in any case, and while one is used for boiler feeding, the other can be used for filling in boilers, running turbines, etc. In addition to these two lines of water service it will be necessary to have a low pressure system operating, say on 25 lb. pressure, which can be used for cooling engine journals, wetting down ashes, for the plumbing fixtures, washing floors, for the make-up water, to the open heater and other similar services. In addition to this "house service" there should be a fire service system, the pump for which should be able to maintain 100 lb. pressure running full speed. These four services must be available at all times, although it is not necessary nor desirable to keep the fire service pressure on all the time. The house service or low pressure lines may be taken off the fire system, using reducing valves and reliefs, and even if there be a reducing valve in the line no loss in economy of operations will be effected as long as the fire system is under the same pressure, say 25 lb. Whenever the fire system pressure is raised the pressure reducing valve and relief will protect the line against any careless manipulation of valves.

There are then various combinations of conditions, all of which should be fully met by the system employed. The following are the different conditions:

(1) Feed main on,
Tube cleaner main on high pressure,
House service and fire main on low service,
With pump on each line.

(2) Feed main on,
House service low pressure, cold water,
Fire main higher pressure, for outside sprinkling.

(3) Feed main on,
House service on,
Two pumps in service.

(4) Feed main on,
House service on through reducing valves,
Fire main on for fire,
With three pumps on, two for pumping into fire main.

(5) Feed main on,
House service on through reducing valve,
Any one of the three pumps in service.

The third condition would be the regular operating one, leaving one pump in reserve at all times. The boiler is so important that with three pumps in the plant it would be policy to arrange all of them so they could feed boilers, making it possible to operate under condition five. It is possible that two of the three pumps may be out of condition at the same time. The two boiler feed pumps would be of the same pattern and size with compound cylinders suitable for boiler feeding, and they should be outside packed.

The fire pump should be of special pattern to fill its various duties. Probably a 500-gallon pump would have ample capacity for fire protection, and owing to its high speed it would necessarily be of the regular piston type. The cylinder ratios should be such that the regular fire pump can be used as a feed pump to deliver a small amount of water such as would be needed for boiler feeding. This pump would be regularly used as a 25-lb. pressure pump and in order to economize steam it would be necessary to compound it, possibly six to one, and use it as a compound pump for the low pressure work only. By operating the port changing slide valve the pump would be immediately changed to two high pressure cylinders for fire service or boiler feeding.

In many ways the gravity storage tank is very desirable, as it provides a storage for water while changing over the pumps and it also helps to maintain a steady pressure of water. If gravity tank water is to be used for cooling engine journals, it will necessitate the use of a much larger amount of water than otherwise due to the tank becoming heated. If the tank be of metal and located near the roof, much trouble will be experienced from its sweating, and in order to avoid dripping, it will be necessary to use a water-tight pan under it. In order to maintain a steady pressure with a small amount of storage, it would be preferable to use a small closed expansion tank in the basement.

The three pumps would ordinarily use different water for the suctions, the boiler feed pump using hot water from the heater and the other pumps using cold water. The pumps must therefore have their suctions so piped that any one of the three can use the heater water or intake water.

Before laying out the piping for this pumping system it is necessary to consider what to do in regard to the heater. Shall one or two heaters be used? Before attempting to determine this question, it is necessary to consider how essential the heater is in securing continuous operation. There are condensing plants using economizers and electrically driven auxiliaries that take water from the hot well and feed directly into the economizers without having any heater at all. Now if the economizers can operate continuously without a heater, why must we provide a reserve heater for the two hours or so that it takes to clean them out? The only directly appreciable loss is the heat discharged from the exhaust pipe while cleaning; this is a very insignificant loss considering the long intervals between cleanings. Another question in connection with the use of two heaters is how to take a uniform amount of water from each heater when using one feed pump. This can be arranged by means of floats and other unreliable devices, but there does not appear to be any practicable method except by the use of two feed pumps working separately, each with a separate heater. This detail should not be lost sight of in determining the heaters.

There must also be considered whether a closed or an open heater shall be used. The only advantage of the closed heater is that the oil in the exhaust steam does not mingle in any way with the feed water. But is this sufficient to outweigh the advantages of an open heater for the service in question? In the first place, the open heater is made of cast iron instead of plate steel, making it able to stand the chemical action within it for a longer time. Another feature of the open heater is that it is not subjected to severe stresses, due to the boiler pressure, as is the case with a closed heater. The closed heater is far more difficult to clean and, in case of a condensing plant, but little benefit would be derived from it, as the closed heater would raise the temperature of the water only about one-quarter as much as the open heater. If sufficient exhaust steam is delivered to an open heater to raise the temperature of the water 75 degrees, the same amount in a closed heater would raise it only about 17 degrees, corresponding to a loss of nearly 6 per cent of the coal consumption. For a non-condensing plant the closed heater deserves careful consideration, but it is quite out of the question for a condensing plant, as the only exhaust steam available for the heaters is that from the auxiliaries. The open heater should be amply large, not so much for the purposes of a heater, but to permit possible chemical treatment, precipitation, and to provide a large filter bed. Therefore one open heater is chosen for the station under consideration.

There are other features still to be considered before laying out the pump piping. Shall a water meter be used, and if so, where shall it be located? Also how shall water be taken from the hot well and delivered to the heater? Water could be supplied to the heater by the fire pump while it is being used on the house service, but, by doing this, water would be delivered to the heater from the intake at possibly 60 degrees instead of 90 degrees, a loss of 30 degrees. If using 90 tons of coal per day at $2 per ton, this would cause a yearly loss of about $1,970. It is essential therefore to save the 3 per cent of heat, even though it becomes necessary to use another pump, but this is objectionable, as it makes another machine to care for, watch and regulate.

A simple solution of this question is to attach the pistons of the low pressure heater supply pump to the plungers of the feed pump, in such a way that they can readily be detached. The advantage of this arrangement is that better economy is secured, there is one less steam end to look after and there is no liability of shortage nor waste of heater water. The amount of water delivered to the heater will be the same as that taken from it. Therefore it is decided to use a double water end feed pump arranged so that the heater supply pump can be quickly disconnected in case of accident, and during a repair water would be taken from the house service line by means of the fire pump.

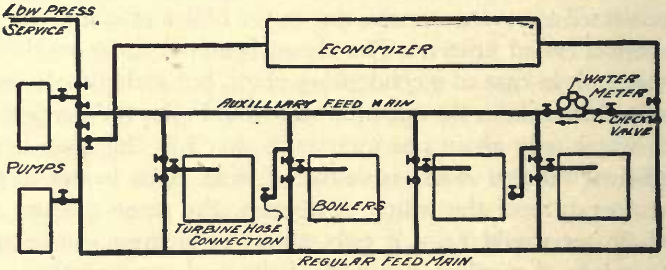

FIG. 13. System; Feed Water Meter, Simple Plan.

Next comes the water meter. This should be so arranged with respect to the piping that the total water fed to any or all of the boilers can be measured, whether fed through the economizers or with the economizers cut out. The meter should also be arranged with a by-pass so that it can ordinarily be out of service. Fig. 13 shows one system of feed water pipes with meter, the hydraulic tube cleaner line being also, in this case, an auxiliary feed main. This system is especially suited to plans that have one economizer to serve one side of the plant. It will be noted that the feed water can be run through the economizers and any one or more of the boilers fed through the meter, the boilers not on the meter being fed through the regular feed main. The only condition that could be improved is in the case of feeding with the economizer cut out. It will be noted that when metering cold feed water, even if only for one boiler, all the other boilers would have to take cold feed water also. The system shown in Fig. 13 requires no extra piping for the meter other than the meter connections themselves. When cleaning the boiler tubes the meter is shut off as well as all feeds to the boilers, and the regular feed main is used for boiler feeding. The test usually made with economizers is to meter the water for all boilers, first with the economizers on and before cleaning them, second with the economizers off and third with the economizers on after cleaning them. This test is to determine how much can be saved by reason of cleaning them, or, in other words, to determine how often it pays to clean economizers, how well to clean them, etc.

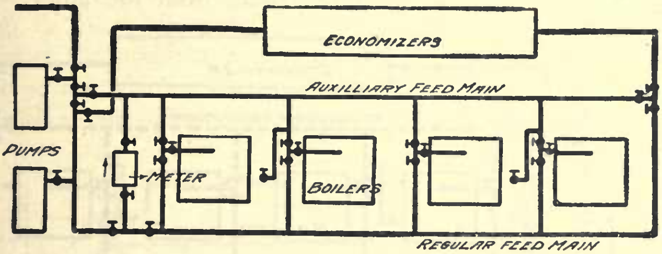

FIG. 14. System, Feed Water Meter, more Flexible Plan.

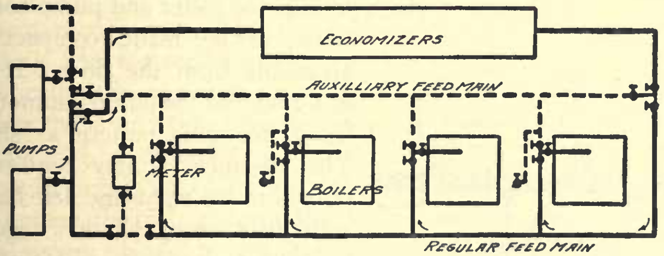

FIG. 15. System, Fig. 14, with Meter out of Service.

Another arrangement in piping can be made, as shown in Fig. 14, which will provide for all conditions and which will permit metering cold water fed to one boiler and feeding through the economizers for all the other boilers. Fig. 15 shows the regular method of operation with the meter out of service and the hose main ready for use. The feed system in this illustration is shown in full lines, and the cleaner system is dotted.

Fig. 16 shows the meter in use with all boilers using hot water. By opening valve *a* and closing *b*, cold water would be fed through the meter to the boiler. The dotted lines indicate the portion of the system out of service, though this portion may be under pressure. The arrangement shown in Fig. 16 would permit the water meter to be placed on the floor next to the pumps, the lines *c*, *d* and *e* being the risers from the latter. After the system is determined, the pipe details can be considerably simplified by changing the relative location of lines, etc., and at the same time maintain the same system. For example, Fig. 17 shows a rearrangement which permits the meter and pump connections to be made compact and accessible from the floor. It may be found that the pumps cannot both be of the same pattern as shown. The distance *f* may require the pumps to be right and left handed with their steam cylinders together, in order to leave room for the required connections. The pumps must not determine the piping, but the piping should determine the minor details, such as those just mentioned.

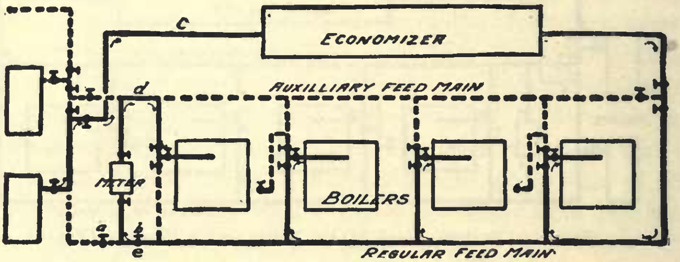

FIG. 16. System, Fig. 14, with Meter in Service.

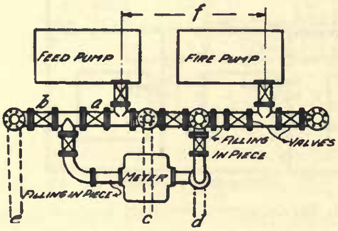

FIG. 17. System; Developing Detail for Fig. 14.

The early diagrams made for a station should be considered as studies and after the pipe work has been detailed in accordance with these diagrams the best plan would then be to change the direction of the lines on the final diagram so that they will correspond closely with the lines as they are to be built. This will enable the men in the station to read the diagram much more readily and with less liability of making an error in the operation of the valves. The valves should be shown in approximately their correct location. For instance, when Fig. 17 has been laid out in detail these data should be used for correcting the diagram as illustrated in Fig. 14 and the final result be shown as in Fig. 18. At first glance the system shown in Fig. 18 appears to be a different one than that shown in Fig. 14, but in reality it is exactly the same. The object in correcting the final diagram is to avoid this deceptive appearance.

Fig. 12 shows the general arrangement which will be used in designing the problem plant. There are four groups of economizers shown which will ordinarily be fed from one pump. If the boiler plant were divided into halves and each half provided with its own economizers, then the pumps could be placed at the dividing line between the two halves, and with possibly a few modifications in regard to the valves Fig. 14 could be used. After adding the connection lines between the two halves the arrangement would be as shown by Fig. 18.

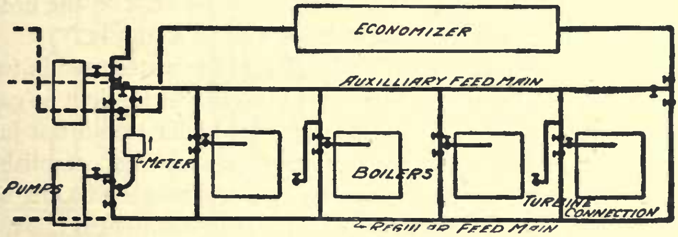

FIG. 18. System; Rearrangement of Fig. 14 to suit Detail.

Having decided upon the general arrangement of the economizers and boilers, the piping should now be laid out in a detailed system. This system should be made as reliable and as flexible as that shown in Fig. 14 and by tracing out Fig. 19 it will be seen that the following conditions are readily secured:

1. Regular operation of No. 1 pump on fire line and house service; No. 2 pump on auxiliary main for tube cleaning; No. 3 pump on feed mains.

2. The meter can be used with either pump No. 2 or No. 3 or with both; the discharge from the meter can be fed to the feed main, auxiliary main or to both at the same time; the meter can deliver through one or more economizers with either heater water or cold water; it can also feed direct to the boilers by passing one or more economizers.

3. Any one pump may be shut down without interfering with regular operation; any two pumps may be shut down and still main-

tain pressure on the feed main and the house service, using cold water or water from the hot well in the economizers.

4. When an economizer is shut off the boilers which regularly feed through it can get feed water from the economizer in the next battery of boilers.

5. The entire feed main may be shut off and water then be fed through the auxiliary main or vice versa.

6. The auxiliary main may feed through the economizer or directly to the boilers.

7. During the winter, warm water may be kept on the fire and house service system by using the hot well as a supply.

This system necessitates the metering of the water used in two of the boilers in each battery. The advantages which might be gained by separately metering the water for each boiler would not justify the addition of the piping connections necessary to accomplish this detail. If it is found necessary to make a separate test on one boiler this can be done when the other boiler is shut down, or if it is necessary to test two boilers which discharge into the same economizer, the meter reading when divided by two would hold, because the boiler which burned the greater amount of coal would be heating the feed water for the other boiler.

The chief requirements for a boiler feed system are well cared for in Fig. 19. They are as follows:

1. Any part of the feed system may be shut off without reducing the capacity more than one-fourth, for four units.

2. The hot-well water may be fed to the economizers when the heater is off.

3. The boilers with economizers off may take their feed from any other economizers which are in operation.

4. An abundance of feed reserve is provided for.

There are various other systems of metering which might be employed such as a separate meter for each boiler, or as shown in Fig. 19 a separate meter with a by-pass might be used for each economizer if placed at the points in the feed system marked *a*. By using four smaller meters they could be operated at nearer their normal capacity than could one of sufficient size to care for the entire plant, thus the readings would be more accurate, but simpler and more accessible details can be obtained by using one large meter at the pumps. This will also allow the meter to be read from the pump room floor. The relative performance of the boiler

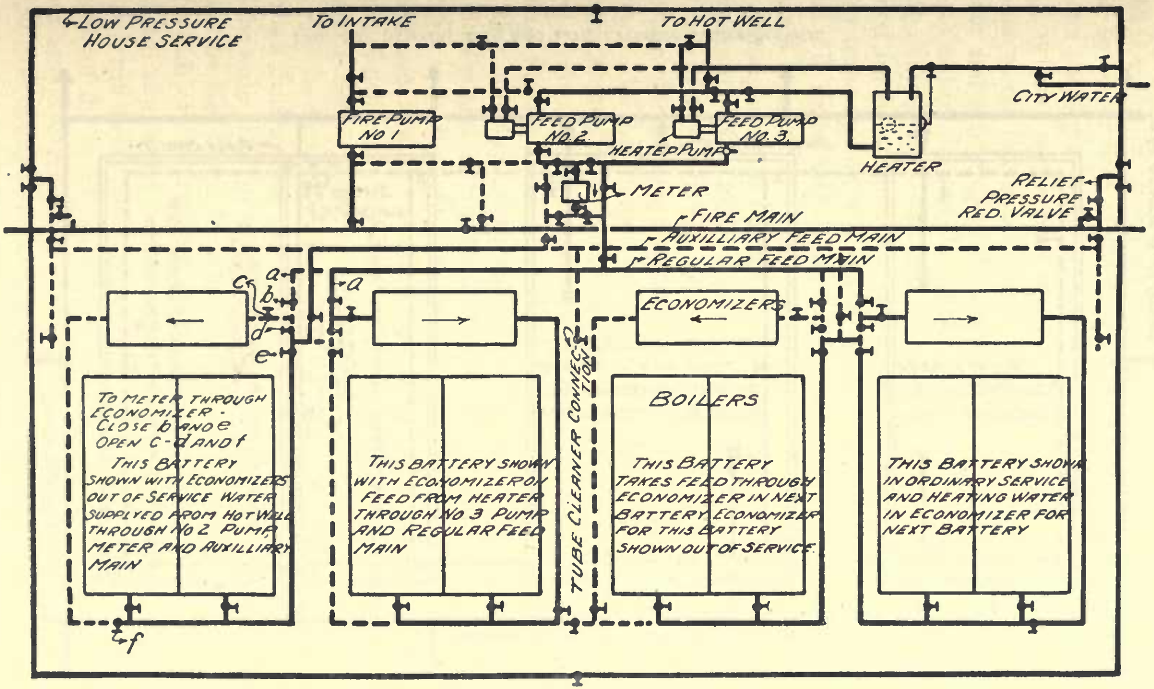

FIG. 19. Sample System; Water Lines, 3 to 4 Division Plant.

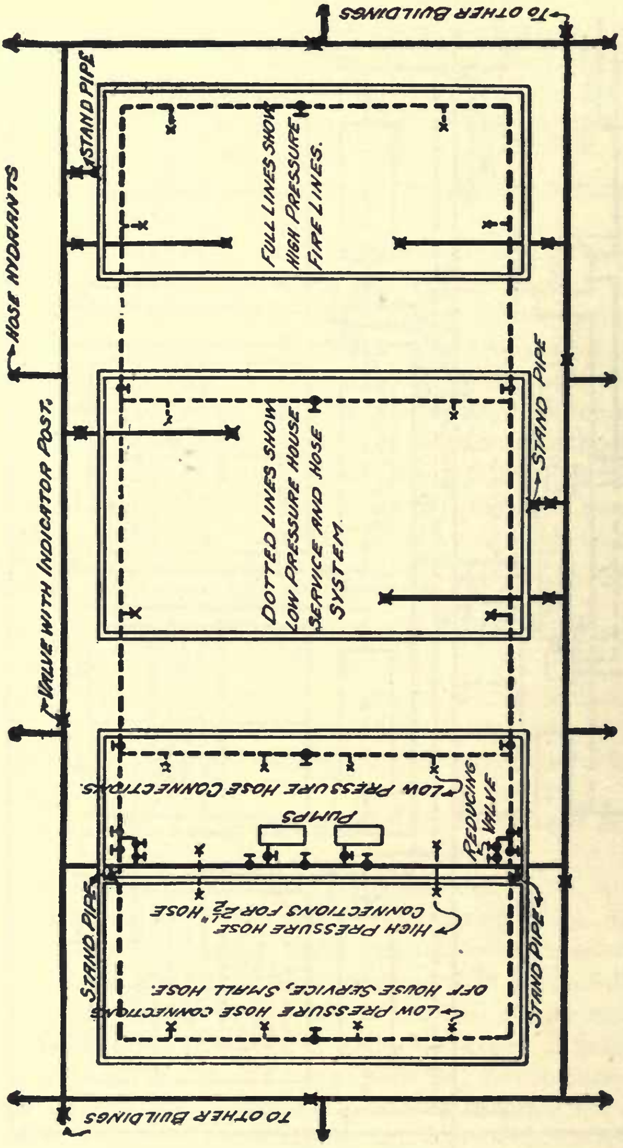

FIG. 20. System; Fire and Low Pressure Water Service.

units can be determined more accurately by using the same meter for measuring all the water. Any difference in the performance which might be shown on two individual boiler meters might be due to one or both of the meters being inaccurate. With but one meter the degree of inaccuracy will show the same for all boilers.

City water connections which are taken from a meter in the city water works line should have a line carried to the house service main and a branch to the heater so that when it is necessary to clean out or shut off the intake there will be another source of water supply for boiler feeding. All these conditions must be provided for because no one can foresee the many difficulties which may come up and it is safe to assume that every line and connection will necessitate shutting down sometime without giving more than a moment's warning.

But a portion of the fire main in the station is shown in Fig. 19. Ordinarily a safe fire and house service can be laid out on the loop system as shown in Fig. 20. Valves should be arranged so that any portion of the loop can be shut off and still have a partial fire protection. The very important connections, such as the water to the heater, should have a valve on either side of them as shown in Fig. 21 and a valve between the two separate sources of supply; then any section of the line may be shut off and water still delivered to the heater.

The branches to the roof, city line, low pressure service, other buildings and lawn sprinklers should all be provided for. As the points to be brought out in considering these are more in the nature of details than of general system, they will be considered later. Ordinarily the hydrants should be kept away from the outside walls a distance not less than the height of the wall. The fire mains and branches must be laid below frost line, the depth of which can be obtained from a neighboring city water works. Standpipes which run to the roof and any hose lines inside of the buildings should have an indicator post outside, so that in event of piping becoming broken or bursting from exposure to frost the water can be shut off and the pressure on the fire piping maintained. All house service valves when connected

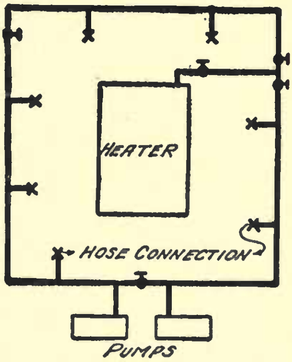

FIG. 21. System; Fire Main supplying Feed Water Heater.

to the fire mains should be readily accessible so that in case of fire they may be closed quickly. Any lawn sprinklers fed from the fire lines should be fully able to stand the fire pressure and should be frost proof.

Before making a final decision on the design of the building or piping it would be well to take up all the details of fire protection with the board of underwriters because some details which an engineer would consider to be of minor importance must be used in order that the underwriters' rules and regulations be obeyed. To secure the lowest insurance rates it will be necessary to install such details as they require, and even though they admit that some of their demands are at times unreasonable they are without authority to modify them.

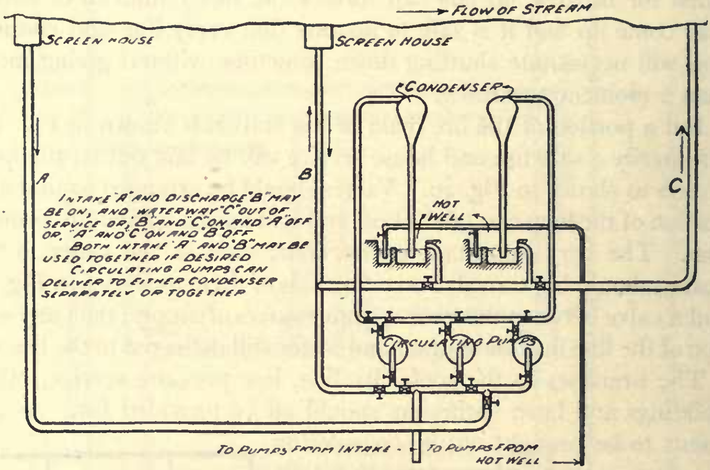

FIG. 22. Sample System; Condenser circulating Water.

The subject of artesian wells is not always a necessary part of power station work, but in the case of many factory plants they cannot very readily be avoided and will be explained later by means of diagrams.

Let it be assumed that the plant in question is located alongside of a stream of water suitable for boiler feeding. The intakes, discharges and connections to circulating pumps and condensers of such a plant are shown in Fig. 22. As in other lines, the chief requirement in this system is that it be possible to shut off any part of the system and yet allow three-fourths of the plant to be operated.

The waterway *A* is always an intake, the waterway *C* is always a discharge, the waterway *B* may be either. Any one of these three waterways may be shut off at any time. Either of the lines from the intake or hot well to the pumps may be shut down and operation continued with the other. Any portion of the discharge main from the circulating pumps may be shut down and the operation of one condenser still permitted. Any one of the three circulating pumps can supply water to either of the condensers. All lines are so connected that repairs can be easily made.

At first thought it would possibly seem that too many valves are used to make this system reliable. On noting the suction and discharge of the circulating pumps it will be seen that there are seven valves on the suction side and seven on the discharge. By disregarding the making of pipe work at all times accessible a shut-off valve would still be required for each machine, each condenser and each source of supply such as intakes *B* and *C*, and if the factor of readily made repairs to the lines is also disregarded it will be found that out of a total of 18 valves but 4 can be saved; thus it is seen that with an increase of about 5 per cent in the cost of pipe work the line may be made entirely accessible. The piping cost is ordinarily about 5 to 7 per cent of the total station cost for such a plant as is being outlined, so the difference in the cost of a station having an inaccessible system and one having a readily accessible system would be about one-fourth of one per cent of the total station cost or about 25 cents per kilowatt increased cost for valves, and if 10 cents be allowed for extra labor, fitting, etc., the total added cost would be but 35 cents per kilowatt or one-third of one per cent of the total cost of the station. The cost should not be considered. The only factor should be the time and study necessary to perfect the layout and provide the station with a flexible and reliable system.

In case three waterways are used instead of two, there would be a slight additional expense in the first cost, but the expense of operation would be lessened because one screen house could be shut down and cleaned of any sediment or obstruction while the other two fed the plant, and during the winter months the waterways *B* and *C* may be used and the liability for interference from ice be lessened by the warm water discharging close to the intake. During the warmer months of the year waterways *A* and *C* could be used since they are placed at a considerable distance from each other.

CHAPTER IV.

CONDENSERS AND HEATERS.

BEFORE taking up any of the other systems for the station in question there will be considered the requirements for a condensing plant having an artesian well and using cooling towers and a surface condenser. The most difficult feature to contend with in connection with using cooled water is that arising from the use of oil in engine cylinders. This type of condensing plant retains all the solids and the objectional matter contained in the water because the vaporization due to cooling the water carries away only the pure water vapor. There is an opportunity for much study in regard to a system and apparatus to be used in such a condensing plant. The elevated jet type of condenser in which the circulating water is not used for boiler feeding is shown in Fig. 23. Artesian well water ordinarily contains large quantities of lime and magnesia,

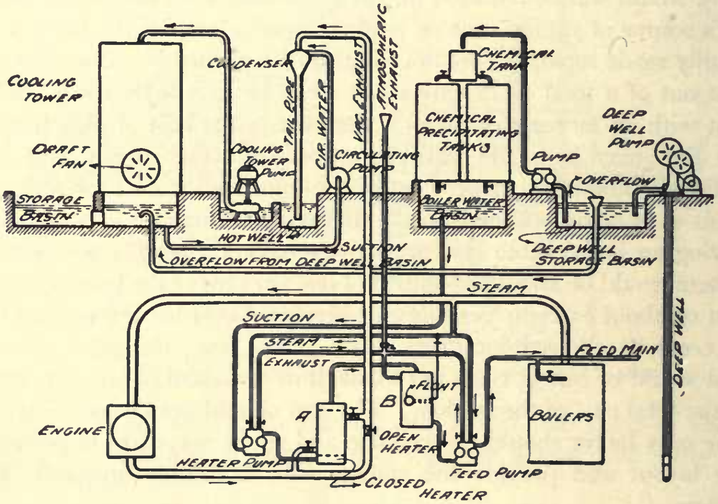

FIG. 23. Complex System; Artesian Water, Chemical Treatment, Cooling Tower, and Condensers.

making it necessary to remove these before feeding this water to the boilers. The amount of water in the form of vapor which would be lost while being cooled would be replaced chiefly by condensation added in the condenser and still more water would be added through a line from the deep well basin to the circulating pump. The loss in circulating water is greater than that required for the boilers, so the feed which requires the least addition will be treated. By treating the boiler feed direct from the well all difficulties from cylinder oil, etc., are avoided.

To retain the heat which would ordinarily be saved by using hot-well water a vacuum exhaust heater *A* and an open atmospheric exhaust heater *B* for additional heating would be used. Since the feed water temperature would be as low with this system as with any other condensing arrangement the using of economizers, though not shown in Fig. 23, should be considered. The system here shown is practical but very expensive both to install and operate. The additional expense of installation of the system shown in Fig. 23 would be:

1. Cost of sinking well, deep well machinery, building, etc.
2. Cost of chemical treating plant, building, pump, etc.
3. Cost of cooling tower, fans and motors, pump and motor and building for the tower installation.
4. Cost of vacuum exhaust heater, by-passes, etc.

The additional operating expenses would be:

1. Raising deep well water to its basin.
2. Raising water to chemical tanks.
3. Raising water to top of cooling tower.
4. Power to operate cooling fans.
5. Cost of chemicals for treating.
6. Increased labor to operate and maintain additional apparatus.

The arrangement shown in Fig. 23 may be simplified by using a surface instead of a jet condenser and omitting the use of the chemical treating plant. This will necessitate the installation of an extra large grease extractor in the exhaust main and a large filter bed in the heater. Fig. 24 shows such a system laid out so that repairs may be easily made. It will be noticed that the large water basin may be completely shut off by closing valves *A*, *B* and *C*, thus allowing water to raise in the cooling tower basin and flow back into the cold water basin. During the time when the cold water basin is used as a supply for the condensers, the house service including the

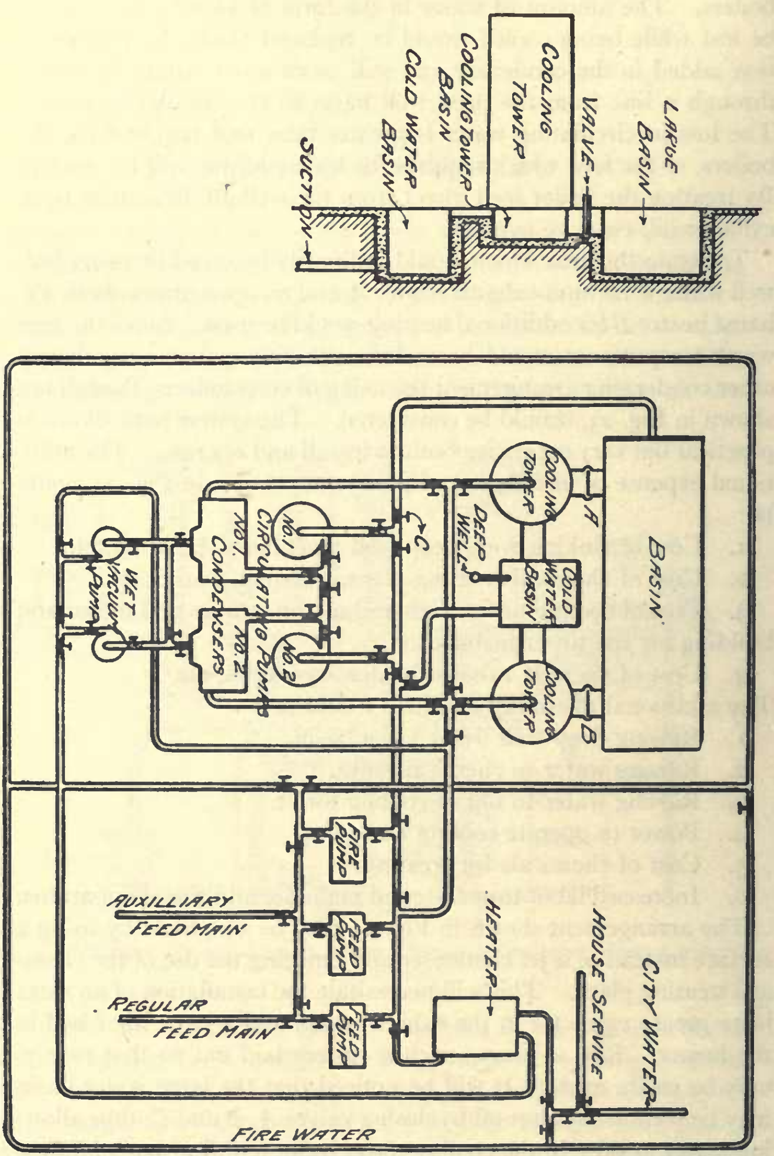

FIG. 24. System; Artesian Water, Surface Condensers, and Cooling Tower.

drinking and journal cooling water would be taken from the city water connection. During regular service the deep well pump would discharge into the cold water basin and the overflow would run into the cooling tower basin. The air traps at the water discharges of the cooling towers are not shown with the diagrams because no attempt is being made to show detail in connections. Note will also be taken that the heater and heater suction may be shut off and the wet vacuum pumps have another connection through which to discharge condensation to the pump suction other than by way of the heater. Any portion of the piping shown or any device may be shut off from service and one condenser still be run.

Particular note will also be taken in regard to cross connections from one machine to another, for instance if No. 1 condenser, circulating pump and wet vacuum pump be running and either of the pumps necessitates shutting down, it is then possible to put No. 2 machine into operation serving No. 1 condenser, and not shut down the No. 1 machine until No. 2 is in operation and supplying No. 1 condenser. When one condenser is out of service the other can be readily run and two circulating pumps used on it. This system enables perfect operation even though there be a circulating pump of one unit, and a condenser of the other unit out of service.

In a piping system there should be no machine piped direct to another without cross connections, so that the shutting down of one would require the shutting down of the other. There should be two separate sources of supply and two ways of discharge, with one machine on either end and the cross connections so arranged that either or both machines could use either supply or discharge. This is absolutely essential because it allows for repairing the pipe line or machines. The system shown in Fig. 24 is about the most satisfactory arrangement which can be laid out for an artesian well, cooling tower and condensing apparatus. The boilers would be fed with condensed steam and only that water lost by leakage at the joints, exhaust drips, etc., would need to be replaced. In a surface condensing plant the steam for the feed pumps would be somewhat differently arranged than in a jet condensing plant. The method of supplying water to the heater and steam pumps would be the same for a jet condenser plant as for a non-condensing station. This detail will be taken up later.

In the heater and pump arrangement for a surface condensing plant as in Fig. 25, the condensed steam from the condenser is free to be discharged into the heater and the speed of the pump is governed by the water level in the heater. The only hand control is a valve in the make-up water line. This line replaces the water which has been lost by leakage, drips, etc.; the loss is a steady, invariable quantity, therefore the valve requires but little attention when slight variations in the relative water level of two boilers may be controlled by the boiler feed valves. If during the day the fireman observes that the total water in all boilers is becoming low or high he slightly adjusts the make-up water valve. The advantage of this style of governing is that regulation is required for an almost constant demand caused by leakage, drips, etc. It is not practical with this style of condenser to leave the pump control to a fireman when he has no control of the incoming condensation. If so, it is fair to presume that fully one-third of the return condensation would go to the sewer. The object in using a surface condenser is to be able to save all the condensation for the boilers, thus using very little new water. This can be accomplished only by connecting the float valve to the pump steam connection, and if it is desired at any time to skim off the top of the heater water this can readily be done by shutting steam off the pump for a minute or so.

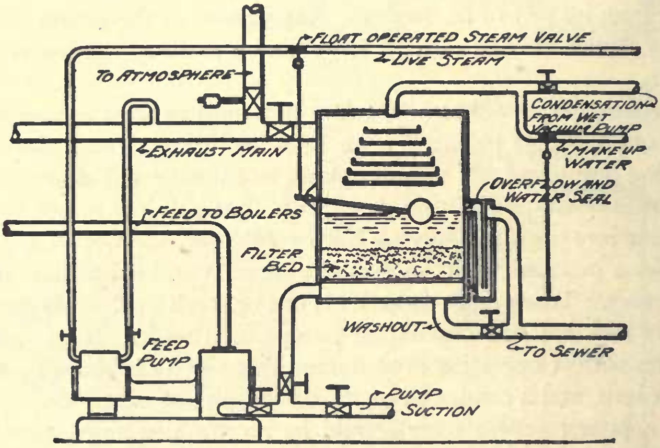

FIG. 25. System; Controlling Feed Pump, Open Heater, and Surface Condenser.

The heater manufacturer will possibly oppose this style of governing, claiming that it is not the regular method. For all other applications their method as shown by Fig. 26 is correct but for surface condenser it is radically wrong. The absurd claim is sometimes made that when a heavy load comes on, the boilers would evaporate water to a low water level and it should be possible for the fireman to speed up the pump in order to increase the water in the boilers. The velocity of steam in pipe lines should not be taken at less than 1,000 ft. per minute and with this speed it would take about five seconds for steam to leave the boiler, reach the condenser, and be condensed ready to deliver back to the heater. The fireman would not have time to even see the change in the boiler water level by the time the feed pumps were under control of the changed condition.

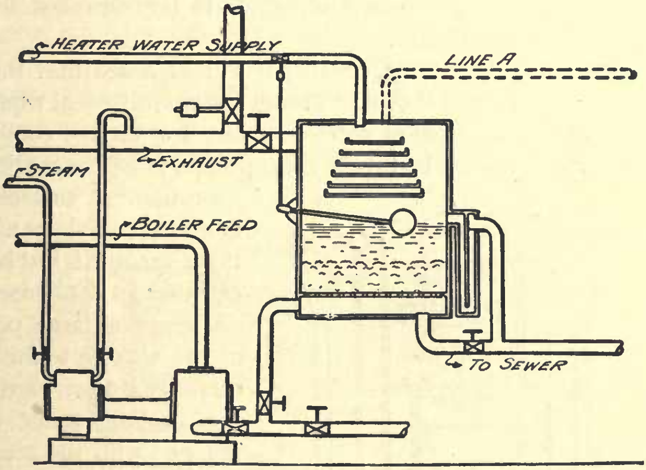

FIG. 26. System; Controlling Feed Pump, Open Heater, and Jet Condenser.

The system shown in Fig. 25 is not suitable for a non-condensing or for a jet condenser plant, but it is desirable for the returns of a heating system which is also a surface condenser. In Fig. 26 is shown the regular method of heater connections using a float control valve in the water supply line. Line *A* is the discharge from the steam traps, etc., which must be left open at all times. This would also be the discharge from the wet vacuum pump in case Fig. 26 were used for a surface condenser system. The line *A* should deliver to the heater a lesser amount than that required for the feed water because the boilers and the pump should never be run slower than is necessary to remove the incoming water from the heater. For the station in question since we are using jet condensers, we will use the system shown in Fig. 26, that is, the line *A* will be the discharge from the heater pumps and the float operated valve will be on a branch from the house service line. The float operated valve will be out of service for the greater part of the time during regular operation of the heater pumps, because these pumps will deliver to the heater the same amount of water as the feed pumps would take away. In case the heater pumps are not being used, the heater supply is to be controlled wholly by the float operated valve.

Referring to Figs. 22, 23, and 24 it will be noted that the dry vacuum pumps are not shown. The dry vacuum system would be the same for either style of condenser but if a surface condenser were used there should be two of these pumps to insure continuous operation. A surface condenser accumulates air until the vacuum is lost but an elevated jet condenser will discharge a large portion of the air due to the great quantity of downward flowing cooling water being mingled with the air. An elevated jet condenser will ordinarily drop its vacuum about 4 in. when running without the dry vacuum pump, in fact the syphon type elevated jet condenser is installed without an air pump operating at a slightly lower vacuum. Fig. 27 shows the two condensers piped to an air pump and having the valves placed as closely as possible to the pump in order that the number of joints and fittings between the shut-off valves and the pump may be reduced. To make repairs between the valves and pump necessitates shutting down the pump but any other repairs can be made and one condenser still be in operation.

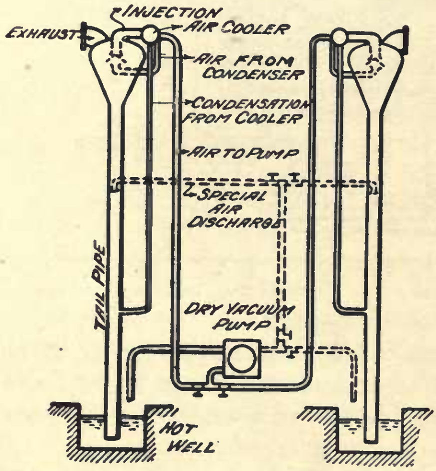

FIG. 27. System; Air from Elevated Jet Condenser to Dry Vacuum Pumps.

The air cooler drains back into the tail-pipe or hot well, the injection water passing through the cooler on its way to the condenser. The air pump is shown discharging over the hot well but may discharge over a sewer catch basin as there is no appreciable vapor. Another method is to discharge the air into the tail-pipe shown by the dotted lines. The advantage of this arrangement is that air showing, say 26 in. vacuum, is taken from the condenser bowl and discharged into the tail-pipe where it would show but 20 in. of vacuum; thus instead of compressing 7 cu. ft. to 1 cu. ft. as would be the case if exhausting to atmospheric pressure, it is necessary to compress but 2½ cu. ft. to 1 cu. ft. This arrangement would not permit raising the vacuum on the condenser when starting and the atmospheric vent would have to be used until the vacuum was on the condenser and the water flowing through the injector shaped air discharge in the tail-pipe. The air cooler shown is used on jet condensers only, the surface condensers admit the cooling water to the condensing tubes in contact with the outgoing air. In addition to cooling the air it is also necessary to cool the air cylinders of the dry vacuum pump, otherwise the high temperature due to compression will prevent proper lubrication.

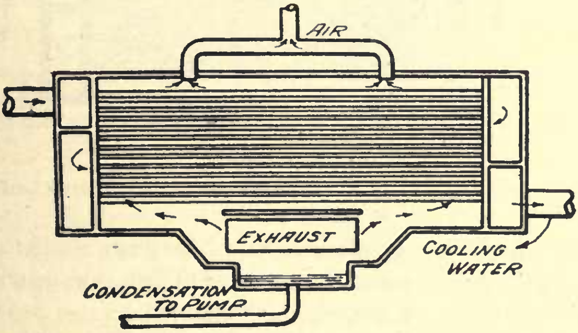

FIG. 28. System; Removing Air from Counter Current Surface Condensers.

Different methods are used for removing the air from surface condensers. Fig. 28 shows the counter current system. The exhaust steam enters beneath the cooling tubes and the air is withdrawn from the top of the condenser. The condensation makes its last pass over the hottest tubes and therefore through highest temperature in the condenser. The air which is removed from the upper portion of the condenser by the action of an air pump is in contact with the tubes which contain the cold incoming circulating water. Evidently the air must be in a continual state of unrest due to the counter current action. The weight of saturated air at the temperature in a condenser is about 0.06 lb. and steam about 0.03 lb., per cu. ft. If it were not for the exhaust steam entering the lower part of the condenser and being deflected over the entire base it would be possible for air to settle to the base of the condenser, but instead it can drop only into the current of incoming steam and therefore be constantly carried upward. Air cannot remain in pockets at the upper portion of the shell because it is heavier than steam and will therefore drop and be caught in the steam current.

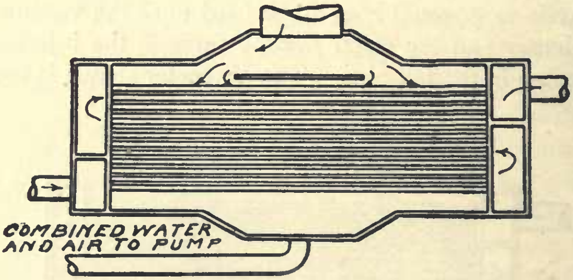

FIG. 29. System; Removing Air from Direct Current Surface Condensers.

The fact that this type of condenser has shown itself to be very effective is sufficient proof of the merits of this most unusual method for removing air from a condensing chamber.

A more usual type of condenser is shown in Fig. 29; the exhaust enters the top and together with air passes towards the bottom of the condenser, the air dropping to the base of the condenser and "flowing" away with the condensation. It is not the intention here to give the "selling points" of different types of apparatus but these two styles of condensers differ so greatly in their system for removing air that they have been described. In fact, the elevated jet type of condensers is also made in these two styles. In the counter current type, the steam enters below the water spray and flows upward retarding instead of accelerating the fall of the injector water after leaving the spray pan. The air is taken from the upper portion of the chamber instead of the lower as the steam entering the lower portion prevents the air from precipitating. This method of removing air must be more effective for both jet and surface type condenser judging by the excellent results obtained from them.

In removing air from either an open or closed exhaust heater having an insufficient supply of steam, the air should be led off at the water line and not at the top of the steam chamber. In cases where all or a large portion of the steam from a non-condensing plant passes through the heater, air will be removed by the rapid flow of the steam, provided the openings in the heater are properly arranged. Fig. 30 shows an ordinary heater connection which is radically wrong, the small air vent *A* being wrongly placed, so that the flow through the side and top connection is very slight; in fact, too slight to carry out air by the velocity flow through the heater. The correct method is shown in Fig. 31, which may appear wrong until more fully considered. The exhaust enters the top and causing no eddy currents will drop to the water line and if the valve *B* is open will pass away to a point of lower pressure.

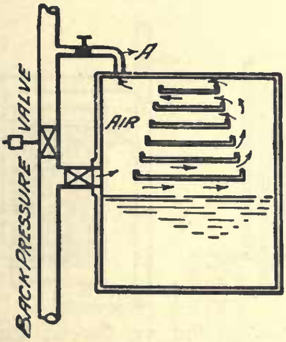

FIG. 30. System; Improperly Arranged for Removing Air from an Induction Open Heater of Insufficient Steam Supply.

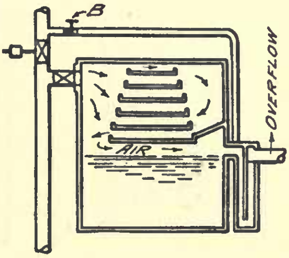

FIG. 31. System; Properly Arranged to Remove Air in Open Heater of Insufficient Steam Supply.

Heaters can also be styled direct and counter current, the same as jet or surface condensers, or open spray or closed tube type of heater. Figs. 32 and 33 show the counter current type, the air being constantly in a state of unrest and due to the large volume of surplus exhaust passing to the atmosphere the air will drop into the current of the steam and be

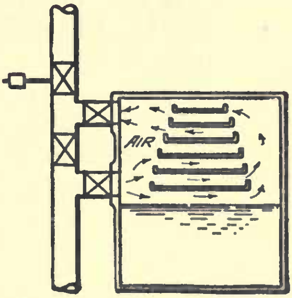

FIG. 32. System; Passing Entire Volume Steam through Open Heater.

carried out of the heater. This type of connection would show better efficiency than Fig. 35 because as in counter current surface condensers air would not be carried to a point where it would remain stagnant and thus insulate any heat conducting surface. The heaters shown in Figs. 31 and 34 are specially suited for use in condensing plants where the amount of exhaust steam supplied the heater is too slight to cause enough upward flow to carry air with it. The valve *B*, shown in Fig. 31 and Fig. 34, should be of a globe or gate type and not a back pressure valve as it is very necessary to prevent a vacuum on the heater unless the apparatus is specially arranged to stand such pressure. The heaters shown in Figs. 32 and 33 are specially suited for use where there is sufficient exhaust to maintain pressure in heater above that of the atmosphere.

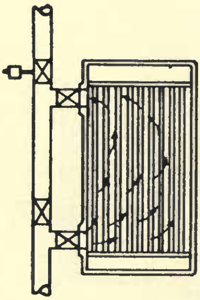

FIG. 33. System; Passing Entire Volume Steam through Closed Heater.

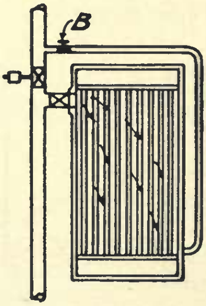

FIG. 34. System; Passing Small Volume Steam into Closed Heater.

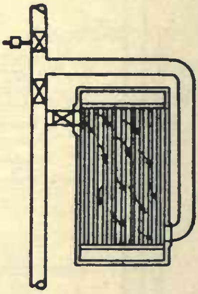

FIG. 35. System; Passing Entire Steam improperly through Closed Heater.

CHAPTER V.

LIVE STEAM DRIPS.

THE system for supplying live steam will next be considered and with this topic live steam drips will be described. A general arrangement which will serve these purposes is illustrated in a preliminary way by Fig. 10, the different lines being subject to revision upon more careful consideration. The general detail of the location of the drips will now be considered, even before determining the main steam connections.

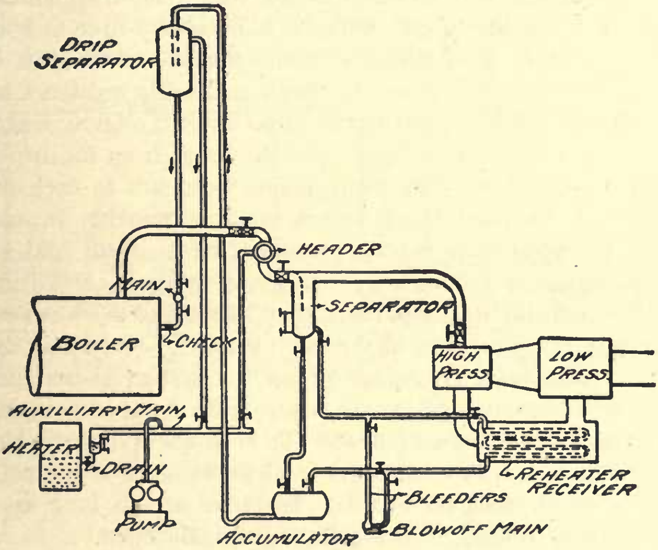

FIG. 36. System; Gravity Return of Steam Drips.

In Fig. 36 is illustrated a gravity drip return system. The branches of the piping system which carry live steam from the boilers drain into the header and this in turn drains into the separators which are placed in the engine branches. The steam used in the low pressure reheater receiver is led off a short distance above the bottom of the separators and, as shown in Fig. 36, the separator drips are run to an accumulator, each pipe having a regulating valve in it. If by accident the drain leading off from the bottom of the separator be closed too much to take away the drip, then a passage will still be open by way of the pipe to the reheater receiver and thence to the accumulator. The elevated drip separator is placed at a sufficient height to insure that the drip will flow into the boilers.

For part or all of the auxiliaries steam is taken from the upper portion of the receiver and the small amount of condensation which may be in the auxiliary main is led to the heater by means of a bleeder or trap.

In operating this system where there are, say, 10 connections into the accumulator, two for each of the four generating units and one for each of the exciter units, it is necessary that each drain be sufficiently open to permit draining the line to which it is attached, but sufficiently closed to offer a noticeable resistance to the flow, thus allowing the auxiliaries to be under a slightly less pressure than the main steam line. The discharge from the drip separator is carried to a drip main having branches to each of the boilers and stop and check valves in each branch. In such a system the difference in the pressures in separator and steam header is greatest just before a "slug" of water is carried up the standpipe into the drip separator, then as soon as the water is out of the way the difference in the two pressures is only that due to friction. The chief advantage of such a system is that neither floats nor automatic devices are required for its operation, in fact there is no mechanism employed. To start the system the bleeder to the heater is opened in order to clear the lines to the point of receiving steam, then the auxiliary is started and as long as there are auxiliaries running this system will remain open.

Another method of returning drips to the boilers, illustrated in Fig. 37, is by using a drip receiver in which is placed a float so connected that it regulates the speed of the pump. This system has the advantage that it is easily understood and therefore will be more likely to be operated properly than the system shown in Fig. 36, which requires someone to instruct the attendants what to do and see that these instructions are properly obeyed. Careful watch must be kept over the system shown in Fig. 36 if the drip is to be returned to the boilers and not be wasted into the sewer.

The difference in the costs of these two systems is not sufficient to be considered. The initial cost of the system shown in Fig. 37 is less than that of Fig. 36, but the maintenance for Fig. 37 is greater. The maintenance for Fig. 36 is very slight.

There is still another system which combines as low first cost, low maintenance cost, simplicity and high efficiency as can be arranged for a condensing plant not using economizers. This system is illustrated in Fig. 38 and discharges the drip into an open heater when so arranged that exhaust steam and drips do not raise the temperature to 210 degrees, thereby allowing a waste of steam. Traps are not very desirable pieces of station apparatus, but by using two as shown and the by-passes, a very reliable system is obtained.

It will be noticed that Figs. 36 and 37 show steam drips discharging direct to the boilers and not by way of the feed main. This is an essential feature because the feed main pressure may be lowered at any time until it becomes less than the steam pressure. Such a condition may be caused by the stopping of the feed pump, thus allowing the water pressure to escape through the pump valves, or it may be due to the filling of an empty boiler, or the blowing off of an economizer. In any case, whenever the pressure in the feed main is lower than the steam pressure, the steam if not checked will force the feed water back and cause very serious damage. An automatic pump between the steam and feed lines is no barrier whatever, because the steam at boiler pressure will open and pass through the pump valves, even when the pump is not running. For the same reason an automatic drip pump cannot be used to discharge into an open heater or another receptacle which is under less than boiler pressure. The discharge pressure

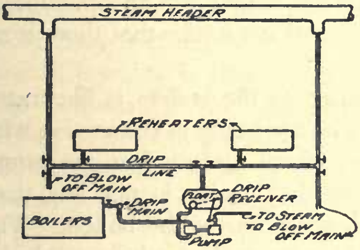

FIG. 37. System; Return of Steam Drips by Pump.

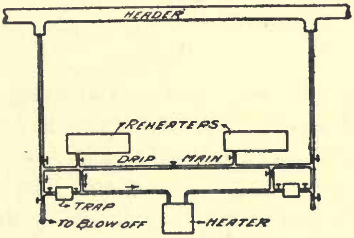

FIG. 38. System; Discharge of Steam Drips to Heater by Trap.

must always be greater than the suction, even though it be caused by only a short column of water additional. The discharge line from the automatic pump should have a relief valve placed between the pump and any valve that may be placed in this line, and the discharge should then be piped to a catch basin where the end of the pipe is open so that any discharge which is taking place may be seen. This relief valve is very essential in order that the pump and pipe line may be protected in case all discharge valves should be closed. It is possible for the automatic pump, which receives its suction under boiler pressure, to more than double the steam pressure on a discharge ; the steam end of the pump ordinarily has twice the area of the water end and therefore when the steam pressure is but 175 lb. per sq. in. a pressure of from 350 to 400 lb. per sq. in. can easily be obtained in case the discharge pipe is closed. Unless the lines and pumps be built for such pressures breakdowns must occur, because when shutting down the boiler it is quite a simple oversight for an operator to close the automatic pump discharge and not notice that there is no other way of discharge.

Another method of returning drips to the boilers is illustrated in Fig. 39. This arrangement can be used only in connection with single acting pumps and in systems where there is but one pump on the line and the header is not less than 5 ft. above the water line of the boilers. The operation of this system is made possible by the pulsating pressure which is present during the operation of single acting pumps. If such pumps carried a uniform pressure this system would not be feasible. A single acting pump discharges a cylinder full of water, then stops at the end of the stroke and the inertia of the water is only overcome by meeting the boiler-water which has a higher pressure; while the discharge from the pump is being brought to a state of rest and the pressure in the part of the system next to the pump is lower than the boiler pressure, the drip line which is at boiler pressure flows into this part of the system and before the returning stroke of the pump, the pressure in the discharge is again returned to boiler pressure. For a small installation this method of draining the steam main would appeal to an engineer on account of

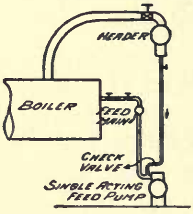

FIG. 39. System; Return of Steam Drips by Pulsation of Feed Pump.

its extreme simplicity, but for a large plant it might be found difficult to maintain the entire arrangement as shown. This pounding action in the feed mains would not be considered very favorably in large station work, and without the pounding this system would necessarily be inoperative. This system also has a bad feature because it discharges into the feed main and not into the boiler direct.

For the station being studied, Fig. 36 may be used as the drip system, and when this figure is arranged in a flexible form it appears as shown in Fig. 40. It will be noted that any or all of the auxiliaries can be supplied with steam through this drip system. Ordinarily steam required for one or two of these machines should be taken from the drip system, to avoid reducing the pressure in the drip separator to such a point that the drips will not flow back to the boiler. In event that no auxiliary is taking steam from the circulation pipe *A* it would be necessary to blow steam into the heater or to the atmosphere, and unless this operation is properly carried out the steam thus blown through the system would be more than that required to run a portion of the auxiliaries. In riser *B* pressure is required to elevate the drips, as is a pressure also necessary in the drip separator to return the drips to the boiler. The pressure in the separator, however, is but very few pounds less than boiler pressure, and so within the maximum and minimum limits of the allowable flow of line *B* the return of drips is possible.

In case the steam for one fan engine is found sufficient to handle the drips, valve *C* may be closed; in case the fan engine requires more steam than can pass through lines *B* and *A*, and at the same time maintain sufficient pressure in the drip separator to discharge water to the boilers, it would be possible to make *C* a reducing valve allowing, say, 3 lb. difference on the two sides of the valve, thus furnishing a portion of the steam for the fan engine direct from the auxiliary steam header. This reducing valve may be placed at *D* in the branches from the main header, thereby keeping the entire auxiliary steam main at about 3 lb. lower pressure than the main steam header. Such a reducing valve may be a heavy cushion check valve and if the port has a diameter of 4 in., the valve would weigh about 40 lb., or the valve could be spring loaded, the same as a safety valve. With reducing valves at the points marked *D*, the system would at all times be ready for opera-

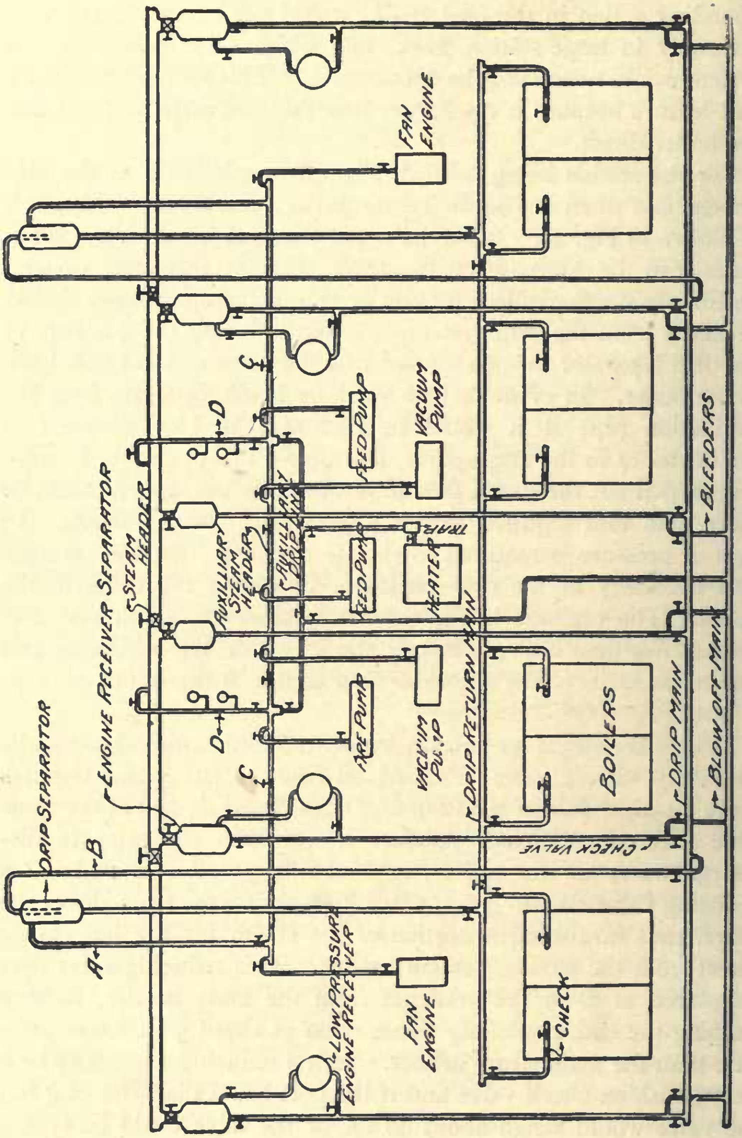

Fig. 40. System; Steam, Boiler Feed, and Gravity Drip Return.

tion. Even after shutting down, in case there should be one pump running very slowly, this pump would be able to take steam through the drip system, and if the fire pump should at any time be put into full service the two relief valves would open and supply the auxiliary main. By placing the reducing valves at *D* there is no danger of their being opened and the pressure run up on the drip system.

The characteristic features of this system are a live steam main well drained to a low down drip main, an auxiliary steam main independently drained to the heater, an overhead receiver into which drips discharge, a connection from the drip receiver to the auxiliary steam mains, and a connection from the main header through a resistance to the auxiliary steam main, this resistance preventing steam from flowing except when the auxiliary main pressure and the receiver pressure are enough lower than the boiler pressure to overcome the resistance and allow water to be returned to the boilers. In Fig. 41 are shown the receiver drip pumps and the low down auxiliary steam main, which main is large and serves for both the drip and steam mains. This system is well drained and has the characteristic that before any damage could be done to the high speed or large units, trouble will make itself known by a cracking noise of water in the steam pumps and piping, but without any liability of injuring them.

The main point to consider in the disposal of steam drips is to keep them away from the large units, and any system that will do this under all circumstances, even though it causes stoker engines, pumps and other auxiliaries to stop during the flooding, is far more preferable than a system which would flood the main units in case the removal of the drips be obstructed.

The system as shown in Fig. 41 would consist primarily of the main steam header and the auxiliary header, the auxiliary header being supplied with steam through the drip openings in the main engine receivers. The steam branches to the auxiliaries are taken off the top of the auxiliary steam main and drains are led from the bottom of the auxiliary steam main to the receiver of the drip pumps. Emergency connections should be made from the auxiliary main to the heater and to the blow-off main so that they can be used in case the lines become flooded. This style of drainage has the great advantage that by means of the cracking noise the auxiliaries are positive indicators of the operation of the drip system.

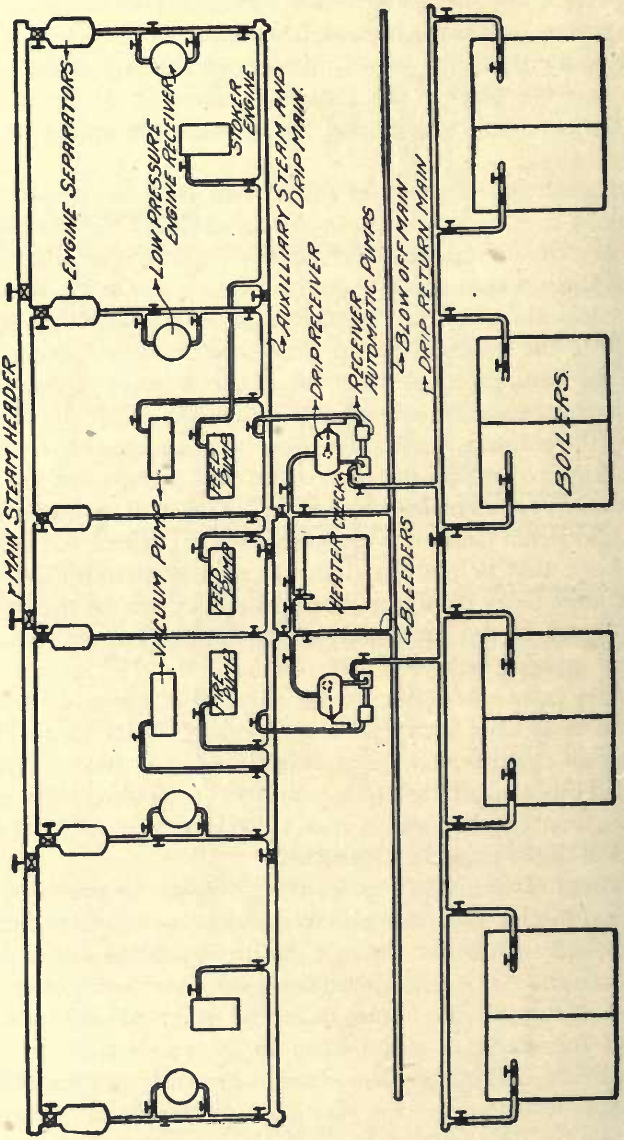

FIG. 41. System; Steam, Boiler Feed, and Receiver Pump Drip Return.

The auxiliary main shown in Fig. 41 would necessarily be placed below the reheater drain.

The reheater as ordinarily placed between the high and low pressure cylinders brings into the station layout a very troublesome detail. An ordinary form of reheater construction is a copper pipe coil with the inlet and outlet of the same size as the opening in the pipe and by using a small size tube for this coil of a very long length, a marked drop in the pressure as measured at the two ends of the coil is obtained. To drain properly such a reheater it is necessary to place the drip main far enough below the heater to provide a gravity column which will make up for the pressure lost in the reheater. If the reheater used were of a pattern similar to the bent U-shaped tube closed heater, there would be an ample area for steam flow and therefore no appreciable drop in the pressure. The receiver should be placed horizontally and as high as possible so that the drips can be properly taken care of. If an automatic receiver pump as illustrated in Fig. 41 is to be used, the intermediate engine receiver must be kept close to the underside of the floor as shown in Fig. 42. This is necessary for two reasons — to

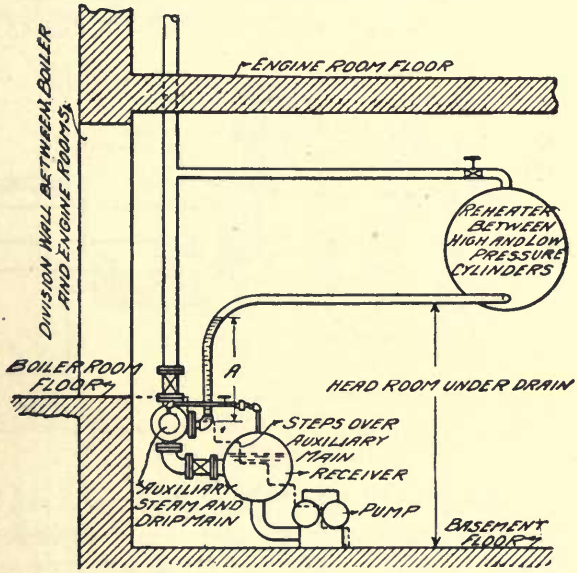

FIG. 42. System; Collecting Steam Drips of slightly Varying Pressures.

give ample head room between the basement floor and the reheater drip outlet, and to provide a sufficient gravity leg, *A*, to overcome the pressure loss in the reheater. In case the boiler room floor line is but a foot or so above the basement floor it would then be necessary to place the automatic pumps in a pit, instead of on the basement floor as shown in Fig. 42.

Unfortunately engine builders are not skilled pipe fitters or they would use better designed connections between their high and low pressure cylinders, and also place their reheaters at a relatively higher level. The reheater connection shown in Fig. 43 is a very simple arrangement which has the advantage that it can be varied about ¼ in. either way between the centers of the cylinder connections. This variation is obtained in the bolt holes at joints *a*, *b*, *c*, and *d*; if *a* is even three-quarter inches higher or lower than *d*, the receiver can be kept level by sliding the joints on their faces at *b*, *c*, *e*, *f*, *g*, and *h*. The bolt holes should be one-eighth inch larger than the bolts. It is advisable for the engineer to arrange this detail when the engine is ordered because it is very difficult to make a satisfactory drainage system if a vertical receiver in the basement must be used, or if for any other reason the receivers should have their drain openings close to the floor.

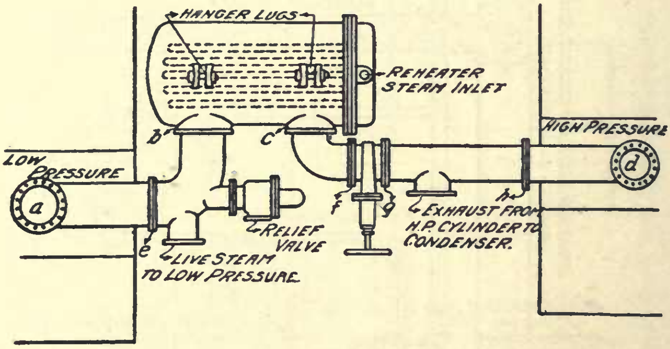

FIG. 43. System; Supporting Engine Reheaters to give Sufficient Head for Drip Flow.

The low down auxiliary steam and drip main can be used with the gravity return as well as with the receiver pump. Fig. 44 shows such a main with a reducing valve at *A*. The pipe lines for the drain system as shown need be only of sufficient size to handle the drains, because when the plant is running one fan

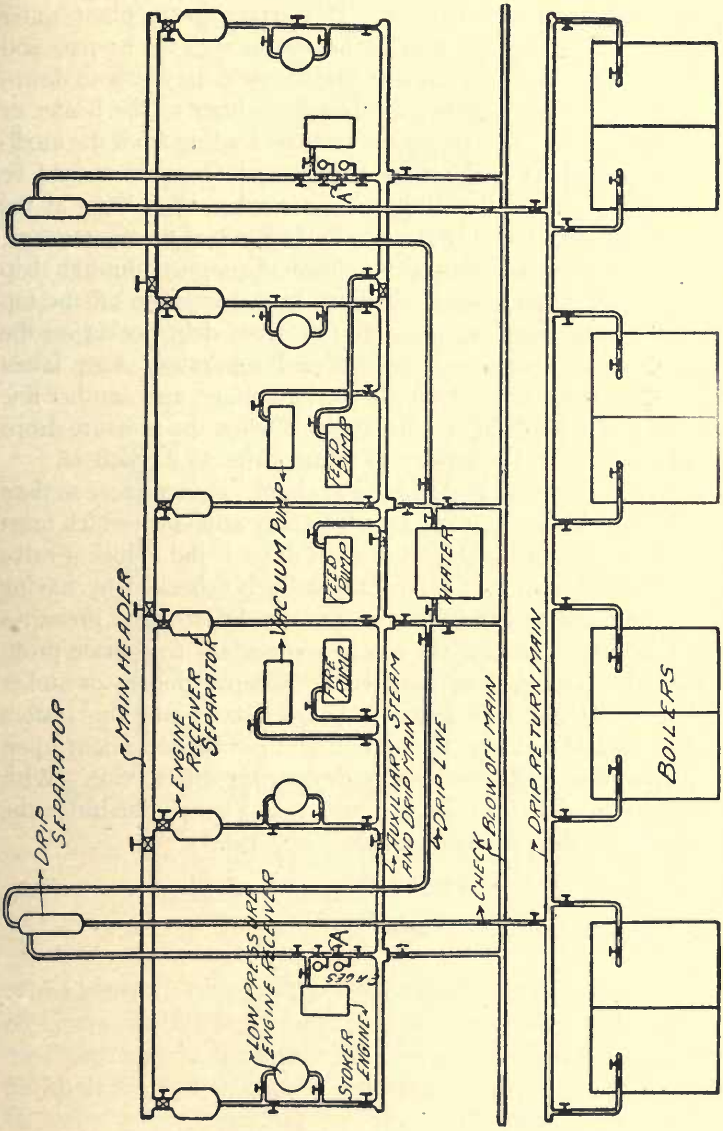

FIG. 44. Sample System; Steam and Gravity Drip Return to Boilers.

engine must also run and this will take care of the drips. When the fan engine is shut down the condensation in the riser pipe will drop back into the auxiliary main. In starting up the plant, water can be run out of this main into the heater through the by-pass and any section of the auxiliary main or drain system may be shut down, and the drips be run through the bleeders either to the heater or the blow-off main. The steam connections leading from the auxiliary main should be long radius fittings and the main should be large enough to avoid the lifting of the condensation lying at the bottom of the line. The characteristic features of this system are, main steam header, auxiliary steam headers supplied through drip openings of the main header, auxiliary branches taken off the top of the auxiliary main, connection run from drip pocket on the under side of auxiliary main to overhead separator, steam taken from this separator to a constantly used auxiliary, and another line run to this auxiliary which will supply it when the pressure drops below the set amount necessary to return drips to the boilers.

The system shown in Fig. 44 is quite simple, in fact, more so than that shown in either Fig. 40 or 41. The only appliance which must constantly be watched and kept in good order is the reducing valve and the operation of this valve can easily be checked by having gages on both sides of the valve so that the difference in pressures can be observed. In case the return system fails to operate properly the drips will give warning in the pump cylinders or stoker engines. This is a very valuable characteristic and the system should be so laid out that the station will not be dependent upon steam traps, bleeders or automatic devices for this service. With these things in view let it be assumed that Fig. 44 illustrates the drip system for the proposed station.

CHAPTER VI.

BLOW-OFF AND EXHAUST PIPING.

Blow-Off Piping. A blow-off system is the next to be studied, and although this may seem but a minor matter, if it is not properly laid out it will be a major torment. A blow-off system is primarily arranged for the purpose of removing the water and precipitation from the lower parts of the boilers, economizers and similar parts of the general system. The difficulties to be overcome in a blow-off system are the sudden changes in temperature with their attendant expansion and contraction stresses, the providing of a means for liberating the vapors and reducing the temperature of the blow-off water before it reaches the sewer, and finally the providing for the repairing of underground work which must be left free to expand and contract. Fig. 45 shows a blow-off system for the proposed station. The blow-off cisterns should be located about

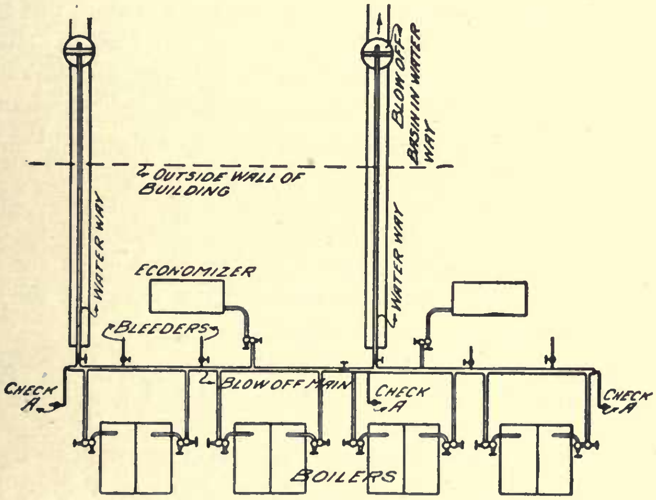

FIG. 45. Sample System; High Pressure Blow-off Lines.

fifty feet from the building and the system should be operative with the use of one basin only, because the other may be used for an intake as shown in Fig. 22.

The underside of the partition and the bottom of the cistern should be about six inches, and four feet, respectively, below the bottom of the water way, with the blow-off pipe pointed towards but not carried into the water way. The different blow-off lines should be free to move longitudinally or transversely, and the ends at the cistern should be passed through a metal sleeve which will permit free expansion. It is safe to say that a blow-off line keeps moving continually. If trouble is to be averted the branches to the boilers must be long. There is less trouble from water-hammer in pipes if the discharge end is above the water line; otherwise the water at boiler temperature expands to steam which drives the water out of the line, then, as soon as the valve is shut, this steam condenses and draws the water back into the pipe in "slugs." When these slugs strike the bends in the pipe line the sides of the fittings are often broken. The strains produced by water-hammer are wholly distinct and foreign to the pressure carried in the pipe, in fact, a line open to atmosphere can be damaged greatly by water-hammer. The writer has knowledge of a 14-in. exhaust elbow, about five-eighths inch thickness of metal, which had its entire side broken out by water-hammer, the strain being much the same as though a man had struck the fitting with a sledge of the same weight and moving at the same velocity as the water.

If it is necessary to place the end of the blow-off discharge below the water, then check valves, marked *A* in Fig. 45, should be placed in the line to break the vacuum formed. These checks should be placed above the main. Air cushions could be used to prevent the hammering but unless they were placed at every point where the direction of flow is changed they would be useless. This method would be quite impractical with such a system as is shown in Fig. 34, because the direction of flow would be greatly changed when shifting the discharge outlet from one cistern to the other. Check valves are inexpensive and reduce the back water flow very materially by filling the main with air, thus causing an air cushion, and it is a good plan to place check valves on the line, even though the main discharges are above the water, but such valves may be of somewhat smaller size.

While washing a boiler through the blow-off valve, this valve must necessarily be left open. For this reason, two blow-off valves for each boiler are shown in Fig. 45, and with this arrangement the valve farthest from the boiler can be used to shut off the main when the boiler is being cleaned. The center piece of the valve close to the boiler meanwhile can be removed, thus allowing the wash-water to flow to the sewer instead of to the blow-off main. This arrangement avoids the possibility of a fireman's blowing off his boiler and thus scalding a boiler cleaner who at the same time may be working on the other boiler, and it has the added advantage that by keeping the wash-water out of the blow-off line there is less liability of this line becoming blocked with scale. In case the outer operating valve leaks, the inner valve may be closed and the outer valve repaired while the pressure is on. Details of valves arranged for washout and also details of the blow-off cistern will be given later.

The branches from the blow-off main to the boiler must have ample length of pipe in them to allow for expansion and contraction. The blow-off for the problem station would be about 175 ft. long and at extreme temperatures would differ in length about 4 in., but by anchoring this main at the center, either end would travel only about 2 in. It is a very common practice to run short, stiff boiler connections to the blow-off main. This is often a source of trouble because 2 in. of movement at the end of the main requires at least 12 ft. of 2½-in. pipe for the boiler branch in order to provide a safe swing.

It may be desired to run the water column drains into a large funnel and pipe the funnel to the boiler blow-off branch, tapping in between the blow-off valves and blow-off main. In order to prevent the blow-off from backing through the funnel there should be a check valve in the pipe leading away from the funnel. If the funnels are placed at each boiler, it will not be necessary to provide vacuum breaking checks in the main because the eight funnel drain checks will serve the same purpose.

In blowing off the economizer, care should be taken that the valves are operated to suit the control of the feed pump because if the pump is controlled by feed pressure, time should be given it to increase in speed and so, by opening the valve slowly, maintain the pressure on the economizer. Located within sight of the operator of the economizer blow-off there should be a gage with a three-way cock, one pressure pipe running to the header and the other to the top of the economizer. The operator can note the steam pressure, then throw the cock to the economizer pressure and, while blowing, not allow the pressure to drop below a point which will cause the economizer to generate steam, which pressure can be determined by observing the temperature of the water. This is one of the most delicate features of economizer operation. The feed pump cannot ordinarily supply water as fast as it can be blown off, so when closing the blow-off, the operator should note the pressure and by closing the valve slowly, give the pump time to slow down under its own control. Closing the blow-off quickly while the pump is working at high speed will throw excessive pressures and strains on the economizer.

The method of blowing off an economizer should be well understood and carefully followed to avoid serious losses due to breaking economizer tubes or headers. For instance, let it be assumed that the plant has been worked hard and the feed to the economizer is taken from the hot well or small heater, the gas temperature being high and the economizer very warm. Now, if the economizer is blown off under these conditions, there will be a very sudden change of pressure and a great possibility of cracking the economizer tubes. The correct method of operation is to go down the line of boilers and blow them off one by one, allowing the pump to run at a high speed, and by the time the boilers are filled again the economizer will be cooled to such an extent that the incoming water will not subject it to very severe strains and, as the temperature is down, the blow-off can now be opened, allowing the economizer pressure to drop to a low point without making steam. If steam is generated, the condensation of this steam causes water-hammer, which is always productive of trouble wherever it occurs. An economizer can give very good or bad results, being dependent entirely upon its design, system of installation and operation.

The blow-off cisterns should have a large open grating at the top to allow the escape of steam, and if this cistern be close to or in the building, it should be supplied with a very large pipe to carry off the steam. The sewer connection should have a deep water seal to prevent steam from blowing into the sewer. Water leaving the boilers at 160-lb. pressure will vaporize 1 lb. out of every 7.5 lb. blown off. This makes 3.5 cu. ft. of steam for each pound of blow-off water, or 219 times as much volume of steam passing out of the top of the blow-off cistern as there is water passing through the sewer. During a blow-off period there will not ordinarily be blown off more than 75 lb. of water per second and 10 lb. of this will be in the form of steam. The atmospheric exhausts for engines are generally arranged with a capacity of about 4 lb. per second per square foot of sectional area. This requires a vent pipe having not less than 2.5 sq. ft. cross sectional area for an engine, but since this flow is steady, we can make the pipe of about 1.25 sq. ft. cross sectional area, or the diameter of the vent pipe would be approximately 16 in. In case the blow-off cistern is very large, the water in it may then have time to cool and so there will not be as much vapor as just stated. This, however, would help matters only a portion of the time, because, when a second boiler is being blown off, immediately following the first, the blow-off will meet water which is of such a temperature that it will not take up any heat without vaporizing and then the full amount of vapor will be formed. The chief object in retaining the water in the cistern is to break up the force of the discharge and thus avoid cutting a hole in the cistern by the disintegrating action of the water of high temperature being directed at one point.

It may be found desirable to provide for taking care of still other drains in preference to discharging them into the sewer, such as the high temperature low-pressure drips from exhaust lines, intermediate receiver drips, heater overflow, washout for oil tanks, etc. Since these drains are located at low level, it would hardly be possible to keep them above the floor without their becoming an obstruction in the engine room. These lines should be made of heavy cast iron soil pipe with the joints well calked and laid in and filled around with sand so that expansion and contraction may take place freely without damaging the calked joints.

A mixed system for taking care of these other drips is shown in Fig. 46; line *A* takes receiver drips, also exhausts drips and oil washout. No catch basins are connected to this line because the question of expansion and contraction would be difficult to arrange for where the lines enter the basins. The line and branches are of iron pipe, calked, and since there would be considerable vapor if any connections were left open, the entire line is made tight and the discharge is dropped into a sump at the bottom of the waste water way. The elbows of this line should be arranged as shown in Fig. 46, so that they may expand without trouble at the joints or at the floor. Line *B* is a regular floor drain and may be of sewer tile and arranged to discharge into the waste water way. Line *C* is of cast iron pipe but, as it is not subjected to very high temperatures, about 170 degrees at the most, the catch basin and drain connections are made into this line. Very little oil passes through this line and a loose joint is not a serious matter. There is no essential reason for duplicating or cross connecting this class of mains, not because they are unimportant, but because they are not under pressure and so can be discharged directly on the engine room floor until any necessary repair is made. Wherever possible, an open gutter should be run alongside of the wall, because such drains can easily be cleaned without interfering in the least with operation. The details of such a gutter will be shown later.

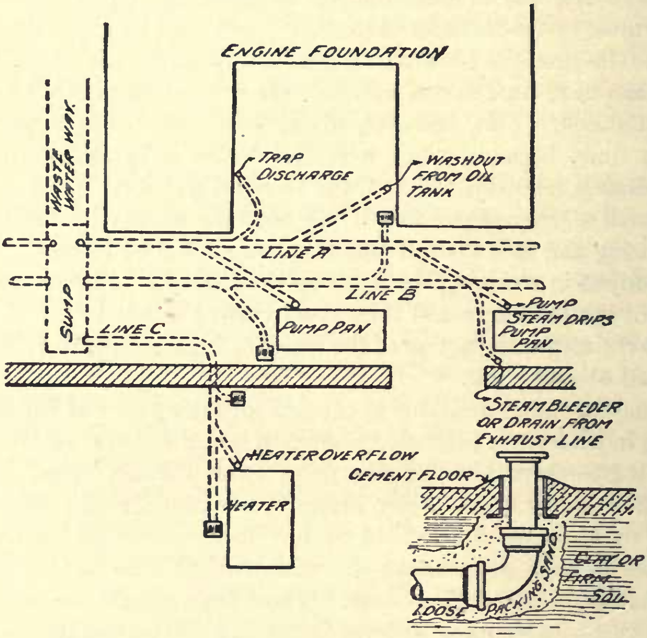

FIG. 46. Sample System; Low Pressure Blow-off Lines.

Exhaust Piping. The next division of the subject which will be taken up is that describing the main engine exhaust lines. In Fig. 10 is shown the general arrangement of the proposed station. The arrangement of the condensers is illustrated by Fig. 22. The problem now in hand is the carrying away of the exhaust steam for six engines and two condensers, realizing that there must always be in operation three large engines, one condenser and one exciter engine.

An arrangement of the exhaust piping which meets the conditions of the problem is illustrated in Fig. 47. These connections permit the repairing of any portion of the vacuum main or branches without necessitating the shutting down of more than one large unit, and always allowing one exciter engine to be run. The atmospheric exhaust main is shown on the drawing by dotted lines, and would not ordinarily be used. The use of one large exhaust main for regular operation of several engines is not as economical in first cost, nor as safe to operate, as individual atmospheric exhaust lines. A method of laying out a large atmospheric main, which would be accessible for repairs at all times, and which would neither furnish a chance for the engine to lose its vacuum nor injure a man by exhausting onto him, is illustrated in Fig. 48. If the connections were all led into the large main without provision being made for dividing this main into sections, the probabilities are that in case of repairs being necessary on the main branches or atmospheric valves, a shutdown would be necessary, but if the main is designed with the proper allowance for expansion and well built of amply heavy materials, there would undoubtedly no trouble arise which could not be remedied before the vacuum

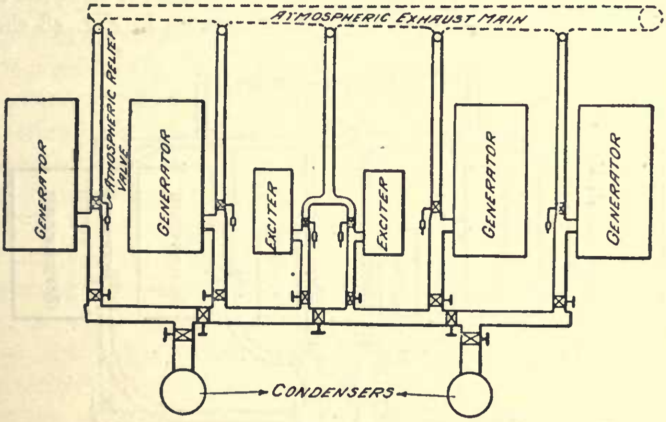

FIG. 47. System; Engine Exhaust to Condensers and Exhaust Main with Undesirable Features.

was affected. However, as the idea from the first has been that a station should be designed so that any portion of it might be shut down for several days, if necessary, and the rest of the machinery care for the regular operation, let this idea still remain foremost. Then Fig. 48 is the best piping system for the exhaust mains, and if desired the condensers may be located in the center of the station as shown in this figure. The general piping system illustrated in Figs. 47 and 48 is the same, these figures differing only in the location of the lines. The curved piping as shown in Fig. 48 should never be used if there is the least possibility of additions ever being made to the station. A better method would be to finish the ends of all lines running lengthwise of the plant with T's having blind flanges ready for future additions. Such a modification is shown by the dotted lines in Fig. 48.

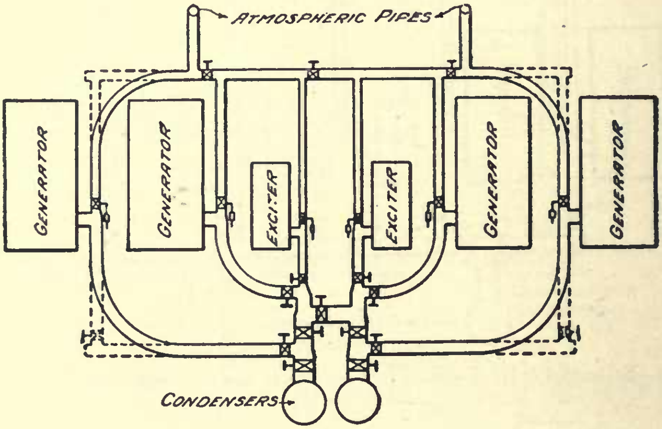

FIG. 48. Sample System; Engine Exhaust to Condensers and Exhaust Main with Undesirable Features.

The next subject to be considered is the exhaust piping for the auxiliary machinery. It is not unusual to find the auxiliaries piped with double connections, so that they may be run either condensing or non-condensing, and exciter engines are also arranged so that they may be connected to the heater. Such systems are never flexible or economical. Consider, for instance, the proposed station: The auxiliaries in this station are the steam pumps, two of which are required to do quite light work, an air pump which uses steam economically, and the compound fan engines, which are also economical machines. The heaters taking steam from these auxiliaries will, by taking water from the hot well at about 95 degrees, raise its temperature to 170 or 180 degrees. In this station, in addition to exciting the main generators, the exciter unit would be called upon to furnish current for all the electrical requirements of the station, such as lighting system, circulating pump, motors, air compressor, blast fan for transformers, crane, coal handling machinery and for motor driven tools in the adjacent shop. Thus it is seen that the exciter engine would carry more load and so deliver more exhaust steam than the heater could condense, which would allow much of the steam to waste to atmosphere. This plant will use economizers, and so there will not be much advantage in delivering high temperature water from the heaters to the economizers, because the economizers will raise water more degrees in temperature when receiving low temperature water than when receiving water of high temperature. In other words, the capacity and utility of an economizer diminishes as the temperature of its feed water is increased, and the greater amount of work asked for from the economizer the better paying investment it will be. An active circulation is not provided for in the general design of economizers on account of practical difficulties, and as actual experiment has demonstrated that twice as much heat is delivered to water circulating at the rate of 3 ft. per second as is delivered to it without circulation, it may be seen that the commercial value of an economizer would be increased greatly if the advantages of free circulation were provided for.

If the plant were supplied with economizers it would be an economical plan to deliver all the steam to the heater that it would condense, exhausting such machines as are economical in the use of steam into the condensers and such machines as are wasteful into the heater. A system for connecting certain machines and allowing them to be run in either of the ways just mentioned is shown in Fig. 49. This system is flexible only in regard to operation and should not be used for any lines which are at all times essential for the continued operation of the station. A portion of the line marked *A* is indispensable, and late at night, when the pumps may be shut down, the exciter engines would be running non-condensing, and this part of the line would then be used by the exciter engines.

Another point to consider, which may be stated as one of the more important details in laying out station systems, is the ability to be able to take apart any valve in the station, not only for repairs needing immediate attention, but for general repairs when the load is light and not over one-half the station capacity is called for. To be able to shut off one section of the piping is only a partial solution of the problem of designing a correct system; it must be possible to shut off the shut-off itself. Figure 48 shows numerous valves, any one of which can be taken out of the line or have repairs made on it and the continued operation of the other half of the station be possible.

Referring to Fig. 47 it is seen that there are two atmospheric valves opening into one pipe, and if one valve is being repaired there is a constant danger of losing the vacuum and exhaust from the other engine reaching the valve. This is not a good system, because each atmospheric branch should run independently to the atmosphere, or have a valve in it.

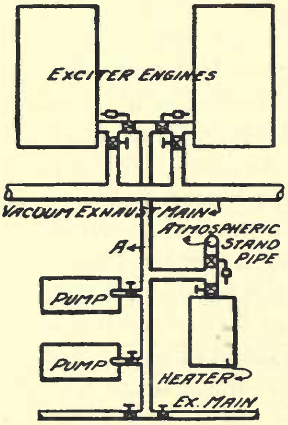

FIG. 49. System; Exhaust from Auxiliaries, Improperly Laid Out.

There is nothing unusual in the appearance of the connection shown in Fig. 49, such an arrangement being very ordinary. The designer of a piping system must not be contented with laying out a system which looks all right, but he should analyze every requirement and see that his design conforms with an established plan.

Referring to Fig. 49 it may be seen that in order to do any work at all upon the valve shutting off the main from the branches, it will be necessary to shut down the entire auxiliary exhaust main. Such a design is not a system, but is the very limit of crudeness.

The auxiliary exhaust main should therefore be next laid out with a view to making repairs to the pipe line possible and still allow the operation of three-fourths of the entire plant, or permit any valve to be removed and allow the operation of one-half the plant.

It should be understood that if a valve blows a gasket or springs a bad leak between the bonnet and the body, it is yet possible to close the valve and operate three-fourths of the capacity of the plant until such time as the load can be carried by half the machines and the repairs be made.

A list of the machinery which must be piped to the heater and atmosphere comprises two dry vacuum pumps, two feed pumps, one fire pump and two fan engines. These machines are shown in Fig. 50, together with the properly located back pressure valves and atmospheric standpipes at the ends of the exhaust main. In case of accidents to valves *a* and *b*, repairs would be found difficult, because it would be necessary to operate with but one pump. This, however, is possible, and as there is low duty on the shut-off valves, further protection is not justified. It is necessary that the exhaust main should be pitched toward the heater so that all condensation will flow in that direction and it will then be possible to run the steam drip bleeders into the exhaust main, thus saving both the distilled water and the heat units.

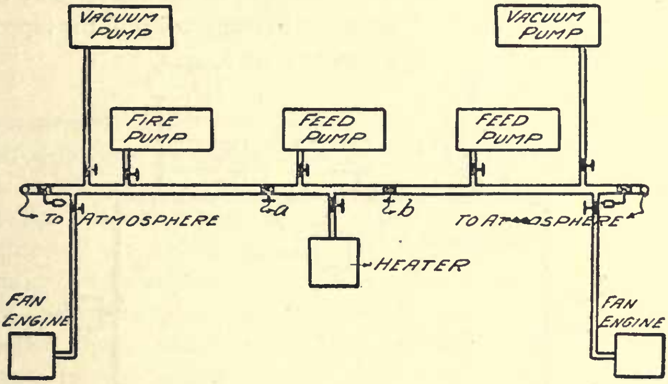

FIG. 50. System; Exhaust from Auxiliaries, Properly Laid Out.

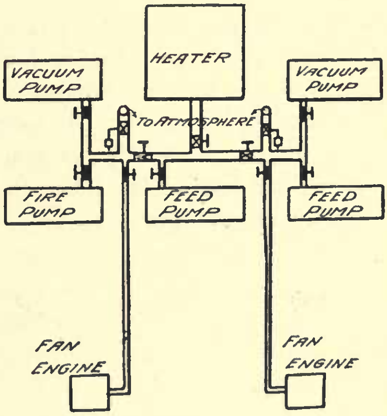

FIG. 51. System; Same as 50, Modified Position of Parts.

The lines may be located in various positions and yet preserve the system shown in Fig. 51. For instance, Fig. 50 shows a different arrangement of the machines, valves, etc., but the general system is unchanged. In Fig. 50 the atmospheric valves are located near the heater so that the air vent of the heater may easily be run into these pipes. The general arrangement of the pipe lines must necessarily adapt itself to local conditions, but the lines should be so run that the original system will be preserved.

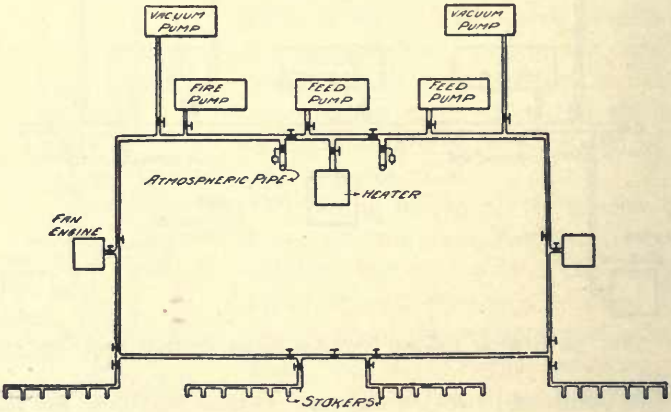

FIG. 52. Sample System; Exhaust from Auxiliaries to Heater.

The general rearrangement of the auxiliary steam and exhaust mains when laid out on the loop plan is shown in Fig. 52. This plan permits the shutting down of the heater, atmospheric pipe, or any portion of the lines, and yet three-fourths of the plant remains in operation.

CHAPTER VII.

AIR AND OILING SYSTEMS.

Compressed Air System. Compressed air is now considered essential in the operation of modern power stations and is chiefly used for cleaning electrical machinery and apparatus; it is also used for other purposes in the plant because it is available. Compressed air service for cleaning purposes is not vital in the operation of the station, and therefore can be laid out on a single main, systemless plan, but of course when the air system is so designed, there should be no vital system dependent upon air pressure for its operation unless such system has another means of supply.

Ordinarily it is not necessary to use a large air compressor nor large lines, but in order to insure an even pressure the system should have a storage air tank of fairly large capacity from which, when needed, a relatively large volume of air can be drawn for a short time. The general arrangement of such a system is shown in Fig. 53.

The piping should be arranged so that the compressor, air main and branches will drain into the air tank. This tank should be provided with a blow-off through which condensation can be disposed of. The compressor, controller, gage, relief and stop valve should be located on the engine room floor, and the tank on the basement floor with the air supply main led off from the top. Hose valves should be placed at the different generators, motors, transformers, switchboards, oil switches, etc., so that 25 ft. of hose will reach any piece of electrical apparatus. If there is an oil room where inflammable stock is kept it is desirable to connect the air main to a can of dry fire extinguishing powder in such a manner that by opening an air valve the pressure from the main will blow this powder forcibly into the room.

Cylinder Lubrication. In designing an oiling system, facilities must first be provided for receiving the oil in barrels, emptying the barrels and disposing of them. If compound engines are used in the station, the cylinder lubrication will require two kinds of oil. There will also be needed a different cylinder oil for the dry vacuum pump and the air compressor. Engine or journal oil is usually the same for the entire plant, the plan being to filter this oil and use it repeatedly. Grease will also be required for some of the bearings, pins, etc. There are some specific requirements in the handling of these materials that to a considerable extent determine the location of the different parts of an oiling system:

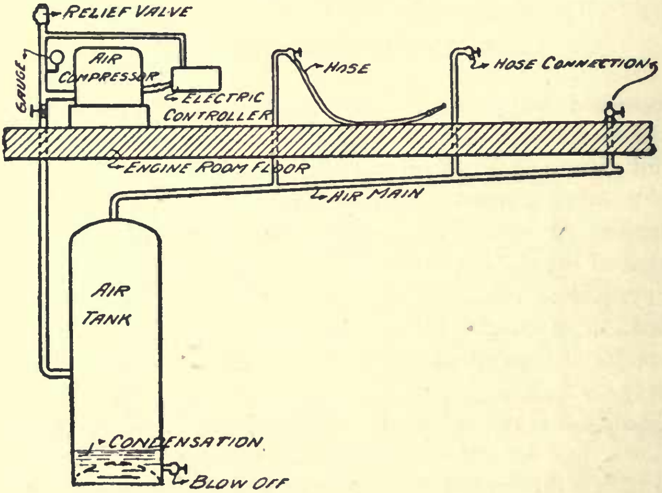

FIG. 53. Sample System; Compressed Air.

1. The oil barrels must be stored in a cool and preferably damp place to avoid leakage.
2. The oil and grease stocks must be separated from other portions of the building in a fire-proof manner and arrangements made so that a fire in the oil room can be subdued and not endanger the station.
3. The oil room must be accessible from the outside, in order that the barrels may be received and discharged.
4. All the drip lines and the drip receiving tank must be located in a warm place so that the drips will flow freely.
5. Gravity tanks should be located in a place which will be cool in the summer but warm in the winter; and warmer in winter than in the summer, so that at all times the oil will be of a temperature that will insure free flowing and render it easily handled.

6. Cylinder oil and grease should be kept so that the amounts used can be charged to the respective shifts using them.

There are numerous methods of handling oil and various systems that can be used in supplying it to the machines. Cylinder and journal oils should be considered from different standpoints, when planning an oiling system; journal oil is fed onto the bearings in a much greater quantity than actually required, the loss being not appreciable because the drips are collected and returned to the receiving tank. The object of piping oil to bearings is to insure complete lubrication; the lubrication of the cylinders is an entirely different proposition. Instead of providing facilities for feeding an excess of oil into the cylinder, the contrary should be done, that is, plan the system so that it will require the least possible amount of cylinder oil.

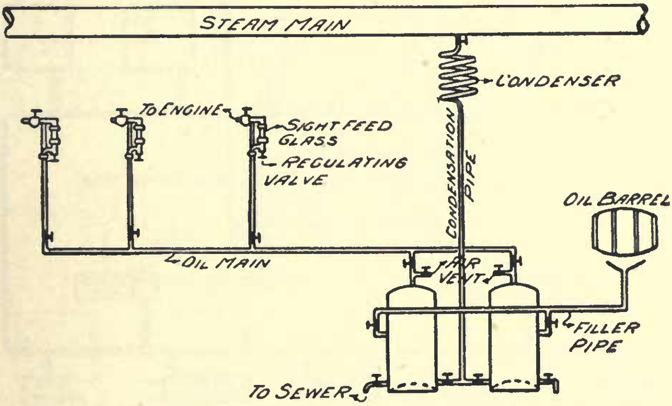

FIG. 54. System; Feeding Cylinder Oil from Tank to Engine.

One of the methods for placing cylinder oil under pressure and delivering it to the steam machinery which is to be lubricated is illustrated in Fig. 54. The necessary pressure is maintained here by adding to the steam pressure the weight of the water in a condensation pipe connecting the steam main with the supply tanks. The principle employed is the same as that of the standard sight feed lubricator so commonly used.

Two tanks are used, so arranged that one may be shut off from the system while being filled from the supply barrel and the other continue to furnish oil for the lubricating system. This equipment and piping system is the equal of the majority of installations.

The most serious objection to it is that the piping is arranged without regard to any definite system.

When this system (Fig. 54) is arranged so that repairs may be made without shutting down the entire oiling system, it assumes the form shown in Fig. 55. For such small, inexpensive lines as go to make up an oiling system it is good policy to make even greater provision for repairs than in the larger and more expensive lines.

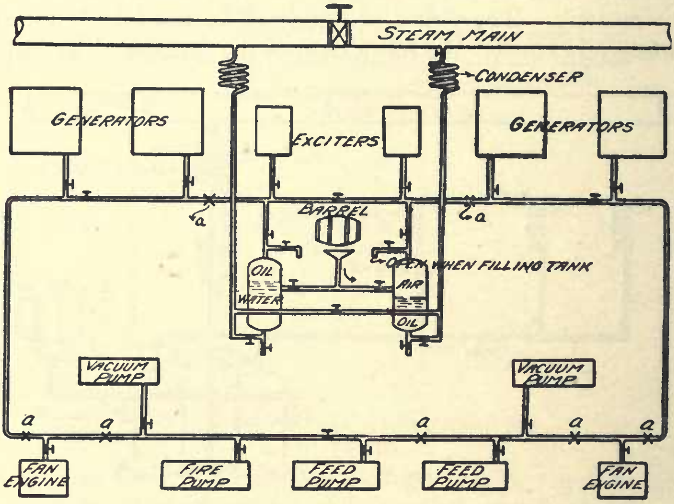

FIG. 55. System; As shown 54, Applied Systematically in a Plant.

If line valves are placed at the points marked *a* in Fig. 55, continued operation is more readily insured. The cost of such valves would be slight.

When the style of lubrication shown in Fig. 55 is to be used with high pressure cylinders, it would be a good plan to use it on the low pressure cylinders also, but the pressure should not be as high on the low pressure cylinder oil supply. If city water at about 40 lb. pressure is available, this can be used instead of the condensation columns shown in Fig. 55. Air pressure could also be used, but since the compressed air system has not been designed with a view for continuous operation, its use with the oiling system would be unsafe unless two air compressors are in use and arranged independently to maintain the required pressure. A low pressure cylinder oiling system which can easily be repaired is illustrated in Fig. 56. In this figure the air compressors are shown connected in a safe manner.

There are various pipe systems for feeding cylinder oil, but the general proposition is subject to many objections, regardless of the equipment used.

There are two styles of feeders used to deliver oil to an engine. The older method is to use a sight-feed glass filled with water and allow the drops of oil to feed up through the water. A drop of oil may seem small in itself, but it is an extremely large quantity when considered from a lubrication standpoint. An engine that is receiving one drop a minute would make, in the case of stoker or similar engines, possibly 250 or 300 revolutions without oil to one with oil. The size of the drop is not controllable by the operator. But if such a drop could be divided into 10 or more small drops it would be possible to obtain more economical results in lubricating with sight feed lubricators. This, then, is the weak point of all drop sight feed lubricators, that they seem to be feeding too little or not at all when in reality they are feeding too much.

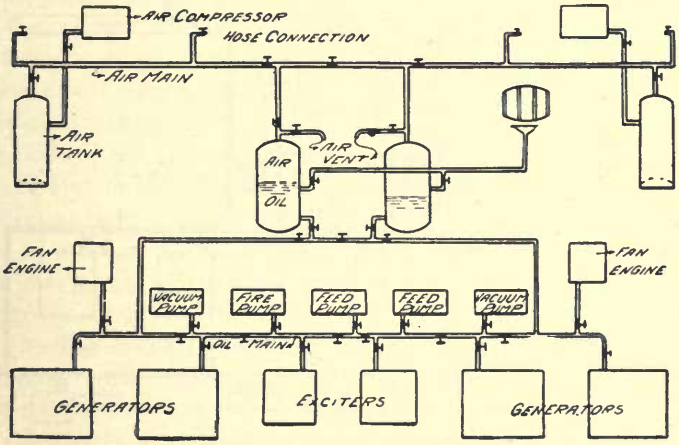

FIG. 56. System; Oiling Journals by Using Tanks and Compressed Air.

The best system for handling cylinder oil is unquestionably one which will give the greatest amount of lubrication for the least cost, and in considering cost both labor and oil must be included. Systems for feeding cylinder oil have so reduced the labor cost of handling the oil that they have made it possible and to a considerable extent excusable to waste oil. Each operator in his shift is relieved of about ten cents' worth of labor and enabled to waste one dollar's worth of oil. Such being the case, instead of spending money to make such installations, it would be better to spend money to avoid their use; however, some people think a plant must be automatic to be modern.

Another method of supplying cylinder oil to sight feed lubricators is illustrated in Fig. 57. This system uses a pump to force oil into the pressure line and controls this pressure with the pump governor, the storage tank being placed higher than the pump so that the oil will flow by gravity from the tanks to the pump suction. Much difficulty is experienced in lifting cylinder oil in a pump suction, and in fact no suction for any service should be arranged except by the gravity method if the machinery is slow running. The system shown in Fig. 57 to be complete must be laid out on the loop plan with duplicate sets of pumps, distribution lines and storage tanks. Ordinarily this loop could be easily arranged by running one line through the engine room to supply all the steam machines there, and the other line through the boiler room to supply all its machinery.

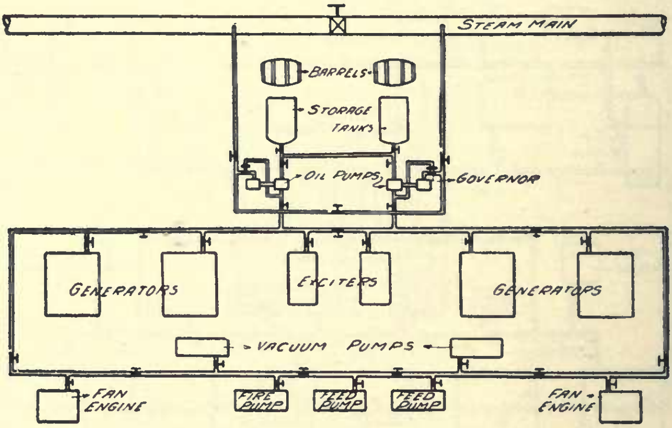

FIG. 57. System; Oiling Journals by Using Pump and Governor.

The fact must be remembered that the piping system alone will not insure satisfactory operation. It is the entire system or method that determines the degree of success. For instance, Figs. 55 and 57 are both good pipe systems, but each has objectional features, common to all cylinder oil piping systems that are not commercially successful. Fig. 55 is mechanically a success, since it maintains a steady pressure on the oil a fixed amount in excess of the steam pressure, this being accomplished by the condensation column. This steady pressure is absolutely essential for securing the best economy in drop feeding, which feeding at its best is not the most economical.

In the system shown in Fig. 57 the speed of the pressure pumps is regulated by governors actuated by the pressure on the oil end of the pumps. This type of regulator must be constructed with a metallic diaphragm, as oil comes in contact with it. Continued service will eventually dish any metallic diaphragm, and when this has occurred considerable force is required to pass the dish from one side of the diaphragm to the other. If such is the case in an oiling system having recording pressure charts on both steam and oil lines, sudden changes of pressure will be noticed and at times the oil pressure will show even lower than the steam pressure unless the governor is loaded down, in which event the steam pressure may be 160 lb. and the oil pressure 161 lb., then due to the snapping over of the dish in the diaphragm a pressure 4 lb. higher than that for which governor valve was set will be needed to close it. Thus if the oil pressure is set at 5 lb. above that of the steam the defect in the diaphragm will allow the oil pressure to run 9 lb. higher than the steam pressure before the governor valve closes. In other words, the head on the oil may be increased or decreased nine times and thus cause such a change in the volume of the feed that three times as much oil will be fed at one time as another. With such a governor it is probable that twice as much oil will be used as would be with the system shown in Fig. 55.

If it is wished to secure greater economy in the use of oil the sight feed method must be discarded for some other.

The most common method for reducing this waste is by the use of a force-feed lubricator directly connected to the moving mechanism of the engine or pump which is to be lubricated. With this type of oiling system the discharge flow can be set for five or ten feeds each minute and the total of the ten discharges can be gaged for less than one drop. Such a system enables the lubrication of each piece of apparatus to be carried on independently and any draft of cool air can have no effect upon the volume of the feed as is the case with sight-feed lubrication.

The force-feed lubricators are ordinarily supplied with oil by hand; in fact, this method has been demonstrated to be the more economical and the labor of filling pumps is too slight to be considered seriously. An important consideration is the saving in the quantity of oil used; as killed operator can more than save the difference between his wages and that of an inferior man by the difference in the amount of oil used alone.

It is due to this fact that the power station should be provided with a means for carefully recording the amounts of oil used by the different shifts. The systems shown in Fig. 55 and Fig. 57 are not designed for this purpose.

If a record is to be kept it may be found necessary to give out oil to each of two men in a shift, one part to be used in the boiler room, the other part in the engine room. The pump supply on each part of the force-feed oiling system should be marked with a line designating the point on the reservoir to which each shift must fill, and the oil used in this filling should be taken from a supply can charged to the proper shift. A great deal of oil is wasted in the lubrication of the auxiliary machinery, which should require but very little cylinder oil.

If it is found desirable to pump oil from a storage reservoir to the force-feed pumps on the units which are to be lubricated, this could be done with the piping system shown in Fig. 58. With this arrangement it is not necessary that duplicate receiving tanks be used. The air line may have its pressure maintained by a single compressor because the use of this supply arrangement would not be essential for the operation of the engine, since the pumps could be filled at opportune times and each shift would have recorded against it the meter readings showing the amount of oil drawn at the start and finish of its run. If a separate record is to be kept of the amount of oil used in the boiler room, this can be drawn from a supply can whose contents have been charged to that part of the station when withdrawn from the receiving tank in the stock room.

In Fig. 58 the tap *A* is added for filling hand oilers, etc. With this system there would be two complete piping arrangements, one for supplying oil to the high pressure and one to the low pressure cylinders. The advantages to be gained by using two kinds of cylinder oils with compound engines are too well known both by the oil manufacturers and the operators to require giving any special reasons for their use.

The installation of a meter in the oil supply line as shown in Fig. 58 allows a possibility of this method being manipulated by the operators. The oil pumps on the engine are not ordinarily arranged to be put under pressure and with the system in Fig. 58 the proper method of operation would be to open the supply valve and fill the pump supply to the limiting point which was earlier described, and then close the shut-off valve tightly. But in all probability a dishonest operator would soon learn that by leaving the filler valves slightly open the pumps would still be kept filled by a slight leakage which would be so small in amount that the meter would not record it. This would result in the showing of "good performance" purely by trickery, because the dishonest operators could reduce the apparent reading of the meter as much as they felt sure would not arouse suspicion.

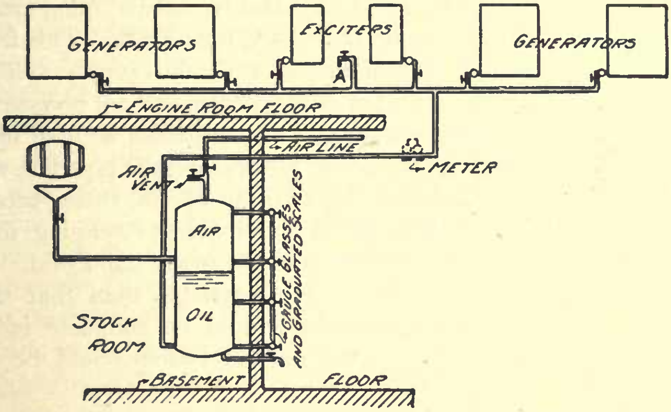

FIG. 58. System; Measuring Daily Consumption of Cylinder Oil.

If oil is to be measured and piped a better method is afforded by the use of gage glasses and graduation on the tank, thus dispensing with the meter. A tank 30 in. in diameter holds 3 gallons for each added inch in height and as the error of reading should be within the limits of one-eighth of a gallon, which with a 30-in. tank means a difference of $\frac{1}{24}$ in. on the scale, this would seem too close reading to be gaged accurately. The reading should not be finer than about $\frac{1}{12}$ in. to the pint. This fixes the diameter of the tank at 22 in. and with such a diameter and a length of 40 in. its capacity would be equal to one barrel. This tank would hold $1\frac{1}{2}$ gallons per inch of its height.

In the problem plant which is being laid out it will be found best to use the piping system shown in Fig. 58 with the 22-in. stock tank, gage glasses, graduated scale, etc., omitting the meter as shown. Two kinds of cylinder oil may be used. Care will be taken that the pipe lines be located in warm places so that the flow of oil will not be sluggish in cold weather. It will be noticed that a connection is led off from the bottom of the tank so that in case the pressure for any reason is lacking in the supply lines, oil for hand filling may then be withdrawn and the entire piping arrangement as shown in Fig. 58 be shut down for repairs. This feature is the most valuable one of this system; this supply system is merely a convenience and labor-saving device and not necessary for operation. The piping system just described can be used in connection with the regular sight-feed lubricators; the pipe line would furnish oil to the lubricators by shutting off the steam pressure, opening the bottom drain, filling the lubricator, closing the oil valve and opening the lubricator into the steam line again. Such a method of operation would be more reliable than that shown in Fig. 55 because each lubricator would be complete in itself and in time of disorder to the general system could be hand filled.

Journal Lubrication. The subject of handling engine or journal oil will next be considered. This is a subject that affords much opportunity for study. The great variety of oil handling systems now in use seems to illustrate a lack of knowledge of this subject because of the widely different types of apparatus employed for the same service.

A few general characteristics of oils should be borne in mind when considering this subject:

1. Engine oil never "wears out." Its value as a lubricant improves by wear, if it is kept free from all foreign materials.
2. Oil will incorporate with water under certain operating conditions and the water so incorporated will not precipitate.
3. Oil containing animal fats and water will become frothed by agitation. This quality can be determined by shaking a half filled bottle.
4. The better the lubricative qualities of oil, the more readily will water incorporate with it.
5. Precipitation will remove impurities which cannot be filtered out of used oil.

6. Filtration to be effective must be carried on slowly, and the filter bed frequently renewed.

7. The process of evaporation will alone liberate water incorporated with oil.

8. Paraffine serves no useful purpose as a lubricant, but causes gumming and retards perfect distribution in the journal.

9. Cylinder oil added to a journal lubricating system makes the oil less fluid and if engine oil is properly compounded any added fats are detrimental.

An oiling system should be purely a commercial proposition; a means of saving in the cost of operation. It should reduce the quantity of oil used and the amount of labor required for handling. The plan of piping oil to such parts of an engine as journals, pins, etc., whose rapid motion tends to throw off the oil, is a useless one if no provision is made for catching the drips. An oiling system has a tendency for accustoming its operators to the use of large amounts of oil and it thus becomes practically impossible to induce an operator to regulate the flow of oil so that it will be just sufficient for lubrication and not allow any waste in drips.

Early in the design and plans for a station, the decision should be made as to whether or not an oiling system will be used, so that when the machinery is ordered there can be incorporated in the design such details as will help to make an efficient and effective oiling system. Main journals, crank pins, cross heads and similar parts should be provided with oil guards, pockets, drains, etc., and it should be specified that all bearings be guarded so that when a continuous stream of oil is fed, all the surplus oil will be caught and directed into drain openings and thus returned to the system. Bearings that cannot safely be flooded with oil do not belong on an oiling system.

Under quite ordinary conditions the engine of a 1,500-kw. unit would have oil fed to it at the rate of a barrel an hour, which would be called simply, "liberal lubrication." When men get accustomed to seeing oil fed in this manner it is useless to try to induce them to feed through an oiling system at the rate of a drop a minute.

For such bearings as have no oil guards, the only practical method is to insist that these bearings be oiled by hand and thus the attendants will use as little oil as possible and save themselves extra labor in filling. Many of the unguarded journals, such as small wrist pins, valve gears, etc., can be well and economically lubricated by using grease in compression cups. Sponge grease is quite successfully used on valve gears of extremely high temperature. Those bearings not provided with oil guards or grease cups should have an ample number of oil holes suitable for lubrication from a hand oiler.

A return oiling system should serve the following engine bearings: Main bearings, crank and crosshead pins, cross head guides, eccentrics and stationary rocker pins of Corliss engines which have drip pans under them. It should be specified that the vacuum pump be provided with oil guards and drains for these same bearings. Much trouble is occasioned by the lack of forethought when ordering machinery, because it is useless to make provision for flooding a journal with oil if there is no provision made for caring for the waste oil and thereby allowing it to discharge onto the floor. The only method left in a case of this kind is to use extremely high grade oil, fill the cups by hand and endeavor to have no drips. In this case the practical method of learning when to check the oil supply is to notice whether the oil has run down onto the floor on account of too great a supply or whether too little oil has caused a hot bearing. Such a method of feeding oil is extremely expensive, not only on account of the oil wasted, but because of the injuries occasionally caused by hot bearings and the extra labor needed in constantly watching the oil feeds. As stated before, the machinery must be fitted for an oiling system in order that the use of such a device may be justified. The running of a lot of pipes to an equal number of oil cups signifies nothing more than that it takes the place of a man carrying the oil. The economy of an oiling system does not make itself appreciable when the journals have not been provided with a means for carrying away the drips and reusing them.

It may seem all right to say, "We will take up the matter of the oiling system when we come to it." The fact of the matter is that an engineer has "come to it" with every system to be installed the moment he starts writing the specifications for apparatus. He should by all means lay out all the diagrams for the entire plant before ordering anything.

Various systems are in use for delivering oil to engine bearings and returning drips to drip tanks. One system is the same as that shown in Fig. 57 for cylinder oil. The tanks, pumps, pump governors and distribution main, also the method of taking steam from two sections of the main header, are the same; the only difference is that the pressure used is not as high as that in a high pressure cylinder oil piping system. The same objections arise in handling engine oil as have been stated regarding the use of cylinder oil; that is, the pressure varies to such an extent that it changes the quantity of oil fed to the journals.

The system shown in Fig. 56 is also applied in using engine oil, the ability to maintain a constant pressure is gaged by the sensitiveness of the air compressor controller. Such a system necessarily gives a perceptible variation in the oil discharge whenever the air lines are used for other service besides supplying the oil tank. It is quite unnecessary to measure the quantity of engine oil used in a return system, because it is difficult to effect any perceptible saving when drips are returned. An operator may run ten barrels through the system during his shift and the shrinkage on this amount during its circulation may not exceed one gallon. A very complicated system would be required if it were necessary to have such a large storage capacity and care for such volumes of oil and then be called upon to measure the loss of but one gallon. In practice this has not been considered at all essential. The chief requirement for an engine oiling system as before mentioned is that it may be thrown out of service on a moment's notice and some hand system substituted without necessitating the stopping of the engine or in any way endangering the journals. The system should be merely a convenience, readily dispensed with when necessary.

There are many styles of oil cups or feeders used to control the amount of oil fed to an engine. The style most commonly used, due possibly to the fact that it was originally used in hand oiling and was furnished with the engine, is the regular pattern sight-feed glass oil cup with the hole drilled in the top for a pipe nipple to attach the oil piping to the cup. A valve is placed in the line to the cup for regulating the flow to the cup the same as the regulated flow from the cup to the bearing. The necessity of watching the cups in this style of feed is its most objectionable feature because it requires very frequent regulation of the valve, and if not closely watched the oil will spill over the top or the cup will run empty. The latter condition would be shown very conspicuously. This style of cup requires constant watching of the feed and much manipulation of the valves.

A second style is that of the closed glass-body pressure-cup with one hand regulating valve. This cup requires less attention than the first style and it has only one-half as many valves to shut off when closing down the system. The glass, however, is under pressure and a slight crack in it will cause a bad leak, and for the same reason the joints at the ends of the glass must be securely made. These cups can be filled by hand by closing the valve in the pipe supply and removing the plug.

The third style is merely a regulating valve, there being two forms, hand closing and self closing. The hand closing valve can be set for the desired feed, so that when shutting down the machine and turning over the cam or other device this closes off the oil flow but retains the set for feeding. This style of valve is made by one manufacturer in conjunction with a regular glass sight-feed cup, making a separate device of each up to the drop sight glass. Automatic or self closing feeder valves are either of the diaphragm or the piston form. An objection to the diaphragm form is that it requires a very high pressure on the oil lines to operate, usually about 60 to 80 lb. when the copper diaphragm is old and hardened. The piston form with a leak port to the journal works on as low as a 15-ft. head, making this type very satisfactory for use with gravity systems.

Self closing valves are arranged to discharge oil to the bearings by opening the one oil main valve, thus allowing the pressure to open the automatic valves to the set position. Diaphragm automatic valves are not used except with high pressure oiling systems. This is due to the pressure required for opening them, and the success of the operation of the machinery is contingent upon the successful operation of the oiling system. In other words, an oiling system of this type must always be in effective operation for continued running and therefore is not merely a convenience.

The requirements are very satisfactorily met by the piston type automatic valve with hand arrangement for feeding and regulating, when oil is fed by hand. This style allows the use of gravity oiling systems, is self closing, free from glass parts and can be used with a small reservoir at each engine as shown in Fig. 59 and allow the shutting off of the main parts of the oiling system, or it can be used independent of all piping as a separate hand-fed cup. An engine oiling system of this type would have as one of its details an emergency tank placed just above the highest cup and arranged so that it could be filled by hand during those times when the oil main is out of service. Should the lines on the engine be damaged during operation the entire engine piping system could be shut off and the cups hand filled until the damaged section was capped up. Then the piping system would be opened and again be allowed to feed into the cups. If one or two of the cups were on the damaged portion of the pipe they could be filled by hand until such time as the engine could be shut down and the pipe work repaired. In regular service when the engine is to be started the stop valve *A* is opened, then all cups open from the oil pressure and start flowing. On shutting down the engine the valve *A* is closed and the lack of pressure to the engine oil supply allows all the cups to close automatically. This is quite a valuable feature on a large compound engine that has between twenty-four and thirty cups, and especially is it advantageous over a system of cups whose set must be disturbed to close the cups.

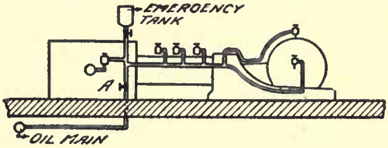

FIG. 59. System; Independent Hand Supply Oiling Systems in Conjunction with Pipe Line System.

The supply to the feed main can be of the low pressure or gravity system for any of the different styles of feeders except the diaphragm pattern self-closing cup. This latter type must be used with a fairly high pressure system if satisfactory operation is to be insured, and so gravity pressure is quite out of the question, because the head required for 80-lb. pressure in a gravity system would be 185 ft. above the cups or somewhere near the top of the stack.

There are various methods of supplying the oil main but these requirements must be provided for if it is wished to have a practical and satisfactory system:

1. Any piece of machinery used to supply the oiling system must be so designed that it will permit of its being shut down for an hour or two without stopping the supply of oil to the engines.

2. All tanks, filters, and similar apparatus should be of the open pattern, which will permit complete inspection at any time.

3. Means must be provided for discharging any water returning with the oil drips.

4. All tanks, filters and similar apparatus must be so designed

that they will permit of thorough cleaning while the system is in operation.

5. Drip lines should be so designed that any branch or section can be cleaned out without taking the pipe work apart.

6. The system should be so arranged that it will operate continuously and not require constant watching to see that one tank will not overflow, another run empty, etc.

Some of the systems for supplying oil do not satisfy these requirements; for instance, engine oil supplied to the main by a pump and governor as in Fig. 57 requires the continued operation of the pump. The system shown in Fig. 56 requires the air compressor to be in operation continuously unless the storage air tank is of sufficient capacity to allow air to expand, say, from 20 lb. down to 10 lb. in discharging oil for 2 hr., which discharge may be 4 bbl. A tank of about 16 bbl. capacity or 100 cu. ft. would be required to run such a system for 2 hr., but ordinarily the air tanks would not have over 2 or 3 bbl. capacity, which would be sufficient for only 20 min. run. Another objection to the air system is the inability to properly clean the tanks, since they are closed in from view so that their condition cannot be noted.

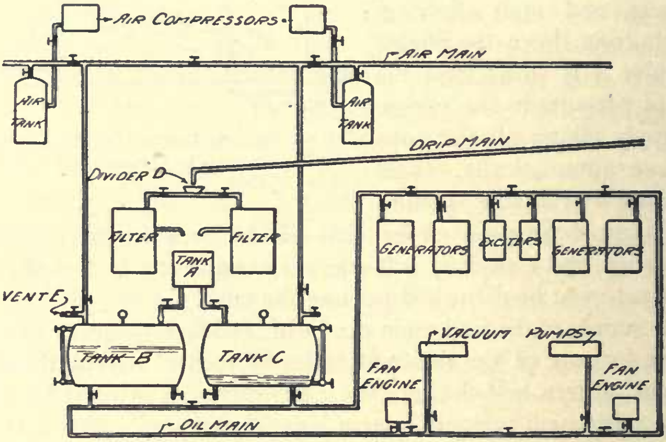

FIG. 60. System; Oil Drip Return, Filters, and Air Pressure Oil Tanks.

Probably as satisfactory an air system as can be laid out is shown in Fig. 60. It will be noted that the tanks and air compressors are in duplicate. The filters are also in duplicate and arranged so that both can be worked in parallel, not in series, because the work done in a filter depends upon the velocity of the flow through the filtrate. The small open tank *A* is a receiver, designed to take the discharge from the filters during the time of changing over from tank *B* to tank *C*. When tank *B* is taking drips from the filter, tank *C* is under pressure. When the oil becomes low in the tank *C*, the drip from tank *A* is closed and air pressure is put on tank *B*; when tank *B* is under pressure the valve to the oil line is opened and tank *B* put onto the system. Then the oil valve at the bottom of tank *C* is closed, air vent is opened and the valve between tanks *A* and *C* is opened, thus allowing the filtered oil to replenish the supply in tank *C*. If these tanks have a capacity of 8 or 10 bbl., this arrangement of valves need not be disturbed for 4 or 5 hrs. The tanks *B* and *C* accumulate much impurity. Unless tank *A* has sufficient capacity to store the drips while tanks *B* or *C* are being cleaned, it may be found necessary to do this after shutting down the machinery at night. The device *D* must be a dividing arrangement which will allow one half the drips to flow each way, and this is rather a difficult detail to provide if it is wished that the division be even fairly accurate. Although not shown in the figure, all tanks would require sewer connections as outlets for water, refuse, etc.

This system, Fig. 60, fails to provide the necessary previously stated requirements, 2, 4 and 6, and unless the air tanks are large it will fail to provide for requirement 1.

Instead of using air as a pressure supply for the oil, the same system as that shown in Fig. 60 can have its pressure supply by water. In this case the oil would be taken from the top of the tank instead of the bottom and the water would be admitted at the bottom. The use of water in oiling systems should be eliminated as much as possible, not only in tanks *B* and *C*, but in the filters, because enough trouble is caused by water incorporating with the oil, even though every precaution is taken to avoid it. In one particular case the system shown in Fig. 60 was originally equipped for water pressure and was operated thus until the condition of the oil required the change to air pressure; about 30 per cent of that which was supposed to be oil was water permanently carried in suspension.

This difficulty does not appear in cylinder oil feeding systems which use a water condensation column to carry oil into a steam pipe, because cylinder oil is much heavier, and even though it would take up water the fact would never demonstrate itself, since the oil does not return to afford the chance to again take up more water and thus by repeated contact combine into a soapy mass of froth and foam that will neither flow in drain pipes nor pass by the needle valves of oil cups.

CHAPTER VIII.

OIL AND WATER PURIFYING SYSTEMS.

Oil Purifying Systems. The filters shown in Fig. 60 are in the path of the return drips to tanks *B* and *C*. If the beds in these filters are close laid and suitable for effective filtration, then in case of flooding journals, the filter will be flooded and overflow onto the floor. Anyone contemplating the use of filters in a return system must provide for a flow through them somewhat greater than the maximum flow fed to the engines. It is safe to estimate that this flow will equal the greatest capacity of the pipe lines which supply the cups. In designing station work it is useless to design for only that which is essential. If one part of the oiling system is designed to deliver 4 bbl. of oil an hour to the bearings, then the return part of the system should have a like capacity. In station operation it is not an uncommon thing to see an operator drag a hole through the filtering material, "so the oil can get through," as he will say. Usually this is the only practical thing to do.

In oil cleansing apparatus using filtering material a satisfactory design is to enclose this material in a receptacle similar to a galvanized iron tub. This tank or tub should have a perforated bottom and a perforated plate laid on top to retain the filtering material. In case the filtering material is 6 in. deep and the sides of the tub are 18 in. high if 12 in. of oil pressure on top of the filtering material is not enough to force the oil through, it can spill over the edges of the tub into a tank in which the tub should be set. This may seem to be a crude method, but it is far more effective than to attempt to force oil under a high head through a filter bed that yet contains those impurities collected from the oil while it was flowing more slowly. Such a system collects impurities at one time and then when an overload is thrown upon it and a larger quantity of oil demanded, this oil under a higher pressure washes the previously strained impurities through the filtering material and back into the oil mains. Such is not the case with the "tub" plan. The tub filter will remove whatever impurities it can and the others will flow over the sides with the oil and be picked out at some other time.

The doubtful value of an oil filtering system can be demonstrated by a simple test. Take two sample bottles of oil, one drawn immediately after it has passed through the filter, and the other taken before being filtered, the latter first having been passed through a fine "milk strainer" wire sieve to remove foreign bodies, such as lint, scale, etc., and let these bottles stand undisturbed for a month's time. Examine them closely and note the marked amount of clarifying that has taken place as a result of precipitation. The observer need not be surprised if he cannot tell which of the two samples of oil is the clearer. He should note carefully the results of precipitation, observing the large amount of separation that has taken place while he has been trying to get equal results from the filter. If a bottle of oil can, in this manner, be so thoroughly purified, why not subject all the lubricating oil to this same treatment?

To accomplish this successfully it will be necessary to take part of the oil out of circulation and allow it to remain quiet while precipitating. Means must be provided for drawing off the clear oil for use in the system and for leading into an empty barrel the heavy, fatty oil lying between the clear oil and the water. The piping should be arranged so that the water can be run from the precipitation tank to the sewer and the tank thoroughly cleaned. After cleaning, the tank can be filled with clear oil and the valves closed. Then the "batch" of oil that has in the meantime been serving the machinery can be subjected to the same process of precipitation with like results. The heavy, fatty oil which forms in a layer in the precipitating tank is wholly unfit for piped oiling systems, but can be made use of elsewhere. Ordinarily much of this heavy, fatty oil is lost in cleaning out the closed tank.

An oil supply system using precipitating tanks is shown in Fig. 61. The two precipitating tanks are alternately used, one as a gravity tank, and the other as a precipitating tank. From the pans under the engines the drips are separately carried to drip pots. The lower part of this type of drip pot is held against the upper portion by a stud bolt passing through the center of the top. The joints between the two sections should be ground and no gaskets used. The purpose of these drip pots is to catch such heavy precipitation as would lodge and choke the pipes. These pots also take the place of T's and the angles are turned with bends in place of L's. With this construction there are no corners or edges around which the drips must pass on their way to the pot and therefore little chance for clogging. The common practice of using crosses and plugs also increases the liability for clogging. The bent pipe avoids these obstructing edges and corners and furnishes a pipe line that can readily be cleaned with a wire, from the inlet all the way through to the drip pot.

There are two discharges into the receiving tank; *A* is the regular inlet and *B* the special connection to be used when the automatic water discharge is being cleaned. The oil drips are conducted to a point low down in the water separator and the cross discharge pipe is perforated, with the openings looking down. The water overflow is located 2 in. lower than the oil overflow. This allows 20 in. of oil over the water in the separator. The three upper trays shown in Fig. 61 are provided with screen wire bottoms. The lower screen tray has a brass wire gauze of very fine mesh. These trays are arranged with the screens graded from coarse at the top to the very fine mesh at the bottom, so that each removes its particular size of impurities. If the top one becomes blocked the oil will then run over the edges and be strained in a lower one. The bottom tray has but one opening. This is located over the funnel leading to the oil pump suction. The tank in which these trays are placed should be provided with doors in its sides to facilitate the removal of the trays for cleaning. In this way the trays can be cleaned, one at a time, during regular operation. The trays should be set back sufficiently far from the cleaning door to enable an operator to inspect the bottom of the tank without disturbing the position of the trays. To aid inspection an electric lamp should be placed inside the tank as shown in the figure. The edge of the water overflow must be long, say 18 in. or more, to avoid building up a head on this edge when discharging a large volume of water as would be the case when the drips were being flushed with hot water. To care for a flow of three or four barrels of oil an hour, the overflow edge between the separator and the tank should be not less than 12 in. long.

A small pump is shown with its direct connected motor of the slow speed type placed above the pump on the engine room floor. This pump should be of the slow speed rotary type so that it will cause the least amount of agitation and frothing of the oil. Telltales are shown connected to the tanks overhead and in view from the engine room. The elevated tanks should have light, loose covers the full size of the top of the tank with suitable openings in

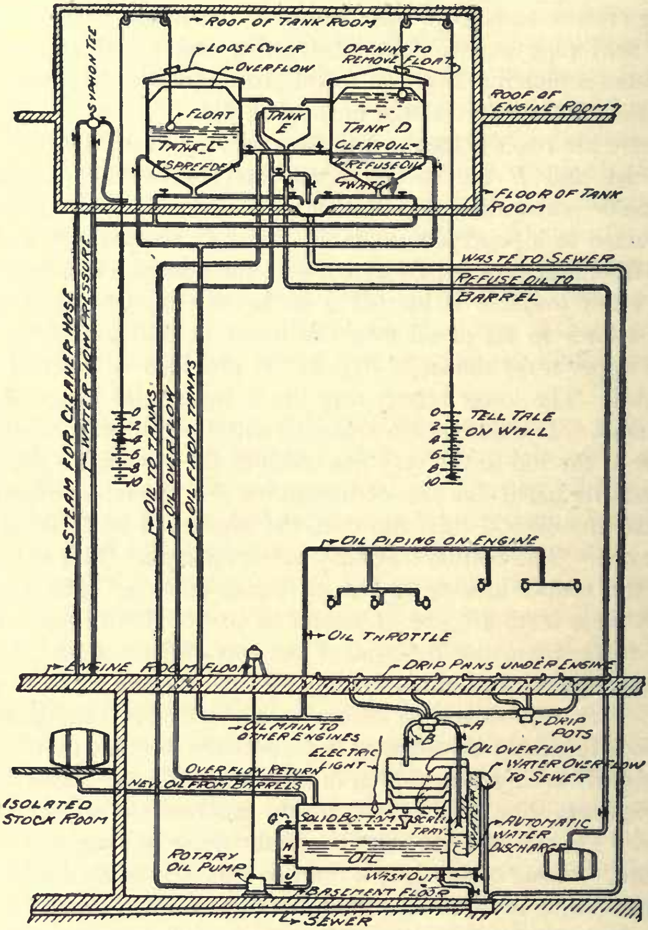

FIG. 61. System; Gravity Pressure Oil Supply, with Precipitation Tanks.

these covers for the removal of the telltale floats during that time when the tanks are being cleaned. Around the tops of these tanks, on the inside, there should be overflow rings with the overflow levels about 4 in. below the upper edges of the tank shells. In the figure, tank *C* is shown in use as a gravity tank and *D* as a precipitating tank. Tank *E* would be of small capacity, not over half a barrel; this tank is used in connection with the overflowing of the large tanks after precipitation. A water connection is run to the under side of the tanks. By this means the contents of the precipitating tanks can be raised as gradually as desired. A perforated disk is placed in the bottom of the tank to dissipate the flow of the incoming water and thus avoid disturbing the precipitate.

Previous to the withdrawing of the clear oil from a precipitating tank, the drip lines and receiving tank should have been well cleaned out, and the impure oil pumped into tank *C*. The suction at the bottom of the receiving tank should be opened to remove all deposits. For illustrative purposes tank *C* will be considered as the tank which has been furnishing oil to the bearings. The suction to the receiving tank would next be closed and oil would be drawn from the lower tight bottom tray *F* through suction *G*, closing suctions *H* and *J*. The discharge of the pumps will keep the dirty oil out of the receiving tank and allow the clean oil from the precipitating tank *D* to run into the receiving tank. Thus the precipitating tank will be made ready to circulate clear oil again. After tank *D* is cleaned the suction of the pump is then changed from *G* to *H* and the discharge is reversed from tank *C* to tank *D*, and as soon as oil is over the discharge opening, the oil main discharge of tank *C* is closed and *D* is opened. By this cycle of operations the system has been cleaned and tank *C* is now out of service, full of oil and ready to remain undisturbed while the impurities precipitate. Funnels are placed under the tank washouts to enable inspection while drawing off water and to avoid losing oil. Steam is carried up to the gravity tank to be united with water for cleaning purposes. The size of tank *E* is such that it will hold the refuse oil, thus giving the attendant an opportunity to draw off this oil from the precipitating tank before going to the basement to arrange for the discharge of this refuse into a storage barrel.

The operation of this system is continuous and if the pump is run all the time there will be no occasion for watching any portion of the system. Even though the pump be shut down, the telltale would show plainly at all times and the pump motor starting box would be convenient for starting or stopping the motor at any time. The pump should be located below the oil tank so that its suction will always be filled with oil. The gravity tank can be filled only to one height. At this level the oil will overflow into tank *E*. When the latter tank is filled it will overflow and the excess oil be returned to the receiving tank. There should be no valves in the return overflow.

This system covers the requirements very thoroughly; the only additional precaution that might be advisable would be to place a small steam pump or another duplicate motor driven pump in this system. The additional pump would serve as a reserve and permit repairs to the regular motor driven pump while the oiling system was in regular operation. The precipitating tanks would be of sufficient size to hold enough oil to run the plant possibly three or four hours.

In Fig. 62 a more detailed system is shown for the arrangement of lines essential to continued operation. It will be noted that two pumps are shown. In fact it is not possible to lay out a systematic plan for continuous operation having but one machine for any particular service. One of these pumps could be steam driven and answer all demands except convenience of operation; a small steam pump is generally a nuisance as the cylinders become filled with condensation, the packings at the rods are constantly leaking, and due to the fact that the pumps should be placed below the receiving tank this ordinarily locates the little pump in the dark, out of the way place so that it gets little inspection and thus a close watch must be kept of the telltale to be sure that the pump is running properly. With a rotary pump in the basement at the tank and the motor on the engine room floor it is very evident what the pump is doing.

Fig. 62 shows the drips of each unit, collected and run separately to a funnel on the receiving tank. This is the most reliable method as it is thus quite possible to clean all the pipes of an engine while out of service or to take down any one of them without interfering with the operation of the other drips. The loop system for drips is not practical since the drips require a fall to aid in keeping the pipes clean. An oiling system is a class of service that is difficult to systematize and it is a service that may block up and give trouble at almost any time. The lines should all be as free from valves and fittings as is possible.

Perhaps a better detail for a long drip main could be made by using a heavy galvanized iron open top gutter well supported and covered with sectional lipped covers. This gutter could be cleaned out readily while the plant was in operation and by having separate connections to the tanks it would be possible quickly to throw out the tank in use and use the precipitating tank, possibly drawing off the precipitated water before doing so. There is no serious

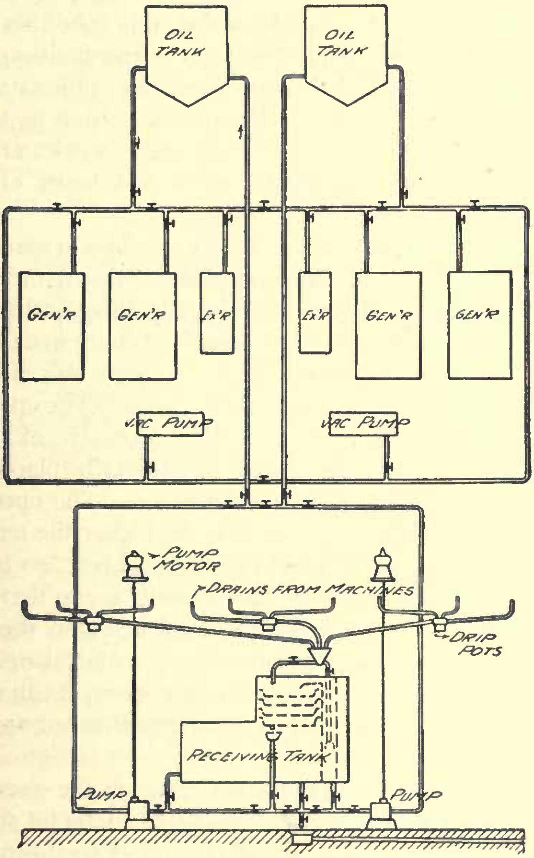

FIG. 62. Sample System; Shown in Fig. 61 and Arranged for Continuous Service.

objection, on a score of continued operation, to the using of but one receiving tank, because there are two separate compartments in the tank with separate discharges into each and separate suctions. With the system shown in Fig. 62 it is possible while changing over the precipitating tank to run one pump on the bottom tray, delivering back to the tank that has been in use, and use the other pump to raise clear oil from the receiving tank back into the clean gravity tank, both pumps being run during this period. In fact, there are too many advantages in the use of two oil pumps to endeavor to run but one, and the cost is too slight to call for a different mode of operation. If it is found necessary at any time to stop the pumps for a considerable period, this condition may find the plant running short handed and cause much disorganization among the operators. This is one of the chief objects to keep in mind in designing systematic station layouts — that is, to arrange the details so that it will be possible to make repairs at any time and not interfere with the regular work and hours of labor as assigned to the station help.

Water Treating Plants. There is another class of station piping systems that as yet has not been considered; this is the system of water treating plants. There are virtually three styles of water treating systems: the intermittent open, the continuous open, and the closed continuous system. These systems will not be discussed in detail except in regard to their piping. The open systems are very large and are customarily placed outside of the power plant proper. The pressure system is ordinarily placed indoors and conveniently close to pumps, heater, etc. The open systems are operated with cold or warm water; the higher the temperature of the water the more quickly will the chemical reaction take place. The advocates of cold water feeding systems argue that a station may not at all times be able to furnish warm water, therefore the treatment plan should meet this condition. And also, if a plant has capacity for part of the time with cold water, it can always be operated at this or a greater capacity; hence it is not necessary to heat water any of the time.

The open systems require elevating water to the upper mixing tanks, whence it flows by gravity through the different stages until it reaches the settling tank. In all the water treatment systems the boiler feed is drawn off close to the upper surface, since the lower water is in the path of the descending precipitates.

The builders of water treating plants are willing to use steam from a steam pump that handles the water for treating service because steam is always available from this source while the treating plant is in operation. In case condenser discharge water is customarily used and the size of the treating plant has been determined with regard to the temperature of this water, if at any time the condensers were not in operation, then means would be required to raise incoming cold water to the same or higher temperature. The higher temperature required is on account of the fact that the engines would use more steam and thus the boilers need more treated water when the plant was running non-condensing. As the demand for water increases beyond the capacity of the tanks, it is necessary to increase this capacity by raising the temperature of the water, and for every given temperature of water there is for the same water a given ultimate capacity. If it were possible to raise the temperature of the water to that of steam by means of an open live steam heater, the reaction would be very quick; in fact, the high temperature alone, without chemical reagents, will precipitate the carbonates and sulphates of lime and magnesia if allowed sufficient time and if ample surface exposure is provided for liberating the gas that holds the impurities in solution.

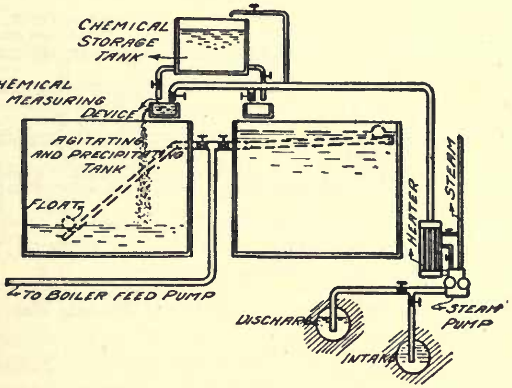

FIG. 63. System; Intermittent Water Treating Plant.

An open intermittent system is shown in Fig. 63. This arrangement requires a greater amount of room and possibly a little more attention than the others, but it possesses points of merit that cannot otherwise be obtained. A predetermined amount of chemical is run from the upper tank into a tank full of water, then thoroughly agitated, the agitation being kept up during the entire time of chemical reaction, then left entirely alone and undisturbed while precipitation takes place.

The success of chemical treatment is dependent upon two conditions, absolute proportioning of chemicals and water throughout the entire mass, and perfect precipitation. The continuous treatment requires constant measuring of chemicals and water and also a constant flow of water during the time precipitation is taking place. It will be noted in Fig. 63 that the exhaust from the steam pump is run to a closed heater, and a live steam connection is also provided, which may be used in case of an increased demand for water, but it should be remembered that too small a plant will increase the operating expenses both for chemicals and steam. If ground space is extremely valuable the high type of continuous system will be a more suitable arrangement. Should there be no space available outside of the plant, then the pressure system will show to an advantage.

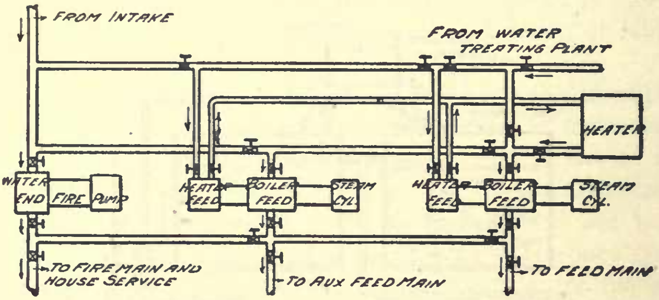

FIG. 64. Sample System; for Water Treating Plant.

The piping plan for the intermittent open systems should be similar to that shown in Fig. 64 in case it is to be applied to the power station plans previously considered, and shown in Fig. 19. If an intermittent open system is used, it would be advisable to install the open heater as shown in Fig. 64.

As in the case of continuous systems, if the water were running constantly through the treating plant the exhaust heater could be differently placed, as shown in Fig. 65; then all the atmospheric steam would be used to heat the water say to 160 or 170 degrees before passing the water through the chemical treatment. By this arrangement the low pressure pump attached to the feed pump would deliver water into the heater and the heater would overflow into the treating plant. The boiler feed pump would then take the treated water by suction. This arrangement of piping supplies a by-pass around the heater and another around the treating plant. The treating plant piping should be as simple as possible; this plant is merely to improve the efficiency of the station, and in case of repair may be shut down at any time.

The mixer shown is operated generally by the flow or weight of the incoming water; it operates on the plan that 10 lb. of water will pump or otherwise discharge into the incoming water 1 oz. of liquid chemical, or such other volume as the device is set for.

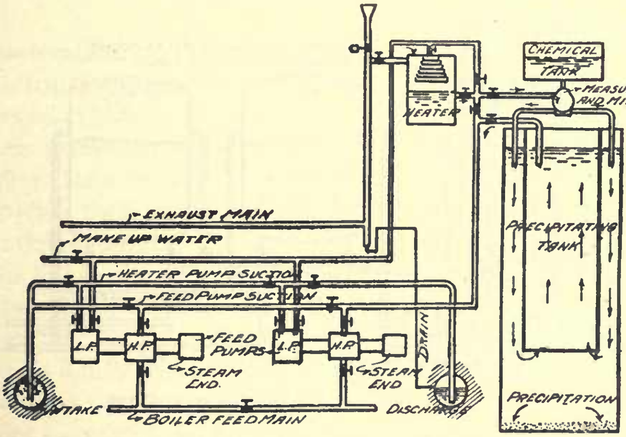

FIG. 65. System; Continuous Water Treating Plant.

The pressure chemical treating plants are evidently all designed with the single idea of "compactness," and since this is their excuse for existence, it may also be called their advantage.

Fig. 66 shows a closed system. The open heater, *A*, is arranged with the precipitating chamber a part of and beneath it. *B* and *C* are the filters. *D* is the pump with a double water end, one cylinder *g* arranged to pump water up into the heater, the other cylinder *h*, designed to pump through the filters to the boilers. The tank *E* is for diluted chemicals which are pumped by the chemical pump *F*. Instead of driving the cylinder of pump *F* by an ordinary steam cylinder, the cylinder is arranged with no valve, but having a hole under each end and a pipe run from each hole to the proper end of the boiler feed pump cylinders. Thus the little chemical pump is operated by and in unison with the feed pump, feeding one cylinder of chemical compound to one of feed water.

The regular operation of the filters is to feed through the top of the tanks and discharge from the bottom to the feed main. The filters may be run in series or in parallel. When cleaning a filter, the feed main connection is closed, as are the heater or small pump connections; the blow-offs are to exhaust across the top of the filter bed, underneath, and up through the filter bed. Filters are used for this system because tanks of their size would be too small to allow water to come to a state of rest and permit the impurities to precipitate. For this same reason filters are also necessary for an open, intermittent or continuous system, if ample time for precipitation is not to be had.

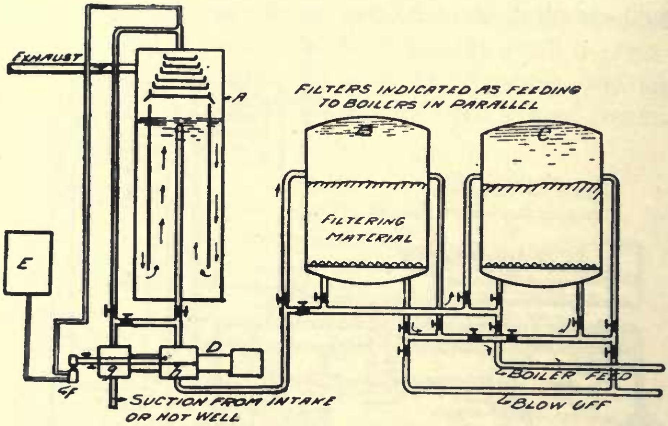

FIG. 66. System; Pressure Water Treating Plant.

There are some interesting details in connection with the different systems previously shown. These will be considered in the same order as the diagrams. There are various minor systems that will not be further considered except in connection with later detail work. It would be useless to endeavor to plan diagrams that could be used as model layouts and suitable for duplication in regular work. No two engineers have even similar ideas in regard to a general layout of station requirements; in fact, no engineer would duplicate his own previous work. It is only by planning and executing that which is not right that we learn what to evade on other work, and each evasion of previous difficulties only brings us in contact with new ones. The chief object in showing these various systems and diagrams has been to illustrate what not to do rather than what to do. There is a great laxity in the methods employed in laying out station work in general, and if these diagrams suggest a method of securing a more perfect system this publication will have accomplished all that is anticipated for it.

CHAPTER IX.

PIPING DETAILS.

Classification. Under this heading will be shown some details of construction, including the assembly of the various parts as well as special details pertaining to these parts. The illustrations of systems previously shown were merely diagrams, and until such diagrams have been laid out, and the selection of the system to employ has been finally decided, but little progress can be made in determining details. Detail work and accurate scale drawings should follow the diagram layouts, and, although the diagrams may be considered the "key" to the piping plans, they should not be regarded as final until the details and scale drawings are completed, as it may be found that some minor connection can be made much more readily by slightly modifying the system rather than running a special long or otherwise objectionable connection.

The station pipe work and system should be as simple as it is possible to have them without sacrificing their reliability. It is a very common mistake in pipe work design to complicate the system to such an extent — in the attempt to provide numerous means of supply to station appliances — that the danger of interrupted operation from piping difficulties becomes greater than that from the apparatus which is being safeguarded. Power station design should be a well-digested compromise of all the various station requirements. If the designer has an extensive knowledge of but one of the different station requirements, such for instance as electrical work, he will have his "diagram" of such work well developed and provided for. If it secures better results to have electrical diagrams well determined before undertaking the details, why should not piping diagrams be given similar consideration?

There are but three factors included in the systems in power station construction, viz., electrical, piping, and coal and ash systems; before any details or scale drawings are attempted a system should be laid out in diagram combining all three factors, as each is affected by any modification of the other. The details shown in the following pages are classified according to the system to which they pertain; for example, class A will include live steam, class B, exhaust steam, etc. The number affixed to the class letter represents a sub-division of that class; for example, A1 represents "live steam, headers or mains"; A2 represents "live steam, engine branches." The different details of the same sub-classes are numbered serially, as A1–1 and A1–2, etc. It would be well for the designer to construct, according to this system, an index of details, containing all the different classes and sub-classes.

This index will be found specially useful in laying out diagrams, as it will be a reminder of the great multitude of lines and connections that enter into a piping system; and it will draw to the attention of the pipe work designer the many little lines and connections that are easily overlooked in preparing drawings and specifications. These oversights often make pipe work "extras" a very large item in station building, and anyone who has had experience in letting contracts knows that many contractors offer bids which permit of but very slight profit, depending upon "extras" to make the job a desirable contract. The index will aid very materially in eliminating these extras, which not only result in a very expensive method of doing the work, but which reflect on an engineer's ability to properly prepare specifications.

Another advantage in using such an index is that it avoids the necessity of bearing in mind every line and connection required, which means much time saved; a line laid out with a connection overlooked may require much time and study in order to place the missing connection at some point where no provision for it has been made. Space should be left after each class in the index to enable the designer to add lines or connections which may later be found necessary.

CHAPTER X.

LIVE STEAM DETAILS.

Class A1 — Live Steam Header or Main. Detail A1–1, Fig. 67, shows the most common method of constructing steam mains and headers, using wrought-iron pipe with flanges attached to it, and cast-iron fittings. In fact, there is no other style of construction that the large manufacturing companies will guarantee. The fittings can be finished so as to have parallel and right-angled faces, and the flanges on the pipe can be faced after they are secured to the pipe, insuring a perfectly straight pipe line when assembled.

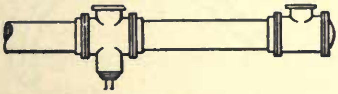

FIG. 67. (A1–1.)

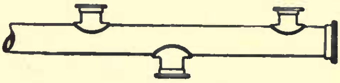

FIG. 68. (A1–2.)

Detail A1–2, Fig. 68, shows an old method of making headers that has been abandoned, due to the great difficulty of keeping riveted work tight. Riveted work should be completely avoided for any lines or branches that are subjected to strains of expansion and contraction. Another objection to this style of header is the inaccuracy of the joint faces. The nozzles are liable to have flange faces on any conceivable plane except the correct one, and the flanges at the ends of the pipes, which are set by hand, are sure to be out of true in some direction, the amount of inaccuracy depending upon the care taken by the workmen in assembling the work. Hand labor is a very uncertain method for securing accurate work. If the conditions are such as to demand the use of nozzles riveted to the pipe the rivets should be threaded, stay bolts screwed tight into tapped holes and riveted over each end to avoid leakage past the rivets. The flange should be a steel casting, so that it can be calked. Instead of using say two tees in the header for two boilers, and another tee for the engine, it is oftentimes more economical to construct one casting like detail A1–3, Fig. 69, and have fewer joints to care for.

It may occur to the pipe work designer that he would be departing from the manufacturer's standards to call for a manifold of this style; that such a detail would require special pattern work and special arrangement of tools at the factory, making it much more expensive to build than two standard tees, and a cross. Large high pressure fittings are not carried in stock by the manufacturers, therefore they are "specials" in the machine shop even though they may be made from standard patterns. To compare the cost of this manifold with a manifold made from three separate fittings we must consider the cost of patterns against that of four-faced flanges, drilled with bolts and gaskets, and the labor for making the joints. The manifold made in one piece will invariably cost the least, and if there should be no saving in cost this detail is decidedly preferable from an operating standpoint on account of its easier maintenance.

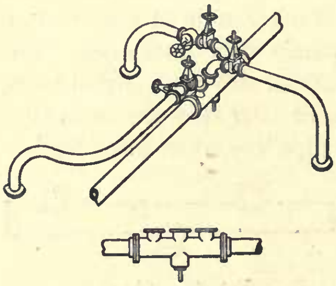

FIG. 69 (A 1–3).

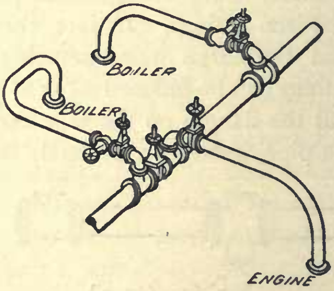

FIG. 70 (A 1–4).

In order to lay out the desired system it may be found necessary to run long connections, say from the boiler, in order to place the header valves according to the diagram previously determined upon. Such a case is shown in detail A1–4, Fig. 70.

The system should never be sacrificed for any notional idea of symmetry of connections. To preserve the desired system it may be found necessary to increase the length of a boiler connection say 10 or 15 ft., a feature which is neither expensive to construct nor to operate, as it would not ordinarily require any additional fittings or valves. In case the header is not over 200 ft. long it will not require any other provision for expansion than the branches to boilers and engines, which should be equal to a full length of pipe in each case. By anchoring the header at the center, the expansion would amount to about two inches at the end of the line, and this would be readily taken up in the boiler and engine branches. The fitter would be able to lighten the strains by drawing the end branches about an inch toward the center of the header when making the joint.

If the connections are flanged so that swings may be used, they will relieve themselves on the flanged faces while the line is heating up, and greatly reduce the strain on the connections. The relief thus afforded can be demonstrated by opening up an old joint and allowing the other joint to throw the pipe connections into a position free from strain.

In cases where extremely long mains are used it becomes necessary to break up the straight line, as shown in the detail A1-5, Fig. 71, and provide anchors for the steam main both at the engine and the boiler branches. In cases where it is desirable to keep the entire length of the header in a straight line, as would be necessary in long, straight tunnel work, it becomes necessary to take care of the expansion at very frequent intervals if elastic details are used to care for the elongation of the pipe. The U-bend for dividing headers is the most common method used in power stations. If the bend is laid flat in a horizontal plane, the drips will flow either way through it; however, placing the bend in a horizontal plane induces severe side strains on header supports, and these must be well cared for to prevent the header from climbing up on them and raising itself out of line. Placing a U-bend vertically throws the stresses in a vertical plane, which ordinarily would be fully counteracted by the weight of the header and branches; the drips must be cared for in this case at each side of the vertical U-bend. Which of these two difficulties can be the more readily cared for depends upon the surrounding conditions of each individual case.

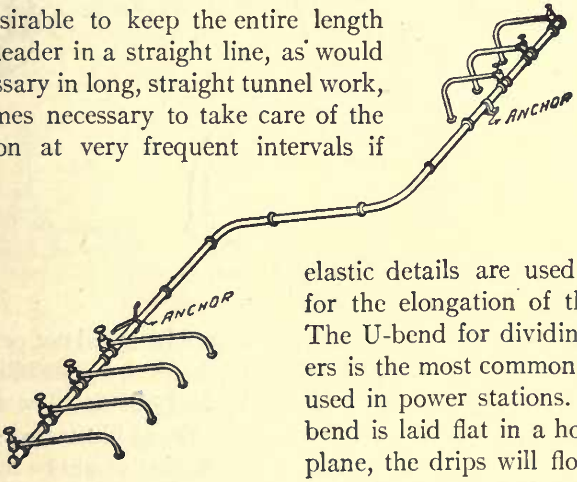

Fig. 71 (A 1–5).

A very elastic design of header is shown in detail A1-6, Fig. 72, in which the header constitutes merely an equalizer from one manifold to the next. The sizes shown are such as ordinarily would be used for a 2,000-kw. unit. The manifolds should be anchored to their supports, and throw all expansion strains onto the connecting lines. Whatever the design for the header and connections may be, it should be so arranged that the elasticity of the pipe will be sufficient to take care of expansion and contraction. This is the only means acknowledged as being permanent and efficient. There are various special devices for caring for expansion, but their use is confined to emergency cases only, or cases which will not permit the use of sufficient length of pipe to secure the desired flexibility.

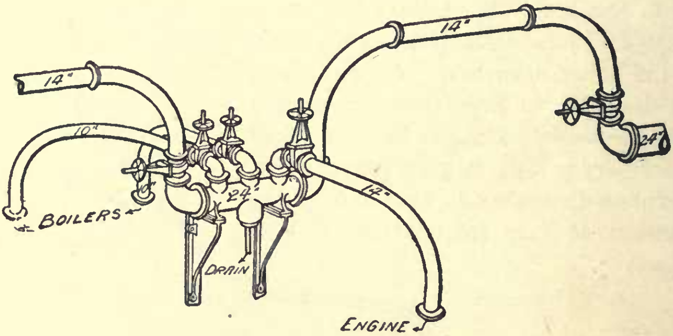

FIG. 72 (A1–6).

Supports for steam mains should be laid out to allow for both expansion and the side movement of the line, as illustrated in detail A1-5, Fig. 71. The points in the pipe line that would be the center of the expansive forces should be anchored to avoid vibration of the lines. Expansion and vibration are two conditions that must be provided for and neither must be permitted to interfere with the other.

The fittings ordinarily used for large steam pipes are made of cast iron and are extremely heavy. A much more desirable fitting could be made of soft steel plate, stamped and lap-welded, as shown in detail A1-7, Fig. 73.

The flanges could be of rolled steel, making an all-steel fitting, light and somewhat elastic. If the manufacturer had his factory equipped with proper machinery for making such a line of fittings he could without doubt produce them for about same shop cost as cast-iron fittings. There is no question but that the engineers would be universally in favor of using the steel plate fitting, and even if their cost were 50 per cent more, large sized fittings would invariably be specified of this make. A demonstration of the general desire for something more reliable than cast iron is evidenced by the very extensive, and in fact, almost universal use of rolled-steel flanges in place of cast-iron ones, which were formerly used for high grade, high pressure work. Manufacturers are using what they term "semi steel" for high pressure valves and fittings, and for no other purpose than to make them more reliable. Valves cannot be made light weight and of extremely strong material, as it is necessary to use sufficient metal in them to prevent any possible springing or distortion that would prevent the valve faces from closing tight. Fittings, however, do not have to be stiff and free from distortion, and in fact the more elastic the body of the fitting, the less strain there would be on the connecting lines.

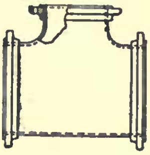

FIG. 73 (A1–7).

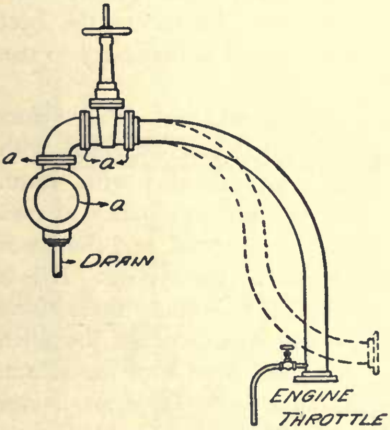

FIG. 74 (A2–1).

Class A2 — Live Steam; Engine Branches. The connection shown in detail A2-1, Fig. 74, is quite frequently used, as it allows a swing on the joint faces *a* and the top of the throttle. The engine throttle is placed at the lower end of the branch, allowing the condensation to accumulate over it when closed — a condition that would be very objectionable for a boiler branch, but not with the engine connection. When water is thrown out of a boiler branch it is carried to the engine while under full speed and in service. An engine branch, if not provided with a drain, will immediately discharge its water into the cylinder and the engine while slowly starting will discharge the water into the exhaust pipe and out of the way. The drain is generally the warming pipe, and before the engine is started the condensation is carried off. This style of connection should be used where the header is large, and it acts as a separator and is provided with drains. The dotted lines show a connection to a side-opening throttle which has a "triple-swing" connection, the same as shown in solid lines. A triple-swing connection, to be such, must have a horizontal and two vertical joint faces at one end of the connection, and the joint face at the other end is placed so that the axial line passing through its center will not coincide with the axial center line of any of the three joint faces at the other end of the connection. To secure the best results possible in steam pipe connections, it is necessary to use the "triple-swing" connection.

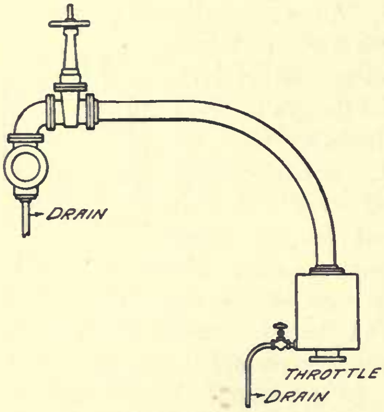

FIG. 75 (A2–2).

Detail A2–2, Fig. 75, shows a very usual, but nevertheless improper connection. The header is small and provided with drains and the receiver also is small and provided with drain. Instead of separating at one point it is designed to separate at two. High pressure drips are troublesome to take care of, and the fewer points there are to drain the simpler will be the system. It is a very common practice to use a large header — about three times the area of the engine connection — and depend upon the pitch of the header to remove the water carried over with the steam. This makes a very simple arrangement for caring for drips, as one drip line will care for the entire system. The objectionable feature of the connection shown in Fig. 75 is that it is necessary to drain at two different points instead of one.

Detail A2–3, Fig. 76, shows a well drained system. The header is of just sufficient size to convey the steam — possibly the same size as the engine connection. The separator is say twelve times the area of this pipe, which greatly retards the velocity, and provides a large volume of steam close to the engine. This receiver-separator would be too heavy to place on an engine throttle, and, as shown, would be a support for the header. The engine branch can be readily connected, as swings are provided at joints *a*. To take a branch out of side of the header similar to that taken out of the receiver would be bad detail, as it would not provide the swing that is always necessary for good pipe work. In case the steam header is placed below the floor the same details would obtain for removing condensation. The receiver located below the header is unquestionably the neatest and safest detail of this class.

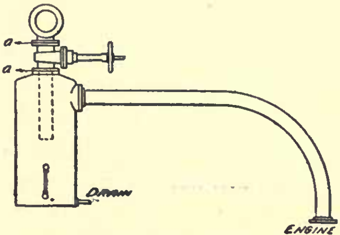

FIG. 76 (A2–3).

Detail A2–4, Fig. 77, shows the horizontal receiver-separator, which may also be placed above the cylinder with the throttle on top of the cylinder in the usual way, as shown by the dotted lines. One of the great advantages in the use of separators independent of the header is that the header can be made smaller, which permits the use of smaller valves and involves much less labor in making repairs, the vibration is reduced and the general operation more satisfactory. A plant that would require a 20-in. separator-header would in case of using receiver-separators be able to use about a

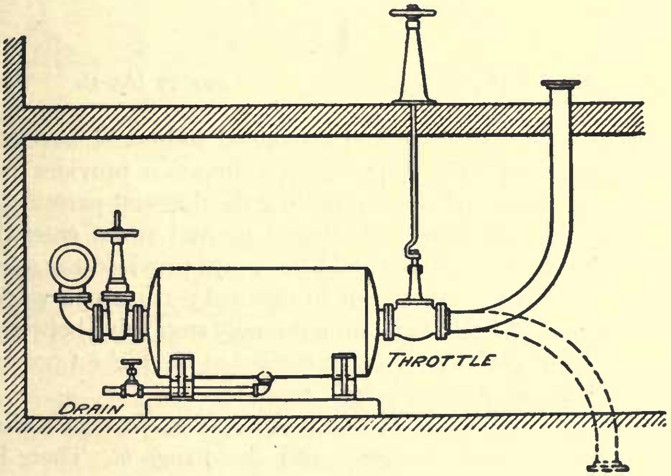

FIG. 77 (A2–4).

14-in. header. However, the large separator-header should not be considered anything but a means of partial separation, as the diameter is too small — even though it be 20 in. — and would cause the velocity of the steam flow to be about four times that through a regular separator.

Class A3 — Live Steam Boiler Branches. The connection shown in detail A3–1, Fig. 78, is one of the most approved forms of boiler connection; it has the triple swing, the same as the engine connection detail A2–1. It is quite difficult, and in fact impractical, to set a boiler or other piped device by the face of its pipe connection, and the result is that in making the connection between a header and a machine there are slight inaccuracies in every direction; and when pipe work is received and assembled additional inaccuracies become apparent. The triple-swing connection provides means of taking up these variations by rolling the different parts on their faces. In case the elbow were turned up and steam entered the header at the bottom, there would be swings provided the same as shown. The connection shown in detail A3–1 has two valves, a gate valve next to header and an automatic stop valve between the gate and boiler, both valves being located at the highest portion of the branch, insuring a dry branch at all times.

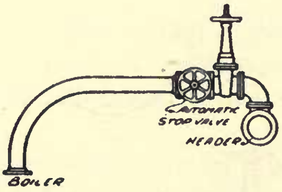

FIG. 78 (A3–1).

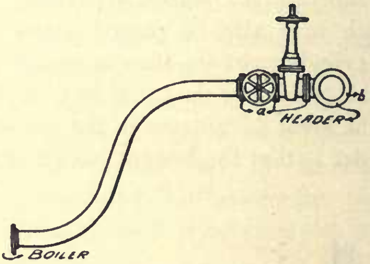

FIG. 79 (A3–2).

The connection shown in detail A3–2, Fig. 79, has a double swing — on the three flanges *a* and the flange *b*. There is no horizontal face to swing on, and if the boiler flange were not parallel with the face of the header tee it would be necessary to make a bend in the pipe connection, or "spring" it by pulling up on the connection bolts. There is no other detail in pipe work erection that will cause as much trouble from joints giving out as "sprung connections," or in other words, forcing two flanges together that do not set parallel, by drawing up hard on the bolts and compelling the pipe work to spring in order to make a joint.

The connection in detail A3–3, Fig. 80, though quite common, is far from good construction. It has but the two swings at joints *a* and *b*, and there are two water pockets, one at each leg of the U. In order to operate such a connection it is necessary to place a drain in each leg, and constant attention must be given to draining the connection before opening it into the header. If the U is made of considerable height to provide for expansion, it is very possible that the upper portion would vibrate to such an extent as to require anchoring, due to the fact that the connection projects a considerable distance from its supports. The amount of motion that any connection will permit without endangering its joints is determined almost wholly by its length and not so much by its form.

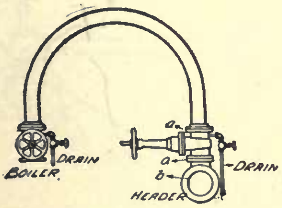

FIG. 80 (A3–3).

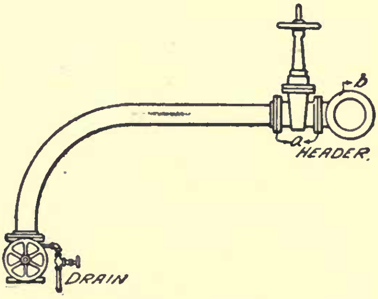

FIG. 81 A3–4).

Connection A3–4, Fig. 81, though a poor detail, has fewer faulty features than A3–3. By having the valve next to the header it would not be a very serious matter to open the lower valve without draining the branch, providing it was opened before opening valve next to header; this, however, is no appreciable advantage, as "regular operation" sometimes means doing the wrong thing until some serious damage is caused. There are only two swings in this connection at *a* and *b*.

Connection A3–5, Fig. 82, has the same swings and general construction as detail A3–2. This connection is shown entering the bottom of the header — a detail which is open to some criticism. There are many who believe that drips from the header will return to the boiler through this connection. This belief is shared mostly by the operating engineer, who argues "We get rid of the drips, where else can they go?" It is hardly correct to presume that the current of steam which because of its high velocity carried water into the header would later on permit it to return against this flow. Nor is it possible that condensation will accumulate in the header under a rapid steam flow through the boiler branches, and then return when the velocity becomes less; the drips cannot accumulate in such a header, nor can they flow along the header to some boiler which is not being worked hard, as the drips must then flow into and through the rapidly flowing steam.

Since water of condensation cannot accumulate in the header without flowing with the incoming steam, there is but one path for drips to take, and that is the path of the steam entering the header and flowing to the engine. The mere fact that the header is dry does not indicate that condensation has been returned to the boilers; it merely proves that drips do not stay in the header in "pockets," but keep moving, and this movement is toward the engines. If this is to be the method of discharging drips, it would be quite as safe to take engine branches out of the bottom of the header and keep the latter constantly drained through the engine. Or in other words, do not try to separate the water from the steam — a course which is too objectionable to be considered; objectionable not only in regard to steam economy, but because it makes it impossible properly or economically to lubricate the pistons under such conditions.

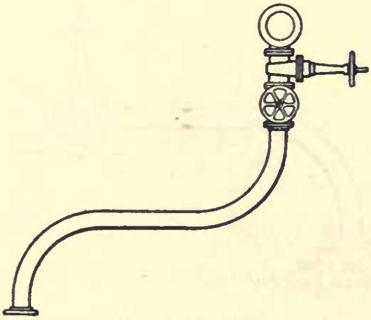

FIG. 82 (A3–5).

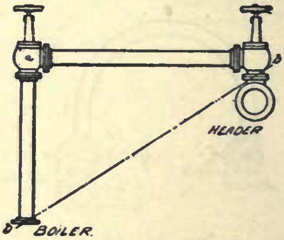

FIG. 83 (A3–6).

The connection shown in detail A3–6, Fig. 83, is objectionable, due to the location of valve at *a*, which is placed at a considerable distance from the line of supports, *bb*. The corner *a* will vibrate even more than the header, due to the amount of weight that is free to move. In case *a* is a fitting, it will also be liable to vibrate to such an extent as to require stay rods run to some support. In designing such branches, care should be taken to keep the heavy portions, such as valves and fittings, either near to the boiler or to the header, or to such parts as project the least amount beyond the line *bb* of pipe. Pipe work that requires tie rods and braces to stay the branches is faulty in design.

Detail A3–7, Fig. 84, shows what oftentimes cannot be avoided, a long branch from the boiler to the header. In case the connection is made as shown in this figure, the valve at the boiler should be at the high point, and entire branch from the valve should be pitched toward the header to avoid "water pockets." In constructing the branch in this way an objectionable feature is brought into the connection which may justify a compromise, a choice of the lesser evil. With the valve located at the boiler, the entire branch would be under pressure when the boiler is off, and this would constitute a large amount of condensing surface. In case any joint in the branch should require repairing it would be necessary to shut down the header to do so. To place a valve at the low point *a* would be inviting trouble, which would be quite sure to happen if the operator should forget to drain off the branch before opening it into the header. If it is possible to rise up from header and make *a* the high portion of the branch, then the valve (or valves, if two be used) should be located at this high point and all possibility of pocketing water will be avoided. Ordinarily this would be best detailed by placing a right angled (square) bend on top of the tee and locating the valve at the upper end. The valve would then be

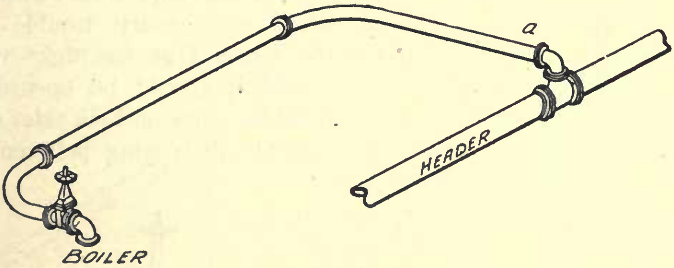

FIG. 84 (A3–7.)

secured against vibration; the long branch from the boiler to the valve should have a gradual pitch from the boiler up to the valve.

Detail A3–8, Fig. 85, shows an almost perfect arrangement for boiler valves, the two being located next to the header on the highest portion of the branch. The valve *a* is the shut-off gate valve, valve *b* is the automatic-stop valve, and valve *c* is the drain. The automatic valve can be taken apart when the header is in operation. Before doing so the leakage past the gate valve can be readily ascertained through valve *c*, and if it is too great to permit working on the automatic valve, much unnecessary trouble can be averted. The valve *a* can be retained as the tight valve by using two valves, *a* and *b*, and it should be opened or closed only when the pressure is about the same on both sides of it. The drain *c* would remove any condensation lying between the valves, but to avoid trouble in case the operator should neglect to open the drain, the valves should be placed as near together as possible to reduce the pocket to smallest possible amount. The mere fact that there is a valve at each end of the pocket does not prevent its filling with water, as it is next to impossible to maintain valves absolutely tight. The leakage continues to condense until the space is filled with water. The drain *c* should discharge into an open funnel so that the operator can see and hear it when it is open. This drain *c* is extremely useful when cleaning a boiler, as it discharges all condensation out of the branch instead of permitting it to run down the branch onto the boiler cleaner, in case he is working under a steam opening.

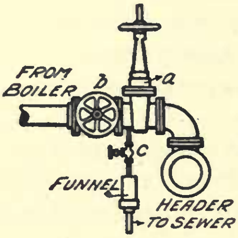

FIG. 85 (A3–8).

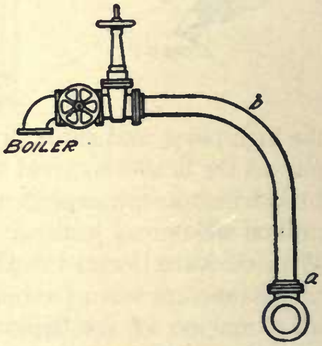

FIG. 86 (A3–9).

The connection shown in detail A3–9, Fig. 86, is such as would be used in case the header were located below the opening of the boiler. There would be the same number of joints between the valves and the header, using the bend shown, as would be used with an elbow, as shown in detail A3–1. The only difference is that more radiating surface is exposed when the boiler is out of service. It is preferable to sustain this loss rather than to run any chances of damaging the steam machinery by water. If the connection from the header to the valves can be made with one length of pipe the radiation loss will be quite slight.

The connection shown in detail A3–10, Fig. 87, is extremely long, and instead of making it as shown by the dotted lines there would be less trouble from vibration if it were constructed as shown by the full lines, its weight being kept close to a line drawn through the supports. The far-projecting bend is almost invariably a badly vibrating detail. The principles of detail A3–10 may be carried out with gate valves also.

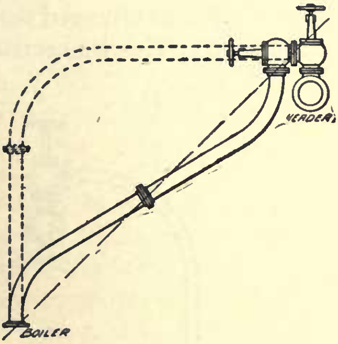

FIG. 87 (A3–10).

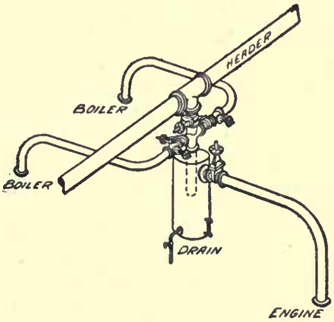

FIG. 88 (A3–11).

The connection shown in detail A3–11, Fig. 88, is specially suited for the systems shown in the previous chapter, in which the mains or headers are merely by-passes from one group of units to another. It is possible with this system to isolate one or all of the units, to run No. 3 engine unit with No. 1 boiler unit, or run all as one system, the header being an equalizer, and only a small portion of the total steam passing through it. It is a very simple undertaking to repair such a header at any time, the only loss being that due to running each unit separately. Tests can be made with perfect ease on any unit, by isolating it from all others. But one extra valve is required for each group of units. If for any reason one steam machine can be worked to better advantage with lower steam pressure, this condition can be quite readily met. With this arrangement one unit can be put into operation without making use of any part of the header.

Class A4–14 — Live Steam Auxiliary Main and Branches to Pumps and Engines. The general features of the auxiliary main deal more with system details than with construction. The auxiliary main should be kept sufficiently far from the steam header to allow for expansion and contraction in the case of one being cold and the other hot. The main should be pitched in the same direction as the flow of steam, and provision should be made for draining it.

Fig. 89 (A4 to 14–1) shows the auxiliary main with an opening at the top, and the governor, valves, and by-pass so arranged that their weight will be easily carried by the main. This connection would be very suitable for flanged work. By taking steam out of the top of the main and keeping the main drained, any auxiliary can be immediately started, and it will not be liable to stoppage or dropping off in speed due to the pump filling with condensation. Any pump or engine using a steam governor should have a valve on each side of the governor and one in the by-pass, also a throttle valve at the pump. A valve on each side of the governor is necessary in order to take the governor apart and to be able to use the pump while doing so. The independent throttle is necessary to

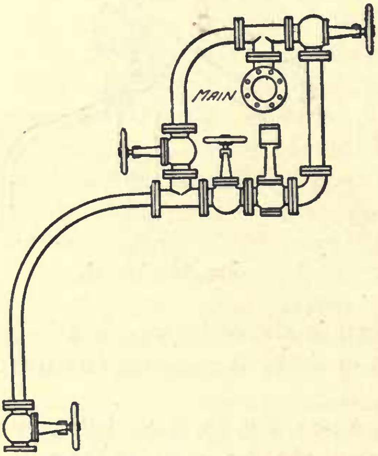

FIG. 89 (A4–1).

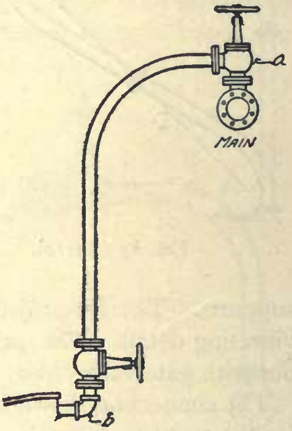

FIG. 90 (A4–2).

save wear on the stop valves, so that when they are used they will close tightly, and will also limit the speed of the auxiliary when the automatic valve opens to its fullest extent.

Fig. 90 (A4 to 14–2) shows a very satisfactory arrangement for branches to auxiliaries not requiring a regulating valve. The stop valve *a* should be placed next to the main. Stop valves should be placed in every branch to the pumps, etc., in addition to the throttle. The throttle valve should always be a globe or an angle valve and should be arranged as shown so that it can be repaired after closing the stop valve. The use of a small drain valve at *b* is both unnecessary and undesirable. The drains can readily be worked through the cylinder, and a valve at this point merely adds an unnecessary point of leakage. Pump builders ordinarily furnish a Y at end of steam cylinders with an outlet on a horizontal plane as shown in detail A4 to 14–3.

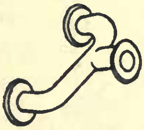

FIG. 91 (A4–3).

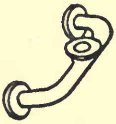

FIG. 92 (A4–4).

Fig. 91 (A4 to 14–3) may be preferable to Fig. 92 (A4 to 14–4) in regard to its manufacture, but in almost every case detail A4 to 14–4 can be used, and this will avoid projecting the steam connection far from the pump. It will make a difference of about 12 in. for a 3-in. steam connection. The pump builders will furnish detail A4 to 14–4 if specified when ordering pumps.

In case a pressure regulator for an engine governor is used, as for a draft fan, the governor should be placed at a considerable distance from the engine, or there should be provided sufficient volume between the engine and the governor so that the cut-off of the engine will not cause the governor to be constantly on the move, resulting in rapid wear and requiring a great deal of attention; if it is desirable to place the governor close to the engine, so as to be within reach, a "receiver" can be used whose volume is about equal to that of 16 or 18 ft. of regular size steam pipe.

As shown in Fig. 93 (A4–14), an engine having a 2-in. steam connection would require a receiver say of 4-in. pipe 4 ft. long or 6-in. pipe 2 ft. long. A receiver is not necessary for a pump, due to the fact that a pump takes about the same amount of steam practically all the time. It is good practice to make the governor flanged, and in case of a plant using two or more engines, to have an extra governor constantly on hand and in good order, so that instead of repairing the governor in position it may be taken out and replaced by the governor which is in good order. Pump governors are almost universally installed in a by-pass. The manufacturer could improve this feature very materially if he would make the design one complete, compact unit, as shown in Fig. 94 (A4 to 14–6), with a strainer, stop valves, by-pass, and flange connections.

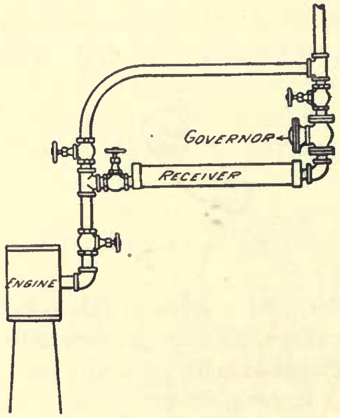

FIG. 93 (A4–5).

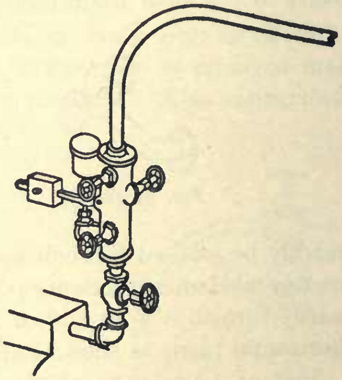

FIG. 94 (A4–6).

By comparing with Figs. 89 (A4 to 14–1) and 93 (A4 to 14–5), it will be seen how compact and neat such a device can be made. There are various types of steam governors used for pumps, draft fan engines, etc., each having its uses, merits and faults. The type ordinarily used on pumps is similar to Fig. 95 (A4 to 14–7); this view shows a self-contained by-pass as part of the governor.

This style of governor serves to maintain the water pressure constant, regardless of steam pressure, the steam valve being practically balanced. The water pressure and spring are balanced at the normal pressure. This is the type of governor ordinarily used for fire pumps. It is not suitable for feed pumps as but one pressure is maintained.

Fig. 96 (A4 to 14–8) shows the boiler feed pump governor.

The water must in this case have sufficient pressure in excess of the steam to close the valve, the weight increasing this resistance as much as desired; the area of the steam valve and the water piston are practically the same. This type of governor will maintain the pressure of the feed water say 8 lb. above steam pressure, regardless of whether the steam pressure is 60, 120, or 180 lb. This is very essential for boiler feeding, as no feed valve will stand such service as 180 lb. of water feeding boilers whose steam has dropped say to 100 lb.; the water pressure should drop with steam pressure, the excess pressure being only sufficient to overcome friction in pipes and enabling the feed valves to be left fairly well open. The governor shown in Fig. 97 (A4 to 14-9) is oftentimes used as a pump governor, being in reality a pressure reducing valve, and maintains a constant fixed pressure of steam in the cylinder.

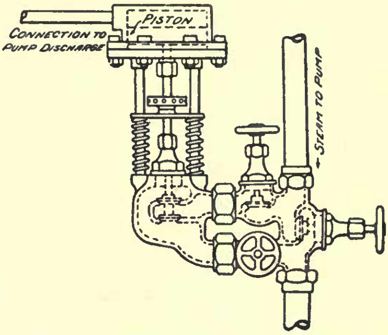

FIG. 95 (A4-7).

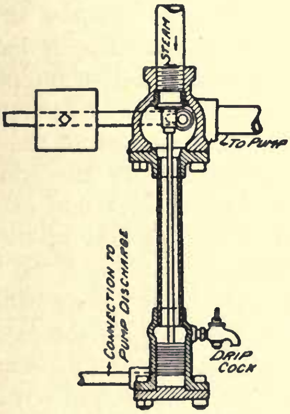

FIG. 96 (A4-8).

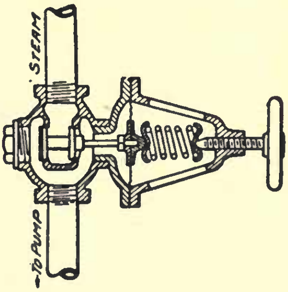

FIG. 97 (A4-9).

When using this style of governor a gage should be placed on the steam branch below the governor, also one in the pump discharge. It may require say 30 lb. of steam to give 80 lb. of water pressure under certain conditions of the pump, and by repacking or tightening the packing it may require 50 lb. of steam to balance 80 lb. of water. This change, however, is not frequently made, and whenever it is, the governor must be reset. This governor has the advantage of having no pistons and stuffing boxes, which soon cause a governor to stick and become very insensitive. In other words, the average operation of this type is more satisfactory than the piston or stuffing box type. The same governor, A4 to 14–9, is used on draft fan engines, the steam flowing in the reverse direction to that shown. The pressure of steam is in this case balanced by the spring, and if the pressure rises, the draft fans are run slower; if the pressure falls, the spring opens the valve and the draft fan engine runs at higher speed. This type of governor is ideal for a draft fan engine — very simple and easily regulated. The governor, A4 to 14–8, can be modified so as to eliminate the stuffing box and piston.

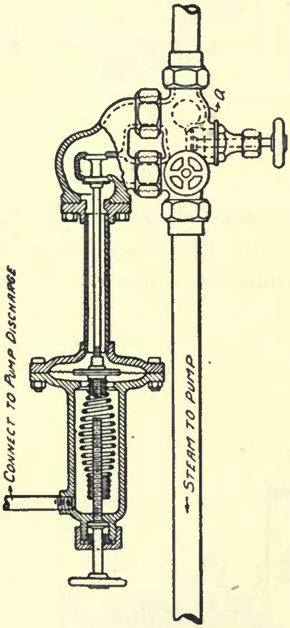

FIG. 98 (A4–10).

Detail A4 to 14–10, Fig. 98, shows the governor with by-pass arrangement. The steam valve is balanced and when water and steam pressure are the same, the diaphragm is balanced. The loading of the spring must be overcome by the additional pressure of water over that of steam. There is a stuffing box at the hand wheel stem, but there is no movement at this point except when the tension of the spring is being set. The by-pass shown in this figure is much preferable to detail A4 to 14–6 as it permits the governor to be readily disconnected while the pump is running, and at the same time leaves the pipe work perfectly supported, which is not the case with detail A4 to 14–5. The by-pass shown in detail A4 to 14–10, indicated by the letter *a*, is virtually three valves attached to the one valve body. The diaphragm and tension spring are both protected from high temperature by the condensation and pump water in the lower part of the regulator. The lower tube is made of brass to aid in conducting heat away from the condensation. This governor covers the requirements for boiler feed pumps in all particulars, and in selecting a governor for this purpose these different features should be considered. The tension spring has a nut attached at each end, the upper end being made fast to the valve stem. The hand screw engages with the lower nut, and for boiler feeding would put a tension on the spring. If lower water than steam pressure is required, then the spring would be placed under compression. For example, if 60 lb. pressure were required, and the boiler pressure were 120 lb., the spring would be loaded so that the water pressure would be 60 lb. less than the boiler pressure. If a fire pump is to be used for a feed pump also, this governor, detail A4 to 14–10, is preferable to the devices shown in detail A4 to 14–17 with stuffing boxes, pistons, etc. The latter is more inferior as a feed pump governor than A4 to 14–10 is as a fire pump governor.

Fire pump governors cannot be made without at least one stuffing box at the steam valve body. Stuffing boxes cannot be made tight unless the packing is forced closely together and close to the stem. The high temperature makes the packing hard, and ordinary pressure then merely presses portions of packing against the stem; to make old packing tight it must be forced against the stem. Any automatic devices such as governors, etc., should be entirely free from stuffing boxes through which the valve is automatically worked, if it be desired that same shall at all times be sensitive.

The governor shown in Fig. 99 (A4 to 14–11) is such as would be used for the steam driven air and circulating pump, controlled by both the vacuum and the steam pressure in the cylinders. With no pressure in the pipe to the pump, the tension spring would open the valve. Assume the incoming steam to be at 120 lb. pressure, and spring loaded for 30 lb. per sq. in. If the pressure to the pump then is 30 lb. without any vacuum the valve will close, or, if the pressure to the pump is 15 lb. and the vacuum is 15 lb., the valve will close. When the pressure to the cylinder is 20 lb. and vacuum 10 lb. the valve will close. This type governor permits a certain speed of the pump for each varying vacuum pressure. If there is no vacuum the pump will not be allowed to run away, and if there is the highest vacuum the pump will be kept in motion. This is absolutely necessary in order to maintain the vacuum. It will be observed that this device would necessitate low initial pressure, in fact lower than would be necessary to run non-condensing, unless an extra large steam cylinder is used.

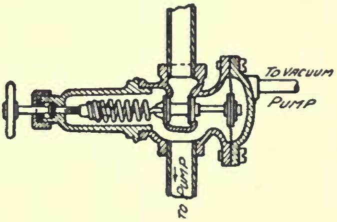

FIG. 99 (A4–11).

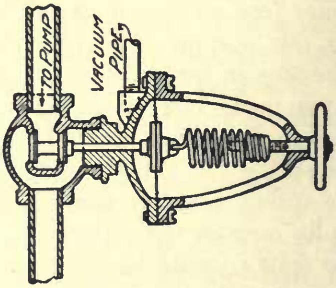

FIG. 100 (A4–12).

The regulator shown in Fig. 100 (A4 to 14–12) can be used for this service, and it allows the steam pressure to the pump to be what it will. This regulator brings in the objectionable feature of the piston, the stem passing from the vacuum chamber to the steam chamber. It is a ground joint and as close a fit as can be made and move freely. There are many regulators made on this plan, and the claim for them is that the leakage is small and does not cause an outside drip. The spring in this regulator is loaded in tension, so that proper speed will be obtained when carrying full vacuum. As the vacuum drops or the pressure rises under the diaphragm, the spring draws the valve from its seat.

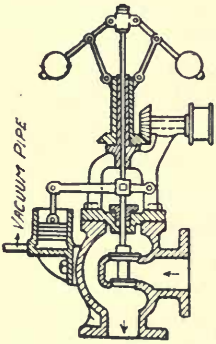

FIG. 101 (A4–13).

This same style of valve, Fig. 100, is used as a governor to maintain a constant pressure higher than atmospheric pressure. The spring then is in compression and the valves close in the reverse direction from that shown. In other words, the increase of pressure under the diaphragm causes the valve to close. The independent crank and fly-wheel dry vacuum pump is ordinarily supplied with a fly-ball centrifugal governor and a small air cylinder and piston that act upon the governor valve in conjunction with speed control, as shown in Fig. 101 (A4–13).

This same style of governor is also used for air compressors working above atmospheric pressure. This style of regulation is quite satisfactory, the air cylinder comprising only a partial control.

Class A15 — Live Steam to Stoker Controller and Rams. There is another feature of governing that will require consideration in case stack fans and force-draft fans are used. An installation of this description brings into consideration numerous details that should be dealt with as a whole and not separately. For instance, it may be desirable to install an induced-draft and fan engine, forced draft for stokers with a separate engine, and coal feeding mechanism. It has been customary to place independent governors on each of these three drives and allow any one of them to increase or decrease in speed as determined by its own governor. That is, the fan engine may slow down before the coal feed or air blast engine and cause furnaces to discharge gases out of the fire doors, etc. Again the coal feed may speed up before the air blast, causing a waste of the gases; or the air blast may speed up without coal, causing loss of heat units in heating useless air.

These three elements should have a better system of control than a separate governor for each. When one is increased they should all three be increased, and vice versa. The governor should control all three. One steam governor to increase or decrease the pressure for the three would be wholly useless. This is a peculiar condition to contend with for the reason that no present form of governing will properly meet this condition and it is a condition that very materially affects the efficiency of the plant. Assume that the pressure is very high and that the three services are running at their extreme low speed. Now undertake to adjust the fan governor to run the engine at such a speed that it will just allow the pressure over the grates to be atmospheric pressure, or say one-tenth inch of water by the draft gage. Note the quantity of air and adjust the coal feeder accordingly; there are then the three elements working in a most economical manner. Leave the governors as adjusted and allow the plant to run up to full capacity and then note the conditions again. It may be found that the steam pressure is about 10 lb. lower than usual, the blast fan is running at a frightful speed, stokers are running at a good speed, and the stack fan has not increased as much proportionately as the other two. The operating conditions are wretched, showing poor economy, furnaces smoking, blast engine fairly pounding itself to pieces — and for all, the governors are working "perfectly"; the fault lies in the system of governing.

It is unreasonable to expect three governors, possibly of different size or make, and for three entirely different services, to "measure" out the requisite steam. To-day, when running one-quarter capacity, the fan engine may want 50 lb. of steam per hour to maintain the proper speed to discharge the gases corresponding to one-quarter capacity. The blast engine may want 65 lb. and stoker drive 20 lb. For one-half load the requisites may be 70, 90, and 30 lb. respectively, and for full load 85, 115 and 45 lb. Any of the three requirements would be varied by tightening the packing, or making any other adjustments.

The ordinary governors are adjustable, so that a certain delivery of steam will be obtained at the particular pressure set. For any other pressure the steam discharge may be almost any amount, and whatever it is, the operator cannot control it in any way. The governor, to be suitable for such service, should be so constructed that it will permit a flow of a certain number of pounds of steam per minute at lowest pressure, and should be adjustable also for a certain volume at the higher pressure. Such a governor is not on the market. Without it no three machines or even two machines can be worked economically except at one particular rate of coal consumption. There are two methods of arranging this style of governing. One is to arrange the governors so that their range as well as their normal pressure can be adjusted. This detail is shown in Fig. 102 (A15-1).

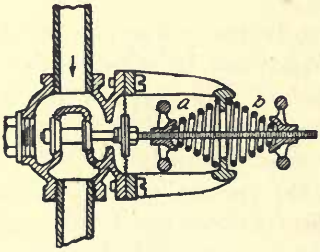

FIG. 102 (A15-1).

Ordinarily the spring *a* would be the spring to balance the desired steam pressure. By having a counteracting spring *b*, the movement of the valve stem through the range of pressures can be varied greatly. For instance, if the tension is taken off spring *b*, the travel of the valve stem may be one-quarter inch while steam pressure is varied between 150 and 160 lb. When tension is put on spring *b*, additional strain would be required on spring *a*. By increasing the strain on both springs the travel of the stem for 10 lb. variation may be reduced to $\frac{1}{16}$ inch or even less.

The other method of governing is as shown in Fig. 103 (A15–2). The stack, blast, and stoker motors would each have a rolling type of valve with a slotted lever, and a rock shaft which would also have slotted levers. The shaft would be rolled by means of a standard damper regulator, the shaft being located possibly at the upper portion of the boiler front. Each of the three valves can be separately set for low speed and high speed conditions. The speed changes would be effected simultaneously on all three valves. The damper regulator can be set so that within 3 lb. variation the engines may be running from no load to full load. This arrangement would be far more reliable and sensitive than separate governors. In case natural draft is used instead of a stack fan, then the rock shaft would operate the dampers instead of the stack fan engine. Counterweights would be placed on the valve levers, keeping all lost motion out of the parts, and enabling them to be made in a comparatively crude way.

An accurate system of regulating furnace auxiliaries will save not less than 5 per cent of the fuel, and for a plant of 3,000 kw. a saving of 5 tons per day at $1.50, or $2,750 per year would be shown. The system shown in detail A4–15, Fig. 103, would cost possibly $100 more than independent governors, and would involve some study and trouble for the engineer. The valve for this work should be of the corliss type, with the engine lubricator placed above it, so that the valve also would be lubricated. The valve shown in Fig. 104 (A15–3) would be very suitable.

This valve requires more effort to open than a balanced valve, but it closes much tighter, and since there is ample power available with the damper regulator, a valve such as is shown in detail A15–3, that opens and closes slowly, is much easier to adjust and will stay adjusted. Any valve of the globe valve type opens too quickly for close regulation. This valve is the standard "throttle valve" with a slotted lever instead of a hand lever. The by-passes and valves permit any one of the three machines to run temporarily

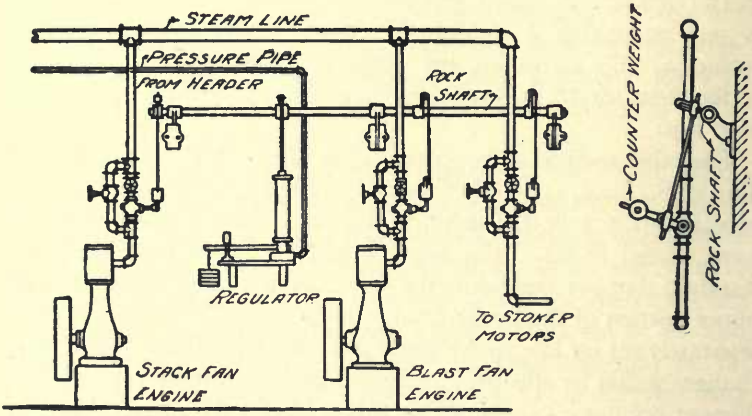

FIG. 103 (A15-2).

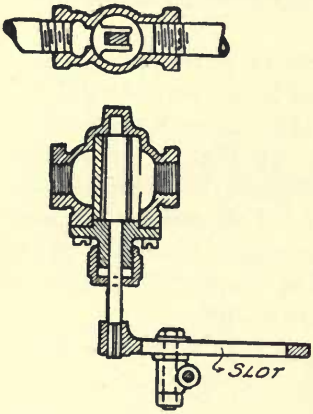

FIG. 104 (A15-3).

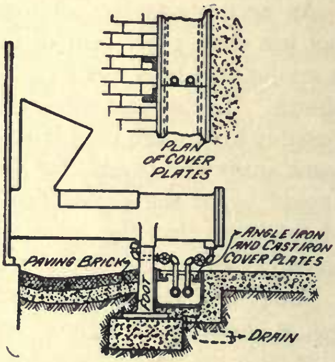

FIG. 105 (A15-4).

at a higher or lower speed, and at the same time the fixed regulation is not altered.

The steam lines to an underfed type of stoker should never be buried, but may be placed in a trench, as shown in Fig. 105 (A15–4), which arrangement is satisfactory if the trench is well drained. If the drainage is poor any water such as waste from wetting down ashes will collect in the trench and be evaporated on contact with the live steam pipes, the steam thus formed interfering with the work of the attendants.

The steam pipes for the stokers should not be covered in any way and the supports should be such as will permit of free expansion and contraction. With the trench as shown in the figure a set of cover plates as also shown should be used. The drawing shows the cast-iron cover plate supported on angle irons. If there is a basement under the boiler room the stoker steam mains can easily be supported under the floor.

To obtain the best results with steam stokers it is advantageous to arrange the piping so that there will be a downward flow from the feed mains to the piston cylinders and through the exhaust. This detail necessitates the placing of the steam-controlling valve above the steam line to the stoker rams, and the exhaust main below the cylinders. If the same main is used for steam and exhaust alternately it should be placed below the cylinders with the steam-controlling valve above and the exhaust-controlling valve below. To avoid water hammer in the pipe line, the drips should at all times have a downward flow and those drips collected in the low down main should be discharged at the low point, even though the exhaust is made from a higher level.

Class A16 — Live Steam to Tank Pump. In feeding steam to the cylinders of tank pumps it is often possible to use the type of pump controller shown in Fig. 106 (A16–1), which is more satisfactory than a pressure-operated governor. By referring to the illustration it will be seen that this type of controller consists of a needle valve, operated by a cable connected with a float in the elevated tank.

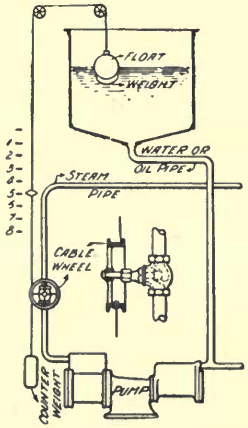

FIG. 106 (A16–1).

The needle valve used should be of the slow-opening type of globe valve. In order to provide for operation of the pump independent of the float it is desirable to run a by-pass around the controller valve.

The arrangement of governor construction just described permits the pump to be run at speeds varying directly with the quantity of water or oil in the tank. It also furnishes the desirable feature of keeping the pump in operation at nearly all times, thus preventing interruptions from condensation. The telltale shows the level of the fluid in the tank, even though the operation of the valve and its counterweights is interrupted. For installations where the storage tank is located at some distance from the pump, or where the pump is required to deliver water for other purposes and at different pressures, it may be found advisable to place a float valve at the tank to shut off the supply and use a pressure regulator to control the steam to the pump.

Class A17 — Live Steam to Smoke Consumer or Oil Burner. The piping for steam to smoke consumers or oil burners would come under class A–17, but these details will not be considered here; a smoke consumer, by reason of the destructive effects on boilers, should be used only in exceptional cases; oil burners are installed by their manufacturers and the piping laid out more according to builder's details than general piping designs.

Class A18 — Live Steam to Soot Blowers. In arranging the piping for soot blowers the steam should be taken from a separate main and not from the boiler. The independent supply is quite necessary in order to enable the clearing of the tubes of a boiler when it is out of service. Openings for soot blowers should be provided at the sides of the boilers. The detail design and arrangement of the soot blower piping are shown in Fig. 107 (A18–1). The branch main for the steam supply to the blower should be strongly supported so that it may withstand the hard pulls and jerks of the operator. A quick-closing valve, located as shown in Fig. 107, will partially relieve the hose of the pressure while blowing and entirely cut off the steam when the blower is being moved

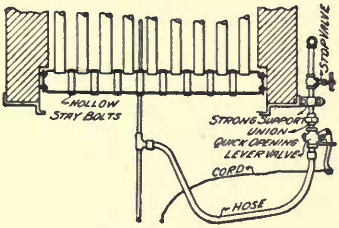

FIG. 107 (A18–1).

from one part of the boiler to another. This quick-opening valve should be attached to the hose and not be a portion of the fixed piping; the tight-closing valve as shown should be used only as a stop valve, since if it were used as a throttle it would soon become leaky. Any slight leakage in the balanced-lever valve will not interfere with the operation of the cleaner.

The subject of soot cleaning appears quite simple, but nevertheless there are many plants running on very poor economy because they cannot clean soot and deposit from the tubes. It is no uncommon thing to find 500-hp. water-tube boilers set with a 3 to 4-ft. passageway and tiled for vertical passes. The outside measurement of such boilers is about twelve feet. Good economy can be secured with vertical passes only when ample provision for cleaning is provided. Horizontal passes permit the use of long blower tubes operated from front and possibly the rear of the boiler setting, thus enabling much more thorough cleaning where it is necessary to place wide boilers with narrow alleyways.

Class A19 — Live Steam By-Pass to Exhaust Heater or Heating System. A steam by-pass to the exhaust heater or heating system is provided to furnish live steam to the exhaust heater when there is but little exhaust and high temperature water is desired. The valve shown in Fig. 97 (A4–9) can be used for this service with the steam flow as shown. Such a valve should be small and have a very large diaphragm. A light spring should be used to balance a pressure of say 1 or 2 lb. per square inch on the diaphragm. Ordinarily when there are differences in pressure of from 2 to 160 lb., it is found more satisfactory to use two regulators of the same design, one reducing to about 60 lb. and the other to the pressure on the heater.

There is a rather peculiar feature in connection with machinery, the back pressure steam from which is used for heating water or buildings: When the demand for low pressure steam increases the back pressure is reduced, at the same time the amount of steam being delivered by the machine is also reduced. When less steam is being condensed in the heating system the back pressure rises and thus compels the engines to take more steam to perform the same work. This wastes steam to the atmosphere. The heater control should be such that when the back pressure drops, the engine should take more steam and when the back pressure rises, the engine should take less steam, this being the reverse of the usual practice. In other words, when the back pressure tends to rise, the engine should be allowed to exhaust to the atmosphere and be relieved of all back pressure, and the pressure on the heater should be allowed to drop before the engine exhaust is again discharged into the heater system. Thus the amount of steam used from the engine would be reduced.

In Fig. 108 (A19–1) is shown a valve arranged to perform these duties. When the valve is open to the atmosphere the weight exerts a pressure per square inch of say 2 lb. against the heater pressure and when the valve is down it exerts a pressure of 4 lb. against the port to the atmosphere. This range may be increased say from 6 lb. back pressure to 1 lb. heater pressure by positioning the lever on the valve stem and by varying the location of the weight on the lever. Such a valve enables the engine to exhaust to the atmosphere all the steam that a heater or heating system does not condense. The valve is now on the market, being used as an atmospheric valve in connection with a condenser, the condenser taking the place of the heater as shown. The lever should roll on a rock shaft similar to that shown, so that the weight will neither pass nor stand over the center of this shaft. If this valve is adjusted so that it closes against atmospheric pressure at 3 lb., then the live steam by-pass should be set to be open only on pressure below 2 lb. This will avoid blowing live steam into the heater while the engine is exhausting to the atmosphere.

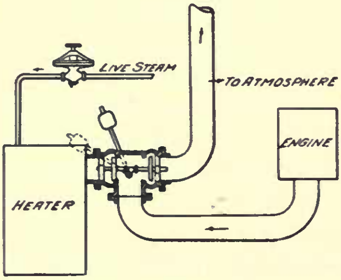

FIG. 108 (A19–1).

Class A20 — Live Steam to Whistle. Whistle connections cause considerable annoyance due to condensation accumulating in the pipes before the whistle is used. The connection shown in Fig. 109 (A20–1) will allow condensation to accumulate at the top of the valve and requires blowing through the whistle before the tone is right.

The connection shown in Fig. 109 (A20–2) necessitates a hole through the roof for the whistle cord and allows considerable condensation of steam in the pipe, which is especially undesirable if the pipe is long.

The latter style of whistle connection is quicker to operate and produces the correct tone as soon as opened, but for a long run of pipe the detail shown in Fig. 109 (A20–3) will be found more satisfactory as it allows the whistle valve to be placed low down, and the upper pipe to be well drained until the steam valve is opened. The drain closes simultaneously with the opening of the steam valve.

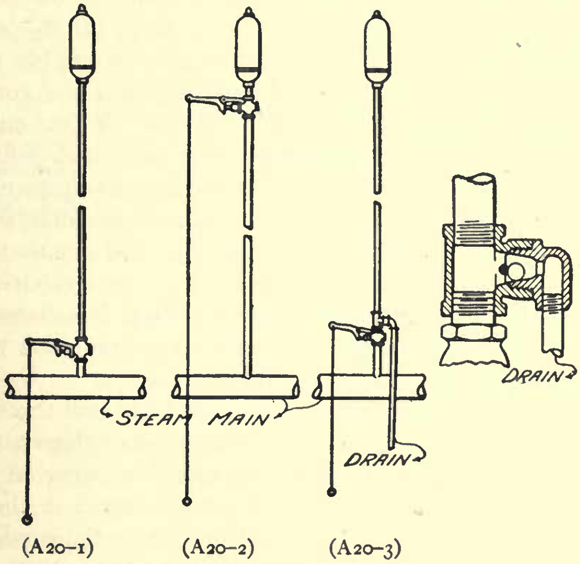

FIG. 109.

Class A21 — Live Steam to Ejector Vacuum Traps. The steam branch to an ejector vacuum trap is for the purpose of breaking the vacuum and discharging the condensation. There is considerable mechanism in these devices because they contain automatic features which permit the steam to blow out condensation immediately following the closing of the vacuum drip line to the trap. The piping details of ejector vacuum traps have no special piping features.

Class A22 — Live Steam to Heating System. The steam required for a heating system would not ordinarily be very extensive in a power station, but in case heat is to be provided for car shops and neighboring buildings some special arrangement in station piping system and machinery may be made so that exhaust steam will be available and can be used for heating. This will be taken up under the details to be later considered in Class C.

Live steam heating should be avoided wherever possible. The high pressure of the steam causes leaks at stuffing boxes, joints and similar connections that will give no trouble at low pressures. To stand high pressures the heaters must be in the shape of pipe coils, and if steam at 160 or 170 lb. be used it is liable to injure whatever it comes in contact with. However, for a condensing plant there is no other system suitable if there are but one or two rooms to be heated. Exhaust steam from auxiliaries, when piped to a heater, is not sufficient in amount to maintain a pressure which will allow the distribution pipes to be of any considerable length. The rooms to be heated are generally the chief engineer's office, lavatory, stock room and an oil room. The use of electric heaters would not be justified because the cost of their installation would equal steam heaters and the cost per B.t.u. of radiation would be possibly 50 times that of steam heating.

If there are but three or four rooms to be heated there is practically no better method in a condensing plant than to use live steam. The temperature can be regulated, as shown in Fig. 110 (A22–1), by allowing more or less air to remain in the heater. The air will lie below the steam and just above the condensation. The drips from the heating coils should discharge to the atmospheric exhaust line. This discharge will save the water of high temperature, together with any leakage of steam passing the trap, and avoid difficulties attendant upon exhausting drips to a sewer, which practice not only injures the sewer but causes steam to leak from the catch basins.

The coils should be laid out so that the pipes will run into a corner and return, allowing free expansion and contraction. Such expansion is very severe in a stiffly connected live steam heater. The corners should be made of pipe bends, but bends for connecting purposes will necessitate unions at either end of each pipe. A simpler method is to use elbows and right and left thread connections in the short return.

Another method of regulating the temperature of a live steam heater is as shown in Fig. 110 (A22–2). In this arrangement the steam valve is a hand controlled throttle; the drip valve has a very small hole drilled through the disk. While in operation the drip valve is kept closed, the discharge of drips being through the small drilled hole. The principle of this detail is more complex than it would at first sight appear. For every varied amount that the steam valve is opened a balance is established in the heater coil. By increasing the opening of the steam valve a greater pressure is exerted in the heater, and a greater quantity of drip is discharged through the lower valve. The condensation, or air, is discharged until the increased heating or condensing surface reduces the pressure in the heater, simultaneously reducing the drain through the lower valve. When the upper valve is further closed the pressure in the heater is reduced, the discharge at the lower valve is retarded until the heating or condensing surface has been reduced by increased condensation to the point where the pressure is about to raise and increase the flow of drip.

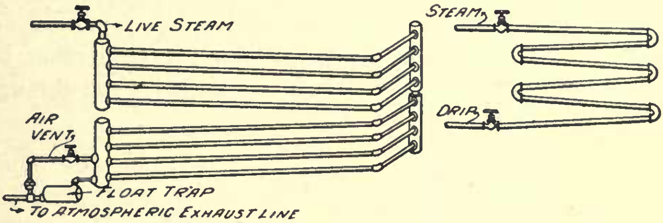

FIG. 110 (A22–1, 2).

Class A23 — Live Steam Cleaner for Oil Tanks. The branch from which live steam is drawn to clean the accumulation from storage oil tanks is seldom used and therefore should have a stop valve as close to the steam main as possible. Steam is used to raise the temperature of the tank cleaning water, so that the grease and precipitation can be removed from the sides and bottom and easily washed out of the tank. The simple method of piping for the tank supply is shown in Fig. 111 (A23–1). The hose is connected to a valve next to the ejector tee which operates as a mixer. The cleaner is made of a length of pipe with a wire brush attached at the lower end and a nozzle from the pipe adjusted to discharge the steam and water on the brush. This device offers a quick method for loosening and washing the gum and grease from the shells of oil tanks. The hose need not be wire-wrapped because it is not under very high pressure, possibly 15 or 20 lb. The brush can be secured to the bent pipe as shown in Fig. 112 (A23–2). The upper portion of the handle should be of pipe with its lower end forged solid.

Class A24 — Live Steam from Header to Atmosphere. It is not customary to install a steam blow-off from a header to the atmosphere. For this reason it often is necessary to reduce the pressure on the header by blowing off through some engine. If the header is divided into three sections, each section should have a blow-off not less than 1.5 in. in diameter run through the roof. Repairs to the steam main can be made much more readily if there is a means of quickly relieving the pressure on a damaged section.

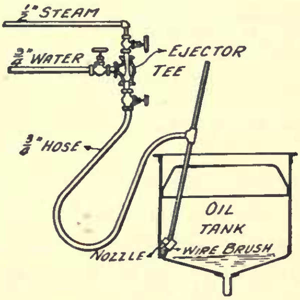

FIG. 111 (A23-1).

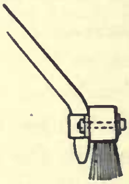

FIG. 112 (A23-2).

Class A25 — Live Steam to Damper Regulator. The steam line which feeds a damper regulator is ordinarily designed to transmit the pressure in the main to the weighing device of the regulator. This line should be tapped from a drip pocket or the bottom of the header, so that condensed water will be delivered to the regular pipe instead of steam. If the valve at the regulator were leaking badly at a stuffing box, the small pipe would then not be able to condense fast enough to supply water to the leak. This would allow live steam to come in contact with and injure the rubber diaphragm. Such damper regulator diaphragms are made to stand the boiler pressure, but they will not stand the temperature of steam at boiler pressure.

Class A26 — Live Steam to Oil Filter. Steam is often fed to a filter so that more rapid work can be done by a filter which is of too small capacity. It is often found that oil is very stiff when cool and requires heating in order to enable it to pass through the filter. The oil when in this condition is "too fat," and has been made so by the addition of considerable cylinder oil returning with the drips. The correct remedy for such a condition is to remove the excess fats by allowing the oil to stand, when the impurities will precipitate. If the filtering arrangement is amply large and the oil is in good condition, better results are obtained by keeping the oil as cool as it can be freely handled in the pipe lines. The better method is to place the filter in a warm place and not to use a steam heater in the filter. The room where the filter is to be placed should have a temperature of 70° F., and the filter bed should be of ample dimensions for oil to pass through without forcing. A simple heater, as used for filters, is as shown in Fig. 113 (A26–1). This view shows valves at both the inlet and the outlet, but it is somewhat safer to use a valve as a throttle at the inlet side only, leaving the other end free to drip into the sewer. The coil when placed is pitched slightly downward, having the outlet about 2 in. lower than the inlet. Such a coil can readily be removed and is well supported.

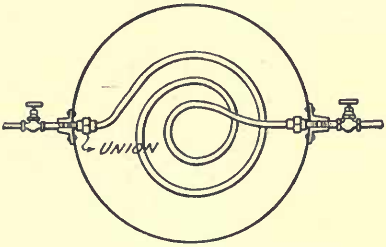

FIG. 113 (A26–1).

Class A27—Live Steam to Blow out Oil Drip Main. A steam branch is led to the oil drip main for the purpose of cleaning it and can be arranged as shown in Fig. 114 (A27–1). The steam

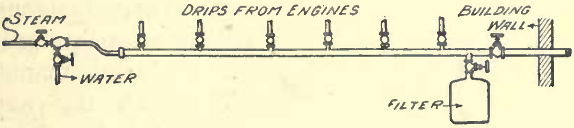

FIG. 114 (A27–1).

line should connect with the drip main through a syphon tee with a water connection below. The steam and the water should each be controlled by separate valves with the syphon tee located somewhat higher than the drip main. The main should have two discharge valves, one to a filter and one to the outside of the building. Each engine branch should connect with the drip main through a valve. The drip, steam and water branches should be sufficiently elastic to allow for free expansion and contraction of the drip main. The end projecting beyond the building should be threaded so that the line can be extended when it is to be blown out. The drip line should blow to the atmosphere so that the steam may escape and thus avoid blowing the grease and gum into the drainage system. Blowing the drip main to the atmosphere also furnishes a means for observing the condition of the wash water.

Class A28 — Live Steam to Water Column and Column Connections. The steam connection to a water column is often made with bends and elbows, thus providing no facilities for inspection. Even though the steam connection is not liable to scale or become blocked, it is certainly safer and more in line with good operating practice to be able to know positively that the steam branch is clear. The connection shown in Fig. 115 (A28–1) has the steam and water connections made with cross and plugs. The plugs should be long threaded and made of solid brass. The column shown is faced for flanged connections and for attaching a supporting bracket. The column manufacturer will furnish the water column faced for flanges and provided with a bracket suitable for attaching to the boiler front. For high pressure work a flanged connection is the only satisfactory way of attaching the water column. By supporting each column free from the pipe work a better line is kept, the piping is more secure, and pipe can be disconnected without disturbing the columns or their connections.

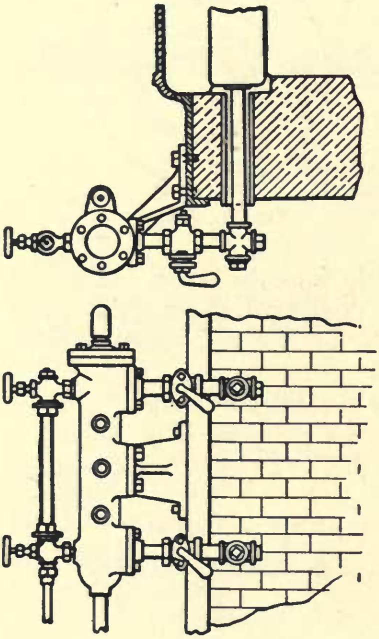

FIG. 115 (A28–1).

Such connection pipes as pass through the boiler settings should be protected by pipe sleeves two sizes larger than the connection pipes. Pipe 1¼ in. in diameter is generally used for connecting water columns, the duty being practically the same for any size boiler. If the connections are more than 3 ft. in total length the column should be separately supported, and if separately supported the individual connections should not be much shorter than 3 ft. This will provide for the differences in expansion of the boiler frame, front and connections. In some localities the use of valves between a water column and its boiler is prohibited. Such practice should be prohibited in all cases unless valves are used which will give an unmistakable warning if they are closed.

Fig. 116 (A28-2) shows an ordinary, outside-packed plug cock with stop screw and small port hole through the plug so arranged that steam will blow to the atmosphere during the time that the column is shut off from the boiler. The amount of steam that this cock would blow through its port hole in case it were closed would be sufficient to give warning, and at the same time not interfere with changing a gage glass, gage cock or such part as might be out of order. A valve of this type will also show by the position of its hand lever whether it is open or shut. If a gate valve is used it should be of the rising-stem type, so that it will show from the outside whether or not it is open. The inside-screw gate type such as is commonly used for high pressure work should not be considered in planning for water column connections. The ordinary types of globe and angle valves are not suitable for water column work because of the difficulty of cleaning them.

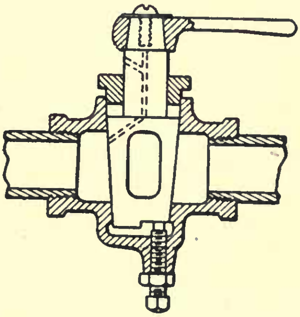
FIG. 116 (A28-2).

As shown in Fig. 117 (A28-3), an extra heavy cross valve can be used and serve the purpose as well as any of the usual methods. The side plug and the center of the valve may be removed when cleaning the pipe branches to the water column. Due to the fact that the stem in a cross valve has such a long travel, it is easily seen by the position of the hand wheel whether or not the valve is open. The valve bonnets should be square instead of hexagonal to facilitate removing them from the valve body.

If the boiler fronts are quite high the level of the water in the column may conveniently be indicated by a low down mercury gage similar to that shown in Fig. 118 (A28–4).

In calculating the proportions for this extension device let the distance $a+b$ be 13.5 in., when there will be 0.5 lb. pressure at the lower end of the column. A column of mercury about 1 in. high would balance this pressure. If the distance a from the top of the water in the column to the upper outlet is one-half the height of the column, 6.75 in., the difference in pressure at the bottom of the two long pipes will be 0.25 lb., and as the water stands at half the height of the column the mercury should also stand at the midpoint of the glass c. The proportions are arranged so that when the mercury has just left the glass there will be a column at d 1 in. high balancing the water column a–b. If c has 0.75 in. incline in its length, then 0.25 in. lengthwise of tube d should have the same contents as the entire tube c. The water columns below b are balanced and their length does not vary the effect on the tubes c and d. This gage can be placed four or five feet above the floor line and will be in plain view of the operator, the mercury vibrating in the glass in the same manner as water would in a water glass.

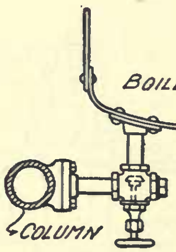

FIG. 117 (A28–3).

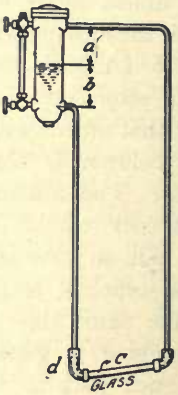

FIG. 118 (A28–4).

Another method of showing the water level conspicuously is by the use of a lamp in an enclosed metal casing placed as shown, Fig. 119 (A28-5), the casing having a slit in line with the glass. With this arrangement the water is well illuminated and the lamp is out of sight, thus doing away with the blinding effect of a naked lamp alongside of the gage glass. The enclosing case ordinarily is made of heavy tin with the outside painted and the inside left bright to serve as a reflector. The top of the case should be left open for ventilation and cleaning. This device can be made by any tinsmith, the water gage being standard with a close nipple and coupling attached between the glass and the column to set the glass away from the column a sufficient distance to accommodate the lamp in its case.

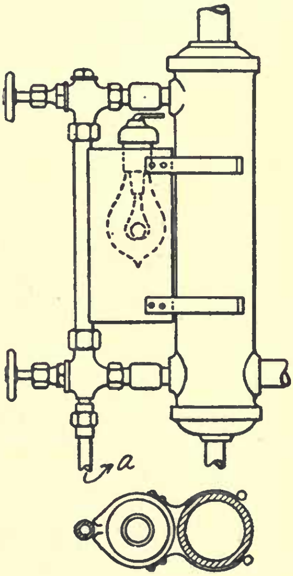

FIG. 119 (A28-5).

Much thought and study have been given toward developing a device that will close the valves of a water column when the gage glass breaks. The principal feature of nearly all these devices is a check that falls away from its seat when the valve is closed but is free to reach the seat when the valve is open. This detail is shown in Fig. 120 (A28-6).

The difficulty with this check for the gage is occasioned by the ball shutting off the gage glass after blowing out through the blow-off lettered *a* in Fig. 119 (A28-5). The trouble necessary in closing and opening such a valve, and dropping the ball off the seat is a strong argument in deciding against their use.

Another type of self-closing water gage is as shown in Fig. 121 (A28-7). This shut-off device is not operated by the steam flow through the valves, and the glass may therefore be blown out as violently and often as desired without danger of closing the valves to the boiler. As the water glass is practically the only means used for ascertaining the amount of water in the boiler an operator should be free to blow it out as often as necessary to satisfy himself that the level of the boiler water is shown correctly in the column. The gage valves shown in Fig. 121 are of similar construction to the one shown in Fig. 120, but with the ball omitted. The valves have either a very coarse or a multiple thread on the stems and have levers attached to the stems instead of hand wheels. The levers are connected together and stand in their upper position when the valves are open. A small wire *a* is run around the glass and attached to the end of the lever as shown. This wire supports the weight *b* which will close the valves should the gage glass break. The spring *c* is to relieve the valves of any serious strains when the stem closes on its seat. The valves on this gage can be closed at any time by detaching the wire from the hooked lever. The small wire does not offer any obstruction to the view, but should be of sufficient size to denote the desired water level which is to be maintained.

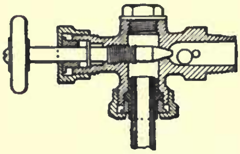
FIG. 120 (A28–6).

Water columns are often loaded with too many attachments such as automatic high and low alarm, boiler feed regulator, self gage-closing arrangement and operating chains, gage cocks with chains, column valves with chains, counterweights, etc. Each of such devices has points of slight merit but there is a danger in using too many safety devices. To evade the use of too many attachments the column valves could be similar to that shown in Fig. 120, and be provided with a projecting pin at the end of the lever; water gages and gage cocks also could have similar pins arranged for operation as shown in Fig. 122 (A28–8 and 9). The rod with which the valves would be operated should have a long handle similar to a window stick. If the water column to be tended is 16 ft. above the floor, the rod should be about 12 ft. long. With a long rod the operator can keep out of the way of steam and water, and the use of automatic devices and hanging chains is done away with.

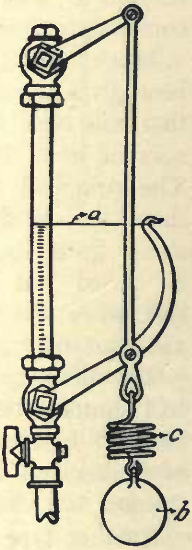

FIG. 121 (A28–7).

Much trouble is experienced in keeping gage cocks tight, and many stations do not allow gage cocks to be operated except when there is no gage glass in the water column. It is good practice to use two water gages and no gage cocks, but if gage cocks are to be used they should be of such form that they can be made to close as tightly as any other valve and not depend on a small weight, spring or boiler pressure to keep them tight. No ordinary valve can be kept tight under such severe service.

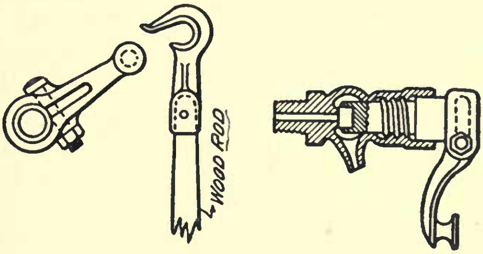

FIG. 122 (A28–8, 9).

Fig. 122 shows a gage cock that is operated by a pole as earlier described. A pressure sufficient to flatten out the valve seat is possible with this device. It is the general practice in boiler rooms to have the chief fireman of each shift, as soon as he comes on, open the gage cocks and blow out the columns and glasses on all the boilers. He may blow out the glasses again during his shift, but not the columns nor the gage cocks. Therefore this small amount that gage cocks and water gage valves are used

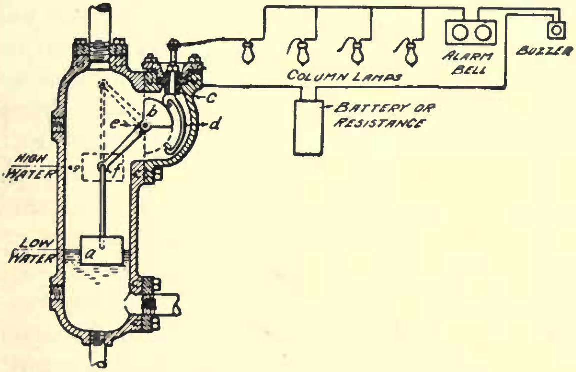

FIG. 123 (A28–10).

does not justify having chains constantly dangling from the columns.

There are numerous makes of high and low water alarms on the market, the majority used being float operated. On high pressures, say above 140 lb., much difficulty is experienced with the collapsing of floats, and the screeching of whistles is also very objectionable. It is, however, good practice to give warnings with an alarm column. Such alarms can be given in high pressure plants by the apparatus shown in Fig. 123 (A28–10), the essential parts of which include the high and low electric alarm column, using a lamp at each boiler, a bell alarm in the boiler room and a "buzzer" in the chief engineer's office.

One alarm bell will serve for the entire plant, and by having a signal lamp at each column the particular boiler or boilers having high or low water will readily be observed. The float *a* is made of aluminum and counter-balanced with the weight *b*. The porcelain insulator *c* has packing above and below where it is clamped to the column and also at the ends where the contactor *d* runs through the insulator. The pin in the counter-weight moves free of the contact segment *d* and so completes the circuit only at high and low water. The only friction that this device must overcome is at the pins *c* and *f*, which are loosely fitted and made of brass. There are no dripping or leaking parts to this column, all being sealed and tight. An open, low-potential circuit would be used with a ground return, the contactors in columns serving to ground the circuit.

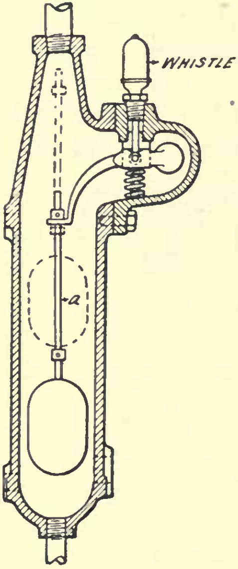

FIG. 124 (A28–11.)

The column shown in Fig. 124 (A28–11) is the simplest form of float column now on the market. This device has one lever which opens a whistle valve for high or low water by pressing either upward or downward on the end of the valve stem. The rod *a* slides loosely through the large eye in the end of the lever. There are but few moving parts, and as long as the float "floats," satisfactory operation and a loud noise can be expected from this device.

Class A29 — Live Steam to Steam Gages. The connection to steam gages should be made so that there will be a sufficient length of pipe to offer condensing surface which will maintain water close to the gage and thus care for any ordinary leak at a cock, union or other joint near the gage. For this and other reasons gages are often placed 12 ft. or more below the level of the steam line. This arrangement is proper, but gages so placed should be designed to take into account the 12 ft. of water in the pipe, which would ordinarily add 5 lb. to the steam pressure. In other words, the pointer should either be set back 5 lb. or the dial should be graduated and marked while there is 5 lb. more pressure on the gage than readings would show.

In ordering gages, if a variation in readings is to be avoided, the condensation column should be given for each gage. In ordinary station construction this water pressure variation is often as high as 10 lb. and leads to confusion and misunderstanding of what the plant is doing. Apparently there may be a large line loss between header and throttle valve as shown by an indicator test, while in reality the difference in pressure is almost entirely traceable to the condensation column. The steam gage should give steam pressure only, not part steam and part water column. This error in gages is often overlooked, with the result that several pressures are indicated in a plant and the gages are often supposed to be wrong.

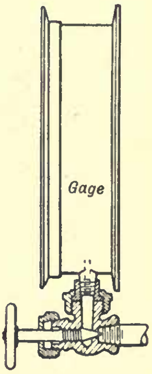

FIG. 125 (A29–1.)

The ordinary type of cock furnished with the gage is often leaky and a cause of much annoyance.

The small needle valve shown in Fig. 125 (A29–1) has a union on the gage side. This permits the removal of the gage without disturbing the valve. The stuffing box with this type of needle valve can be made tight and kept so, which is difficult to do with the small plug cocks often used, and the needle valve may be had for a small additional cost.

Single-tube gages should be selected for power plant use, as in such service a gage is quite free from excessive vibration. For locomotives where the vibration is severe a single-tube gage with its higher degree of sensitiveness is not available because of the injurious results of the vibration of a long single tube.

For such plants as are built purely on a commercial basis and where expenditures are not to be made for decorative features, the iron back gages with a nickel-plated brass rim are found quite satisfactory. Marble gage boards are now out of date. For all practical and artistic purposes the painted plate iron gage board has many advantages. The gages may be easily attached to an iron board, heat and water will not damage it, and if it should accidentally be damaged the iron gage board can be straightened and put back in order. If its surface becomes badly marked, an iron board can be repainted by station help. There is but little chance to improve the appearance of an old or damaged marble board.

Such a steel board is shown in Fig. 126 (A29–2). There should be a slit in the floor back of the board through which the pipes could pass, and back of some or all of the gages should be a 6-in. hole in the plate to facilitate making the piping connections. The tools can be supported by clips attached to the plate by small machine screws. The board should have about 6 in. of space behind it and should be made of about $\frac{3}{16}$-in. plate with corner angles of 2 by 2-in. angle iron. The shelf should be about 3 ft. high and 10 in. wide, with the angle iron projecting above the shelf. In the shelf should be a 2-in. hole through which dirt could be brushed. Round head rivets with the heads perfect on the outside should be used. The board could be painted and varnished in harmony with the nearby engines. It would also be a good plan to make the top removable for inspection or repairs and to enable a light being dropped inside.

The gage board can be illuminated in three different ways: By illuminated dial gages, by lamp brackets attached to the gage board, or by a small headlamp set back from the board and directed toward the gages. The illuminated dial gage brings into the design many details such as wires behind the board, a lamp, switch, etc., for each gage, and a much more delicate and expensive type of gage. It is difficult to place lamp brackets so as properly to illuminate the board and not obstruct the view of the gages. The use of a single small headlight is by far the simplest arrangement to construct, operate and maintain, and the illumination will be found to be better than can be secured with side lamps and quite as good as with the illuminated dial gages. If the gage board is placed at the wall between the high and low pressure cylinders of one of the engines, then the small headlamp can be mounted on a generator sufficiently high so that its light will not cast the shadow of the operator on the board in front of him. The boiler steam gages should be placed as low as possible, and care should be taken that they are graduated for the known column of condensation.

In Fig. 127 (A29-3) is shown a steel gage board placed above the floor with a cover channel over the pipes and wire conduit leading to it. The anchors for holding the board to the wall should be of 0.5-in. wrought iron with polished or nickel-plated nuts. The rims of the gages and possibly the name plate and valves would look well if nickel plated. The lamp brackets and rosettes should also be plated. The board, channel and cases of the gages should be painted and varnished the same as nearby machinery. The exposed rivet heads should be carefully preserved while heading the rivets at the back of the gage board. Such a gage board as this can be made at small cost and will be found very serviceable and attractive, in fact even more attractive than the nearby stairways, trusses, building columns and structural work. When erecting the station the structural steel contractor could be asked to furnish the board and channel, and the steam fitter could erect the board and connect the piping. The

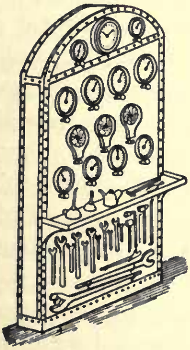

FIG. 126 (A29-2).

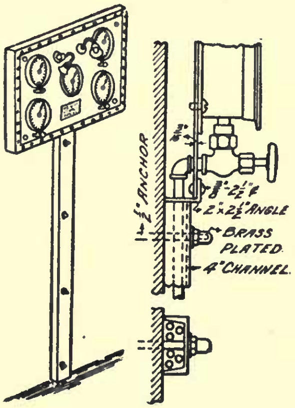

FIG. 127 (A29-3).

painting should be done by the same contractor who paints the machinery.

Class A30 — Live Steam from Safety Valves through Roof. In piping safety valves, the most satisfactory method is to run the pipe for each valve through the roof. When there are a large number of boilers each having two valves, this will require considerable cutting of the roof, but as a rule it is cheaper to run each pipe to the atmosphere. The increased expense would in all probability be justified, because with the separate pipes the operator can, by going up on the roof, readily tell which valve blows first, which is leaking, the amount of leak, etc. If, on the other hand, the pipes are tied together in one main, it becomes difficult to determine which valve is blowing or leaking. Many plants use a short stub and allow the steam to escape into the boiler room whenever the valves blow off. This is wrong, as the firemen have enough hardships without having any more put upon them under the plea that if they look after the pressure it will not blow. There are times when the pressure can be controlled, but more often this is not the case. By allowing the steam to escape into the boiler room the operator will lose money, for no one will stay in the room full of steam if he can, by any excuse, get out, and if he does stay, he will do nothing until the disturbance ceases.

In most cases one valve will open before the others and may continue to blow by itself for 5 min. This may be one of two valves on a 250-h.p. boiler, discharging say 10 per cent of the output of the boiler. The boiler might possibly be using 1,000 lb. of coal per hour, hence a 10 per cent blow-off would waste 100 lb. of fuel or a loss of 10 cents per hour for coal. If for any reason three employés leave the room during the blow-off period, the employer will lose at the rate of not less than 60 cents per hour. Thus if he desires that the inside blow-off arrangement be profitable he must reduce the number of blow-offs to less than one-sixth of what it would be if piped through the roof. This is impossible. Fig. 128 (A30–1) shows an independent pipe from the safety valve passing up through the roof. Where there are a number of such pipes the use of cast iron roof collars is justified. These collars should be about three-eighths inch thick, with the exception of the threaded hub of the umbrella, which should be about five-eighths inch thick. The upper portion of the umbrella is used as a coupling for the two lengths of pipe, permitting upper portion of pipe to be cut at the shop. The lower section, or roof sleeve, should be provided with several projections which will just allow the sleeve to slip over the pipe and at the same time steady it. This roof sleeve should be set after the pipes are in position. The roofing felts should be cleared of gravel and coated with a hot cement in which the sleeve should be firmly bedded and tightly bolted through the roof boards. The joints and the tops of the flanges should also be well coated with this cement. The sleeve should not be less than 4 in. in height, and there should be at least one-half inch clearance between the sleeve and the umbrella. Galvanized sheet iron is generally used in this work, but this is frail and easily damaged. Whenever the safety valves are taken off for repair, the light galvanized iron work usually becomes so badly injured that it is unfit for further use. If the sleeve and umbrella be made of cast iron they will stand abuse and furthermore will be inexpensive.

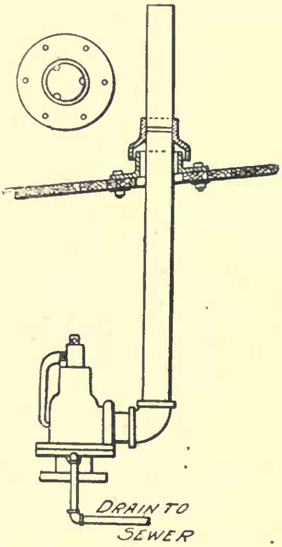

FIG. 128 (A30–1).

Attention should be given to the safety valve drain. This opening should be free to the atmosphere at all times, as much damage results if water or condensation is allowed to remain in the valve and cause water hammer when the steam is escaping. A rule should be observed that only the discharge from safety valves on boilers that are commonly shut down at the same time should be tied into a common pipe line. It is quite imperative that this rule be observed, as boiler insurance companies will not allow gate valves in safety valve branches, and without gate valves in the safety valve branch connected to more than one working boiler, the operator would be liable to serious injury when making repairs. If but one boiler at a time is shut down for cleaning, then but the two or three valves on that boiler should be tied into the one line to the atmosphere. If the plant has a number of boilers which are shut down in batteries of two, then the safety valves on these boilers may be discharged into a common main. In most cases it is better to tie in only the discharge pipes from the one boiler, and if the roof is not over 20 ft. above the safety valve, it will be found less expensive to run separate pipes. The tie should be made far enough away from the safety valve to allow for expansion, and the side outlet foot tee should be provided with a drain as shown in Fig. 129 (A30–2). The foot tee should have a substantial support to enable it to carry the weight of the standpipe and its branches so that a valve can be removed without causing any severe strain.

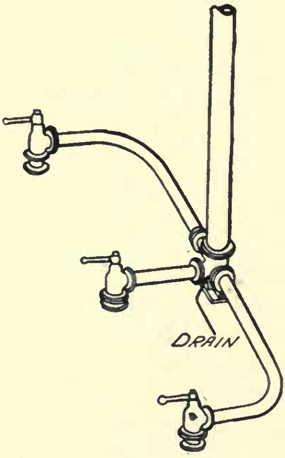

FIG. 129 (A30–2).

The arrangement shown in full line in Fig. 130 (A30–3) is not considered good practice. The safety valves should not be taken off of any boiler steam branch or from that portion of the boiler where steam is on its way to the pipe main. They should be placed where there is the largest volume of steam. The steam flowing through the pipe line does not flow with a uniform velocity. The variation in pressure at the boiler connection may be as much as five pounds when steam is being delivered to a large low-speed engine. This fluctuation of pressure exists in all the steam lines as well as in the boiler, but since there is such a large steam volume in the boiler, the pressure there is not noticeably affected. In the pipe line this variation is very perceptible, and its amount may be determined by placing an engine indicator on the lines and moving the drum slowly, allowing the pulsations to indicate a diagram which will resemble the teeth of a saw. When the safety valves are subjected to this pulsating pressure they will chatter if the pressure is close to the blow-off point. If the safety valves are set for a drop in pressure of 3 lb., the pulsating pressure due to the engine cut-off is sufficient to run the pressure up to the blow-off point, after which it drops almost instantly to the closing point, so that by synchronous pulsation with the engine the valve will make from 150 to 200 beats per minute or twice for each engine revolution. One minute's wear occasioned by this beating is equal, possibly, to a month's wear due to ordinary service. To secure the proper wear the safety valves should be separated from the steam connection as shown by the dotted lines in Fig. 130 (A30-3). This may be done if provision is made when the boiler contract is let.

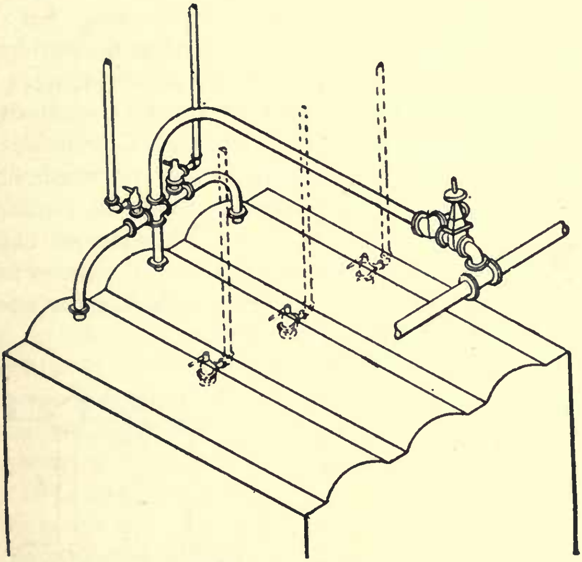

FIG. 130 (A30-3).

Class A31 — Live Steam for Heating Purposes. Steam connections to heat water for the lavatory should be avoided whenever possible, as numerous difficulties are thereby occasioned. A coil can be attached to a blind flange at the end of a header through which the water to be warmed may pass as is shown in Fig. 131 (A31-1). In order to avoid generating steam when but little water is being used, the water should pass to the coil at boiler pressure. After leaving the coil, the water should pass through a pressure reducing and a relief valve before reaching the plumbing fixtures. When high pressure and high temperature water is reduced in pressure by passage through a reducing valve, it will partially evaporate in the low-pressure line, thus causing water hammer and very unsatisfactory water service.

A very satisfactory method for heating low-pressure water with steam of a higher pressure is shown in Fig. 132 (A31-2). The heating coil *a* takes steam through the valve *b*, which is controlled by means of the thermostat tube *c*. The thermometer *d* shows the temperature of the water, which can be altered by changing the set of the valve stem at the sleeve *e*. This sleeve is similar to a turn-buckle, having lock nuts as shown. The post *f* is made of a solid bar which assists in holding the valve securely and prevents springing. Water is fed in at *g* and passes out at *h*. The lower end of the coil is open, which allows the steam drips to discharge into the warm-water receiver *j*. In case an unusually large temporary demand is made on the heater, the steam will flow through the coil and into the water direct. In regular operation the coil should be partly filled with water.

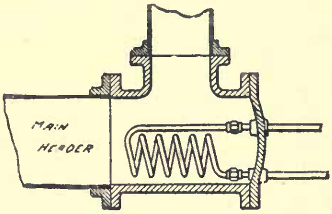

FIG. 131 (A31–1).

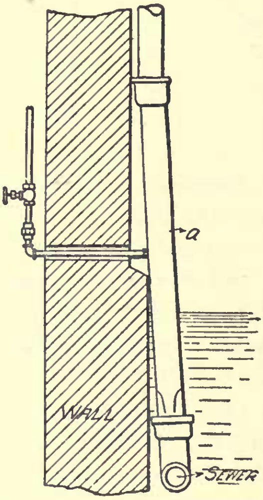

FIG. 132 (A31–2).

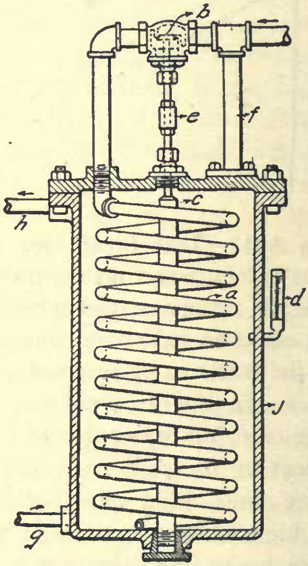

FIG. 133 (A32–1).

Class A32 — Live Steam to prevent Freezing of Roof Conductors. Wherever possible, the conductors should be so arranged that they will not be exposed to lower temperatures than that of the roof. If it is necessary to locate conductors outside of the building this cannot be effected, and the only thing to do is to supply the conductors with either exhaust or live steam. If the plant is operated condensing, it is quite probable that all the exhaust steam from the auxiliaries will be condensed in the heater. The openings into conductors should be quite small. For this purpose about a three-eighths inch pipe with the valve inside the wall should be used and it should be drained into the conductor as shown in Fig. 133 (A32–1). The lower section *a* should be of cast iron. The upper portion of the conductor may be made of galvanized iron and the sewer of tile. The small pipe should pass through a 1.5-in. pipe sleeve built in the wall. This is a somewhat extravagant use of steam, but it is less expensive than the frequent renewing of conductors. In general the roofs of power stations are quite flat and are not exposed to any extent to the wind. For this reason they are usually very warm even in the coldest weather, but conductors placed on the outside of buildings will usually freeze unless heat be admitted to them. Some saving may be effected by the use of high temperature drains. A system that will discharge vapors into sewers so that the vapors will pass through the conductors will usually cause as much damage by rusting out the conductors as would be occasioned by freezing. The best arrangement that can be made with outside conductors is to use live steam only when needed.

Class A33 — Live Steam to Low-pressure Cylinder. In many cases a live steam connection to the low-pressure cylinders is furnished by the engine builder. This connection may be either a warming pipe or a steam line to the low-pressure side to be used when the low-pressure side is run independent of the high-pressure side. There are cases where it is good policy to arrange a cross-compound engine so that the low-pressure side can be run without the high-pressure side. Ordinarily this detail is found necessary when the plant has been arranged with but one or two large engines. In such cases there is no reserve provided, and in order to enable the plant to operate it is necessary to use the half of the engine that is in order. There are also certain instances where it is good practice to lay out a plant with but one or two engines. This would be the case when the original installation is to be increased within a short time by the addition of engines of the same size, as by this means the use of small and large engines in the same plant is avoided.

A suitable arrangement of piping is shown in Fig. 134 (A33–1) whereby the high-pressure side can be exhausted to the condenser or to the atmosphere, or the low-pressure side can take steam through the reducing valve *a* and be protected by the relief valve *b*, set at about 25 lb. The small valve *c* is the by-pass for warming up the low-pressure side. The valve *d*, which shuts off the condenser, should be motor operated if it is larger than 20 in. The atmospheric valve is shown at *e* and the main steam throttle at *f*. The horizontal valves are used only when changing over these connections and should not be fitted with operating stands on the engine-room floor as they are not used often enough to warrant the additional expense or the extra floor space which they take up. The high-pressure throttle *f*, the low-pressure throttle *g*, the by-pass *c*, and the electric buttons for the valve *d*, are the only operating devices which are necessary on the engine-room floor.

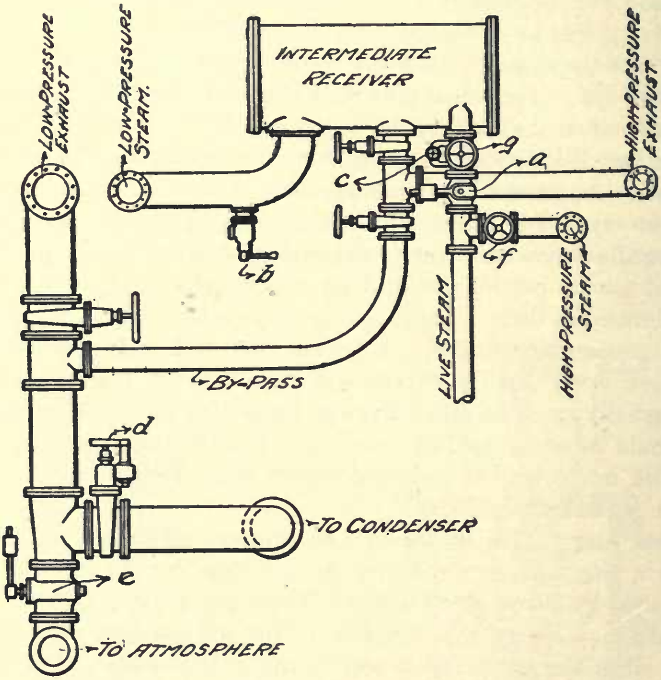

FIG. 134 (A33–1).

This system of piping to both the high and low-pressure cylinders is frequently carried to an extreme. In stations having three or more units it is useless to complicate the piping with the extra parts required. If an engine is out of order the operator will invariably shut down the entire unit, notwithstanding the fact that it may be piped to run on either side. There are many plants piped in this manner that have never made use of the arrangement, and there are cases where it would seem that they would certainly find it to their advantage to use this piping system rather than shut down the entire unit. For stations having a large number of units it is the better practice to provide the simplest possible arrangement that will insure the best protection of the entire unit as a whole. Straight connections from one opening to another should be avoided, as continuous trouble with the joints is almost certain to result.

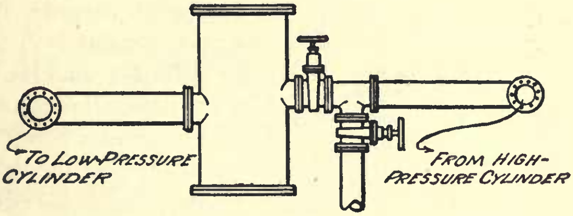

FIG. 135 (A33-2).

Fig. 135 (A33-2) illustrates the "straight-line connection" which is used by a number of engine builders. This connection is difficult to make and so little provision is allowed for expansion that severe strains are placed on the joints under the cylinders. Such strains should be relieved as much as possible in order to avoid the necessity of frequent renewal. These joints are so situated that it is quite difficult to make a connection that will stand ordinary strains and therefore when subjected to the strains of the piping as shown in Fig. 135 (A33-2) a great deal of trouble will result.

The use of a warming pipe for low-pressure cylinders is not universal with corliss engine installations. It is possible to send steam through the high-pressure cylinders to the receiver without the use of a separate warming pipe. Before the engine is started steam should be blown through the steam valves in and out of the cylinder and through the exhaust valves on both sides of the piston. This is possible with any engine having a release connection at the end of the valve rods and a lever for rolling the valves by hand. When a warming pipe is used the steam is discharged into the intermediate receiver or one of the pipe connections through a small pipe, say a 2-in. pipe for a 2,000-hp. engine, with the valve stem run through the floor and fitted with a stand. If the valve gear is not provided with a releasing device, it is advisable to run a warming line to the intermediate connection between the high and low-pressure sides, so that the low-pressure side will have steam when the engine starts to roll over. In case steam is taken from the header above the engine having a branch to the throttle over the high-pressure cylinder, the low-pressure live steam connection should be a separate branch from the header. This will simplify the piping arrangement.

Class A34 — Live Steam to Engine Cylinder Jackets. Steam connections to engine cylinder jackets are not ordinarily required, the general practice being to furnish the engines without jackets. Where the jackets are furnished, the steam to and the drips from the jackets are under full boiler pressure and the drips are returned to the boiler through a return system similar to that used for the other drips in the plant. In order to discharge these drips together with other drips of boiler pressure the jackets used must be of ample size to avoid any perceptible pressure loss due to the small size of the pipe connections.

Class A35 — Live Steam to Live Steam Purifier. There is but one important requisite in the steam connection to the live steam purifier which is to deliver steam to the purifier at a pressure sufficient to permit water to flow by gravity to the boilers. If the purifier is mounted at a sufficient height above the boilers to allow a loss in steam pressure before delivery to the purifier, the steam branch may be run from the header. A good method of piping when the purifier is placed but a few feet above the boilers is shown in Fig. 136 (A35–1). If three or four boilers are supplied by the purifier, the branches can be run into a main which has a single connection to the purifier or the three or four branches may be separately run to the purifier with a valve in each branch. The water column *a* indicates the head at which water is to be delivered to the boiler. This head must be greater than the combined losses of the steam flowing through its branches to the purifier, the loss in the head of the water flowing from the purifier to the boiler, the loss in the head of the water passing through the check valve, and the loss in the head in the main steam header as measured at the different boiler branches. These losses could scarcely be measured on a gage reading to 165 lb. of steam, but when considered in connection with the head *a*, that pressure may be sufficient to prevent a flow to the boiler. When *a* is 4 to 6 ft. there can be but very slight losses. In fact the combined losses previously mentioned would be less than 3 lb. per square inch. These losses should be calculated for not less than three times as much water and steam flowing as the boiler rating would indicate, in order to permit bringing the water up to its proper line while the boiler is being crowded.

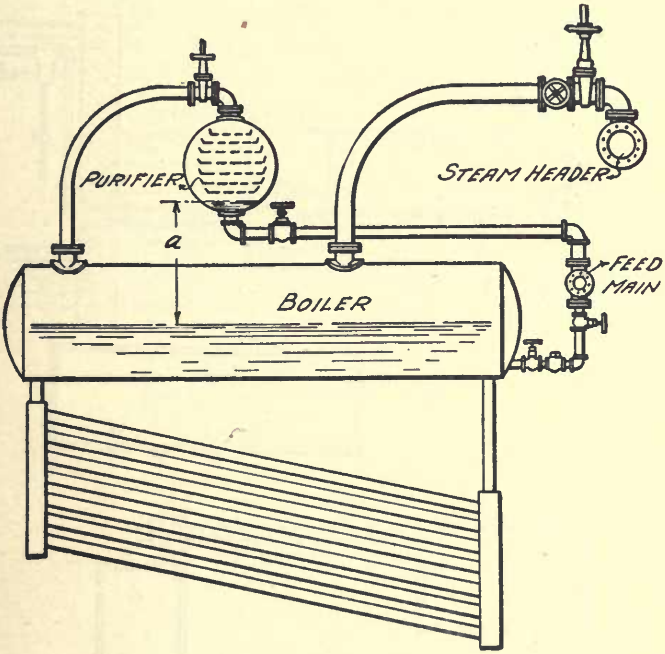

FIG. 136 (A35-1).

Class A36 — Live Steam to Other Buildings. An inexpensive and satisfactory method of running supply lines to other buildings for driving machinery, heating, etc., is shown in Fig. 137

(A36–1). The piping is run through tile and if a straight run cannot be made from the one building to the other, a well is placed at the intersection to enable a line that is out of order to be disconnected. The lines should be located so that they can be drawn back into the room at least the length of the pipe, enabling the removal of the entire line without disturbing the ground. If the building *a* will not permit drawing the pipe into it, the line from the building *a* to the building *b* may be drawn through into the building *b*. The steam separators *c* and *d* are so placed that they will take care of the condensation. The pipes in the tile should be left bare and the air space closed by a manhole cover with the end openings at the walls plugged with asbestos. The tile should be cemented at the joints and, if convenient, the well should have a

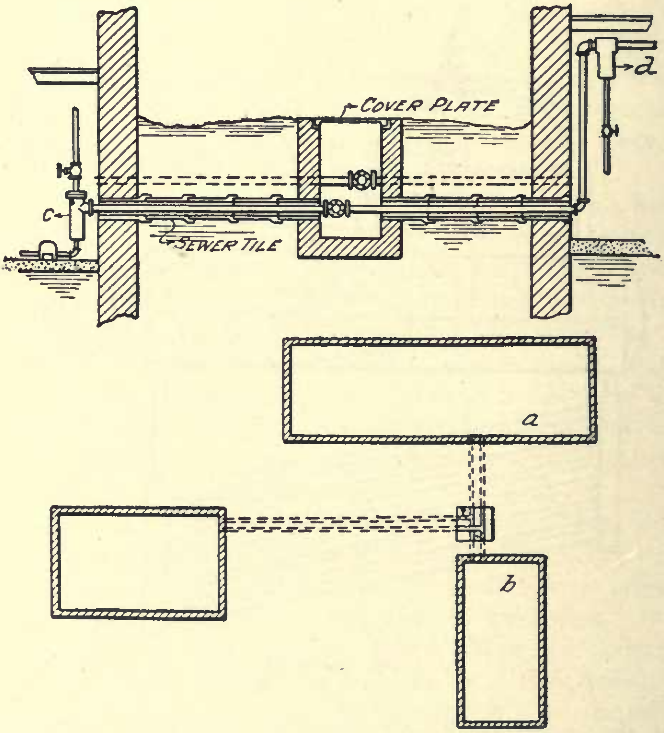

FIG. 137 (A36–1).

drain to the sewer. What little moisture would work into the tile or well would be quickly evaporated.

Class A37 — Live Steam Branch to the Heater Coil in the Engine Receiver. This steam connection belongs to that class of small station piping details which secure economy only by complicating the general system of operation. It is generally known that reheating the exhaust after it leaves the high-pressure cylinder greatly improves the lubricating conditions in the low-pressure cylinder, but little other benefit is thus secured. To avoid an actual loss of heat it is necessary to return the drips from the reheater to the boiler in such a manner that the heat units in this high-temperature water are retained. An efficient method of accomplishing this is to pipe the return drips to the boilers independent of the regular feed main.

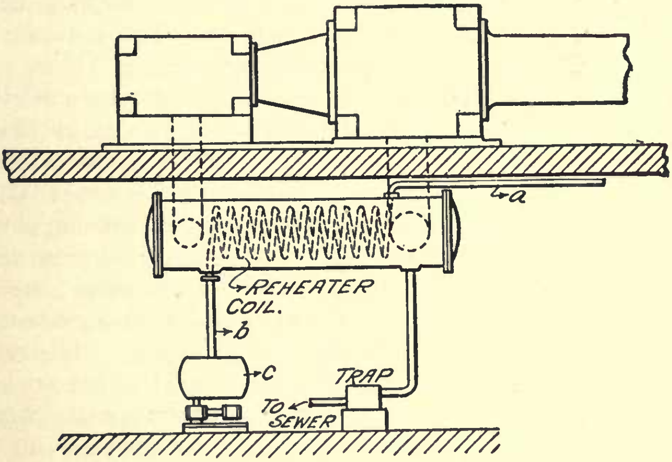

FIG. 138 (A37–1)

In Fig. 138 (A37–1) is shown the usual arrangement for connecting a receiver between the high and low-pressure cylinders. The live steam passes to the reheater coil through the connection *a*. The drips pass through the pipe *b*, and are received by the pump *c*. This pump allows the pressure in the pipe *b* to be less than that in the steam pipe *a*. The steam branch *a* may be taken from the engine branch or from the upper portion of the main header, but a better method is to take the steam from the drip opening of the steam separator or from a drip pocket in the main header. These drain details will be taken up more fully under the subject of "Drips."

Class A38 — Live Steam Branches to and from Superheaters. The superheater when placed in a boiler setting becomes a part of the boiler and no provision should be made for a by-pass around it, since its location in the furnace is such that unless steam is flowing through the superheater it will soon be damaged.

The principal difference in pipe lines for superheated and saturated steam is the reduced size of the former. This reduction is favored by the manufacturers of superheaters since they have proven by demonstration that it is more economical to increase friction losses and reduce the loss by radiation than it is to increase the loss by radiation and decrease the friction losses. This radiation loss may also be reduced in the use of saturated steam.

The subject of radiation from extremely large pipes, receivers, etc., is not sufficiently considered in connection with the use of saturated steam. The boiler manufacturer will guarantee a certain quantity and quality of steam as it leaves the boiler and the engine manufacturer will guarantee to perform a specified amount of work with a certain quantity and quality of steam delivered at the throttle. Until the superheater manufacturer came into the market, no one had interested himself sufficiently to guarantee a minimum loss between the boiler and the engine. The manufacturer of the superheater has to assume this loss in connection with his apparatus since the success of his business virtually depends upon reducing this loss to a minimum and in seeing that the superheater receives the credit for the saving.

The use of small radiating surfaces for superheated steam is essential on account of the high temperature and rapid radiation. The entire volume of superheated steam in a pipe is not all of the same degree of temperature, and this point should not be overlooked in making piping arrangements for superheated steam. This fact is well understood by manufacturers of superheaters, and to insure a uniform amount of superheat a number of methods are resorted to for bringing all or as much of the steam as possible to the heating surface.

One method of doing this, by removing the "core" in a superheater tube, is shown in Fig. 139 (A38–1). The steam in the space *a* is out of the circulation of the flowing steam, being confined inside the tube *c*. The steam in space *b* is that which is flowing and taking up the heat delivered by the outer tube *d*. If the tube *c* were not placed in the position shown, the steam would travel through the space *a*, and, due to the frictional resistance of the tube *d*, the steam next to this tube would move slower than that at the center. Since this steam at the center will take up superheat slowly, it will cause the tube *d* to be raised to a very high temperature and thus reduce its conductivity and capacity.

When passing through supply lines the superheated steam flows through the center of the pipe. The steam lying next to the pipe is deprived of its superheat and condenses. The amount of steam that will be thus condensed is determined by the radiating surface of all the lines between the boiler and the machine using the steam. If the lines throughout their entire length are small, very short, and the steam flows through them at a rate of 10,000 ft. per minute, little or no condensation will take place, and the losses by radiation will be shown by the loss of superheat. Large headers, steam receivers, etc., should be avoided when superheated steam is used. Condensation may not show in the lines while running, but it is necessary to provide as ample means for removing the condensation as would be used in piping for saturated steam. Large drip pockets, etc., should be avoided, and in every detail radiation should be reduced to the least possible amount. It may be possible to locate the steam main and its branches in a portion of the building where air can be confined and the radiation losses reduced. The principal advantage to be gained by the use of superheated steam is the saving in condensation losses.

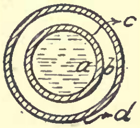

FIG. 139 (A38–1).

Whatever precautions are taken toward reducing the condensation losses between the boilers and the steam driven machines are savings, whether the steam used be saturated or superheated. A slight pressure drop in the use of superheated steam may be allowed in order to save heat units, but the maintenance of the boiler pressure as far as the engine throttle when using saturated steam is open to argument.

There is a certain size of line which will give the least total loss for every requirement. With a given line a slight saving in the one class of loss is accompanied by a correspondingly greater loss in the other class. The tendency seems to be toward the use of large headers and pipes, thus increasing the heat unit losses. In many situations the present pipe lines could be considerably reduced in size and if carefully planned would not cause any increase in the pressure drop from the boiler to the steam-driven machine. Fig. 140 (A38–2) shows a system of piping suitable for superheated steam. The header is small and more in the nature of an equalizer or emergency line, being possibly the size of the engine connection. For regular service the steam would pass from the boiler directly to the engine without any abrupt turns. The small amount of steam passing through the header from one unit to another would bring about the only noticeable heat loss. If it is found to be desirable the header may be shut off and each unit used separately.

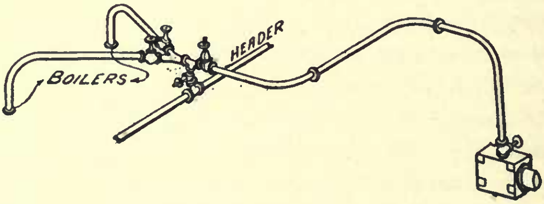

Fig. 140 (A38–2).

Class A39 — Live Steam Branch to Turbines. The general design of steam branches to turbines should be much the same as those for engines, embodying in addition the special features pertaining to superheated steam. One special feature in regard to these connections is the size of pipe required. An engine which cuts off at one-quarter of its stroke and has a pipe branch in which the ultimate steam velocity does not exceed 10,000 ft. per minute would require a branch which would have four times the cross-sectional area of the turbine branch in which the steam is flowing continously. A reciprocating engine not only requires a full amount of steam at short periods but also makes necessary the alternate acceleration and retardation of the volume of steam flowing through the steam connection. The pressure in a large steam main will show a very perceptible change on account of the cut-off of the engine, this change being caused both by the sudden withdrawal of the steam to the engine and its consequent expansion, and also on account of the inertia of the steam at the high velocity being suddenly brought to a stop. Steam turbines relieve the pipe systems of these steam vibrations. Such vibrations as may be caused by the turbines in taking steam are not productive of pipe vibrations on account of the short period of the vibrations and the inability of the heavy masses to pulsate in synchronism with them.

CHAPTER XI.

VACUUM EXHAUST PIPING.

Class B1 and 2 — Vacuum Exhaust Piping Main and Branch to Engines. The vacuum lines are in most cases the largest pipe lines in the plant, and special care should be taken in their design in order to reduce the loss of head in the flow through them. The loss of but one-half a pound in the pipe line means 1 in. less vacuum at the engine than at the condenser. A loss that would scarcely be measurable in a steam line would be too great to be allowed in a vacuum line. Ordinarily, with 26 in. of vacuum, there would be 70 cu. ft. of steam passing through the vacuum line for each cubic foot passing through the live steam line, and 10 cu. ft. of atmospheric exhaust to 1 cu. ft. of live steam. An engine having a 12-in. steam line will ordinarily have a 24-in. exhaust. Assuming that the continuous flow of a 6-in. line is equivalent to the flow of a 12-in. line when steam is cut off at one-quarter of the stroke or in one-quarter of the time, there is a diametrical ratio between the 24-in. exhaust and the 6-in. steam main of 4 to 1 and an area ratio of 16 to 1. The volume of vacuum exhaust being seventy times that of steam, it is then true that steam in vacuum lines must have a velocity about four and one half times that of the steam in the live steam connection.

It is due to this higher velocity, bad bends in the line and other friction losses that the vacuum at the engine is in many cases so much less than at the condenser. In steam turbine practice where an extremely high vacuum is maintained, 1 cu. ft. of boiler steam will expand to a volume of about 130 cu. ft. in 28 in. of vacuum. Therefore the diameter of the exhaust should be eleven times that in the steam lines to maintain the same velocity as that of the boiler steam. If it were possible to reduce the velocity of the vacuum steam by using larger lines, then it would also be possible to use a longer pipe line with the condenser located in a more advantageous position. By way of illustration a 10-in. steam line under the stated conditions would require a vacuum exhaust line 9 ft. in diameter.

It has been found practical to pipe only the smaller turbines into a high-vacuum main. The economies of the different vacuums have been determined by actual tests, and the engineer is therefore able to determine how much yearly loss he will think justifiable in order to effect any desired piping system. For large units using higher vacuums the type of construction affording the highest vacuum and the least resistance to the flow of steam is the one most desirable. Not only should the connections be short and of a large diameter but the shape of the mouth and discharge openings should also be properly designed, as the loss between the turbine and condenser can often be reduced one third by so doing. The loss of 1 in. in vacuum on a compound engine causes an increase in the steam consumption of less than 1 per cent, but the loss of 1 in. from 28 to 27 in. of vacuum on a steam turbine increases the steam consumption about 6 per cent. It would therefore be possible to design a vacuum main for engine work that would be quite impracticable for use with turbines.

The friction losses should also be reduced as much as possible in the vacuum lines. A 1,500-kw. unit will in most cases generate about 9,000,000 kw-hr. per year, the generating cost for labor and fuel being about $60,000 per year. This would mean a yearly loss of $600 for each inch of vacuum lost by friction. This sum would pay the interest and depreciation on an additional investment of $6,000 to cover the necessary cost of larger piping, which would reduce the loss 1 in. The increased cost to reduce this friction loss would in most cases be comparatively slight, being possibly the expense of more careful study in laying out the original system.

But little useful data is available to determine the amount of the losses through the fittings, valves, etc., required in the different pipe lines. The branch from the vacuum main should be short to avoid line loss; to care for expansion this connection should be long, as in the case where but two pieces of apparatus are tied to the main. To comply with these conflicting demands a compromise is necessary. The amount of strain that can be safely placed on pipe work has not been sufficiently determined to be useful in making calculations.

The details used in providing for expansion other than that of the pipe itself are invariably some form of elastic joint or pipe. Fig. 141 (B1–1) shows a diaphragm joint made of steel plate, riveted and calked. This joint has been found very satisfactory for use on large, riveted mains. Such riveted work is used extensively for large exhaust and vacuum pipes. It is not the riveted work that is especially wanted, but the increased size of the mains.

Fig. 142 (B1–2) shows one of a variety of forms of diaphragm joints used on welded pipe and made in the pipe shops. The form shown in Fig. 142 is a design which must be made in the pipe shop and should be assembled by the pipe fitter. The form illustrated in Fig. 141 should be made in the boiler shop and assembled by the boiler maker. If the large mains are made in the boiler shop it will be found advantageous to have the boiler makers assemble and erect them. The practice of riveting heavy flanges to the shell of the pipe is not considered good detail work, whether the flanges be made of cast iron or steel. The best boiler shop practice is to rivet together sheets of like thickness and allow the riveted joints to be as flexible as possible. The form shown in Fig. 141 is considered good boiler shop practice since it affords an opportunity for applying the rivets and for driving and calking the joints, all the rivets being short.

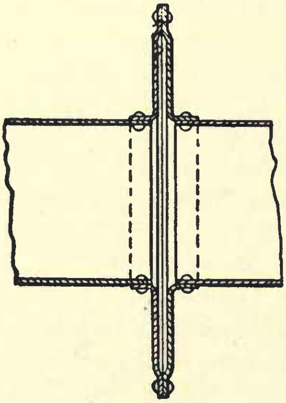

Fig. 141 (B1–1).

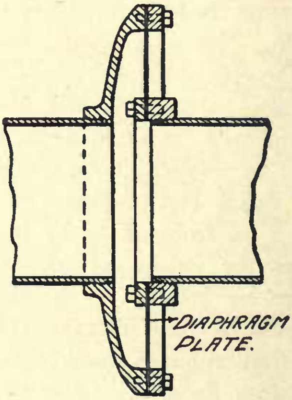

Fig. 142 (B1–2).

To avoid such a design as is shown in Fig. 143 (B1–3), where the pipe lines connect to the flanged faces of the machines, the connection as illustrated by Fig. 144 (B1–4) should be used. The portion *a* should be made of steel plate about 12 in. wide and without a straight seam. The lap edges of the plate should be welded before the flange is turned over. The holes should be punched in the circular seam *b* for the plate *a* only. The end of the section *c* should be left long and the rivets in *d* omitted for a distance of about a foot from *b* until the circular seam is riveted. The section *a* should be bolted in place and *c* be in position before marking off the holes in the seam *b* at the end of section *c*. If the flange end of *a* be turned over on a faced forming block and a wooden maul be used to drive the flange over and a true flatter be used to finish the face after it is turned down, it will not be necessary to face the joint *e*, since the unevenness will be very slight.

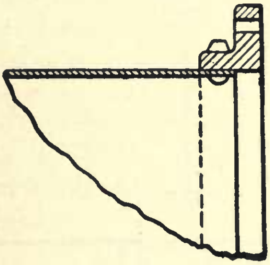

FIG. 143 (B1-3).

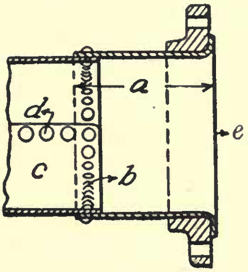

FIG. 144 (B1-4).

In a design as shown in Fig. 145 (B1-5) the expansion and contraction would be taken up by a side movement of the different sections. Fig. 146 (B1-6) shows a diagram in which the position of the parts when cold is indicated by solid lines and when heated, by dotted lines. The difference in position of the parts when cold and hot as indicated by *a* may be assumed as 1 in., the joint *b* be-

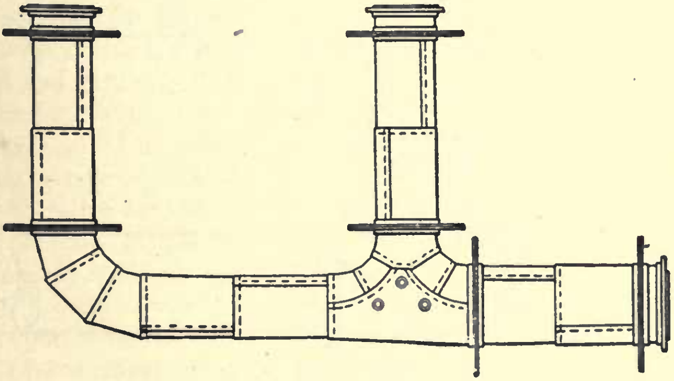

FIG. 145 (B1-5).

ing on a 36-in. pipe. The radius of the pipe being 18 in. and the swinging section 96 in. long, the movement at the joint *b* will be $18 \div 96$ in. of compression on one side and the same amount of tension on the other, there being no movement at the top and bottom

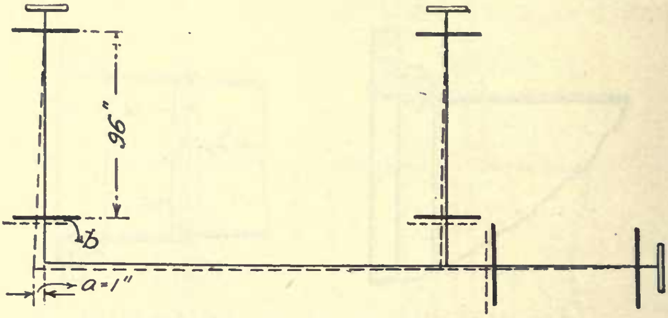

FIG. 146 (B1–6).

of the diaphragm. The movement at the joint *b* would be $\frac{3}{16}$ in. or $\frac{3}{32}$ in. on each of the diaphragm plates. Unless some such provision as is here shown be made for the expansion strain, much trouble will be caused by leaks throughout the riveted work.

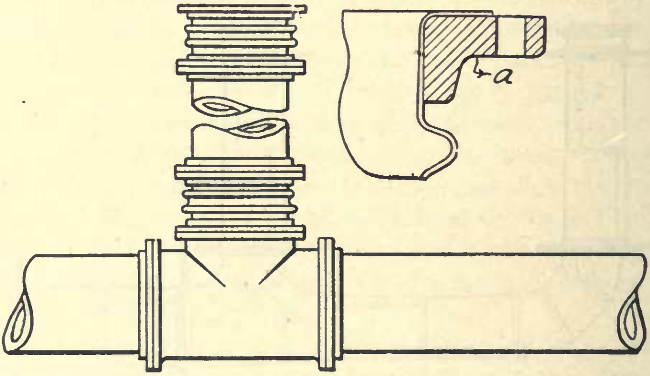

FIG. 147 (B1–7).

In case the line be made of regular welded pipe with flanged fittings the strain can be similarly taken care of with corrugated copper connections as is shown in Fig. 147 (B1–7). The flange *a* should be made of wrought iron, steel or a steel casting because corrugated copper expansion joints are quite expensive and it becomes very difficult to make repairs in case of the breaking of the cast-iron flange. If the joints are to be ordered it should be specified that they be made of steel, as it is customary to furnish such joints with cast-iron flanges. The joint faces of fittings and flanges should be made with an adhesive gum packing which should be preferably free from graphite, so that in case the pressure on the gasket is released, there will be no danger of a portion of the gasket being sucked into the pipe by the vacuum.

A simple method of preventing the gasket from being drawn into the pipe is to make the edge of the raised joint face as is shown in Fig. 148 (B1–8) and let the outside diameter of the gasket be the diameter inside of the bolts. The gasket will have a thick edge on the outside of the joint, shown at *a*, due to its compression on the joint faces only. The shoulder on the gasket should be formed gradually without any perceptible angle and not as shown in Fig. 149 (B1–9), which practice causes a weak point in the gasket where the bead and the compressed portion join. This weakness may not show for a considerable time, probably not until the gasket becomes hard and brittle from the heat of the steam or soft and gummy from the effects of the cylinder oil. Cloth insertion or rubber packing is not as suitable for gaskets on a vacuum line as some adhesive type of packing.

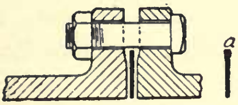

FIG. 148 (B1–8).

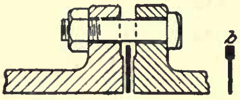

FIG. 149 (B1–9).

The valves for vacuum lines are invariably of the gate pattern, and in order to give satisfactory service they should be what is commonly styled the 100-lb. pressure valve. The so-called "light-pattern" exhaust valves are not rigid enough to maintain their perfect form under excessive expansion strains and do not permit of their being closed air-tight. In the general arrangement diagrams, Figs. 47 and 48, the vacuum lines are shown and each engine is provided with a shut-off valve. When the load drops from the engine it is advisable to provide some means of quickly opening or closing this shut-off valve to prevent the engine from running above normal speed. The operating device should be placed close to the steam throttle. A wattmeter should be provided for each generating unit, located on the gage board or at a place where it can be clearly seen from the operator's position while at the engine throttle. The exhaust valve may be operated by a small motor or by a hydraulically-driven piston. The wattmeter shows instantly when the load is thrown on the machine and whether the load is being increased or diminished, thereby enabling the operator to regulate the steam and vacuum valves accordingly.

The value of a wattmeter at the engine has been so fully demonstrated that where it has been installed, the attendant is often guided more by it than by the steam or vacuum gage. He keeps a constant watch on the wattmeter and intermediate gage and raises the intermediate pressure when he sees that the load on the engine is increasing. The wattmeter at the engine has nothing to do with switchboard work or with the electrical control. It merely shows the attendant what work the engine must do and makes his duty more definite.

Where there are two or three large engines on a condenser and the load is liable to drop off instantly there is always a possibility that the engines will run away. To avoid this it is quite necessary to break the vacuum as soon as possible. On account of the large volume of steam at a rather high pressure in the low-pressure intermediate receiver it is not sufficient to close the steam throttle. Even though the main throttle be instantly closed when the load falls off the engine it will be some time before the pressure in the intermediate receiver is lowered through the low-pressure cylinder. The automatic stop valves furnished by engine builders are not as a rule sufficient to save the engine. A 1,500-kw. unit might be in parallel with other machines running condensing and developing 500 kw. with the automatic butterfly valve closed. This entire load would be carried by the low-pressure side alone. By observing the wattmeter and tachometer on an engine it will be noted that the highest engine speeds occur when very light loads follow the heavy loads. This situation occurs in its most severe form when an engine has been very much overloaded, thereby throwing the breaker and losing its entire load in less than one revolution. The attendant should be able to at once throw a switch on the engines and close the vacuum valve.

For two reasons it is quite out of the question to operate large vacuum valves by hand. First, because it takes so long to operate the valves by hand that much harm may be done elsewhere before the operator can get away. Second, because after quickly closing say a 30 or 36-in. valve the operator is in no condition to do anything else for a time, since the handling of these large valves requires the expenditure of considerable energy. Referring again to Fig. 48, it will be noted that the vacuum stop valves for each engine are so situated that it would be extremely difficult to reach them while controlling an engine. By using a motor-operated valve, the switch controller may be placed wherever it is most convenient.

The atmospheric valve should also be given full consideration in connection with engine control as it must operate in unison with the vacuum gate valve. In Fig. 150 (B1–10) is shown the general form of an atmospheric relief valve of the vertical type. The dash pot is placed on the outside where it can be inspected, cleaned or repaired while the valve is in use. This type of valve is suitable for plants that are to be well maintained. If they are not to be well kept it would be advisable to use an interior type of dash pot, using condensation in the dash pot instead of oil as would be the case with the exterior type of pot. An oil dash pot, when in good order, will operate very satisfactorily, but if it is allowed to become gummed or clogged with dust and dirt its smooth working will be greatly interfered with. The stuffing box of the valve shown in Fig. 150 may be loosely packed, as it is on the atmospheric side of the valve. The atmospheric valve should be provided with tapped openings say three-eighths or one-half in. in diameter for a small water connection and an overflow. These connections are valuable in determining whether or not the valve leaks, and in showing the amount of leak, and in preventing air from leaking into the vacuum line. Without this connection it is very difficult to determine whether or not the valve leaks air.

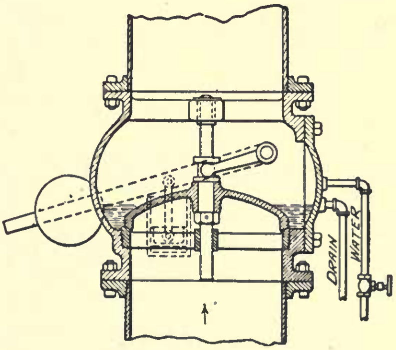

FIG. 150 (B1–10).

One of the most approved forms of the interior dash-pot type of atmospheric valve is shown in Fig. 151 (B1–11). This is of the horizontal type. The opening *a* is for the small water connection, while the opening *b* is for the overflow. The flange *c* is provided to retain water over the valve face. The hand wheel and screw shown at *d* are used to raise the valve from its seat as would be required if it were running non-condensing for a considerable time. The valve shown in Fig. 150 should have a side plate that can be removed in case it is necessary to regrind the valve to its seat. The valve shown in Fig. 151 can be readily reground by removing the top cap. The guide can be held in place by using blocks under the heads of the screws.

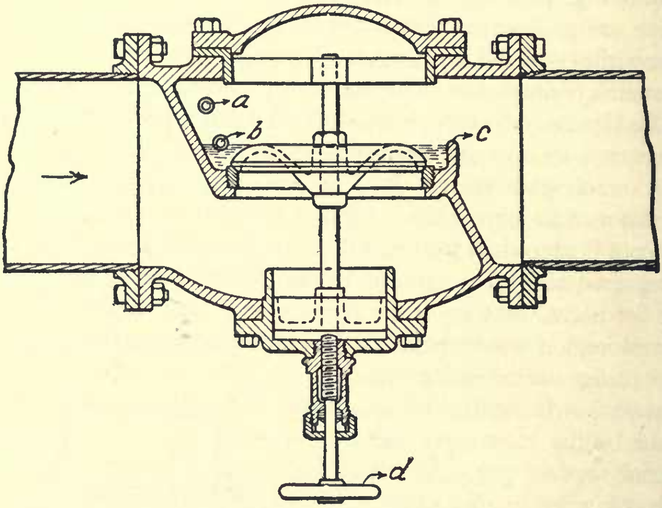

FIG. 151 (B1–11).

Atmospheric valves are subjected to rather extreme demands, the requirement being a tight valve with but little pressure on the seat face. These valves can be ground in and made tight in the shop, but in most cases after they have been put into service they will soon show bad leaks. This condition is quite unavoidable and can hardly be called a defect. The body of the valve is a heavy casting in which the molding strains are relieved by subjecting it to the steam temperature. At the end of a week's run the valve may leak badly, and after grinding it may be perfectly tight. Then at the end of a month's run it may again show some leak and require regrinding. It may not then show any perceptible leak for a year or more. The tendency of a casting is to relieve itself of the molding strain, and each time the valve is reground it is in better shape than before. There does not seem to be any practical way of overcoming this difficulty.

There is another type of atmospheric valve, illustrated in Fig. 152 (B1–12), which is frequently furnished by the engine builders. This valve is intended to be positively operated by hand instead of being automatic in closing. The valve must be held in position on its seat until vacuum has been introduced on the line, after which the valve will be held shut by reason of the difference in pressure due to the vacuum. In case the vacuum valve is motor operated it can be thrown in and the atmospheric valve partially closed with the hand lever. The operator will then be able to ascertain, by feeling, when the vacuum is increasing in the line, and can force the valve to its seat and hold it closed.

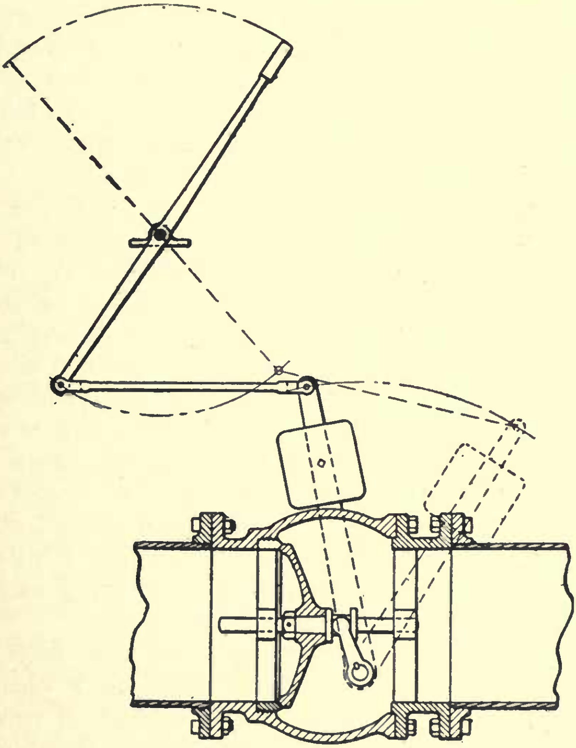

Fig. 152 (B1–12).

With this valve, the objectionable feature of chattering can be practically eliminated. There is nothing that injures the valve faces of an atmospheric valve as much as this continuous chattering. On valves of 20-in. diameter and over, the chattering becomes particularly severe. A 20-in. valve will have an area of 314 sq. in., and if the travel of the valve is 5 in. and that of the hand lever 30 in., it would be possible to hold the valve against a 1-lb. back pressure or 2 in. of vacuum by exerting a pressure of 50 lb. on the lever. There are some objections to this valve, one being that it is a difficult valve to regrind and keep in perfect alignment with its face. This is a fault common to all beat valves which lie on their sides. Another objection is that a water seal cannot be used to shut off any leaks which may occur.

There are certain essential features that an atmospheric valve should possess to meet the requirements in the most efficient manner: The valve should be of the beat form; the valve face should be placed in a horizontal position; a water seal should be provided for the valve seat; a cap plate, which may easily be removed, should be provided to facilitate inspection or regrinding; the valve should be rotatable with respect to its operating lever or guides, so that the same device that is used to raise the valve from its seat will be an aid in regrinding; when the cap plate is removed all the valve guides should be in place to allow a proper regrinding; the dash pot should be of such a form and so located that it can readily be inspected and kept in good order, and some means should be provided for holding the valve off its seat when the engine is to be run non-condensing.

The sizes of an atmospheric valve and pipe may be considerably less than those of similar parts on a vacuum line because of the difference in the volumes of steam at atmospheric pressure and under vacuum. The volume of a given amount of steam at 26 in. of vacuum is seven times that of the same steam at atmospheric pressure. It is thus seen that the area of the atmospheric connections can be made one-seventh the size of those for the vacuum line and still maintain the same velocity of flow. There would, however, be but a slight loss in case the velocity flows varied, since the atmospheric connection is in use but a small portion of the time.

For fixing the relative dimensions of the different engine connections of a compound engine, so that the flow will be the same at all parts, the following argument should be considered:

The volume of live steam at 160 lb. pressure which would flow into the high-pressure cylinder for one-quarter of the stroke until cut off may be arbitrarily assumed as 1. The steam in the high-pressure cylinder will expand its volume six times in exhausting to the receiver, but as the flow from the live steam main into the high-pressure cylinder was cut off after one-quarter of the stroke, and as the exhaust to the receiver takes place during the full stroke, the relative areas of the admission and exhaust ports are not as 1 is to 6, but as 1 is to 6 ÷ 4; or the exhaust port should have an area 1.5 times that of the admission port. As the steam in the receiver has expanded to six times its original volume in the high-pressure cylinder, the admission valves of the low-pressure cylinder, in order to maintain the same velocity flow, should have an area of six times the admission valves to the high-pressure cylinder, since the valves of both cylinders cut off at one-quarter stroke. If the low-pressure cylinder exhausts to 26 in. of vacuum, the steam in the condenser will occupy 72 times the volume it did in the high-pressure cylinder up to the time of cut-off, but as the exhaust ports of the low-pressure cylinder are open to the condenser during the full stroke and the admission ports from the receiver to the low-pressure cylinder are open but one-quarter of the stroke, the necessary area to maintain an even flow will be one-quarter of 72, or 18 times the area of the live-steam ports of the high-pressure cylinder. In case the engine exhausts to atmosphere the relative volume of live steam to steam at atmospheric pressure will be as 1 to 10, but the live steam flows into the engine only one-quarter of the time and the exhaust steam flows to atmosphere during the full stroke. Therefore, instead of the atmospheric valves having an area ten times as great as that of the admission valves, the area need be but 2.5 times as large to maintain the same velocity of flow. The foregoing argument reduced to diameters appears as follows:

Pressure lb.		Volume.	Area.	Diameter.
160	Steam to the High-Pressure Cylinder	1	1	1
10	Exhaust from the High-Pressure Cylinder	6	1.5	1.22
10	Steam to the Low-Pressure Cylinder	6	6	2.45
0	Exhaust from the Low-Pressure Cylinder	10	2.5	1.58
26*	Exhaust from the Low-Pressure Cylinder	72	18	4.24

* Inches of vacuum.

Following this argument, if the steam line is 10 in. in diameter, the exhaust to the receiver will be 12¼ in. in diameter and the steam line to the low-pressure cylinder will be 24 in. in diameter. The atmospheric exhaust will be 16 in. in diameter. The vacuum exhaust is usually made by the engine builders twice the size of the live-steam line, giving the exhaust steam a velocity four times that of the live steam, instead of 42 in. and the same velocity.

The tendency in engine building is to make the connections to the high-pressure side of an engine larger and to the low-pressure side smaller than is necessary. In receiving bids for engines, the engine builder should be required to state the size of the port openings, as the efficiency of an engine is considerably affected by the frictional losses in the restricted area of the low-pressure ports. The atmospheric connection can consistently be made three-eighths of the diameter of the vacuum exhaust and still maintain the same velocity of flow in the atmospheric connection as in the vacuum connection. In other words, a 9-in. atmospheric pipe could be used in connection with a 24-in. vacuum line. This ratio is rather extreme in practice and it is not used. The low-pressure port opening in the exhaust valve of a compound engine having a 12-in. live-steam connection will have an area of 5 by 64 in. or 320 sq. in. This is 2.83 times the area of the steam pipe and corresponds to a diameter of 1.68 when the diameter of the live-steam port is 1. It will be noted that this area is but slightly greater than that required to exhaust to the atmosphere and maintain the same velocity for the exhaust as for the live steam. If the port-ways in the low-pressure cylinder are made larger, the cost of the low-pressure cylinder will be materially increased.

Class B3 — Vacuum Exhaust to Condenser. With an elevated jet condenser installation it is a rather general practice to place an entrainer at the lower end of the riser to the condenser as shown in Fig. 153 (B3–1). The principle of the entrainer is that instead of the water of condensation lying at the bottom of the entire vacuum main, the condensation flows into the trap-shaped fitting and congests the passageway for the steam to such an extent that the steam will pick up the water and carry it up and into the condenser. But very little condensation will be held in the trap before it fills up to a point where the steam will carry it. Instead of allowing a long main to become partially filled with condensation on light loads, which condensation is later picked up on heavy loads and thrown against the elbows of the main, the entrainer allows but little water to lie in any part of the line. It is of course necessary that the main be given a pitch toward the entrainer. This method of removing condensation has been found very satisfactory.

Another method of removing the drips from a vacuum main is by means of a vacuum trap. A vacuum trap is quite interesting

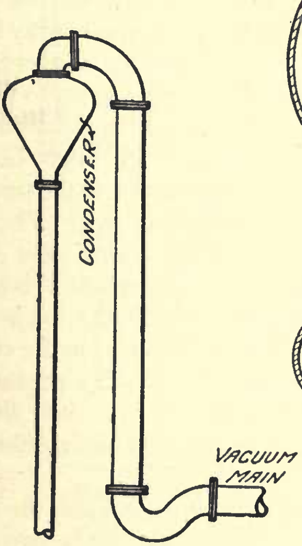

FIG. 153 (B3-1).

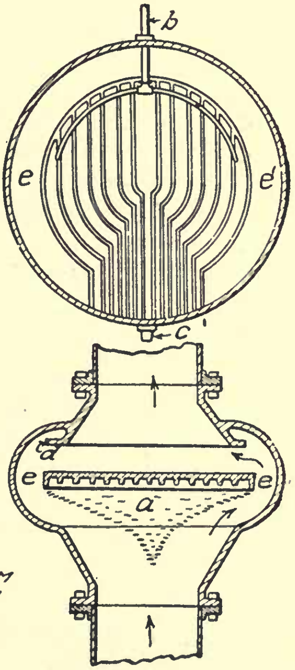

FIG. 154 (B4-1).

in its intricacies of steam, drip, and discharge connections, and also in its automatic arrangement for opening and shutting these connections at the proper time, but as a power station appliance a vacuum trap is considered a troublesome device; usually some means other than the use of such traps can be devised to drain the lines if the idea is kept in mind while laying out the vacuum system. If other disposition of condensation has not been provided for, a vacuum trap should be used as a last resort. It is the elimination of such devices that shows careful and competent station engineering.

Class B4 — Vacuum Exhaust; Grease Extractor. The usual type of grease extractor has the same form as a steam separator. The oil carried with the steam is in combination with the condensed vapors. The principle of operation of the separator is to lessen the velocity of the steam before changing its direction of flow and thus allow the heavier particles of grease to continue in the same direction as when entering the separator and be deposited on a "baffle" which is out of the path of the steam.

Fig. 154 (B4–1) illustrates the general principle of all grease extractors with a few minor changes in the location of the baffles. There is no current in the space indicated by *a*, since the ribs on the baffle prevent any flow across its face. A water spray is introduced through the pipe shown at *b*, which further reduces the temperature of the mist on the baffle and conveys it down to the drain pipe shown at *c*. The lip, *d*, is provided to prevent oil from creeping on the inner surface of the separator, which might be due to the flow of the impinging steam, and being carried to the condenser. The water spray is also connected with this ring. The spaces indicated by *e* and *e′* are the passages for the steam. The drain, *c*, is run to a vacuum trap or an entrainer. The drain, *c*, is one that should not be carried to the condenser, and in order to eject water the entrainer is quite necessary. The discharge from the entrainer should go to a sewer or to a large grease trap. If a grease trap is used, all drips containing any oil should be run into the same system throughout the plant. This system will be described more fully in a later chapter.

With surface condensers the oil is removed from all the exhaust steam, since all the condensation is returned to the boilers. However, if jet condensers are used, it is quite difficult to remove the oil from all of the exhaust and quite useless since only from three to five per cent of the exhaust steam is returned to the boiler, the remainder being discharged with the tail water from the condenser to the stream from which the water is taken. If a cooling pond or tower is used, all exhaust steam should be run through a vacuum separator. Unless this is done, the greater portion of the cylinder oil will be discharged into the cooling pond or tower. The interest on an investment for grease extractors will be recovered by the lessening of boiler repairs and by the reclaiming of oil and grease.

The reclaimed grease cannot be used again in the oiling system, but there are many other valuable uses to which it can be put.

For a jet condensing plant, a very efficient arrangement is to use a small elevated jet condenser for the boiler feed water only. There may be two large station condensers for a station generating 120,000 lb. of steam per hour and a small condenser that will circulate 120,000 lb. of cooling water per hour or at a rated capacity of 4,000 lb. of steam per hour. This latter would be about one-thirtieth of the capacity of the entire plant. This small condenser

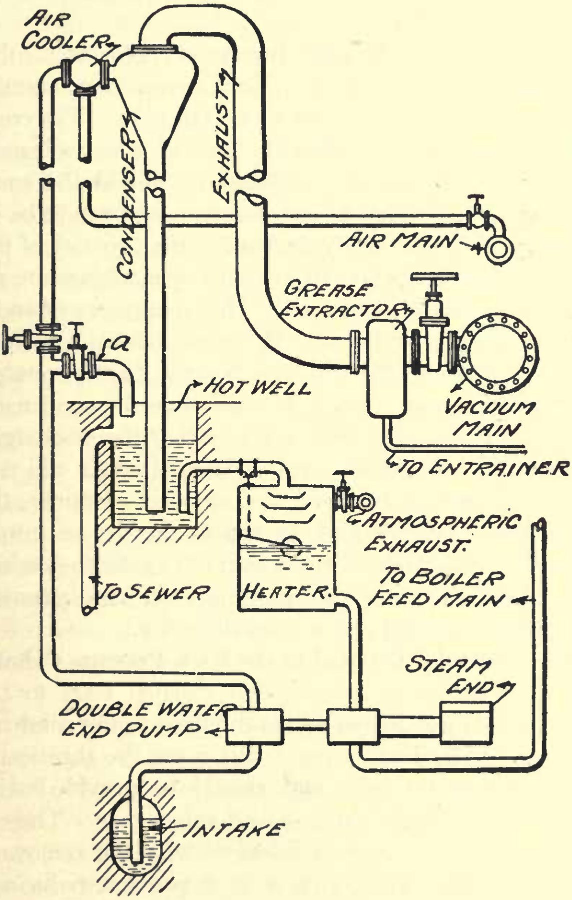

FIG. 155 (B4-2).

may have air taken from it through the regular air main used for the main condensers. The small condenser would have only the feed water passing through it, and the hot-well water would be maintained at a high temperature, possibly 10 degrees higher than in the large condenser. The oil could be eliminated from this condenser by using the grease extractor as shown in Fig. 155 (B4–2).

If the plant is supplied with two 30-in. condensers, the small condenser should have an 8-in. exhaust connection, about a 4-in. circulating water connection, and a 5-in. tail pipe. The cost of this condenser will be low and ordinarily the fuel saved will more than cover the increased cost of installation. Should the small condenser not be used the boiler feed water would have to be handled in the large condensers, thereby increasing the capacity of the plant in condenser capacity. No extra pumps or machines are required to operate the small condenser. The double-water-end pump would be required in any case. If the condenser is not used, the low-pressure pump would be used as the heater pump. The by-pass connection, shown at *a*, is used when the condenser is not in operation. Due to the float valve closing the discharge to the heater, the small amount of surplus hot-well water will discharge through the overflow. To avoid the use of an entrainer, the drips from the grease extractor may be run to the dry vacuum pump, since there will be but one-thirtieth part of the steam flowing to the small condenser. The dry vacuum pump will handle considerable moisture without causing any serious difficulty.

Class B5 — Vacuum Exhaust to the High-Pressure Cylinder. In Fig. 134 were shown the steam and exhaust lines to the high and low-pressure cylinders and also the lines to the condenser and to the atmosphere. The valves *f* and *g* are the throttles for the high and low-pressure sides and should be provided with floor stands and hand wheels close to the valve gear. These stands should be so placed as not to interfere with the removal of the valves and pistons. The valve *a* is a pressure-reducing valve. The valves in the exhaust from the high-pressure cylinder and also the one next to the low-pressure cylinder are only operated when one side of the engine is out of service and the other side is to be run as a single-cylinder engine. Operating devices for such valves, running through the floor, are neither necessary nor desirable. The valve *d* should be either motor or hydraulically operated.

The valve *e* is the atmospheric self-opening and closing valve. The valve *b* is the relief valve to prevent the pressure from running too high on the receiver.

It will be noted that the receiver is used when the low-pressure cylinder is operated with steam passing through the reducing valve, and also that the reducing valve discharges into the receiver and not into the line to the low-pressure cylinder. These two features should not be overlooked because otherwise money will be wasted for these low-pressure connections and at the same time the reducing valve could not be operated.

Reducing valves have been connected to low-pressure cylinders without receivers and have failed completely in controlling the pressure. There must be a large volume of steam between the reducing valve and the cut-off valve of the engine in order to avoid the constant jumping of the valve. Usually this volume should not be less than that of the cylinder. The pipe from the receiver to the low-pressure cylinder will cause a greater drop in pressure during the flow of steam than will the receiver. In order to produce a more steady flow through it, the reducing valve should be discharged direct to the receiver and not into the branch from the receiver. If the engine has no receiver, the pressure-reducing valve should be located away from the cylinder as far as would be necessary to give an area to the pipe equal to the area of the low-pressure cylinder. It will be noticed in Fig. 134 that the high-pressure cylinder can exhaust either to the condenser or to the atmosphere when the low pressure is off, and that the low-pressure side will act in the same manner when the high-pressure side is off.

Class B6 — Vacuum Exhaust to Auxiliaries. In most cases a condensing plant can be laid out so that only the pumps and single-valve engines used for stokers, stacks, etc., will exhaust into the heater. These machines would show only about a 10 per cent increase in power if they were run condensing. In order to be able to determine how many of the auxiliaries should be run to the heater or to the condenser, the B.t.u. losses under various conditions and when run condensing and to the heater should be considered as follows:

1. If live steam at 160 lb. pressure is fed to an auxiliary that exhausts to the atmosphere, it will require 1,195 B.t.u. per lb. of steam, taken as one unit of work.

2. If live steam at 160 lb. pressure is fed to an auxiliary using 90 per cent of the steam when run condensing, it would require 1,075 B.t.u. per unit of work.

3. With the same conditions as in No. 2, but using 80 per cent of the steam, the auxiliary would require 956 B.t.u. per unit of work.

4. With the same conditions as in No. 2, but using 70 per cent of the steam, the auxiliary would require 836 B.t.u. per unit of work.

5. If live steam at 160 lb. pressure is fed to the auxiliary, delivering 90 per cent in exhaust steam and 10 per cent in condensation to the heater, it would require 146 B.t.u. per unit of work.

6. With the same conditions as in No. 5, but delivering 50 per cent of the steam to the heater and 50 per cent to the atmosphere, the auxiliary would require 622 B.t.u. per unit of work.

7. With the same conditions as in No. 5, but delivering 30 per cent of the steam to the heater, the auxiliary would require 802 B.t.u. per unit of work.

8. With the same conditions as in No. 5, but delivering 10 per cent of the steam to the heater, the auxiliary would require 1,080 B.t.u. per unit of work.

It will be seen from the foregoing that auxiliaries using a large amount of steam per horsepower, or in other words, auxiliaries that show but a slight decrease in steam consumption when run condensing, are most economical when exhausting to the heater. In No. 2, for instance, where the auxiliary runs condensing, there is required the consumption of as many heat units as under the conditions illustrated in No. 8, where the pump uses but one-tenth of its steam in the heater, the remainder being wasted to the atmosphere. In No. 4, which illustrates the economy of a compound condensing unit, the consumption of heat units would be less if, as in No. 7, it were delivering but 30 per cent of its steam to the heater and were running non-condensing.

In the effort to secure high economy, electrically driven auxiliaries are frequently used, the idea being that the economy of the auxiliaries will be nearly that of the large main units. For example, an electrical auxiliary may require through its main unit but 16 lb. of steam per horsepower, which at 1,195 B.t.u. per lb. would be a total of 19,120 B.t.u. per hour. If a steam auxiliary, run non-condensing, is used, all of the exhaust being used in the heater, as in No. 5, the consumption would be 146 B.t.u. per lb. of steam or 14,600 B.t.u. per hour, if it requires 100 lb. of steam per horsepower. This represents a saving of 4,520 units, which would be a saving in steam over the motor drive of 24 per cent. The question now arises as to where the dividing point is between operating condensing and non-condensing to the heater.

In the first place, water delivered to the heater at from 90 degrees to 100 degrees, as would be the case from the hot-well delivering the water at 210 degrees, would require from 10 to 11 lb. of exhaust steam for each 100 lb. of feed water. More than this amount of exhaust could not be condensed and the excess would waste to the atmosphere. The auxiliaries should be arranged to furnish all their exhaust steam to the heater provided this exhaust steam does not exceed from 10 to 11 per cent of the whole amount of steam generated by the boilers. When the exhaust steam is wasting to the atmosphere an amount equal to 75 per cent of the whole amount delivered by a compound engine or 90 per cent of that delivered by a pump, it will then be slightly better economy to connect such a machine to a condenser. It is useless to connect the large generating units to the heater. In the case of four units, there would be 25 per cent of the steam delivered to each unit, and if exhaust could not be obtained from any other source, it would then be necessary to condense 30 per cent of the exhaust in the heater in order to equal the economy of the condenser. In other words, 7.5 per cent of the station steam would be delivered by one of the generating units alone. When the auxiliaries are added to this, there would then be about 15 per cent of the steam generated to be condensed in the heater, which would not be possible. In most cases, not more than 10 per cent of the exhaust of one of the large units could be used, and if the exciter engine be exhausted to the heater, the auxiliaries being, as they generally are, steam consumers, no additional steam can be condensed. It is customary to allow about 10 per cent of the station steam for the requirements of the auxiliaries, which is practically all that the heater will take economically.

The exciter engine should be piped both to the condenser and to the heater main if the heater is able to condense one-half of the steam from the exciter engine together with that from all the other auxiliaries. The small pumps, stoker engines, etc., should be connected to the heater main only. It is seldom that the exhaust from the exciter engine cannot be condensed in the heater, and the saving effected by running it at any time condensing would be very slight. Assuming that the large unit uses 15 lb. of steam per horsepower-hour, it costs not less than 1 per cent of the whole power of a large unit to operate the condensing apparatus. Since pumps and other auxiliary apparatus require from six to seven times this amount of steam per horsepower-hour, it would require from 6 to 7 per cent of the pump power to operate condensing machinery that will effect a gross saving of 10 per cent, leaving a net saving of but 3 to 4 per cent in the steam consumption of the pump. The amount of steam available in the shape of pumps, stoker engines, etc., should be determined and also the possible demands in the shape of exhaust steam for the heating system. It can then be better determined whether some of the small generating machinery is to be arranged to run either condensing or non-condensing.

Another detail that enters into the consideration of exhaust steam lines is the exhaust heating system. In Fig. 156 (B6–1) is shown a simple arrangement of the exhaust heating system from exciter engines. The valve *a* is closed when the heating system is not in use, and the valve *b* is open when the exciter engines are run condensing. When both *a* and *b* are closed, the exciter engines will exhaust to the heater. The back-pressure valves serve both for atmospheric relief and for relief in case the pressure in the heating main exceeds the pressure as set. All the main units should be on the vacuum main and all other auxiliaries should be on the heater main. In laying out the station the machines may be selected and arranged so that they will give only the amount of steam required for the different classes of service. This is another instance where the nature of the system must be fully determined before the machinery is purchased or in any way decided upon. The ideal system is one which will deliver to the heater all the steam it will condense and at the same time not waste to the atmosphere more than one-half of the exhaust of the smallest machine.

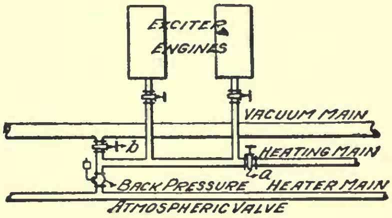

FIG. 156 (B6–1).

Class B7 — Vacuum Exhaust to Cylinder Relief Valves. The cylinder reliefs on an engine are frequently left open to the atmosphere to show when they are "snifting." The actual working service of this valve is quite insignificant, since it is very seldom in operation. The valve is placed in such a position that it will relieve the cylinder of any excessive pressure which may be caused by improper valve setting or by excessive compression. The high-pressure side may be left open to the atmosphere provided the engine and the relief valves are properly set and do not show any leakage that may cause trouble. Unless the low-pressure cylinder relief valves are kept absolutely tight, they will cause considerable trouble on account of the air which is liable to leak into the vacuum lines. To avoid this difficulty, these valves are frequently piped to the exhaust from the low-pressure cylinder.

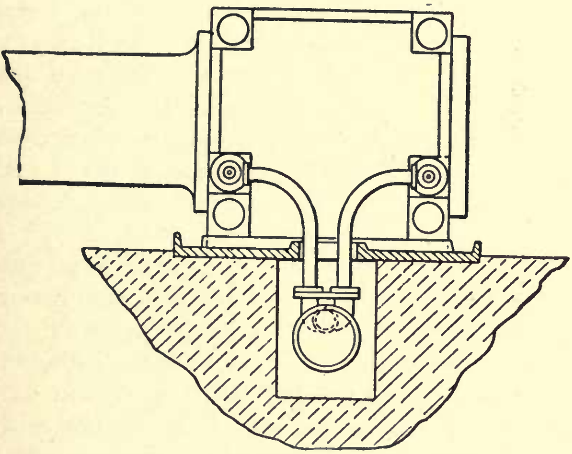

FIG. 157 (B7–1).

The connections shown in Fig. 157 (B7–1) will work up very nicely, using flanged relief valves, cast-iron bodies, pipe bends, an opening in the bed plate for the pipe to pass through, and flanged faces on the exhaust elbow to which are attached the relief pipes. The Corliss valves can be removed without interfering with these.

If the high-pressure side of the engine is to have reliefs piped from it, the piping should be done in the manner illustrated in

Fig. 157. The reliefs should discharge into the high-pressure exhaust, in which case there should be used a flanged side-opening return bend, as shown by the dotted lines, to which the pipe bends may be attached. The piped relief is objectionable because it allows the relief to be neglected and to waste steam in the most expensive manner. Engine builders in general prefer to have the valve left open, their reason being that if everything is as it should be, the valve will not blow. If these connections are to be used, the engine builder should be required to furnish them.

CHAPTER XII.

ATMOSPHERIC EXHAUST PIPING.

Class C1 and 2 — Atmospheric Exhaust; Main and Branches to Engines. The exhaust main and its branches which connect the exhaust ports of the engines in a non-condensing plant with the atmosphere are constructed with details similar to those of a vacuum exhaust line. The various parts of atmospheric exhaust systems may be made sufficiently tight with somewhat less effort than is necessary for condenser connections. In atmospheric exhaust piping spiral-riveted, light-galvanized iron pipe is found quite satisfactory. If the pressure on the exhaust line is kept at about the atmospheric point, the light valves and fittings, sometimes called the "50-lb. standard," may safely be used. The connections may be made with rubber-cloth gaskets. If the piping is of the riveted type it should be well galvanized after the flanges are put on. This galvanizing serves to close any leaks and tends to hold the joints together even if the rivets become loosened. The use of tarred or other paper in joints should not be sanctioned on account of the bad effects that may be caused by oil in the exhaust steam. The tendency of boilermakers to make use of some elastic material such as tarred paper in riveted seams apparently shows that it is an expensive job to make tight seams in piping having a shell but one-eighth or three-sixteenths in. thick. The use of thin punched, rolled and riveted galvanized plates should be avoided, as better joints can be made with riveted and calked black plates. If the main is sufficiently large to admit of the use of a quarter-inch plate, it then becomes a simpler matter to calk the black plate than to galvanize it.

For small pipes, six inches or less, the difference in cost between light-weight, commercial, lap-welded pipe and riveted pipe is too small to be worth considering.

For a very high grade of work the light "casing" or tubing attached to the flange in the manner shown in Fig. 158 (C1–1) will be found quite satisfactory. The flange as shown in this illustration can be attached in the field and the light-welded pipe may have a maximum diameter of 30 in. The end of the pipe should project slightly beyond the face of the flange in order that the joint may be made at the end of the pipe. The flange should be shrunk on and the pipe well peened into the flange.

There is another style of connection shown in Fig. 159 (C1-2) which makes a very satisfactory flange, but owing to the great amount of "drawing out" of the metal used in making the flange, the connection should be made at the shop where there are special facilities for doing this work. The flanges used in this joint are made large enough to be loose on the pipe and serve only to draw the flanged ends together. In Fig. 159 the flanges are made of cast iron, but for peened work as in Fig. 158 the flanges should be made of wrought iron, rolled steel, or steel casting. For light casing pipe a cheaper form of construction is found in the use of fine casing thread-ends and screwed flanges.

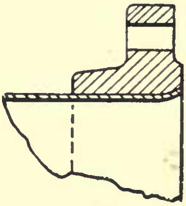

FIG. 158 (C1-1).

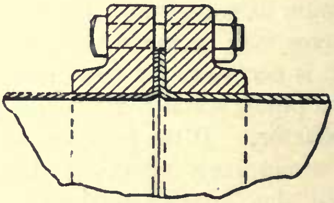

FIG. 159 (C1-2).

Atmospheric exhaust lines up to 24 in. in diameter should be made of metal with a thickness of not less than one one-hundredth in. per inch of diameter. Exhaust lines 10 in. in diameter have been made of No. 20 galvanized iron. Since the exhaust from an engine is intermittent and the pipe a condensing body, the vacuum in such a light pipe will cause it to collapse even though the end be open to the atmosphere. An atmospheric line should be designed as if it carried about five inches of vacuum. Cast-iron ells and tees should be used on exhaust lines of 30 in. and less, but for larger vacuum exhaust mains the ells and tees can be made of riveted plates with the flanges placed as shown in Fig. 159. A diameter of 30 in. is virtually the dividing point between pipe-shop and boiler-shop work. Vacuum exhaust mains 30 in. or less in diameter can be made of welded pipe with screwed flanges and cast fittings. If the size is larger than 30 in. the pipe thickness becomes sufficient to make good calked work possible. Cast-iron fittings for a five-foot line would be extremely heavy and short-radius bends would be used to reduce the weight.

Fig. 160 (C1–3) shows a 5 × 3 × 4-ft. tee made up of plate metal and loose cast-iron flanges as shown in Fig. 159, with tension or compression posts (marked *a*) to strengthen the flat faces. This tee as shown has turns of large radius and is of a size which would be quite out of the question for a cast fitting. There are about 12 sq. ft. of flat face on each side of the tee which must resist the atmospheric pressure at 15 lb. per sq. in. This is a total of about 26,000 lb. pressure, or 3,700 lb. for each of the seven posts. These posts should be of pipe and have steel flanges at the ends riveted to the shell.

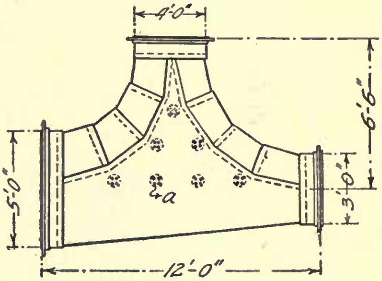

FIG. 160 (C1–3).

As exhaust lines are of a light type of construction it is necessary that they be well protected against water pockets and water hammer. The drains should be in the same direction as the flow of the steam and there should be some sort of a water seal as shown in Fig. 161 (C1–4). In Fig. 161 the distance, *a*, should be made sufficiently great to prevent the pulsating pressure from churning the water out of the seal. While the gage may show but little back pressure, the exhaust may still be blowing through if there is a short water seal at *a*. Twenty-seven inches of still water will provide an effective seal against a back pressure of one pound, but in actual practice such a short seal will not be effective if the engine is running. To have the seal operative under all working conditions, the distance, *a*, should not be less than five or six feet. The casing pipe should not be less than four inches in diameter, and a loose cap should cover the top of the well to facilitate the removal of the drain pipe. The drain to the sewer should be left open so that an operator may, by inspection, know what is passing away through the drain.

If the exhaust pipe is not less than three feet above the floor the seal may be made of elbows and valves as shown in Fig. 162 (C1–5). In case of a considerable back pressure with this arrangement of piping the upper portion of the loop may be used. The closing of valve *a* will make the loop about five feet high, if its top is placed two feet above the bottom of the exhaust main. By placing a check valve at *b*, the surging can be stopped and a shorter seal used.

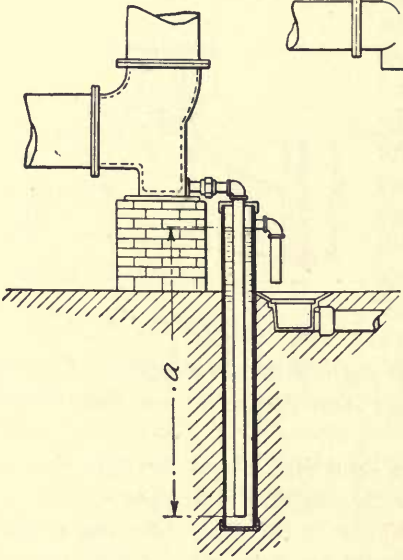

Fig. 161 (C1–4).

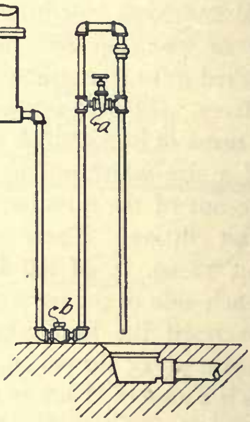

Fig. 162 (C1–5).

Class C3 — Atmospheric Exhaust to Atmosphere. The atmospheric connection from non-condensing engines should in all cases be provided with a sealed drain, and an exhaust head should also be provided with a drain and a short seal. For condensing engines the atmospheric pipe may be run to the atmosphere without an exhaust head. A simple form of exhaust head which will be found more serviceable than one made of galvanized iron is shown in Fig. 163 (C3–1). This form is suitable for use on condensing work. The spiral, *a*, throws the condensation to the side of the pipe, and the lip, *b*, overlaps the face of the upper portion of the head, *c*. This allows the water to be carried into the annular recess, *d*, and conducted to the sewer through the pipe, *e*. The entire upper portion of the head is made of cast iron and is heavier and more durable than the pipe itself.

Where the exhaust and drain pipes pass through the building roof there should be provided a roof sleeve and an umbrella which will care for the expansion and contraction of the pipe and at the same time will prevent leakage at the roof. Fig. 164 (C3-2) shows a roof sleeve made of heavy galvanized iron with a thimble, *a*, through which the drain from the exhaust head passes. The diameter, *b*, of the roof sleeve should be made large enough to allow the flange at the end of the pipe to be passed through. The umbrella should be made in two pieces, with each piece attached to a half clamp. At least three ply paper should be laid on the roof and the roof plate of the sleeve should be well tacked down upon it. After erection, the roof plate should be mopped and at least three ply paper placed over it. Such gravel as is used on the remainder of the roof should then be placed over the plate and the roof cement run into the joint, *c*, and up the side of the

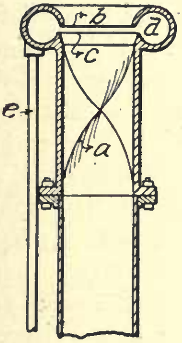

FIG. 163 (C3-1).

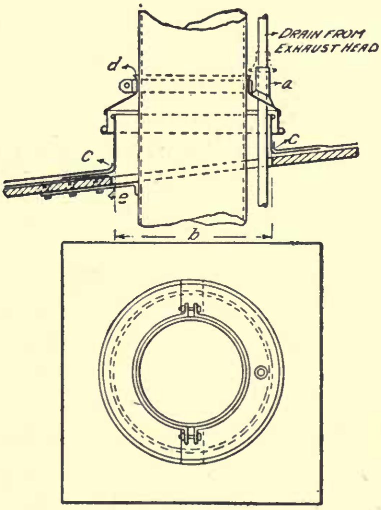

FIG. 164 (C3-2).

sleeve to protect it against the weather. After the umbrella has been well secured to the pipe the joint, *d*, may be filled with lead to prevent leakage. The thimble, *a*, should fit the pipe closely and what little leakage occurs at the joint ordinarily will not cause any trouble. If necessary, a coupling with the umbrella soldered to it may be placed immediately above the sleeve as indicated by the dotted lines. Stays such as are shown at *e* should be attached to the roof sheathing to prevent the pipe from swaying sideways and damaging the light roof sleeve or umbrella. There should be nothing to interfere with the free expansion of the pipes running through the roof, and if the building is very high the umbrella should be made with a deep drop flange to suit the amount of travel caused by expansion, which for an exhaust line varying in temperature from 32 degrees to 212 degrees would be about 1¼ in. per 100 ft.

Class C4 — Atmospheric Exhaust; Auxiliary Main. In a condensing plant an auxiliary exhaust main should be used for the auxiliary machinery. Ordinarily this main would be designed to take care of less than one-sixth of the total steam generated. Its area would be about one-sixth of that of all the exhaust steam openings including those of the auxiliaries. Such a main in a plant having four 1,500-kw. units would have an area equal to that of four 24-in. main exhausts and the auxiliaries. This would be about 2,000 sq. in. Since one-sixth of this area is 333 sq. in. a 20-in. pipe would be required. If most of the larger auxiliaries are electrically driven the exhaust may be of such a small amount that if the water be taken from the hot-well at 100 degrees the exhaust will not raise its temperature higher than 170 degrees. With motor-driven auxiliaries but one-fifteenth of the steam generated would be returned to the heater, and the cross-sectional area of the pipe would need to be but one-fifteenth of 2,000 sq. in., or 133 sq. in. Thus a pipe with not less than a 14-in. diameter would be required. This size is more often used for such service.

Since the auxiliary exhaust is used in connection with auxiliary machines and will have small branches, it may be found more economical to use standard pipe, screwed flanges, and cast-iron fittings throughout. To avoid the separate handling of drips, the branches to the auxiliaries should enter above the bottom of the main, and the main should have a slight pitch towards the heater. The pitch, however, is not absolutely essential, as the flow of steam towards the heater will carry the drips with it. It is often difficult to make suitable provision for an auxiliary exhaust system, and therefore it should be given careful consideration before floor levels and similar details are determined upon. Care should be taken in designing so that the exhaust will drain to the heater and the heater be placed sufficiently high to enable the water to flow to the feed pump suction by gravity.

Class C5 — Atmospheric Exhaust; Auxiliary Main to Atmosphere. As it will be necessary when cleaning the heater to discharge all exhaust steam through the atmospheric connection, the atmospheric connection from the auxiliary main should have the same capacity as the main itself. The amount of steam wasted to the atmosphere in such a short time would be so small that it would neither pay to install a reserve heater nor make any double connections to allow for the running of the auxiliaries under vacuum. An atmospheric connection also serves as a safety-valve line on the exhaust system to prevent the pressure from exceeding some predetermined amount. The type of valve that should be used in an atmospheric connection should be selected for such service and no other. In fact, if there is more steam supplied to the heater than can be condensed, a back-pressure valve should not have a seat, but should serve as a resistance in the line, maintaining a fixed pressure and allowing the excess steam to waste to the atmosphere.

Fig. 165 (C5–1) shows a good form of noiseless back-pressure valve. The piston has toothed edges, which decrease the resistance to the flow as the steam is admitted through the port opening. The cushion, *a*, serves to lessen the jar on the valve when the lever drops. There are no seats for the valve to pound upon, and since the piston slides its action is noiseless. Although the piston does not close tightly the leakage past the valve is very slight. This valve is well suited for exhaust systems carrying a back pressure and in which the quantity of exhaust supplied to the heater is ordinarily greater than can be condensed.

For a heater which is being supplied with an insufficient amount of steam to raise the temperature of the water, it would be advisable to use a valve of this form with seats to close upon. Such seating faces are shown by the dotted lines at *b*. This type of valve will close sufficiently tight for the purpose just described. Owing to the fact that the valve leaves its faces when steam is discharging through the serrated portions of the piston, this valve will be free from any great amount of pounding. The atmospheric pipes should be provided with a roof sleeve and an umbrella similar to those used for the pipes from the engines. The drain *c* should be piped to the sewer, as it is not possible to lead the drips back through the valve if the pressure is slightly above atmosphere. This drain may connect with the drain from the exhaust head.

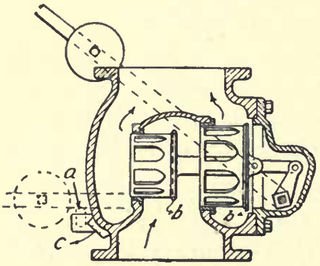

FIG. 165 (C5–1).

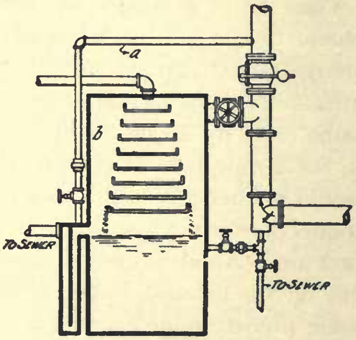

FIG. 166 (C6–1).

Class C6 — Atmospheric Exhaust; Branch to Heater. If possible, the exhaust branch to the heater should drain from the exhaust main into the heater. If the bottom of the exhaust main is above the overflow of the heater, the detail shown in Fig. 166 (C6–1) will take care of the drains and allow steam to enter at the top. This will be a desirable arrangement if the heater is able to condense all of the steam fed to it. The pipe *a* serves a double purpose, as it allows air to either enter or be discharged from the heater. Since the arrangement shown in Fig. 166 is for a condensing plant, the amount of water sent to the heater, when an air pump is used, would ordinarily maintain a vacuum of 16 or 18 in. To allow the water to flow to the pump suction it would be necessary to raise the heater 1 ft. for each inch of vacuum carried. If the pipe *a* is open, any increased amount of steam or a decreased amount of water will cause the air to be partially discharged until the condensing surface is just sufficient to condense steam at atmospheric pressure. As soon as the amount of water is increased or the amount of steam diminished the air will rush back into the heater. The line *a* automatically cuts the condensing surface in or out. Instead of discharging the steam through the atmospheric valve when there is too much air in the heater the air alone is discharged from the heater and no steam is wasted in the process.

If the exhaust main is much lower than the heater this main can be drained with an entrainer as shown in Fig. 167 (C6–2). This is the regular method of draining vacuum mains in connection with an elevated jet condenser. If the flow of exhaust steam is very light the bleeder *a* may be left open to the sewer. Instead of placing the grease extractor at the heater opening as indicated by *b*, it would be advisable to locate it at a lower point, *c*, and allow the grease extractor to handle both the entrained oil and water. If this practice is followed there will be no other drain required. The exhaust branch connecting the separator with the heater should drain either to the heater or to the separator. If the auxiliaries are placed close to the heater their exhaust should be run back and discharged at the head of the separator as shown in Fig. 168 (C6–3). In this figure the grease extractor is shown at *a*. The exhaust from an auxiliary is carried by the pipe *b* to the exhaust main *c*. The drain from the grease extractor should be run to the sewer, as the water contains too much grease to make it advisable to return it to the boiler.

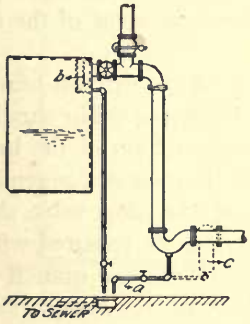

Fig. 167 (C6–2).

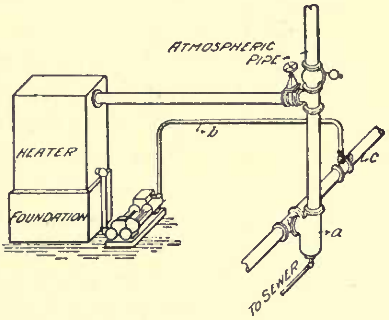

Fig. 168 (C6–3).

Class C7–17 — Atmospheric Exhaust to Pumps and Small Engines. The connection shown in Fig. 169 (C7–1) is considered standard for all the auxiliary machines in the classes from C7 to C17. If the exhaust main is 2½ in. or more in diameter it should be fitted with flanged tees even though the side outlets are as small as 1½ in. If the branches are 2½ in. or larger the stop valve should be flanged and connected directly to the tee, using, if desired, a screwed drip ell at the bottom with the flange connected to the pump. The drains for the exhaust branches should be made of not less than three-eighths-inch pipe. The connection shown in Fig. 169 allows a swing in both a vertical and horizontal plane. If the auxiliary branch is made of 4-in. pipe the net cost of a 4-in. flanged angle valve would approximate $6.35 and the combined cost of a 4-in. flanged elbow and gate with an extra joint, $8.10, or a difference in favor of the angle valve of $1.75.

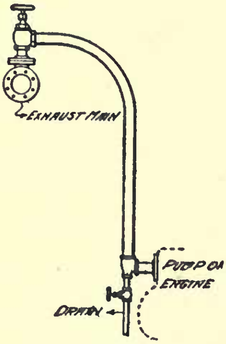

FIG. 169 (C7–1).

The arrangement of the exhaust branches is quite simple. First, the drain should be placed at the lowest portion of the branch in order to clear the branch of condensation when starting or running slowly; second, the stop valve should be placed at the main to enable the branch to be repaired without interfering with the main, and also to prevent the branch from filling with condensation when shut off; third, the branch should enter the main above the bottom and preferably at the top; fourth, long branches should rise to their highest point at the auxiliary and should then be given a pitch for the remainder of the distance to the exhaust main, although this requirement is frequently a difficult one to fulfill.

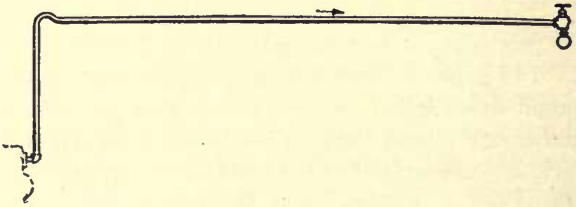

FIG. 170 (C7–2).

Fig. 170 (C7–2) illustrates a long branch running to the main in the most approved manner. The horizontal connection should have a slight pitch towards the main in order to avoid pockets where the line sags.

Fig. 171 (C7–3) shows a line with a considerable pitch which in reality is an "up-hill" line before discharging into the main. A line supported in such a manner that it is level throughout would serve quite as well and would make the pipe fitting a much simpler matter. The machinery that lies in basements, etc., is generally difficult to keep properly drained without resorting to drains to the sewer.

FIG. 171 (C7–3).

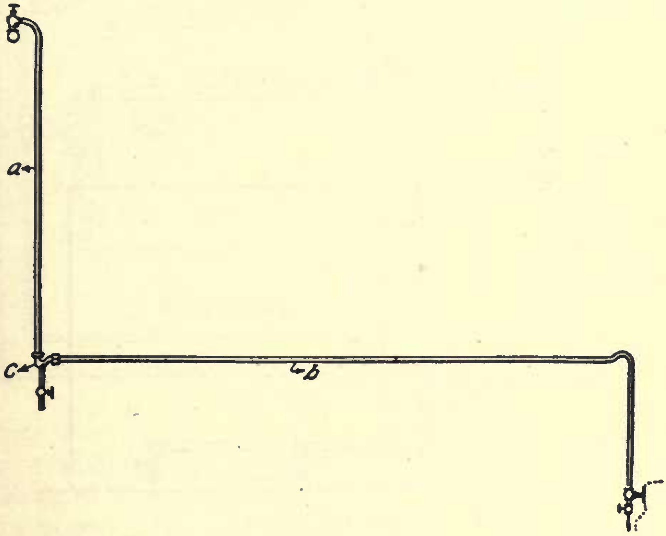

FIG. 172 (C7–4).

Fig. 172 (C7–4) shows such a line as has just been mentioned with sewer drains that can be closed as soon as the steam unit is in operation. To reduce the length of the "lift" to the least amount possible, the riser *a* should be placed close to the exhaust main. The line *b* should have a fall through the entire distance to the entrainer *c*. These entrainers are standard articles, being listed by the manufacturers as a "drainage fitting," and are made in different sizes of from 2 to 8 in.

Class C18 — Atmospheric Exhaust to Stoker Operators. The majority of stokers are operated by an engine, and the exhaust in some cases being fed in under the grates, the clinker is thereby broken up and does not adhere to the grates. In other stokers it is required that the exhaust be used to protect the castings used in connection with the furnace. The stoker steam unit should be connected to the exhaust main in such a manner that its exhaust can be delivered to the exhaust main without going to the furnace. The furnace can then take the exhaust from the main if the engine is not running, or the engine can discharge direct to the furnace if it is necessary to shut off the main.

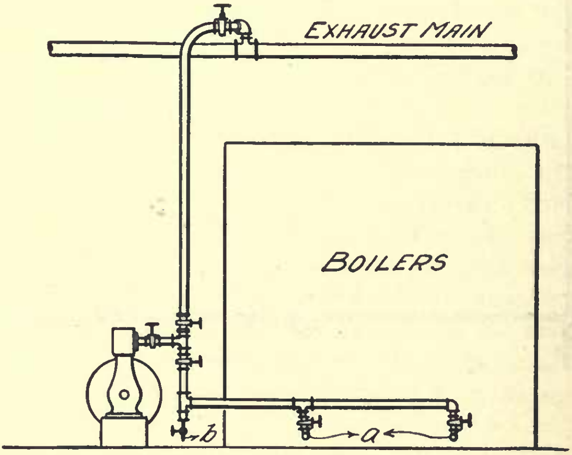

FIG. 173 (C18–1).

This can all be provided for in a simple manner by adopting the design shown in Fig. 173 (C18–1). If the engine supplies more steam than the stoker requires the excess flows to the exhaust main. If the engine does not furnish sufficient steam the extra amount will flow from the main. The branches indicated by *a* should always be the low connections, otherwise the low line will accumulate condensation and if the furnace valve is opened to a considerable extent, this condensation will then be thrown over and crack the hot castings. The practice of working the small amount of condensation that accumulates in the low line through the furnace all the time is considered safe, but it is dangerous to pick up a "pocket" of water and throw it upon the hot iron. In starting up the engine the drain *b* should be left open for a time.

With underfeed stokers the exhaust line should be run under the floor and if the slide valves of the cylinders are located at the rams the exhaust and drips can be led to any exhaust main that may lie in the boiler room basement. Unfortunately, there are few installations provided with basements for exhaust mains and the piping for such stokers is usually one of the crudest details to be found in a system of station piping.

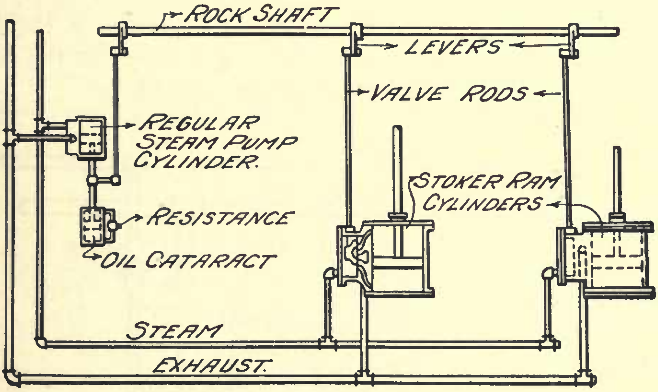

FIG. 174 (C18-2).

Fig. 174 (C18-2) illustrates the older method of reversing the strokes of the rams with the reversing valves located at the ram cylinders. The arrangement shown in Fig. 175 (C18-3) is laid out on the same principle as the older form with the difference that in the new form the reversing valves are located away from the ram cylinders and long pipe ports are used from the valve to the cylinder. The reversing valve is operated by a steam pump cylinder with its time regulation governed by oil resistance. The port opening in the oil by-pass from one end of the cylinder to the other is increased or decreased by means of a hand-operated valve. A check valve is placed between the two ends of the cylinder, which allows an unobstructed passage of oil on the instroke of the rams and forces the oil through the resistance on the outstroke.

The design shown in Fig. 174 requires more mechanism to convey motion from the controller to the cylinder valves, but it reduces the port length to but a few inches. The steam and exhaust lines in this older style of controller have their flows always in the one direction and the drips are being constantly worked out of the lines. The pressure of the steam in those lines is always maintained and is not wasted to the atmosphere at each stroke as is the case in the design shown in Fig. 175. This latter form possesses the advantage of being free from levers, rock shafts, etc., and thus makes a cleaner device in the boiler room. In the latter arrangement the two lines to the cylinders cannot be drained and the condensation causes much snapping and cracking from one line to the other. This makes it impossible properly to lubricate the ram cylinders and increases the stresses and wear on the entire stoker-operating mechanism.

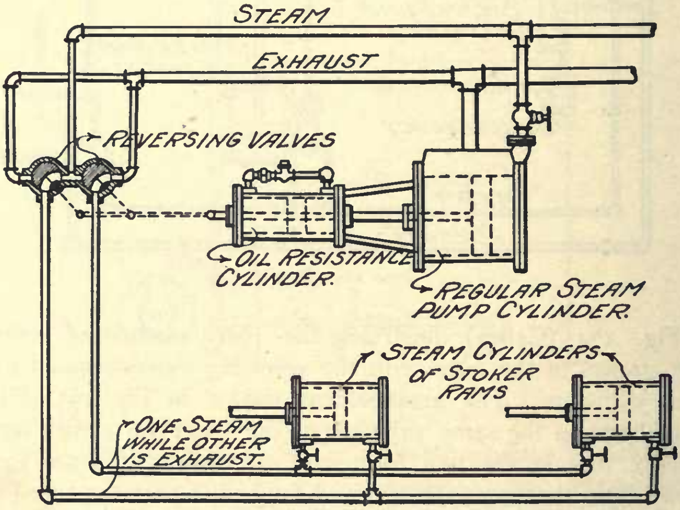

FIG. 175 (C18-3).

The desirable features in stoker-operating machinery include elimination of all rock shafts, levers and similar parts, and the maintenance of a constant pressure and direction of flow in the pipe lines. At present each of the two styles just described complies with one requirement and fails in the other. A desirable feature which neither of the two types provides is that the ram shall remain in until the controller starts it for another charge. The ram should then make the outstroke and the instroke immediately following each other and then remain in until it is again started by the controller. If this method is followed the coal will not cake around the mouth of the bore to the retort and thus prevent the ram from entering.

These are more in the nature of machine than piping details, but as has already been stated many other details must be considered in order to provide a good piping system. The piping, whether it has the arrangement shown in Fig. 174 or 175, should not be buried, confined or subjected to the corrosive action of cinders and water. Such piping should be free to expand and should at all times be accessible for repairs. The stoker contractor should be asked to furnish the lower part of the boiler front, the controller, the stand to carry the ram cylinders, and possibly the cast-iron conduit as shown in Fig. 176 (C18–4).

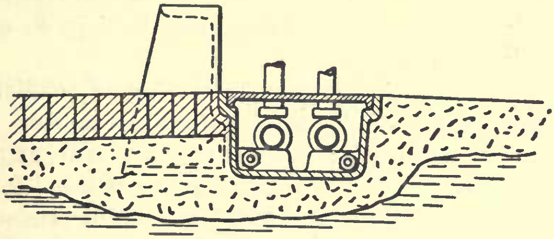

FIG. 176 (C18–4).

All these details should be furnished completed so that the steamfitters can place the pipe work and the masons build in the floor. If there is a basement under the boiler room floor the stands only would be required as the piping in this case could be placed below the ceiling of the basement.

Class C19 — Atmospheric Exhaust to Roof Conductors. In a non-condensing plant where steam is exhausted to the atmosphere it is advisable to warm the roof conductors with exhaust instead of live steam as a large quantity of the exhaust steam is wasted in any case. However, as the live steam has sufficient pressure and if there is a partial passage through the conductor where the most trouble occurs, it will be found that live steam can be more readily forced to the roof.

Class C20 — Atmospheric Exhaust to Heating Systems. The many details of heating systems will not be considered here except as they form a part of the power station equipment. The subject of heating is one of considerable importance for isolated stations and for large buildings. In an exhaust heating system the return drips are in some cases quite sufficient to feed the boiler and in this event it may be necessary to deliver live steam to the exhaust system in order to maintain the desired back pressure. In this case the generating and auxiliary machinery should be run non-condensing with a back pressure on the exhaust. In fact the heating system should be the chief duty of the plant.

A power station is not often designed for supplying steam to a heating system, and wherever heat is taken from the plant for such purposes it is somewhat difficult to provide for, as the amount of heat required is usually comparatively small. If a 20-hp. boiler were provided for heating a given plant it would not be considered good engineering practice to allow the condensation to go to the sewer, but if the plant had a 20,000-hp. boiler capacity the same amount of steam and drips may both go to waste and but little note be taken of it.

The heating system, together with the heater auxiliaries, etc., should be connected to the atmospheric exhaust system. Heating system requirements cannot be determined to any great degree of nicety. There will be a constantly varying demand for exhaust steam, and since the supply of exhaust steam is determined by the quantity of steam used to generate power the boiler feed water fed through the economizers may vary in temperature between 125 and 210 degrees. There is no serious objection to this change in feed water temperature, nor is there any other way to better the economy. For a condensing plant using economizers it would be quite wasteful and unnecessary to deliver live steam to the heater in order to maintain a high water temperature.

The system of exhaust steam heating which is being considered may be operated with a back pressure on the auxiliaries or a vacuum return system on the heating coils and radiators. If a vacuum return system is used, the air should be allowed to enter and be discharged from the heater as shown in Fig. 166. If the air were removed from the heater it would cause a vacuum on the heater as well as on the heating system. The vacuum pump for a heating system should be independent of the other station apparatus in order that it may be shut down in the summer and run at night in case all other machines were shut down. The vacuum pump should deliver the return condensation and air to the exhaust heater, allowing the air to be precipitated, and leave the heater through the vent.

If the plant is provided with surface condensers and but a small amount of steam is required for the heating system, it may be found simpler to return the air and drips to the surface condensers as shown in Fig. 177 (C20–1). The drips should all flow to the drip receiver as shown. The riser, *a*, should be as short as possible and of small diameter in order to insure a high velocity. The drain, *b*, should be given a slight pitch to the condenser and can be of a larger size of pipe than *a*, since high velocity in this pipe is not essential. The reducing valve, *c*, is in reality a safety or relief valve arranged to blow off its absolute pressure of 10 lb., the results obtained being practically the same as though the exhaust were under a 3-lb. back pressure. This 3-lb. vacuum on the drains would lift a solid drain in the line *a*, a distance of about 6 ft. If the drain can be returned as shown by the dotted line *d*, less vacuum will be required on the drain system. The objection found in draining to the condensers is that much difficulty may be encountered at night when the plant is shut down and the drains are not working. If the plant is to be shut down for 3 or 4 hours at night during severe weather it will not be safe to stop the drains.

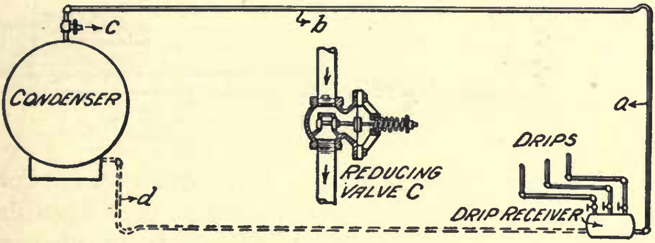

FIG. 177 (C20–1).

Fig. 178 (C20–2) shows a back-pressure exhaust heating system and its exhaust lines. With the heater under atmospheric pressure the valve *a*, may be set for 30 lb. if necessary, as the heater is not subjected to the back pressure. The valve *b*, should be set for about one pound. If the drain *c*, could be pitched to the heater as shown, the back pressure could be quite small; but if the drain lies lower than the heater as shown at *d*, it will then be necessary to increase the pressure enough to raise the water in the riser, *e*. If the riser *e*, is say 10 ft. long it may be then found necessary to run the back pressure up to 6 or 8 lb. Gages should be placed on the exhaust main and on the heater to show the set of the back-pressure valves.

The system shown in Fig. 178 requires no additional apparatus, and the condenser need not be of the surface type nor be run so as to remove the drips. The exciter engine would in all probability be run to supply current for the lighting system, even though the plant were otherwise shut down. A live-steam connection can otherwise be made to the exhaust main and used when there is not enough exhaust steam to maintain the necessary pressure. A reducing valve can be set to open the live-steam connection into the exhaust system whenever the pressure in the exhaust main drops to 3 lb. It may be found that this exhaust system can be more economically operated by wasting the drips to the sewer than by carrying the necessary back pressure to elevate and return the drips through a considerable distance to the heater. With drip returns as shown in Fig. 178 there would be no heat lost due to wasting condensation nor by leaving the drain valve open so the steam will blow through to the atmosphere. In fact, the capacity of the heating system would be very materially increased by using the returns *c* and *d*. The steam which does not pass through these returns to the heater would be free to pass through the valve *a*.

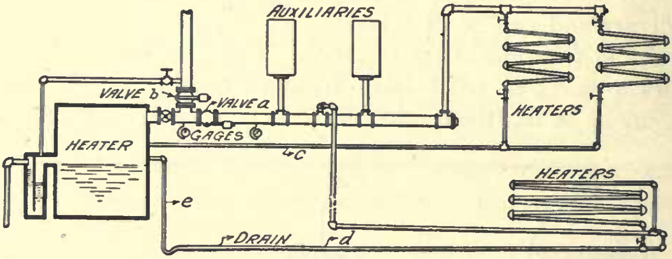

FIG. 178 (C20–2).

The arrangement of this system as shown with the heater under lower pressure than the exhaust system makes the handling of drips possible in the most extreme cases. For instance, Fig. 179 (C20–3) may illustrate a coil for car-shop pits with the drip main on a higher plane than the bottom of the coil. But very little back pressure on the exhaust main would be required to handle the drips. If the riser *a* is 4 ft. in length a 2-lb. back pressure would be required to raise the drips. If the drips are blown to the sewer in starting the coil, then but a fractional part of a pound of back pressure will carry the condensation along with the steam in the form of vapor if the drain valve be left open and the steam be allowed to flow through it back to the heater. If the riser *a* is 10 ft. in length and the difference in pressure of the steam supply and the drip main is but 1 lb., it will then require 4 ft. of steam plus 2 ft. of water in the form of vapor to equal 1 lb. of back pressure. Since the steam would have a volume 1,600 times that of water it would require but one-four-hundredth of the steam necessary for heating to atomize the condensation, and by lightening the column be able to raise the condensation 10 ft. in a vapor column weighing 1 lb. Since the heating system requires from 1 to 2 per cent of the total steam and the vaporizing steam but one-four-hundredth of the amount, it will be noted that the steam flow through the drip lines will be an insignificant amount and only sufficient to raise the temperature of the feed water a fraction of a degree. The drips can then be left well open, the drains and the air well cared for, traps or vapors rising from the sewers avoided and no heat units wasted. This system is especially suited for installations requiring other feed water than for the heating system alone and where all the exhaust steam is condensed in either the heating system or the heater.

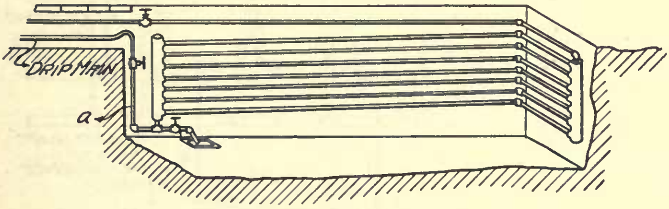

FIG. 179 (C20–3).

The exhaust line to the heating system should be provided with a large grease-extracting separator having either a water seal or a trap in the discharge to the sewer. If the plant is run non-condensing and the exhaust wasted to the atmosphere, then such steam as would be blown through the drip system would cause waste due to the lost energy occasioned by the back pressure on such an amount as was used to remove the drips. The amount so used would in regular practice be considerably greater than that required for the heating system.

The system shown in Fig. 180 (C20–4) is applicable to non-condensing plants such as isolated stations, etc. The auxiliaries have one exhaust connection to the heating system and a second exhaust which is free to the atmosphere. The valve *a* would be set with say a 0.25-lb. back pressure and the valve *b* with 3 to 5 lb., or whatever amount is necessary to return the drips. The valve *c* is placed in the heater connection to provide for an exhaust to the atmosphere if the heater should be out of service. By using two mains as shown it is necessary to place the back pressure only on such machines as are required for the heating systems.

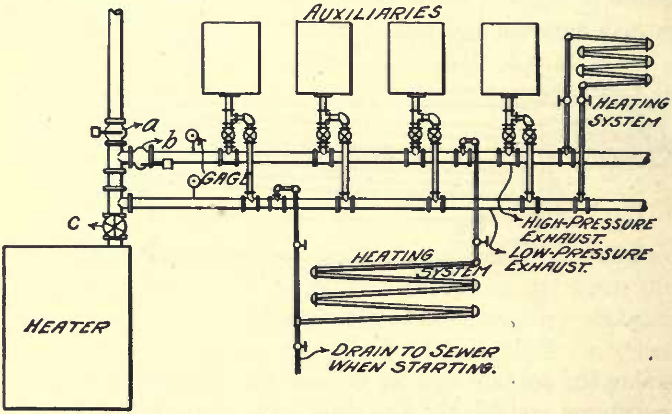

FIG. 180 (C20–4).

In order to avoid the necessity of cutting the auxiliaries in or out to suit the demands of the heating system the atmospheric valves may be placed at each of the auxiliaries as shown in Fig. 181 (C20–5). The valve shown in detail will blow open to the atmosphere when the back pressure in the heating main reaches some set amount, say 5 lb., and when the back pressure drops to say 3 lb. the valve will close to the atmosphere and discharge steam to the heating system. The valve weight should be in the position indicated by *a* when open to the heating main, and in the position *b* when open to the atmosphere. When the valve starts to close or open it takes the full travel without stopping, as the greatest change in pressure available is required to start the valve from either position.

With the heating system arranged in this manner some machines can be set to throw in before others, and the last machines to go in on the heating system would be the first to go out in case of an increase in back pressure. The machines can be adjusted to throw in at any desired time by sliding the weight on the lever. Ordinarily, the best station systems are those which can easily be controlled by hand rather than those which are dependent upon automatic devices. A simple form of quick-reversing, three-way valve, if applied to the system shown in Fig. 180 in place of the two valves shown in the auxiliary exhaust, would, in all probability, provide a more reliable design than that shown in Fig. 181, and furthermore, it would be free from the pound of the automatic valve shown in the latter figure. This automatic valve can, however, be supplied with a dash pot and be made as quick and reliable as any atmospheric valve.

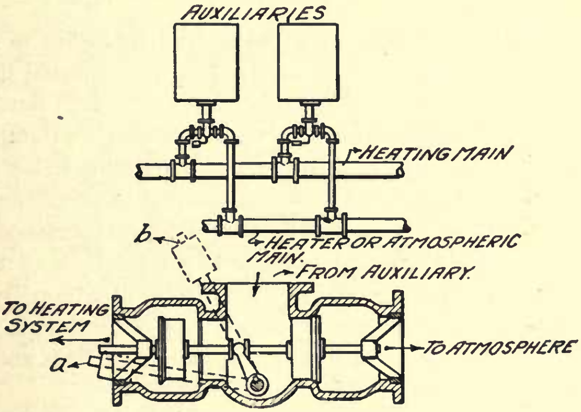

FIG. 181 (C20–5).

CHAPTER XIII.

BOILER FEED MAINS AND BRANCHES.

Class D1 and 2 — Boiler Feed Mains and Branches to Boilers. Since the boiler lines in a plant are frequently subjected to 50 per cent higher pressure than exists in the boilers, the feed lines should be constructed to withstand such excess pressures. Pump governors and relief valves will in time reduce the pressure to the amount set, but the fact should not be overlooked that these extreme pressures are a part of the ordinary feed line performance. This excessive pressure will occur occasionally regardless of the precautions which may be taken, but with careful attention and slow-speed pumps the excess can be reduced to a minimum. Relief valves simply aid in protecting the pumps and pipe lines and do not insure the maintenance of a constant pressure.

A pump, when operated at a constant speed in connection with water relief valves, will give the following results: Reliefs that start to discharge or leak at a pressure of 60 lb. discharge but little water at a pressure of 80 lb. When water passes through the reliefs at the rate of 15 ft. per second the pressure runs up to 140 lb. The reliefs discharge a certain quantity of water at a certain pressure, and to discharge a greater quantity a greater pressure is required. In order to prevent a constant leakage through the reliefs they should be set considerably above the working pressure, that is, if the working pressure is 160 lb. the reliefs should be set at 180 lb. If such leakage is not stopped, it is probable that the valves will be ruined. Much of the trouble from excessive pressure can be avoided by the use of well-designed relief valves.

In the relief valve shown in Fig. 182 (D1–1) the pilot relief valve, *a*, is used to admit pressure to the cylinder under the piston, thus balancing the piston and allowing the valve, *c*, to open. There is an opening through the stem, *b*, by means of which the same pressure is maintained above the piston as under the valve, *c*. Since the hub opening at *f* is made fairly tight, the pressure in the chamber, *d*, is wasted through the partially opened drain, *e*.

The leakage can occur through the hub, *f*, only at such times as the valve, *c*, is open. The capacity of the valve, *a*, should be somewhat greater than the waste through the drain, *e*, in order to maintain pressure in *d*. The drain, *e*, should not be discharged into the waste pipe from the valve, *c*, as this pipe is under pressure due to the volume of water which passes through it, and the resulting pressure in the space, *d*, would cause the piston to close slowly. Since the piston acts as a dash pot, this valve cannot chatter on its face. If very hot water is used the piston can be made of composition metal fitted with packing rings. The valve is guided by means of the hub, *f*, and can be readily reground by removing the upper cylinder and clamping the hub piece with the screws which attach the cylinder.

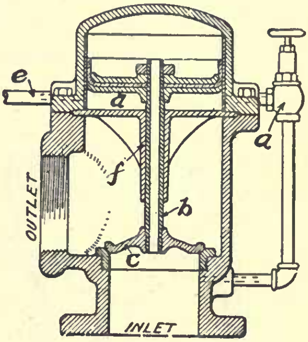

Fig. 182 (D1–1).

The pilot relief valve, *a*, should be of a sensitive and high-grade type, and if different sizes of main relief valves are used in the same plant they should all be supplied with pilot valves of the same size. A spare pilot valve should be provided for substitution in case it is desired to repair one in use. The valve, *a*, has but little service to perform, and if it is merely off its seat, the pressure will enter the chamber, *d*, allow the valve, *c*, to open and remain open during the time the valve, *a*, is discharging. When the valve, *a*, closes, the pressure on the under side of the piston is zero. Then if it is assumed that the pressure on the upper side of the piston and on the under side of the valve, *c*, is 120 lb. with the pressure above the valve 20 lb., and if the piston has twice the area of the valve, *c*, or the area of the valve is 25 sq. in. and that of the piston 50 sq. in., there would then be a pressure of 6,000 lb. tending to close the valve and a pressure of 2,500 lb. tending to open it. This is a net pressure of 3,500 lb. tending to close the valve. When, owing to the opening of the valve, *a*, the pressure in the chamber, *d*, is the same as that on the upper side of the piston, there will be a pressure of 3,000 lb. exerted in opening the valve, *c*. When the valve, *a*, is closed and there is no pressure in *d*, there will be a pressure of 3,000 lb. exerted toward closing the valve, *c*. The objectionable feature in the type of valve shown in Fig. 182 is that there is pressure upon the piston at all times and therefore a tight fit must be maintained in order to avoid excessive leakage.

The valve shown in Fig. 183 (D1–2) has a loose-fitting piston, the clearance affording an opening for the waste from the chamber, *a*, which is put under pressure by the relief valve, *b*. The chamber, *c*, is always open to the atmosphere. The stem, *d*, slides loosely in the sleeve. The drain, *e*, is made of sufficient size to take care of all drips past the piston and stem. The capacity of the valve, *b*, should be made greater than the leak past the piston. This type of valve is readily reground and requires no close-fitting or tight pistons. The valve may be placed in the reverse position to that shown in the illustration by the use of the spring, *f*, which has sufficient tension to support the valve.

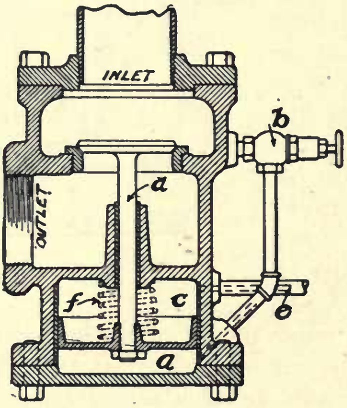

FIG. 183 (D1–2).

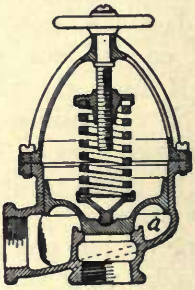

FIG. 184 (D1–3).

Another type of relief valve is shown in Fig. 184 (D1–3). This valve requires pressure in the chamber, *a*, in order to decrease the resistance to the flow of water at the valve. The piston is open to the atmosphere and the small leakage passing it may be piped away. This valve may not be as complete a relief valve as those shown in Figs. 182 and 183, but its simplicity is a good feature.

There are various methods employed in the general construction of feed lines. It is the general practice to use iron pipe for cold-water lines carrying water at a temperature of less than 200 degrees and brass pipe for high-temperature lines carrying water at a temperature above 200 degrees. If the working steam pressure is not over 175 lb. full-weight iron pipe is frequently used. Above that pressure extra heavy iron pipe is used. The heavy pipe is used, not because the lighter pipe will not stand the pressure, but in order to insure longer life.

The material to be used in the construction of feed lines depends largely upon the water to be handled. If low-temperature water passes through the mains a lighter weight iron pipe may safely be used, since with low temperature there will be no trouble from scale or pitting. If the water is chemically treated before it is fed to the boilers, it will neither scale nor pit the pipe, even though the water is raised to a high temperature. If an open heater is used and the temperature is raised to the boiling point, or 212 degrees, pitting will not occur, but the water may deposit scale. The smoother the interior of the pipe the less trouble there will be from scale. If it is known that the water tends to scale the pipe there will then be no danger of its pitting or eating the pipe. In this case seamless-drawn iron tubes may be used and afford a smooth, clean main. In ordinary practice, however, screwed iron pipe of full or extra heavy weight is used.

If the feed water contains acids which, while preventing scale, eat the iron pipe, the feed main should be made of seamless brass tubing one-eighth inch or less in thickness. It is not practicable to use screwed connections with light brass tubing. Such tubing is expanded into cast-iron flanges with a tube roller and the end of the tube turned back on the flange as shown in Fig. 185 (D1–4). To prevent the flange from working back while the end of the tube is being turned over, the diameter of the tube is increased at the point, *a*, back of the flange.

It is a common practice to make feed-water mains and branches of brass pipe of the same diameter as iron pipe which would serve the same purpose. The thickness of the brass pipe should be about the same as that of the commercial-weight steel pipe generally sold. This weight of pipe should not be understood as the "full weight" pipe generally found in pipe tables. Fittings should be of flanged cast iron regardless of what material the pipe is made. Screwed fittings should not be used on pipe of greater diameter than two inches.

A very satisfactory arrangement of feed mains, since they are generally three inches or more in diameter, is to use brass tubing as shown in Fig. 185 and make the boiler branches, which may be 2 in. or less in diameter, of standard threaded brass pipe. If the branches are 2½ in. in diameter and are flanged throughout it is nevertheless good practice to make them of brass pipe of iron pipe size, because it is less expensive to use pipe than to bend tubing. The boiler branches usually consist of numerous small pieces which if tubing were used would require the attaching of a large number of flanges. If 2-in. branches are used the valves and fittings should all be screwed.

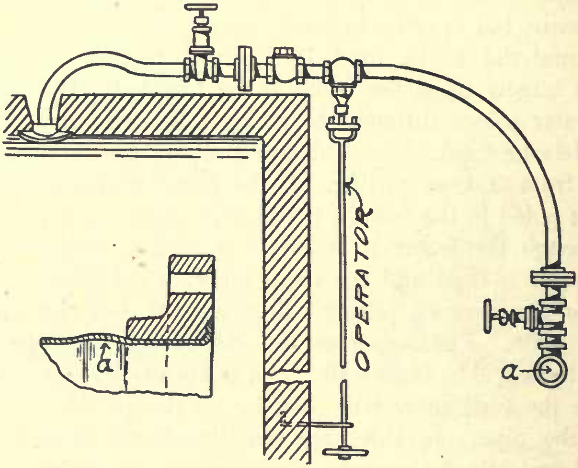

Fig. 185 (D1-4). Fig. 186 (D1-5).

The fittings, such as elbows, tees, and flanged unions should be of extra heavy cast iron. It is unnecessary to install brass fittings for feed-water service, and their use will increase the cost of the piping system. If fittings of brass were used they would be of a lighter pattern than cast-iron fittings, while in reality they should be of a heavy pattern so that they would not stretch under any ordinary conditions of service. It is better for a fitting to break than to stretch, because if a fitting is broken during erection a new one can be substituted immediately, but if a fitting is strained its joints cannot be closed without excessive tension on the threads.

Good joints are easily made between brass pipe and iron fittings, while joints of brass pipe with brass fittings are difficult to make. When two metals in a joint are united with the threads turning under heavy compression, one metal should be hard and the other soft. If they are of the same degree of hardness the threads of one will tend to destroy those of the other.

In the general design of a feed-water main and its branches long-radius bends should be used rather than short, right-angle turns. In many cases it will be found possible to use bends instead of elbows. The long-radius bend shown in Fig. 186 (D1–5) is preferable to an elbow fitting such as would ordinarily be used close to the boiler. Such bends afford more pliable connections which will better withstand expansion strains, and since they also offer less resistance the regulation of the flow of water to the boiler will be better.

The ideal method of securing a uniform flow of feed water to all boilers would be to make the connections as shown in Fig. 187 (D1–6). It is quite certain, however, that the improvement in operation would not justify the additional joints and parts and the attendant increased cost. To secure results that will compare favorably with those obtained with the arrangement shown in Fig. 187 it is necessary to make the main, *a*, in Fig. 186 of a size sufficient to enable about the same pressure to be maintained throughout its entire length. It is not necessary to run a large line between the pump and the first boiler branch from the feed main, but from the first boiler branch to the last one the pressure drop should be kept as low as possible. If the boilers are under 175 lb. steam pressure and the feed water is under 180 lb. pressure at the first boiler connection and under 176 lb. pressure at the last boiler, then the available water pressure at the first boiler is four times that at the last boiler, yet there is but a 4-lb. drop in pressure. The available pressure, which is the difference between the steam

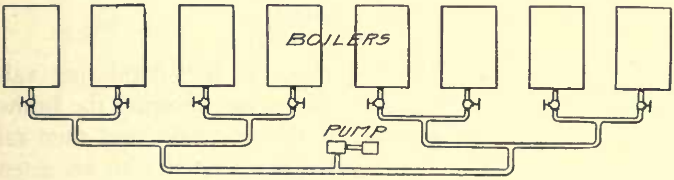

FIG. 187 (D1–6).

pressure in the boiler and the water pressure in the feed main, should be kept as low as possible, thus permitting the line to operate with the feed valves well open.

The arrangement of boiler connections shown in Fig. 188 (D1–7) would probably afford nearly uniform pressure at the different outlets of the feed main. The first two boilers would each have a wye outlet fitting turned as shown, so as to offer resistance to the flow of water through it, the resistance increasing with the flow. The wyes at the last two boilers would offer the least resistance, and by using standard tees at the two center boilers the resistance at this point would be intermediate to that of the two boilers on either side.

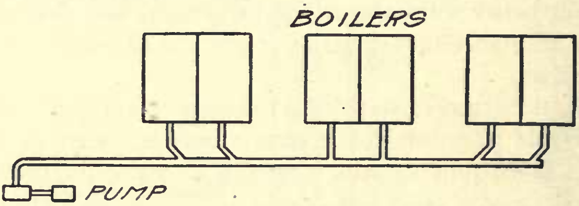

FIG. 188 (D1–7).

It will be noted in Fig. 186 that the feed-regulating valve is located at the top of the boiler. To avoid lowering the branch to a point which may be reached by the operators and then raising it to the top of the boiler, the valve is operated with an extension stem.

The feed branches should be made as short as possible and at the same time should have sufficient length to allow for free expansion and contraction. With most installations of six or eight boilers this result can be obtained with about 8 or 10 ft. of boiler branch.

Fig. 189 (D1–8) shows a simple feed branch arrangement for a double system of feeding. The regular feed main has its operators carried down and placed close to the front of the boiler setting. The auxiliary feed operators at the rear setting are used only in case of emergency; the inconvenience found in operating them in this manner is too slight to require any more expensive arrangement. It will be noted that Figs. 186 and 189 show branches taken from the tops of the feed mains. This arrangement is advisable wherever possible, as it affords a ready means of discharging any air from the main that may be delivered by the pump. It will also be noted that there are two stop valves, a check and a regulating valve, for each branch. This arrangement permits the opening of the check valve at any time by closing the two stop valves. The feed-regulating valve should not be regarded as a shut-off valve, as the nature of its service is such as to prevent its remaining in a condition to close tightly. The independent stop valves are necessary to admit of quick repairs to the feed valve. The stop valves should be of the gate pattern and the regulating valve of the globe or angle pattern.

It will be noted in the designs shown in Figs. 186 and 189 that the regulating valves are turned with their stuffing boxes downward. This arrangement would be objectionable if used on the steam connection, since it permits condensation to leak through the stuffing boxes. Valves used on water connections are as liable to leak at the stuffing boxes in one position as another. The objection to placing water valves with the stuffing boxes downward is that the heavier particles carried with the water will lodge in the bonnet of the valve and in valves of the gate pattern will prevent them from opening fully. This objection is not as marked with valves of the globe and angle patterns because the space that the valve disk opens into is in the path of the water flow and therefore no great amount of deposit can collect. This method is demonstrated by the many similar valves successfully operated in the reversed position.

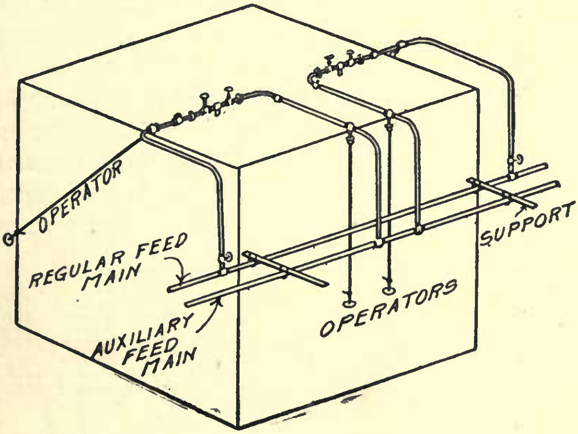

Fig. 189 (D1-8).

In Fig. 190 (D1–9) is shown a detachable feed-regulating and check valve made up as a unit. Since the joints between the valve and the flange are ground, the valve may be removed by simply loosening the nuts. This arrangement allows a valve to be removed for repairs and a spare one quickly substituted without shutting down the boiler. Feed water should enter the boiler at a point considerably below the water line in order to prevent any portion of the feed branch from filling with steam, which would cause water hammer when the feed valve is again opened. In order to minimize the expansion and contraction strains it is advisable not to allow the feed water to come in contact with the boiler until it has been heated to the temperature of the water in the boiler.

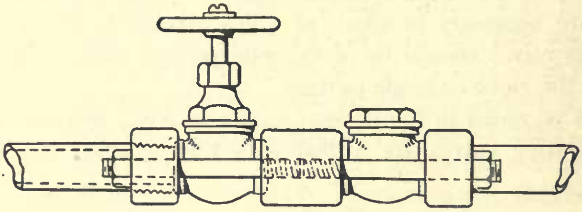

FIG. 190 (D1–9).

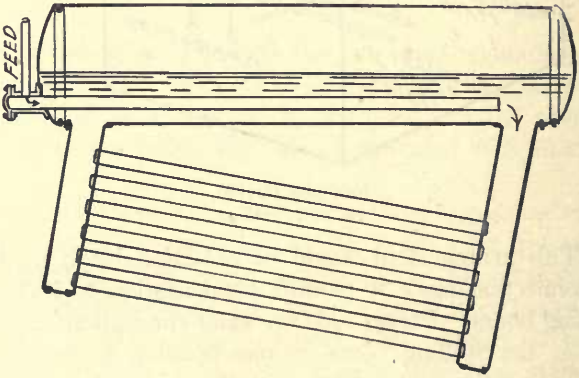

FIG. 191 (D1–10).

Fig. 191 (D1–10) shows a feed-water tube arranged to discharge into the coldest part of the boiler. The nozzle attached to the drum has a blind flange which closes the end opening. The feed opening is at the side of the nozzle. As this tube is the same size as the boiler tubes it may be cleared of scale at the same time. As feed pipes quickly fill with scale they should not be run into the boiler without providing ample means for cleaning.

In considering the details of feed-regulating valves it should be borne in mind that such valves are at all times but partly open. The valve disk of a globe valve is held firmly when the valve is entirely open or shut and therefore will not chatter. The steam throttle is not subjected to as severe service as a feed-water valve, since steam is elastic and passes the throttle at a constant speed. The feed water on the other hand passes the regulating valve intermittently, in unison with the pulsations of the pump, and is therefore constantly rocking the loose disk on the valve stem. A disk held as shown in Fig. 192 (D1–11) will remain stationary on the stem, as it is held rigid by the spring above it. The swing check valve, having a flat-faced disk, opens and closes more quickly than the poppet type, and though the swing type may not be quite as tight while new, it is more suitable for a boiler-feed check, since it retains a good face and guide much longer than the other type.

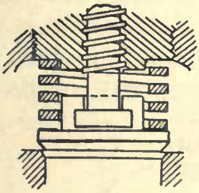

FIG. 192 (D1–11).

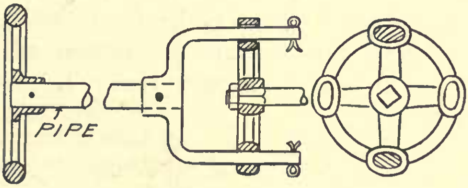

FIG. 193 (D1–12).

A regulating valve is seldom operated directly by the hand wheel, since the location of the valve is such as to invariably require an extension stem. In Fig. 193 (D1–12) is shown a valve hand wheel with an extension fork and a hand wheel for the extension. The rod is of pipe pinned as shown, and the hand wheel on the regulating valve has openings in the rim to receive the operator fork. If the hand wheel is not provided with holes the ends of the fork may be run through between the arms of the hand wheel, which is the usual form of construction for valve extensions.

There are a number of forms of automatic feed controllers designed to shut off the feed when the water in the boiler is high and to open it when the water is low. Some are operated by floats and others by thermostats. The earlier form consisted of a float attached to a lever valve placed inside the boiler, the construction being very similar to that of a tank float valve. To overcome the objection to placing the device in such an inaccessible position the float was placed in an independent water column with a shaft passing through the stuffing box and operating the balanced feed valve as shown in Fig. 194 (D1–13). An objection to this device is that hollow floats are very uncertain, and to operate a regulating valve against the friction of two stuffing boxes would require a float of considerable size. The available power is very slight, and it requires almost constant adjustment to keep the regulator in continuous operation. To overcome the difficulty encountered with large floats and the lack of available power the float is made small and without the stuffing box. Connection is made to a pressure feed valve as shown in Fig. 195 (D1–14). This device has a further advantage in the location of the feed valve. This can be operated without regard to the position of the float, since the connection, *a*, is run from the float to the valve. The waste, *b*, is open a sufficient amount at all times to relieve the

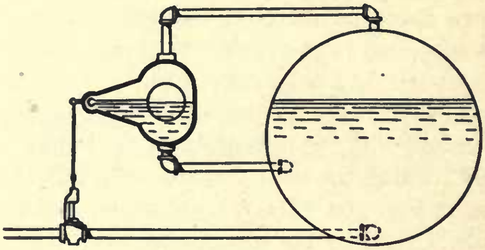

FIG. 194 (D1–13).

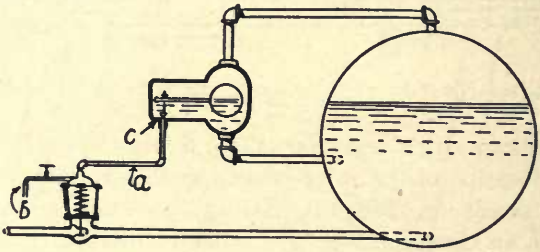

FIG. 195 (D1–14).

pressure over the diaphragm when the small float valve, *c*, is closed and thus allows the feed valve to open.

To overcome the fluctuating movement of the float, float valve, and feed valve caused by the constantly varying feed-water level, which variation occurs in any boiler worked approximately at its rating, the float chamber has been made with but the one connection as shown in Fig. 196 (D1–15). This connection is placed at the low-water level, and when the water in the boiler reaches this point

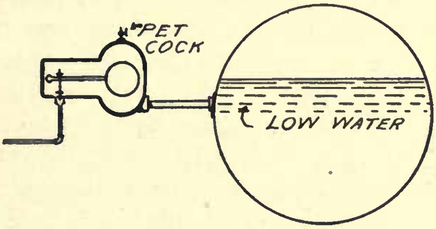

FIG. 196 (D1–15).

the float chamber empties its water back into the boiler. The float chamber then fills with steam and the float drops. When the water in the boiler rises and covers the connection the steam in the float chamber condenses, draws the water in and raises the float, thereby closing the feed valve.

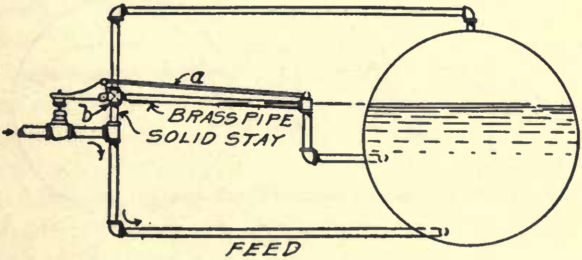

FIG. 197 (D1–16).

It will be observed that a hollow float is used with the various types of feed regulators and that it is located inside a part of the boiler under pressure where it can neither be observed nor adjusted. To avoid the use of the float-controller regulator the expansion-tube type has been introduced. One of the earlier forms was direct connected to the feed valve as shown in Fig. 197 (D1–16). The brass tube is given a slight pitch (about 2 in.) and the compression bar, *a*, is made adjustable in length to allow for the closing of the feed valve when the water is at the desired elevation. The air cock, *b*, is placed in the steam branch in order to keep air out. As the regulator is dependent upon extreme temperatures it is necessary that the water in the brass pipe be as cool as possible and that the steam be of a high temperature. If air is allowed to accumulate in the steam tubes it will eventually reach the brass tube and by radiation cause the tube to drop in temperature to that of the water; therefore it will be unable to raise the feed valve and admit water to the boiler. The regulator shown in Fig. 197 and other direct-connected types, including Fig. 194, are defective because the valve disk is ordinarily held just off its seat. With the valve just raised from its seat and the pressure in the feed-water main enough higher than the boiler pressure to allow a sufficient quantity of feed water to pass the valve, this difference in pressure soon causes a grooving of the valve and an increased inability to close tightly.

The most successful regulating devices are those which use a pressure-operated feed valve as shown in Fig. 195. This same method is sometimes employed with a thermostat controller, the thermostat operating a small valve that admits pressure to the feed valve. In Fig. 198 (D1–17) is shown a thermostat controller of this type, and it will be noted that the mechanism is entirely external. The expansion of the brass tube is opposed on one side by a rod which causes the end of the tube to rise and lower in accordance with its varying length. The pipe, *a*, to the feed valve is very small and the waste valve, *b*, is set to waste the water away by drops. The valve, *c*, is constructed to with-

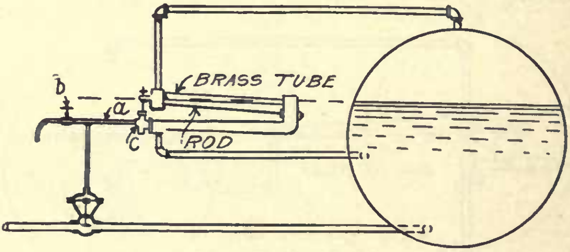

FIG. 198 (D1–17).

stand a considerable wire-drawing through it. The details of this valve are shown in Fig. 199 (D1–18). In many respects this type of regulator is free from the uncertain working parts contained in all the other forms here shown. The parts are sufficiently heavy to be handled safely by the attendants ordinarily employed in boiler rooms, which is not the case with some of the delicate thermostat arrangements that are attached to water columns. Automatic devices in a steam plant must withstand not only the severe use of regular operation, but also the abuse of the attendant. It is also necessary that a regulator be so designed that if the boiler should become cold or the diaphragm in the feed valve break, the feed valve will immediately assume the open position and flood the boiler rather than close and endanger life and property by running the boiler with low water. The arrangement shown in Fig. 198 provides for these conditions in a satisfactory manner.

Thermometers should be placed in the boiler feed mains at points where water enters and leaves the heater, where water leaves the economizer, and also at least one at the point where the water enters the boiler farthest from the economizer or heater. It will not be found satisfactory to permanently locate thermometers at these different points, but provision should be made for holding a thermometer tube at any of them so that the tubes may easily be interchanged and accurate temperature readings obtained.

An inexpensive method for obtaining accurate temperature readings is to place mercury pots fitted with caps that may be screwed on by hand at the different points where temperatures are taken, as is shown in Fig. 200 (D1–19). The openings for the thermometers should be tapped in a tee or ell where there is a considerable thickness of metal and where the area is greater than that of the pipe. This will avoid reducing the cross section of the pipe and impeding the flow. To hold the mercury there should be inserted in the hole a 0.25-in. steel nipple with a thread at its upper end long enough to allow a cap to be screwed over it. The lower cap and the bushing should be of brass, the bush being 0.25 to 0.5 in. These dimensions will permit the lower cap to pass through the tapped opening. The use of the small nipple requires but a small amount of mercury to cover the thermometer bulb. The mercury standing in the well will have the same temperature as the water in the pipe, and readings can be taken soon after placing the thermometer.

If the thermometer is to remain in place a more suitable arrangement is as shown in Fig. 201 (D1–20). The thermometer here shown is of standard design. It has a metal case which is attached to the well with a knurled union, *b*, and its bulb is in the tube, *a*. There should be as many wells as there are points where the temperatures are to be taken, and a little oil should be placed in the well before inserting the thermometer. A cap is furnished with each well to protect it from dirt and damage to the thread.

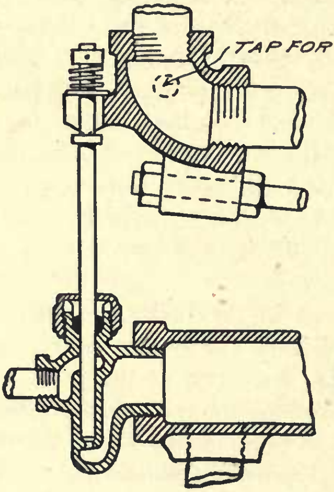

FIG. 199 (D1–18).

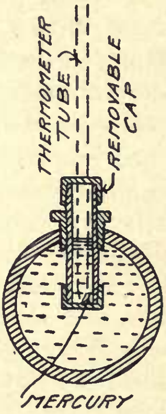

FIG. 200 (D1–19).

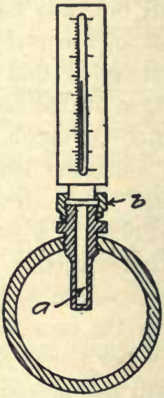

FIG. 201 (D1–20).

Class D3 — Boiler Feed Branches from Pumps. Each branch from a boiler feed pump should be provided with a stop valve of the gate pattern so that the pumps can be shut off from the main. Between this valve and the pump there should be a check valve and a pressure relief valve. It is possible to operate the pump without any one of the three valves, but if the safety of the pump is to be considered, the relief valve is necessary. To insure the continuous operation of the pump it is necessary to use an outside check valve. A swing check will be found most satisfactory for this service.

Instead of introducing a tee for the relief valve the detail shown in Fig. 202 (D3–1) will be found more compact and more economical. The pressure from the pump is free to pass the check valve, the relief in this position protecting the pump quite as fully as though it were directly on it. The relief valve should be about one-half the size of the discharge pipe. The outlet should be left open to the atmosphere to show when it is discharging, so that an operator will be more careful to avoid overpressure in the line or pump when by discharging over the floor it leaves unmistakable evidence of his carelessness. The relief should not be placed between the pump stop valve and the feed main with the idea of protecting the main. The relief valve should protect the pump, as it is not an unusual oversight for an operator to start a pump with the discharge valve closed. It is quite useless to place the relief valve on the feed main, as there is nothing to cause excess pressure between the pump and the boiler valves unless there should be an increase in the temperature and the volume of water confined between these valves.

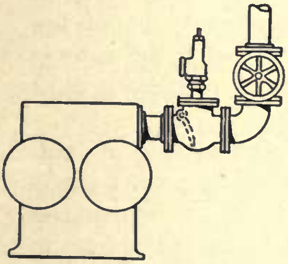

Fig. 202 (D3–1).

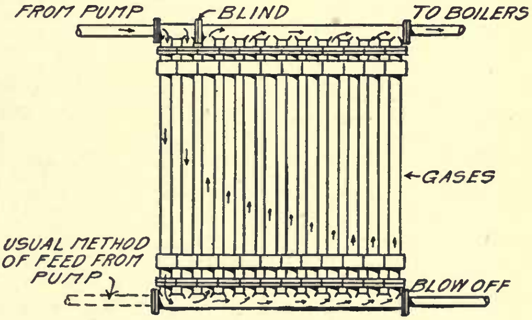

Fig. 203 (D4–1).

If a closed heater or economizer is used there should be a relief valve placed between the inlet and outlet water valves which would protect the heater should heat be turned on when the valves are closed. If the relief valves are placed in this manner there is then no necessity for placing a relief valve on the main itself. If the pumps are provided with suitable relief valves the relief valve for the heater or economizer may be made small. The relief valves used on the heater and economizer serve to relieve the pressure due to expansion and need not be over three-fourths in. in size.

Class D4 — Boiler Feed to and from Economizers. The regular method of feeding water to and taking it from an economizer is to introduce the water at the bottom and discharge it from the top, with the flow of the water in a direction opposite to that of the gases. If the installation is of such a nature as to make it necessary both to receive and to discharge the water at the top, the upper manifold may be blanked so that the water will not take a direct path from the inlet to the outlet.

In the arrangement shown in Fig. 203 (D4–1) a solid disk of thin copper is placed between the two gaskets in the upper sections of the manifold. The water takes a downward course in the first two sections and is delivered to the lower manifold, which in turn delivers the water to the bottoms of all of the remaining sections. It will be noted that in all but two of the sections the hottest water is at the top, and since the hottest gases also lie at the top there is no extreme difference of temperatures which will induce a circulation of water. The water passes slowly and freely, always moving in the one direction. With such a path water from the first section may be of low temperature while the water in the outgoing sections is quite hot.

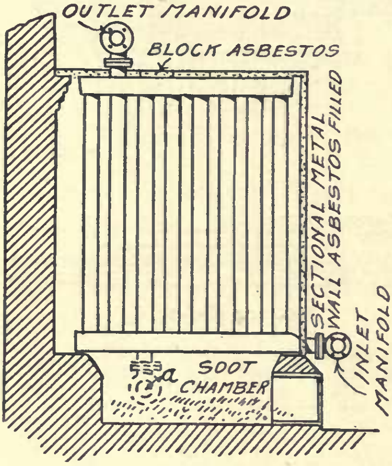

FIG. 204 (D4–2).

The usual method of feeding by which the water enters the bottom of the economizer is shown by the dotted lines in Fig. 203. With this arrangement, if the pump is fitted with a governor, since the bulk of the water flows through the lower manifold which is not exposed to the high-temperature gases, there is less danger of the cold incoming water cracking the tubes when the economizer is blown off. In Fig. 203 the lower manifold is below the lower headers. This detail should be avoided wherever possible. The gaskets are difficult to place, and if renewals are necessary such repairs must be made in an inconvenient place.

The detail shown in Fig. 204 (D4–2) should be used even though it is more expensive. The objectionable manifold below is shown in dotted lines at *a*. To permit the ready removal of a damaged section one wall should be of asbestos-lined sheet metal. The top of the economizer should be covered with asbestos, and means should be provided for attaching chain blocks over the economizer sections to facilitate their removal. It will be noted that all gaskets shown in Fig. 204 are open to inspection even while in operation. In case of a slight leak the joints can be followed up without interfering with regular operation.

Class D5 and 6 — Boiler Feed Branches to and from Closed Exhaust and Vacuum Heaters. The exhaust closed heater and the closed heater that may be used in the line of the vacuum exhaust should be provided with relief valves as previously stated. Where there is an abundance of exhaust steam there is no perceptible saving in heat units by the use of an open exhaust heater and, with a closed heater, since the feed water is kept separate from the exhaust, the difficulty of eliminating cylinder oil from the exhaust is overcome. U-shaped copper tubes are not subject to expansion strains and therefore are suited for this class of heaters.

There are two distinct types of closed heaters, the steam-tube and the water-tube types. Fig. 205 (D5–1) shows the water-tube type and Fig. 206 (D5–2) the steam-tube type. The form shown in Fig. 206 has been used more extensively than the water-tube type notwithstanding the fact that the area for the exhaust is much more restricted than in the water-tube type, which is a condition that would make the heater somewhat more efficient at the expense of engine economy. The heating surfaces of the tubes in the steam-tube type are very efficient, due to the rapid flow of steam through the tubes and the complete removal of the air that may be contained therein. The outside casing, *a*, of the steam-tube type of heater is subjected to the full boiler pressure and is exposed to the eating action of the water. If the feed water contains a large amount of carbonate of lime or magnesia, considerable scale will form in the heater. In the form shown in Fig. 206 it is easier to remove scale from the outside of the tubes than from the inside.

The closed heater is superior to the open heater only because cylinder oil in the exhaust steam is kept out of the feed water. If the water used tends to form scale, the open type of heater, with ample space for accumulating scale, should be used. The oil should be removed with a grease extractor. The closed heaters have small hand-hole plates for removing the deposits in them, and by the use of a large amount of chemical with the heater shut off from the system it is in some cases possible to loosen the scale sufficiently to allow it to be washed out through the hand-hole openings. In steam-tube heaters the water should be fed to the heater at a low point and taken from the heater at a high point, with a blow-off at the extreme top of the heater to remove floating impurities. The feed branches should be by-passed so that the heater can be shut off and the feed go directly to the boilers. A thermometer cup should be placed between the stop valves and the heater as indicated at *b* in Fig. 206, so that it can be repaired when the heater is shut off. There should be no stop valve placed between the small relief, *c*, and the heater. It is preferable to place the relief, *c*, directly on the heater to lessen the possibilities of impurities blocking the connecting pipe.

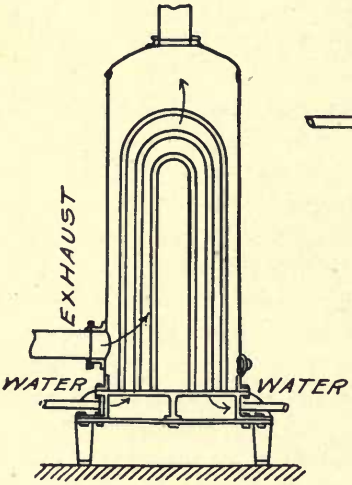

FIG. 205 (D5-1).

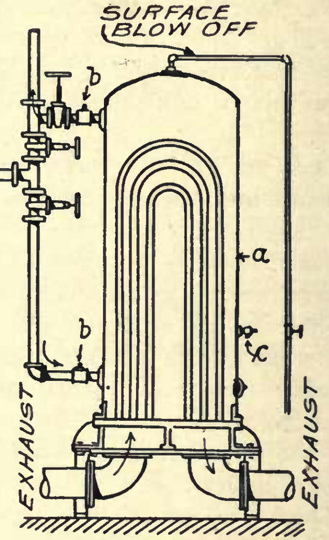

FIG. 206 (D5-2).

Class D7 — Boiler Feed; Branches to and from Live Steam Purifier. The usual method of installing a live steam purifier is to place it at a sufficient elevation above the boilers so that it will feed by gravity. This arrangement is shown in Fig. 207 (D7–1). The purifier is maintained under full boiler pressure. The pump delivers water to the scale-collecting pans at the top of the purifier, after which the water overflows from one pan to another and is finally discharged into the bottom of the purifier. By virtue of the head, *a*, the water is delivered from the purifier to the boilers. This head must be greater, measured in pounds per square inch, than the combined losses of the steam through the steam pipe, *b*, the water line to the feed main, *c*, the feed main, *d*, and the branches, *e*. These losses will include friction through the pipe fittings, check and feed valves, and the filter, *f*, should a filter be installed in the purifier. There is another loss that may interfere with the feeding of some one boiler in the battery. This loss would be due to that particular boiler being crowded much harder than the others, while they were taking water and carrying as much higher pressure as the resistance of the steam line would amount to. If there is head room it will lessen the cost of installing the purifier to make the head, *a*, about eight feet and use ordinary sizes of feed main branches, etc.

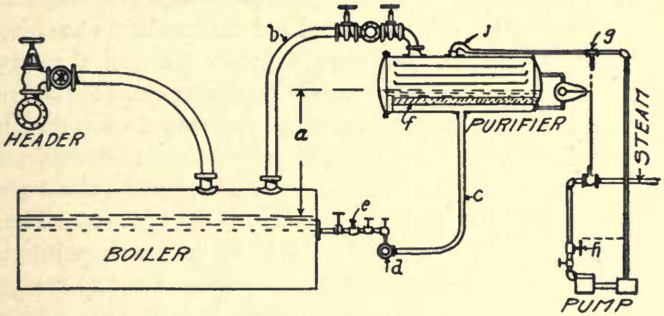

FIG. 207 (D7–1).

There are two methods of delivering water to the purifier, one as shown in the illustration with a float to control the steam to the pump. This arrangement is especially suited for a plant with but one purifier. If there are a number of purifiers, each supplying one or two boilers, it is necessary to connect the float with the water-admission valve shown by the dotted lines at *g* and use a pressure-controlling pump governor shown by the dotted lines at *h*. In this case the pump will maintain a set pressure in the purifier feed main and each purifier will take water independent of the others. The goose neck, *j*, in the discharge to the purifier is used for the purpose of sealing the water line and preventing it from draining into the purifier. Such draining would cause serious water hammer when the water started feeding again, and steam would also mingle with the water in the pipe. A purifier is one of the station appliances the use of which may cause more or less trouble, but if properly installed it can be operated with very little attention. In cases where the feed water carries a considerable amount of sulphates a purifier will aid materially in keeping the boilers clean, and is the only means, aside from chemical treatment, that will remove the sulphates before the water reaches the boilers.

Class D8 — Boiler Feed; Branches to and from Injectors. Injectors are so little used in the large power plants that they seldom enter into station plans or systems. It has become quite a general practice to install two feed pumps even in small plants. The only advantage offered in the use of an injector in power plants is the means afforded for feeding warm water when for any reason the heater may be out of service. Feeding boilers with cold water may cause damage much in excess of the cost of an injector and its use is therefore safer practice. The injector may be connected with the same suction, discharge, and steam lines as the pump, using a stop valve for each of the three branches.

Class D9 — Boiler Feed; Branches to and from Meters. As a rule, meters in power plants are used only for testing purposes. Meters should be installed in by-passes, and if a separate meter is used for each boiler the most direct connection through the meter should be used, as the meter itself offers obstruction to the flow of water. This arrangement is, however, open to the objection that the meter by-pass is in use the greater part of the time, and any added friction would tend to become a regular operating loss. When some of the boilers in service are operated with meters and the others are not, it would then be necessary, in order to control the feed, to close the feed-regulating valve almost tight upon its seat and hold back the feed, which service is severe upon the regulating valve. Instead of placing a separate meter on each boiler branch, one meter fitted with a by-pass, flanges, etc., can be used on all the boilers, all boiler branches having exactly similar straight sections flanged at each end so that they can be removed and replaced by the meter.

Fig. 208 (D9–1) shows a meter arranged in the manner just described and also the removable straight section. The hangers which support the ends of the pipe when the removable section is out are shown and also other hangers which support the meter and enable a ready connection of the flanges. The section can be removed and the meter installed while the boiler is in operation, as the connection requires but a few minutes to make. An advantage in using the same meter for the different boilers is that the readings will be relatively the same and an exact comparison of the performance of the different boilers can be had. With different meters on the different boilers one may read in excess of the exact quantity, since all mechanically registering meters are inaccurate to a greater or less extent.

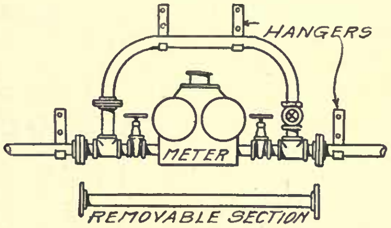

FIG. 208 (D9–1).

Another method of measuring the water to boilers was described in a previous chapter under the head of "Boiler Feed System." In this method one large meter is placed between the auxiliary feed and the regulating feed main and the water allowed to flow through the meter to the auxiliary mains for such boilers as are to be tested. The boilers have separate feed branches to each main. The most objectionable feature found in such a system is that a meter of sufficient size to accurately record the water flow for a large number of boilers is inaccurate when used with a small flow through it, as would be the case if a test were made on but one boiler. Another disadvantage is found in the use of many valves which open into other boilers and lines and which in case of leaks would permit water to pass the meter and go elsewhere than into the boiler that was being tested.

If the feed branch to the boilers is inaccessibly located the detachable boiler meter can be located in the by-pass and placed close to the floor with two wheels mounted on an axle screwed into a tee as shown in Fig. 209 (D9–2). In order that the meter may fit the different locations the distance, *a*, should be maintained either when placing the branches to the boilers or when putting down the floor. With this arrangement one man can roll the meter to the desired boiler and place the by-pass between the removable section and the boiler wall. When he is ready to remove the straight section, *b*, the meter connection may easily be swung into place.

Class D10 — Boiler Feed; Branches to Hot Water Plumbing Fixtures. Ordinarily, the water fed to the boilers is sufficiently hot for lavatory use. It is not good practise to take water from the feed mains for any other purpose than for boiler feeding, but as the amount used in a lavatory is small it is better to take the water from the feed mains rather than provide a steam heater. If the line from the feed main to the lavatory is very long it should be of three-eighths or one-half inch pipe, covered to reduce the water loss occasioned by wasting cold water at the faucet when warm water is desired.

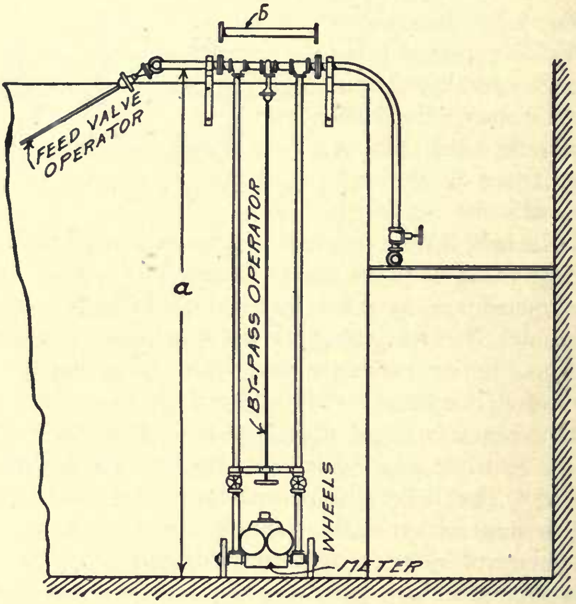

FIG. 209 (D9–2).

There are two distinct methods of supplying water at the wash basins or sinks. One is to carry it under full boiler pressure to the point where it is wanted, using a standard high-pressure valve in place of the ordinary plumbing fixtures. The other method is to lower the pressure to say 20 lb. by means of a reducing valve and use standard plumbing fixtures. This latter method is liable to cause considerable trouble, especially if the water is from an economizer at a temperature higher than the steam for the pressure of which the reducing valve is set.

The use of the reducing valve is not alone sufficient to protect the plumbing fixtures from overpressure, since all reducing valves will allow the pressure past the valve to increase by reason of the leakage when the flow is slight. With water a very small amount of leakage, possibly half a pint, will raise the pressure of the water on the low-pressure side to that on the high-pressure side. In order to protect the plumbing fixtures it is necessary to use a relief valve on the side that has become reduced in pressure in order to waste water when the pressure increases. Such service, however, is very severe on both the reducing valve and the relief valve, since the leakage past the valve faces will soon cut them out, allowing the leakage cost to run into an appreciable amount.

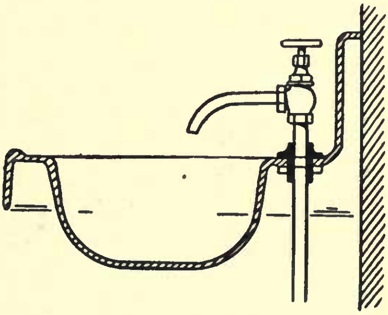

FIG. 210 (D10–1).

A much simpler method is to use extra heavy materials throughout and avoid complicating the operation by the use of low-pressure plumbing fixtures. A very satisfactory detail for this work is to make both hot and cold faucets of extremely heavy angle valves with brass hand wheels and a small polished brass sleeve under the valve as shown in Fig. 210 (D10–1). Fixtures fitted in this manner are free from the continuous troubles that the reducing valves and reliefs always develop.

CHAPTER XIV.

AUXILIARY BOILER FEED MAINS AND BRANCHES.

Class E1 — Auxiliary Boiler Feed Mains. The line used as an auxiliary feed for the boilers is often designated as a feed main, though in reality it is a general service main having boiler connections that enable its use as a feed main when desired. The regular duties which this main performs include the following: Low-pressure hose service for wetting ashes, washing floors, etc., filling boilers through its feed branch after cleaning, boiler washing, water supply for turbine tube cleaners, and fire protection service in the boiler room. The method of connecting the auxiliary boiler feed main has been shown in an earlier chapter on feed mains.

Since it may be called upon to perform the same duties, the construction of the auxiliary main should be as thorough as that of the boiler feed main, but as such duties would be infrequent smaller pipe may be used. The difficulties encountered in feeding the boilers through small mains would occur for such short periods of time that saving in the cost of piping should determine the relative sizes of the boiler feed main and the auxiliary main. For the same reason the auxiliary main should not be covered, as the saving in heat during the short use of the piping for boiler feeding purposes will not warrant the original outlay for heat insulation.

No boiler plant should be installed without an auxiliary boiler feed main, as its uses aside from boiler feeding are important ones, and water for them should not be supplied from the boiler feed main.

Class E2 — Auxiliary Boiler Feed; Branch to Boilers. In Fig. 189 (D1–8) was shown a satisfactory connection between the boiler and the auxiliary feed main. The two mains were shown side by side on the same supports. These supports also were designed for carrying a plank runway.

Another method of connecting the auxiliary feed main to the boiler is shown in Fig. 211 (E2–1). The single feed valve with its extension stem, check and boiler stop valve serves both mains. If the feed and check valves are installed as earlier shown in Fig. 190 (D1–9) this connection will not be a cause of trouble, but with feed and check valves screw-connected into the feed branch it would not be safe to attempt repairing them unless the boiler were shut down. With the double set of feed and check valves, as shown in Fig. 189, it would be but a few minutes' work to put the auxiliary main into service so that the boiler could be fed through its auxiliary feed and check valves, thus allowing the repairs to be postponed until a convenient time. The presence of twice as many feed and check valves does not signify that any extravagant outlay has been made, as the operator will always have in reserve "good valves" in the auxiliary main, and thus he will be able to transfer the valves in good condition to the regular main and use the old valves in the auxiliary main when they become badly worn.

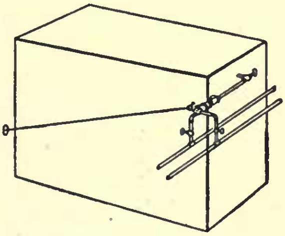

FIG. 211 (E2–1).

Class E3 — Auxiliary Boiler Feed; Branch from Pumps. Ordinarily it is the best practice to use two feed pumps for boiler-room service. These pumps should be of the same pattern and size and specially designed for boiler feeding. Their discharges should connect into a single main with a valve between the pumps, one end of the main connecting with the regular feed main and the other end with the auxiliary main. By placing a valve in the auxiliary main it is then possible to use either one of the pumps for feeding purposes or each can be separately used, one furnishing water for boiler feeding and the other for tube cleaning, boiler filling, or any similar service.

If fire service of a limited amount be required the auxiliary main may be used for such purpose, this main then being fed by one of the regular feed pumps. If, however, the buildings and plant are to be insured it will be desirable to install a standard pattern underwriters' fire pump with such a capacity as the insurance board may direct. Before deciding upon the use and purchase of the reserve feed pump the insurance details should be studied and advice sought from the underwriters as to what capacity of pump they will insist upon having installed. The underwriters' pumps are made to conform to their standard specifications and are designed to carry 150 lb. pressure. Some of the makes recommended will barely comply with the specifications, and others are generously designed so that they will carry far greater pressures, supply a larger quantity of water, and are in every way better able to withstand service.

If the fire pump is also to serve as a reserve feed pump it should be one of the better makes. A ready means of roughly determining this point is by asking the bidders for the pump contracts what weight of pump they propose to furnish. For fire protection it is best to have the fire pump in continual easy service, as this practice assures that the pump will always be in operating condition should it be suddenly called upon for fire duty. This class of daily service is approved by the insurance companies, and in fact they approve of using pumps with high and low pressure steam ends that will serve for all ordinary uses, such pumps being supplied with a quick-throw valve that will change both cylinders into high-pressure ones for fire service.

Class E4 — Auxiliary Boiler Feed to Hydraulic Tube-Cleaner. The branch from the auxiliary main which supplies water to hydraulic tube-cleaners should be taken off at a convenient point for attaching the hose. A gate stop valve should be placed at the main and means provided for attaching a valve at the end of the branch, this valve being shifted with the hose from one cleaner branch to another. The operating valve must be located so that it can be reached from the platform used when cleaning boilers. Fig. 212 (E4–1) shows such a branch when provided with a

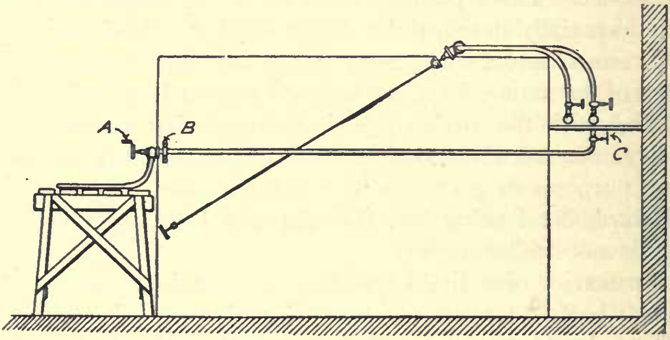

Fig. 212 (E4–1).

quick-operating valve, *A*, a rigid hanger, *B*, to relieve the strains due to shifting the hose, and a stop valve, *C*, that is left open when the valve, *A*, has been attached.

A usual type of construction for the valve, *A*, is to bolt a flat bar to the hand wheel of an angle valve having a handle secured to the end of the bar and thus making a crank with increased leverage for opening and closing the valve.

The platform shown in Fig. 212 is ordinarily constructed of wooden horses supporting planking; in fact, it is common practice to use such a platform in the larger plants which have many boilers and which are designed with every detail in masonry and metal carefully planned. Such a platform is a crude, unsightly device, almost continuously in use and conspicuously in view. In a plant having twelve 500-h.p. boilers and cleaning these every 60 days,

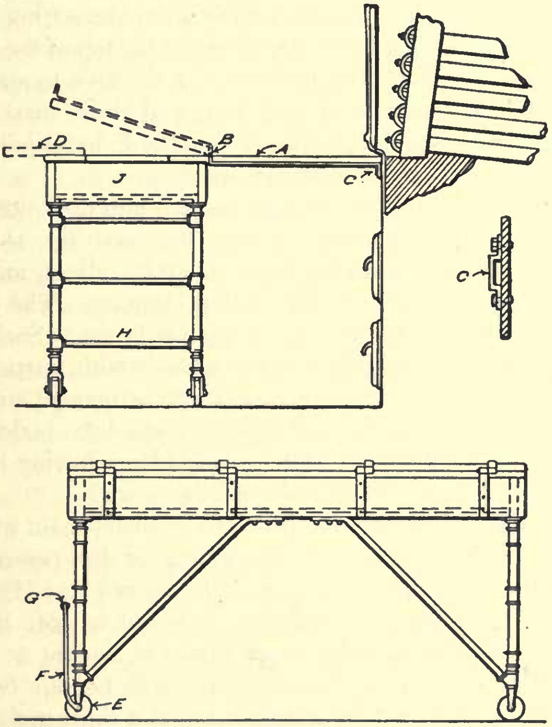

FIG. 213 (E4-2).

taking three days for a boiler, the cleaning outfit would be in use over half the time.

A satisfactory substitute for this temporary cleaning device as designed by the writer is shown in Fig. 213 (E4–2). This device, which has the form of a truck, is constructed with its upper portion of wood in the shape of a shallow box with two 2 by 8 in. side stringers. The top lid, *A*, when closed rests on top of the box. This top is hinged at *B*, and is supported on the boiler fronts by the U-shaped straps, *C*, into which the hinge bars fit. This locking to the front of the boiler is quite necessary in order to prevent the truck being shoved away from the setting while the men are at work. The cover, *D*, closes up the top of the box, thus making a solid and smooth platform for the men to stand upon. The wheels are broad-faced cast iron, and those marked *E* are casters which can be rotated with the handle, *F*, loose jointed at *G*. The cross pipes, *H*, serve as braces and steps.

This entire platform can be kept painted and does not disfigure the boiler room. The box, *J*, may be used for storing the cleaning tools and also for laying aside crabs, plates, and gaskets which are taken from the boiler during cleaning. The cover, *D*, closes the box while the turbine cleaner is in use. Such a truck can be made at a moderate cost by a blacksmith, carpenter, and pipe fitter. If it is profitable to construct permanent metal platforms for cleaning the vertical type of water-tube boilers, would it not seem equally profitable to supply plants having horizontal water-tube boilers with devices for similar work?

In addition to the branches from the auxiliary main which have already been described, there are numerous low-pressure lines. These lines will be described more fully under Class H — "Low-Pressure Water Lines." Ordinarily it would be safe to assume that there should be as many water mains in a plant as there are pumps. If there are two pumps there will be but two mains necessary, since it would be necessary to cut a third main into one or the other of the first two in order to get water.

CHAPTER XV.

FEED AND FIRE PUMP SUCTIONS.

Class F1 — Feed and Fire Pump Suction Main. Under ordinary conditions, being free from pressure, a suction line should be simple to construct and operate were it not that the water end of a pump has such a large clearance. The chamber between the suction and the discharge valves of many designs of pumps is as much as six times the volume of piston displacement. If absolute pressure is assumed as 15 lb., the piston displacement in such pumps would reduce the pressure in the cylinder to 12.5 lb., which in case of starting a pump without priming would make the head about 2.5 ft., an amount less than that necessary to open the suction valves. As the amount of air in the cylinder is lessened the ability of the pump to lift water is increased, and if there were no air in the cylinder the amount of pump clearance would not affect the ability of the pump to lift water. This absence of air, however, is not obtainable in regular practice, and the air is taken into the cylinder with the water, through leaky joints and stuffing boxes, or gases are liberated from water containing vegetable matter in solution.

The pump builder's guarantee as to what height of column his pump will lift is of little or no use in determining the relative merits of pumps. Such pump comparisons can better be made by using the ratio of piston displacement to cylinder volume and the head necessary to pass the desired quantity of water through the suction valve. All designs of pumps are affected by air in the cylinder, and when the speed is lessened the quantity of air increases, which in turn lessens the lift of the pump. A pump which lifts water from a level 26 ft. below that of the discharge valve must have extremely tight connections, the water handled must be free from vegetation, and the pump be run quite fast to prevent even a small amount of air from accumulating in the cylinder. Such conditions are too severe for regular station work, and in proportion to the shortening of the lift are pump-suction troubles reduced. It should not be inferred that pumps with short suction and with excessive air leaks in the suction connections are always operative, and it is only by delivering the pump suction under a head above that of atmospheric pressure that difficulties caused by air leaks are entirely eliminated. In the case of a pump with a 2-ft. lift, or under 13 lb. absolute pressure, delivering water at 150 or 165 lb. absolute pressure, the air would be compressed about one-thirteenth of its volume, which would be equivalent to the volume displacement of a piston with a 13-in. stroke when clearance equals one inch of stroke.

About the only practical way of putting in service a pump which is unable to compress the air to a sufficiently high pressure so that it will pass off through the discharge valve when such a large amount has accumulated, is to discharge the air to atmosphere through a pet cock. Feed pumps should have a valve larger in area than a pet cock located about three-quarters or one inch below the valve deck. This valve will provide a ready means of discharging the air. Another method which is sometimes used, but is nevertheless faulty, is to place a small air-discharge valve between the pump-discharge valves and the gate-stop valve in the pump discharge. To relieve a pump of air it is usually necessary to run it at a high speed. This is due to the inability of valves to hold air properly, and when the water does reach the cylinder it comes in a slug. With the valve in the discharge line closed there is a physical danger under such circumstances, as the water pressure may reach a destructive point in the pump before the steam valve can be closed or the discharge opened. The advantage of closing the discharge valve is to prevent water from the pressure line leaking back into the pump through the pump valves. If the pump is provided with relief valves placed between the pump and the discharge valve the operation will be satisfactory.

If the suction main for a pump is underground it should be made of cast iron, and if it is subject to vibration, settlement of ground, or excessive expansion strains, it should be flanged and have metal gaskets. The most satisfactory arrangement for long underground suction connections is to locate the underground piping at a level below the water inlet or water surface and build the lift pipe so that it is exposed free to expand and opportunity is afforded for readily making repairs. Fig. 214 (F1–1) will illustrate the details of a very satisfactory arrangement of piping for such service.

The well should be about three feet in diameter, have a ladder inside and a manhole top covering so arranged that the suction pipe will be supported from above. If the water line, *A*, to the well is large, about 24 or 30 in. in diameter, it may be built of clay sewer pipe with cemented joints, which will prevent any leakage of sand. The construction of pump suction wells is often expensive even when the work is done with cheap material. The location of the suction line below the water level brings about many difficulties such as the caving in of the trench, the handling of loose and wet earth, the laying of pipe on a soft bottom while water is flowing, and difficulties with the men who are doing the work, because they must either be ignorant and incompetent men who are obliged to do such labor or, if more capable, they are working with a grievance.

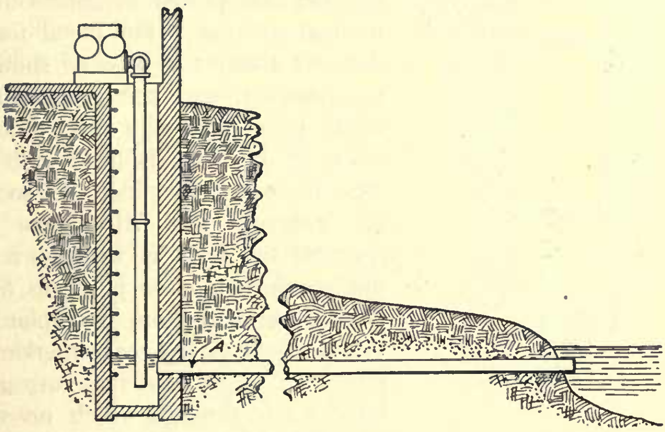

FIG. 214 (FI–1).

For such work sewer pipe can be used and satisfactory results obtained if the work is properly done, but under such conditions as prevail in this character of work it is next to impossible to lay sewer pipe properly. Cast-iron pipe is made in longer lengths, which affords an opportunity for supporting the sections by filling around the centers, leaving the joints clear for calking. If pumps are used to keep the water away from the work it will be necessary to have one on either side of the hole in which the work is carried on so that the water will not interfere with the leading of the joints.

Another method of constructing such a line is illustrated in

Fig. 215 (F1–2). With this method the larger part of the cost is for material, as the work can all be done with common labor. Referring to the illustration, the form, *A*, is made up of plates connected by handles in the shape of an inverted U. In beginning the work the trench is first dug, then the pipe, *B*, is screwed together and placed in approximately its final position. The metal form is then set about the pipe as shown in the drawing, and the space outside of the form filled with dirt, while the inside of the form is filled with concrete to encase the pipe. As soon as the concrete and dirt have been rammed the form is withdrawn and the trench then loose filled up to the point, *D*, at the bottom of the planking. With this type of construction old pipe may be used, as it is surrounded by concrete through which no water can leak. The work can be carried on even when the trench is wet, as the pipe may serve to lead away the water during the progress of the work and the concrete can be placed in water. Two or three of these portable forms are required so that they can be moved ahead as the work advances.

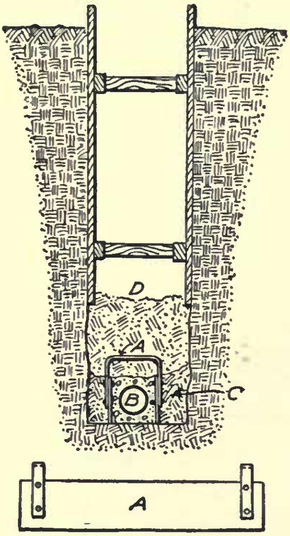

FIG. 215 (F1–2).

The most satisfactory method of executing the work shown in Fig. 214 is to build the suction well before disturbing the outside ground. With this well in operating condition the trench can be dug from the well toward the waterway and the pipe laid as fast as the dirt is removed. This will allow the water in the trench to drain to the well, from which it can be removed by the regular pump or a temporary one. It is important that the joints in the pipe be tight if they are to be encased in concrete, as water passing through the fresh concrete to the inside of the pipe will wash out the cement and leave only the loose material. Further discussion of this subject as considered for large suction mains will be found under the heading "Condenser Intakes — Class I."

Many suction lines are provided with foot valves which aid the pumps in holding their vacuum. The use of foot valves is quite limited. If the pump valves are in good order the foot valves will retard rather than aid the pump in its operation. When foot valves are used the pump suction must constantly support the weight of the valve, which amounts to about 0.5 lb. for each square inch of area, or an increased lift equivalent to 1 ft. Sometimes the operation of a pump is improved by the use of a foot valve because the suction valves fail to hold, but better results could possibly be obtained by renewing or repairing the suction valves. There are some instances, however, where foot valves are indispensable for pump starting, as is the case with pumps of the centrifugal type in which, when priming, it is necessary to fill the body of the pump with water and expel the air. Without a foot valve in such a pump the water would be lost through the suction. As a centrifugal pump is wholly unable to remove the air it must be removed by filling the pump with water or by using a steam ejector attached to the periphery of the pump case. If a steam ejector is used it is not necessary to use a foot valve, as the ejector will support the column of water

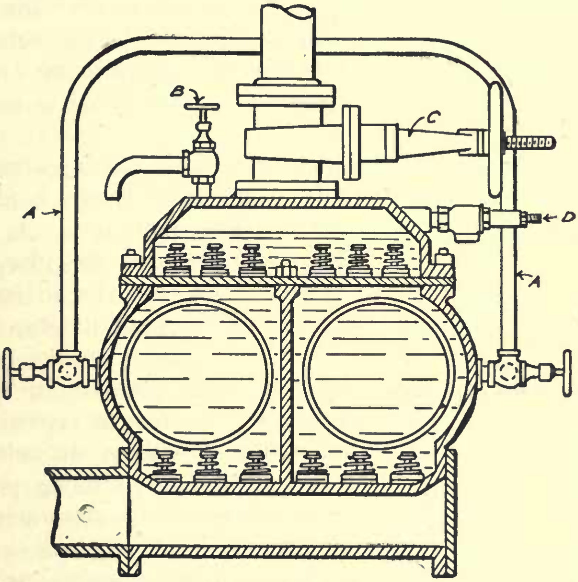

FIG. 216 (F1–3).

in the suction pipe. Air could also be removed with a steam ejector from the suction of a steam pump, but this process would not be as simple as the discharging of the air to atmosphere or by priming.

If the steam pump has a high lift and a large clearance in the cylinder, air cannot be discharged without priming with or without a foot valve. If the ratio of the cylinder clearance to the piston displacement is but as three to one, the absolute pressure in the cylinder at the end of the stroke would be five pounds, or the equivalent of a 10-ft. lift, and for a lift of over this amount the pump could be run indefinitely without taking water. It is not necessary to fill the suction pipe of a steam pump with water, but in nearly all cases the cylinder must be filled to reduce the clearance.

In Fig. 216 (F1–3) is shown a very simple starting arrangement for a pump that connects with a line which always is filled with water. The pipe lines, *A*, can be turned on and with the valve, *B*, open to furnish an outlet for air (and water also in starting) and the stop valve, *C*, closed, the pump being protected against excess pressure by the relief valve, *D*, can then be started and the air removed without difficulty. The lines, *A*, are the priming pipes and may be connected to any water supply, as pressure is not required.

That a pump requires priming to lift its water does not in the least affect its efficiency unless possibly it be increased by the reduced friction of the larger waterways. If priming water is not readily obtainable, or if a pump of the centrifugal type is used, a very satisfactory foot valve may be built as shown in Fig. 217 (F1–4). With the valve so constructed, if the pump is to be shut down the valve can be lowered so that it will bear on its seat and operate the same as the more common types of foot valves. While the pump is in operation the valve

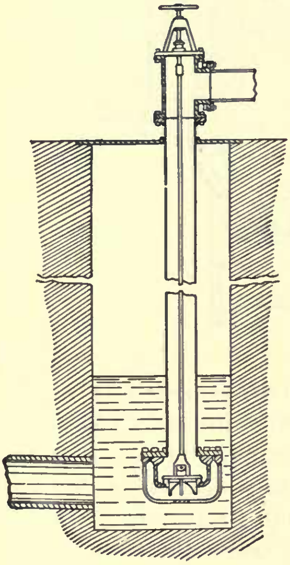

FIG. 217 (F1–4).

can be raised clear of its seat. When the pump is out of service the valve can be closed tightly. A valve so constructed has so little service to perform that it should require practically no care or attention to keep it in perfect operating condition.

Class F2 — Feed and Fire Pump Suction to Pumps. It is often found necessary to connect the different suctions to one suction main. Such an arrangement should be avoided if possible and the more satisfactory one as shown in Fig. 214 be used. This arrangement, with the separate suctions from each pump to the well, permits of free expansion and contraction of the line and facilitates repairs on any branch without interfering with the operation of neighboring pumps. The arrangement with separate suction pipes does away with shut-off valves, and air chambers can be omitted at the ends of the suction branches. In fact, the operation of the pumps is made comparatively simple, while on the other hand connecting the different pump suctions into one main, more particularly if this main is of considerable length, brings about many difficulties.

If several suction lines are to be connected to one main the piping must be sufficiently large to supply all the pumps, thus increasing the size and number of the joints. A large main located above the water level and supplying several pumps should have a foot valve at its end to prevent emptying, otherwise, if the suction were lost, considerable time would be required in which to remove the air accumulated in the large pipes. In any event long suction mains are troublesome, and to avoid the shock due to the starting and stopping of the large column of water contained therein, which movements are due to the action of the pumps, it is necessary to use an air chamber which will absorb the impact. The use of a foot valve in connection with such a combination of suction pipes results in the saving of the energy of the moving column.

To be effective in relieving the pumps from shock an air chamber must be located so that the flow from the suction lines is direct to the chamber, and the opening in the chamber should be of the full size of the pipe as is shown in Fig. 218 (F2-1). If the suction chamber contains no obstructions the air chamber may be placed on the side of the pump opposite the suction. In no case should the air chamber be attached to the side outlet of a tee. The difficulties occasioned by water flowing to the pumps are not due to pressure but to inertia. When water is brought to rest it should not be necessary to create a pressure in the line in order that the column of water may be diverted into an air chamber, nor should it be necessary to set other water in motion which would in turn flow into the air chamber; it is this sudden retarding of moving water that causes water hammer.

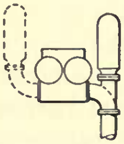

FIG. 218 (F2-1).

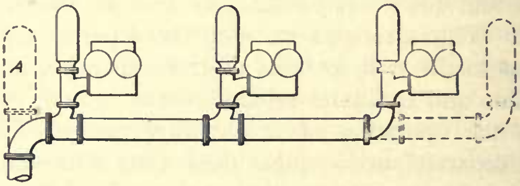

FIG. 219 (F2-2).

In case the suction must be long and connected with two or more pumps it is necessary to cushion the movement of the long heavy body of water with as little obstruction between it and the air cushion as possible. Fig. 219 (F2-2) illustrates, in full lines, a complete system for cushioning the entire moving body of water except the smaller amount in the air chambers, which amount is negligible in effect. If the pumps are close together, with a short main connecting them, one air chamber, as indicated at *A*, may be used to absorb the impact of the long line, thus allowing the inertia of the water in the connecting main to be taken up or dissipated in pumps without air chambers. In no case should the air chamber be placed at *B*, because it then would not cushion the movement of the long line, due to the fact that a large portion of the water in the horizontal main would be at rest at the time of impact. Before this body of water could move, the shock would be taken up throughout the piping. Such shocks are usually very severe and are often sufficient in amount to break the fittings even though practically no pressure is observed on the line. An air chamber on a long suction causes a pump to work more smoothly than otherwise, reduces steam consumption, and though it can be dispensed with in certain cases it is in no case an objectionable feature.

Class F3 — Feed and Fire Pump Suction; Branch for Heater. The suction branch used in connection with open heaters serves to handle water which in many cases is of a sufficiently high temperature to form a vapor if the pressure falls below the atmospheric point. To avoid reducing the pressure to a troublesome point it is necessary to place the heater at an elevation sufficiently high above the pump so that the head of water, measured from the water level in the heater to the discharge valves, will exceed that required to overcome the friction of the pipe, water ports, and the resistance of the pump suction valves. By increasing the suction connections to one size larger than the pump opening and by reducing the tension of the springs on the suction valves this difference of elevation has been made as low as 2 ft., but for safe, reliable operation a head of from 4 to 5 ft. should be provided.

The heater should be placed as close to the pumps as possible and the friction of the connections be reduced by using bends and long-radius fittings. This class of service requires a special hot-water pump whose parts are free from rubber and which is packed with some material not affected by hot water. Under ordinary conditions metal valves with brass plungers and rods that pass through the packing are suitable. When working in extremely hot water the packing will not retain a lubricant, and for this reason a dense surface-metal is required to avoid cutting or wearing out of the packing. Cast-iron plungers are too porous and steel stems are quickly roughened by rust. Brass plungers passing through outside packing and bronze valve rods are found most satisfactory for this service.

Class F4 — Feed and Fire Pump Suction; Branch from Hot-Well. The hot-well should have a separate compartment for the pump suction. The supply to this compartment should be so arranged that the pump will not take any of the air discharged by the condenser and the suction water be free from agitation caused by the condenser discharge, which in turn would cause such cylinder oil as might enter the hot-well to be mixed with the water. The hot-well should also be arranged so that the surface of the pump-water compartment is constantly being drawn off. This will remove any such oil as may rise to the surface. The pump suction should be so placed that it cannot remove the water from the hot-well and cause the water seal to be broken when starting the condenser. These various requirements are quite simply met with in the arrangement shown in Fig. 220 (F4–1). In this plan the pump suction is located at a low position which, as far as possible, will allow oil to rise to the surface and escape. The partition at *A* should be a trifle lower than the other partitions. This will insure the water passing through the pump box rather than to the overflow. The pump suction should reach as low a level as possible so that the suction of air will be reduced to a minimum.

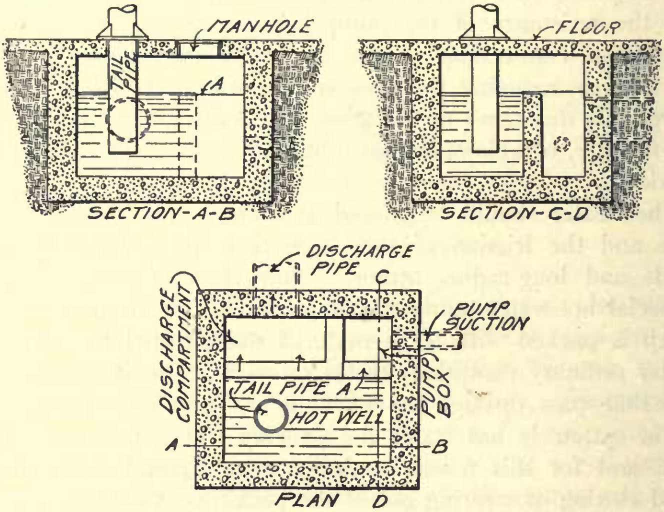

FIG. 220 (F4-1).

If the suction line is of considerable length (over 50 ft.) it should discharge into a small suction well and the pump suction be taken from this well. If the condensers are of the low-down jet type

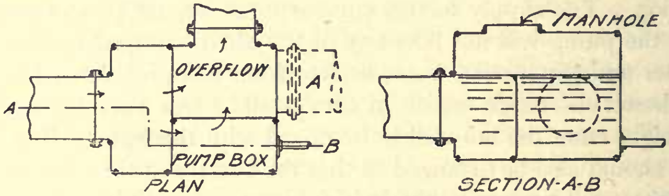

FIG. 221 (F4-2).

with vacuum pumps the pump box would be quite similar to the hot-well, this box being located at some point along the condenser discharge and convenient for the pump suction. Fig. 221 (F4-2) shows a pump box in the discharge line from the condenser, the box taking the place of an elbow. With such a box the discharge may be run straight through as shown by the dotted lines at *A*. Such a box may be constructed in various forms, but the following requirements should be observed: "Water enters pump box at top," "water passes over top on way to discharge," and "water shall flow to pump box rather than to overflow."

The function of the pump box is to avoid oil and air in the condenser discharge. This object is very essential, and if the water carries other impurities or an excessive quantity of oil it will be found advisable to pass the pump water through excelsior and renew this excelsior filter as often as it becomes clogged with oil.

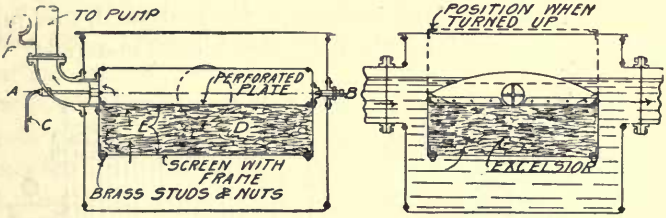

FIG. 222 (F4–3).

Fig. 222 (F4–3) shows such a filter so arranged that it can be inverted while the condenser is in operation, thus raising the entire filtering device out of the water, revolving it on the line, *AB*. When the filtering device is to be rolled the handle, *C*, is used to release the pipe union connecting the filter chamber and the pump box. The space, *D*, is filled with excelsior, and screens are placed at *E*, so that they will retain the filling. The joint between the filter case and the pump suction, which is of the tongue and groove type, may be made of leather.

There are many other materials that may be used for this work, but excelsior is cheap, easily handled, and has a great affinity for oil and grease, which, coupled with the fact that it is readily disposed of in the boiler furnace, make it a very suitable material for the purpose. The filter box can be cleaned by lifting the foul excelsior with a pitchfork and carting it away in a wheelbarrow. A plant provided with such a device and using water containing a large amount of impurities in addition to cylinder oil, uses 1 cu. ft. of excelsior for each 100-hp. capacity of boilers. The filter in this plant must be cleaned once a week, because the excelsior then becomes very foul. The waste excelsior is very black and has oil and grease thoroughly absorbed into the wood; this is quite a different action from that of material which would merely filter, as excelsior serves more as an absorbing medium.

The gage, *F*, shown in Fig. 222, is used to indicate the condition of the filter bed. When this bed is clear and unobstructed the gage may show 5 in. of vacuum (depending upon the lift), and as it becomes foul it may show 6 or 7 in., due to the passage of the water through the bed becoming obstructed.

If the principal impurity in water is sand or small particles a better filter can be constructed with a series of screens, as in this case the mesh would be uniform and as fine as desired, this quality being unattainable with excelsior or other fibrous materials.

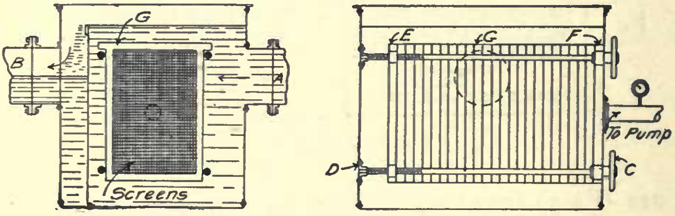

FIG. 223 (F4-4).

A method of constructing such a filter box with screens is shown in Fig. 223 (F4-4). Water from the condenser enters at *A*, and discharges at *B*, the oil passing over the overflow. The four tension rods are provided with hand wheels, *C*, and are supported at the opposite end of the box in the bearings, *D*, which will permit of rotation. The frame, *E*, is metal, with threaded connections to the tension rods; the frame, *F*, is also made of metal, but is attached to the shell of the tank. The frames, *G*, are of cypress or other wood that will wear well in water and support the screens. If it is desired to remove the screens from the frame, *G*, the frame, *E*, is released with the hand wheels, *C*. This allows the screens to be lifted off the upper rods.

In operation the water enters through the metal frame, *E*, and passes through all the screens to the pump suction as shown in the illustration. If there is a slight leak around the frame no difficulty will be occasioned unless the leak opening is so large that the filtered impurities can pass through it. Ordinarily the tension on the screws will prevent this leakage. The filtering material may be cloth instead of metal, and when the screens are being removed they should first be washed in the water in the box, thus allowing the impurities to remain in the tank and be taken out at one time, when all the screens are removed. The screens may be graded in mesh starting with coarse metal and finishing with fine cloth. Such a device may strictly be called a filter and operates very satisfactorily in removing fine silt and mud. If a connection is provided for draining the bottom of the box the screens can be washed with a hose without removing them, but they should first be loosened by releasing the clamp screws. A gage on the suction pipe will serve to show the condition of the screens.

Class F5 — Feed and Fire Pump Suction; Branch from Intake. A suction branch from the intake should be provided in addition to the suction line from the hot-well, as at any time it may be found necessary to shut down the condensing apparatus. If two or more pumps are used the suction lines should be arranged so that the feed pumps may be using hot-well water while the general service water is taken from the intake. This arrangement would be quite essential in a plant having journals or any other apparatus water-cooled.

Class F6 — Feed and Fire Pump Suction Branch; from City Water Mains. It is invariably good practice to provide a suction connection with the city water supply which can be used in case of need even though a plant has its own source of water supply as from a stream, canal, pond, or deep well. The city water should discharge into an open well or at a point that will be suitable for the pump suctions. The connecting of city lines direct to pump suctions will cause some difficulties, but if such connections must be used an air chamber should be provided which will prevent water hammer in the city water lines, meters, etc. The fact that the suction water comes to a pump under pressure is more of an advantage than otherwise, as the work of the pump is lightened and difficulties from air in the lines are eliminated. Any pump will operate more satisfactorily with the pressure head on its suction.

If the city water is connected direct to the pump suction and the other suction be from a well, stream, or the like, there should be a foot valve at the regular low-pressure suction so as to avoid any possibility of wasting city water back through the regular suction. Ordinarily it is advisable to place a vacuum gage on the pump suction, and in case city water is also used this gage should be compound, showing both pressure and vacuum. With such a gage as normally operated the attendant can quickly note any change brought about by altered conditions, thus enabling him to remedy a difficulty before it becomes serious. Such troubles may be from the foot valve, pump-suction valve, accumulation in suction line, city water under pressure leaking past its stop valve, or from numerous similar causes. The saying "A stitch in time saves nine" is very applicable in station operation, and such devices as aid in anticipating trouble in power stations are well worth the expense of installation.

Class F7 — Feed and Fire Pump Suction; Branch from Economizer. The suction branch from the economizer is only used where boilers are operated under an extremely high pressure, say 200 lb., and where it is desired to operate the economizers under a low pressure, say 40 lb. Such a system was shown in Fig. 6, which may be found in an early chapter. The chief requirement of the suction line from the economizer is that it may be maintained under the set pressure of 40 lb. if it be so set, thus avoiding the possibility of the hot water from the economizer forming a vapor. At 40 lb. pressure water can be heated as high as 286° F. before difficulty will be encountered from steam vapor in the feed-pump suction. If, however, the economizers raise the temperature of the water above this point, which would be a rare case, the pressure may be increased sufficiently to avoid vapors. The pump cylinders would show slightly less pressure than the line to the pump, possibly two pounds, which would necessitate raising the pressure a like amount to balance this loss.

The pump which supplies an economizer must be sensitive to pressure and preferably should have a governor which controls for a fixed pressure. If the lowest pressure be above a possible steaming point no serious result would arise if the pressure in an economizer varied within a considerable range. A quite simple method of controlling water fed to an economizer, as has been described, is to use a motor-driven centrifugal pump, possibly of the two-stage type, and allow this pump to run continuously, the head under which it would operate being equivalent to 84 ft., which is ordinary service for a two-stage pump.

Class F8 — Feed and Fire Pump Suction; Branch from Storage Tank or Basin. The line from a storage tank or basin is a rather unusual suction connection, being virtually a suction from some tank into which a pump discharges. This branch is quite necessary if there is but one source for obtaining water. The storage tank ordinarily would be used as a general low-service reservoir supplying water by gravity pressure. The pump would raise water to this tank, and if for any reason it be found necessary to shut off the regular pump-suction supply the tank water will be available for use as boiler feed or for any other water supply which must be maintained constantly. If there is another means of securing water it is quite unnecessary to make this connection unless there are two or more supplies which are insufficient for fire service and water in storage is desired for this purpose. This would be the case if the plant had two wells of limited capacity. The only objection to such a system is the somewhat complicated arrangement of valves necessary to transfer the pump suction and discharge and the possible confusion which may be occasioned in handling such valves, more particularly in case of excitement at the time of an alarm of fire.

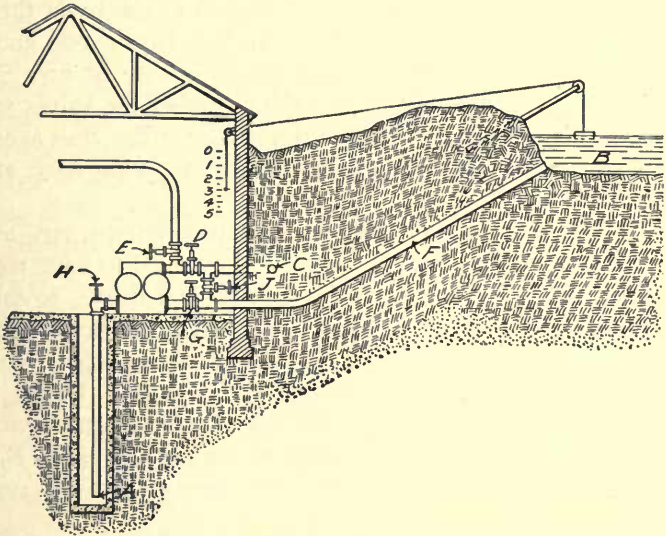

FIG. 224 (F8–1).

Fig. 224 (F8–1) illustrates the connections to a large low-pressure water storage with a tell-tale for showing the relative water level. The well, *A*, as shown, usually is so limited in capacity that it is quite unfit for fire service, but by constant pumping ample water may be obtained at such times for the boilers and also to keep the water basin, *B*, well filled. For the storage of a large amount of water such a basin is practical only when at a low elevation, as otherwise the expense for building a high structure would be excessive. The line, *C*, is the fire main and is regularly used as a low-pressure service main. Whenever the water in the basin is low and the pump is not in use for boiler feeding or other high-pressure work, the valve, *D*, is open and the valve, *E*, closed; thus water is delivered to the basin through the pump discharge, *F*. The valve, *G*, is always closed and the valves, *H*, and *J* are always open except in case of fire. With such a system it would be necessary to number the valves which should be operated in numerical order in case of fire, thus avoiding any possibility of the two suctions, *H* and *G*, being open at the same time.

In regard to the proper handling of valves, pumps, etc., at the time of fire, it is becoming quite general practice to have regular fire drills which will accustom the men to their duties, so that in emergencies such errors as have been stated will not be made. In many installations the well, *A*, Fig. 224, is a deep-driven one with a regular deep-well pump to raise the water. Under such conditions there should be no confusion at times of emergency, as the deep-well pump would discharge to the storage basin, *B*, and the feed and fire pumps would take their suction from this storage supply.

CHAPTER XVI.

HEATER WATER SUPPLY PIPING.

Class G1 — Heater Water Supply; from Condenser. There are four possible types of branches for supplying water from condensers to heaters. These may connect surface or jet condensers with open or closed heaters. In Figs. 220 and 221 suction boxes are shown as a part of the jet-condenser discharges. If a closed heater is used its water supply may be taken directly from the pump box and the boiler-feed pump be used for this purpose if the lift is not too great. The steam temperature at 25 in. of vacuum is approximately 135° F. If the water from the condenser has this temperature it will vaporize when the pressure is lowered to a point less than that at which it was condensed. A 25-ft. lift would bring about conditions suitable for vaporization, but water at a temperature of 135 degrees and a lift of 25 ft. are not met with in practice. The capacity of a condenser (condensing volume) is usually restricted, for commercial reasons, so that the common type of condenser requires its discharge water to be of considerably lower temperature than the steam under vacuum.

Very few jet condensers will maintain a vacuum of 25 in. with the tail-water above 100° F., and in most cases 90 degrees is considered high. In regard to the vaporizing of tail-water when the pressure has been reduced by the suction of the pump, it can be stated that it is possible to lift such water as many feet as there would be inches of vacuum and water at its highest possible temperature. This, however, has not been found possible in practice because of other elements than vaporizing which must be considered. The most important obstacle is the gas liberated at heats as low as 90 degrees, this gas being thrown off from the organic matter found in the water.

The presence of such a gas is quite fully demonstrated by the action of a dry-vacuum air pump in which it is noted that a much higher rate of speed is necessary in the summer season to remove the larger quantity of air due to the fact that the water contains vegetation that it does not contain in the winter. The temperature of the tail-water is practically the same for both seasons, but its quantity is reduced during the winter. It has been further noted that during winter months the vacuum will not drop more than an inch below 25 in. when the air pump is out of service, but during the summer months the vacuum will drop 4 or 5 in. under similar conditions.

By arranging the hot-well as shown in Fig. 220 (F4-1) the liberated gases will not be taken into the suction line, and if the suction lift is not greater than 12 ft. little or no trouble should be experienced by pumps losing their water due to gases accumulating in the pump cylinders. To further insure the successful operation of the feed pumps working under these conditions the size of the pump should carefully be considered in connection with the work which it is to do. The smaller the pump the greater the number of strokes and lesser liability of becoming "air-bound," or in other words, losing its suction.

If an open heater is used with a jet condenser it will be found necessary to install a hot-well pump for delivering water to the heater. This pump will be necessary on account of the usual conditions which determine the location of the hot-well at a low elevation and the heater at a much higher one. With an elevated jet condenser a very simple method of handling water to the heater is as shown in Fig. 225 (G1-1). In this arrangement the same motor or belt drive that operates the injection-water pump is also used to operate the heater-supply pump. A float-operated valve such as is regularly furnished with open heaters may be arranged to control the water fed to the heater, the centrifugal pump maintaining the same speed for varying requirements. The unit shown in Fig. 225 is free from pump valves and reciprocating parts. It thus requires very little attention and the cost for maintenance is quite low.

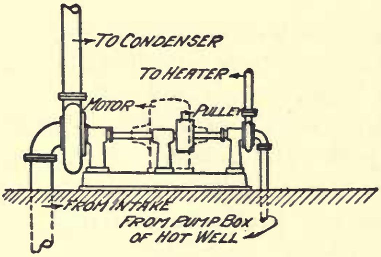

FIG. 225 (G1-1).

If it is necessary to raise the hot-well water to the feed pump where a closed heater is used, this same arrangement as shown in Fig. 225 may be used and the discharge from the small centrifugal pump piped direct into the feed-pump suction. A pump of the centrifugal type is the only one that can be operated successfully when discharging into the suction line of another pump. It is also the only type which can vary in capacity without having its speed altered.

There is the same opportunity for choice in the branches from a surface condenser to the heater as was stated for jet-condenser conditions. The surface condenser requires a pump to withdraw the condensation. This condensation is fed to the heater instead of the circulating water as with the jet condenser. If the pump is made amply heavy for duty in boiler feeding it can also serve both purposes as shown in Fig. 226 (G1–2). This arrangement, of course, applies only to the use of closed heaters as shown in the illustration. The feed pump in this case would be controlled by the amount of condensation in the pocket, *a*, the float in this pocket operating the valve of the pump.

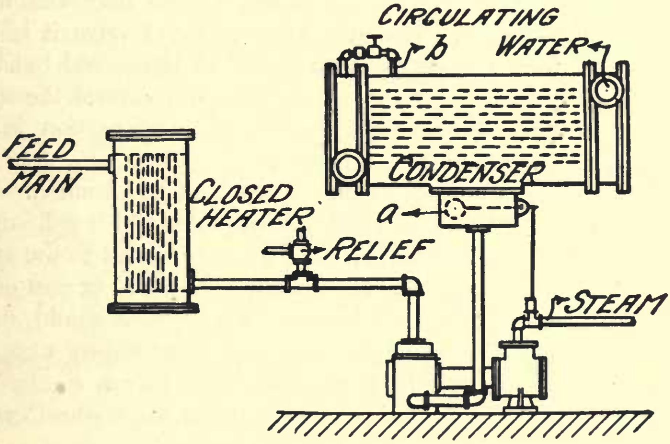

FIG. 226 (G1–2).

With the arrangement as shown it would be necessary to have one or more feed valves open at all times to avoid the loss of condensed water. In fact, this is necessary in any piping system using a surface condenser. Such steam as condenses in other parts of the system outside of the condenser itself must be replaced by water added to the condensation. This is an almost invariable quantity, and the loss can be provided for by leaving the by-pass, *b*, open wide enough to allow a sufficient amount of circulating water to be admitted into the vacuum chamber of the heater and from there pass with the condensation to the pump.

The relief valve shown in the illustration should be so located that if it discharges a boiler-room operator can readily notice it and open a feed valve, thus avoiding any waste of condensation. If the feed valves are properly handled this relief valve should never discharge. Hand-operated feed valves will be found much more satisfactory with this piping system than any automatic feeding devices. With the hand-operated valve it is possible to save the water of condensation at all times, and but little regulation should be required, as the float will control the speed of the pump according to the amount of condensation in the pocket at the bottom of the condenser.

The pump may be located out of reach of the fireman. The by-pass, *b*, should be quite small and of a size which will supply steam to the system to make up for that which is fed to the auxiliaries. This make-up will not ordinarily exceed 10 per cent of the total amount of water fed the boilers. The by-pass would, therefore, be about two inches in diameter for a plant having 5,000 hp. boiler capacity. It may be found convenient to run the by-pass piping to a point in the boiler room where a hand wheel can be placed so that it can be operated by the fireman.

The pump used for this service would not be subjected to the pounding strains common to the so-called air pump, which removes both air and water from the condenser. A separate dry-vacuum air pump would be required with the system as shown. Such a pump is necessary for perfect operation. The feed pump would be called upon to handle nothing but solid water, but in order to assure this it is necessary to place the pump a sufficient distance below the water line in the bowl, *a*, to make certain that the water will pass to the cylinder without lowering the pressure therein.

If an open heater is used the condensation pump may be of a lighter design and arranged to discharge the condensation into the heater without any restricting device operated by the water level in the heater. Such a pump may handle air and water together and discharge both into the open heater. This arrangement, however, requires a separate pump for boiler feeding. It is practical to run the auxiliaries condensing, not using a heater, and thus have little or no water passing through the by-pass, *b*. Such practice, however, is far from economical. A steam pump will not use more than 50 B.t.u. per lb. of steam delivered to it if the remainder, in exhaust, is delivered to the feed water, but an engine will require the expenditure of 1,100 B.t.u. per lb. of steam delivered to it. In other words, the pump can use 22 times as much steam per horsepower as the engine and yet be as economical if all the heat of the exhaust is taken up by the feed water. It will thus be noted that no engine is operative with a sufficiently small number of pounds of steam per horsepower, nor is any steam pump sufficiently wasteful of steam to warrant running a feed pump condensing, even though it is possible to reduce the steam consumption of a feed pump to that of the most economical steam unit known.

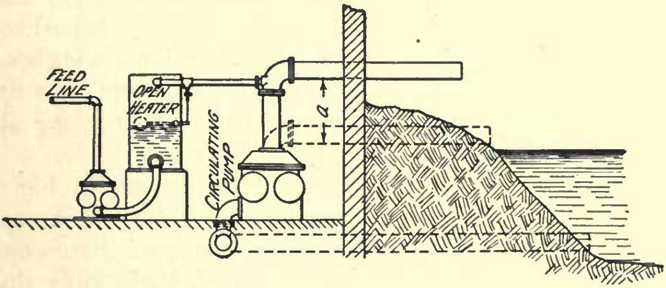

FIG. 227 (G1–3).

Another method of delivering water to a heater by means of a suction pump from a low-down type of jet condenser is by elevating the discharge to such a height that the water will flow into the open heater by gravity as shown in Fig. 227 (G1–3). When considering such a connection it should be remembered that for every foot the discharge is raised, as shown by the dimension line, *a*, this lift is equivalent to raising the feed water 30 times this amount, as the quantity thus lifted is ordinarily about 30 times that fed to the boiler. The only advantage in this style of connection is the elimination of one pump.

If a house pump is used to supply the cold water it may be found better practice to utilize this same pump for supplying water to the heater rather than by increasing the duty on the air pump by raising the head.

To make a comparison of the relative economy of the two practices it may be assumed that *a*, in Fig. 227, is 5 ft., that the condenser uses 30 lb. of water per pound of steam condensed, that the temperature of the intake water is 55 degrees and the discharge water 90 degrees, and that the pump requires 100 lb. of steam per horsepower. Then for each pound of feed water there will be required the following additional B.t.u. necessary to raise the water 5 ft.: B.t.u. = (30 lb. × 5 ft. × 100 lb. steam per hp. × 50 B.t.u. per lb. steam) ÷ 33,000 = 23. If cold water is used, one-thirtieth of the result just obtained will be required for pumping, thus 0.75 B.t.u. plus the difference between the heat units and water of 90 degrees, or 58 B.t.u., and water of 55 degrees, or 18 B.t.u., which is 35 B.t.u., equals a total of 35.75 B.t.u. It will thus be noted that the cost will be less to raise the entire condensing water more than 5 ft. (about 7 ft. 6 in. being the balance) than to use cold injection water. If more steam is being delivered to the heater than can be condensed and heat units are thus being wasted, the cost of raising this water will be increased twenty-two times. This is equivalent to the difference of elevation, *a*, being about 3 in. if all the steam from the condenser is wasted.

Under ordinary circumstances the details shown in Fig. 227 should be avoided, as this arrangement fails to provide means for supplying water to the heater when the condenser is not in operation, and also causes the air pump to work unsatisfactorily, due to the higher column against which it must work.

Class G2 — Heater Water Supply; from Intake. It is generally found necessary to make a connection for general service purposes from the intake line to the pump suction, two pumps being used for this service. With such details no further provision is necessary to supply the heater from the intake. However, a connection for supplying the heater from the intake is absolutely necessary, and if but one pump is used it should have connections to both the hot-well and the intake. The condensation pump shown in Fig. 228 (G2–1) should have a suction line from the intake that can be used to supply either the closed or open heater if the condenser is out of service. This figure shows the intake with suctions to the condenser and the feed pumps. The feed pump No. 1 ordinarily would be used for feeding the boilers and No. 2 would be the general service pump. In regular operation condensation pump No. 3 would take the condensation from the

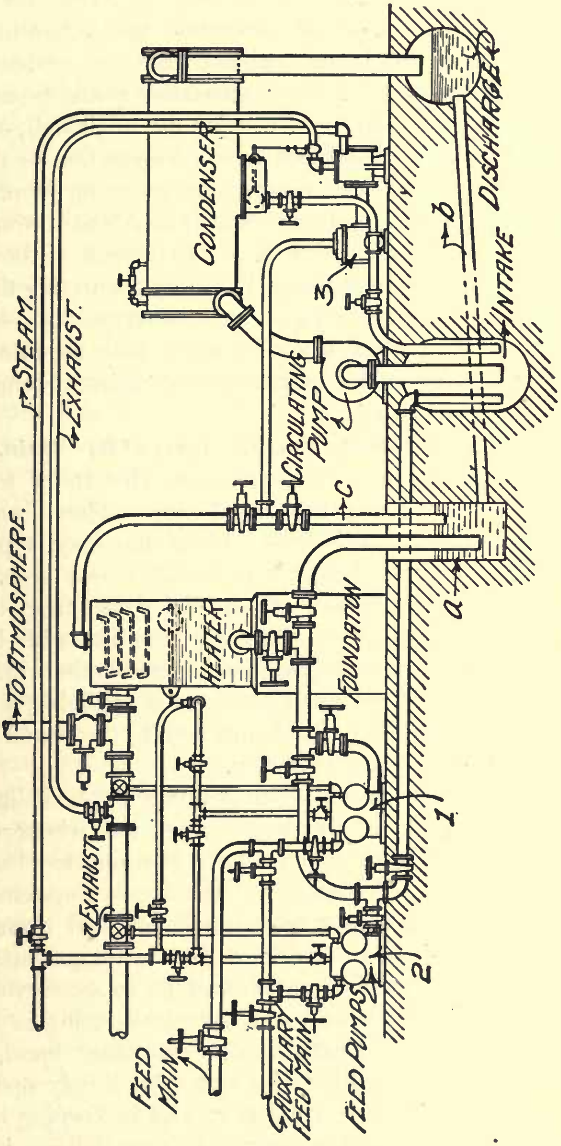
CONDENSER
STEAM.
EXHAUST.
TO ATMOSPHERE.
EXHAUST
CIRCULATING PUMP
3
b
c
a
1
2
DISCHARGE
INTAKE
HEATER
FOUNDATION
FEED MAIN
AUXILIARY FEED MAIN
FEED PUMPS

Fig. 228 (G2–1).

condenser and deliver it to the top of the heater, while pump No. 1 would take its suction from the heater and No. 2 from the intake. If the condenser should be out of service then the suction for pump No. 3 would be from the intake and not from the condenser. If the heater were out of service the condensation would be delivered direct to the suction of pump No. 1, using the small well, *a*, which would be open to atmosphere and have a connection to the condenser discharge. If the feed pump were pumping more or less water than that delivered to pump No. 3, then water would flow either to or from the well in pipe, *b*. If the length of the line, *b*, is short, the well, *a*, may be dispensed with by connecting the lines, *a*, *b*, and *c*, and by having the line, *b*, with its connection below the water level it will then be possible to operate with the intake shut down. To insure continuous operation these different connections as stated are quite necessary.

Class G3 — Heater Water Supply; from City Main. Such boiler installations as are dependent upon city water for their feed are of necessity non-condensing plants. These conditions suggest that the heater used should be of the open type, thus reducing the cost of water below that for the closed type. Such being the case, the open heater can be fed direct from the city line, using the float control as regularly supplied with heaters. If the plant is ordinarily supplied with water other than that from the city mains and yet the city water is available, it will be found advisable to have the city connection to the heater supply line which can be used when necessary.

To provide this connection without running a special line some plants use a hose valve at the heater inlet, and whenever it is necessary to use city water the fire hose is connected from this valve to some convenient point in the fire or other systems using city water and the heater thus temporarily supplied through the hose. This may seem to be a rather crude arrangement, but it has the advantage that the operator must go to some trouble to make the hose connections, and whenever he is using city water the fact is conspicuously evident. On the other hand, if an operator knows that he can get city water by simply opening a valve it is not likely that he will be as careful in keeping his own water supply in good working order. If wastefulness is made easy in a boiler plant this fact will invariably be taken advantage of, and for this reason many conveniences and precautionary devices have been removed in such plants for the purpose of avoiding their abuse by the employees.

Class G4 — Heater Water Supply; from Low-Pressure System. The regular supply for open heaters used in non-condensing plants having their own water supply such as a well or stream, is taken from the low-pressure system. The same pump that raises the water for the low-pressure system ordinarily discharges into a low-down service tank which is placed at a sufficient height to supply the heater. As the pressure on the low-pressure system is ordinarily quite low, possibly five pounds, this makes it necessary to use plumbing fixtures of a comparatively large size. The higher the tank is placed the greater will be the steam loss in raising the water to this tank, as practically all the water is used for boiler feed.

If it is necessary to have a high tank for fire service it will be more economical as regards the use of steam for pumping to install two tanks, one at an elevation, say 100 ft. above grade, and the other at an elevation of 12 ft. above grade. Such an arrangement is shown in Fig. 229 (G4–1). The same pump may be used to supply both tanks, making use of a float-operated valve, *a*, for the lower tank and a check valve, *b*, in the discharge to the higher tank. The valve, *a*, should be full-open or full-closed, allowing the free travel of the float on its rod. With such connections when the valve, *a*, is open the high head will at once be taken off the pump discharge and kept off until the lower tank is full and the valve again closed. Then the pump will slow down and discharge its surplus into the higher tank, the check valve, *b*, opening and allowing the water to pass. With the tanks thus arranged the pump could be so regulated that it would supply about the amount

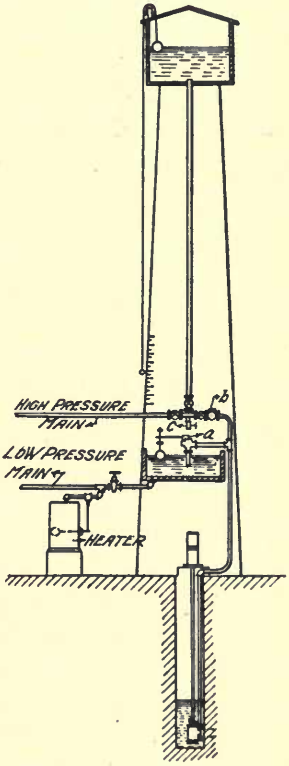

FIG. 229 (G4–1).

of water required for boiler feeding and not discharge to the higher tank more than five per cent of the water raised. Valve, *c*, can be placed in the high-pressure line to permit drawing off part of the water in the upper tank in case it becomes too full.

The lower one of the tanks can be used for reserve boiler-feed water, and should be made much larger than the upper tank, with the suction to the pump so arranged that water can be fed to the fire main, thus fully utilizing the water from both tanks and not requiring the expenditure necessary to make a structure for supporting all the water at the higher elevation.

However, if the tower is arranged to store all the water at the high elevation, then an open heater should not be used. A closed heater may be placed either in the line from the tank to the pump or from the pump to the boilers, less pressure being placed upon the heater if it is connected between the tank and the pump. If a closed heater is used the full amount of head on the feed-pump suction is utilized and the work imposed upon the pump that much reduced. Since the installation considered would be non-condensing with a surplus of exhaust steam there should be, as regards heat units transmitted to the water, no perceptible loss if a closed heater is used, providing, of course, that the heating surface of the heater is ample.

Class G5 — Heater Water Supply; from Special Pumps. Referring to Fig. 225 (G1–1) it will be noted that a special pump is provided for supplying the open heater from the hot-well of the jet condenser. If the plant has more than one condenser and more than one pair of centrifugal pumps it is quite probable that water for the heater will be available at all times. If it is necessary to operate non-condensing for a part of the time it will be found advisable to use a separate drive for the heater supply pump and arrange the connections so that this pump can take suction from the intake as well as the hot-well. The independent condenser pump No. 3 in Fig. 228 is so arranged and permits the use of the heater at all times, which is a very essential requirement.

Instead of using a power-driven pump, as shown in Fig. 225, the heater supply pump may be operated in unison with the boiler-feed pump, as shown in Fig. 230 (G5–1). The feed pump illustrated is a regular pattern ram-type pump with a connecting boss, *a*, so designed that the independent heater pump drive may be dropped into it. The cylinders, *b*, are for the low-pressure heater supply, and adjustable lock nuts, *c*, are placed at the end of the piston rod to regulate the travel at *d*. In designing the pump the piston in the cylinder, *b*, would be made a trifle larger than that of the feed pump, and by observing the overflow of the heater the stroke can be regulated, reducing it by increasing the lost travel, *d*, by running the lock nut, *c*, toward the end. In this way the overflow can be reduced to a very slight amount, which is just sufficient to run off any oil that may lie on top of the water in the heater. The joint, *e*, permits disconnecting the pumps, *b*, when the heater is out of service, thus enabling the feed pump to take water from the hot-well direct.

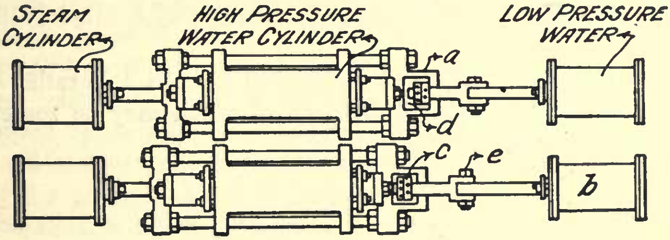

FIG. 230 (G5–1)

This system of pumping water to the heater requires no automatic devices for its regulation, the supply pump having practically the same capacity as the feed pump. The economy is increased as the duty of this light-running pump is put upon the heavy-service pump, being equivalent to raising the water pressure in the high-pressure pump about ten pounds above that which would ordinarily be carried.

Class G6 — Heater Water Supply; from Injection to Surface Condenser. It is the usual custom for surface condenser manufacturers to furnish as a part of the condenser equipment the connection, *b*, shown in Fig. 226 (G1–2). This connection with its valve offers a passage from the circulating water space to the vacuum chamber of the condenser. Unless the valve, *b*, can be so located that it is convenient for the boiler-room operator, it will be found advisable to obtain water for the heater in some other way, possibly by taking it from the fire-pump suction through a conveniently located regulating valve and discharging it into the condenser.

The heater supply connection should be used for handling only small amounts of water, because if the steam condensed is only a comparatively small part of that generated, the addition of a large amount of water will unnecessarily increase the work of the condensation pump. If it is necessary to add water in larger quantities such additional water should be delivered direct to the heater either from the low-pressure system or some other available source.

It is often found advisable to neglect a small loss rather than to provide a more complicated system which may be somewhat more economical.

CHAPTER XVII.

LOW-PRESSURE WATER PIPING.

Class H1 — Low-Pressure Water; Main. Unless the plant be of smaller capacity than 100 or 200 hp. a low-pressure water main is usually provided in station piping. It is quite essential in the larger plants to have a low-pressure supply other than that afforded by the city water mains. About the only use for which city water is essential is for drinking purposes.

If the plant is operated condensing the intake water will be found suitable for the low-pressure service. The use of discharge water for this service is quite unsatisfactory for many of the purposes to which the water is put. Discharge water is suitable for filling and washing boilers, for wetting down ashes and for similar services, but if there is a supply needed for water-cooled jackets, engine journals, dry-vacuum pumps, etc., injection water will be found more suitable.

In considering the details of low-pressure water mains there are many features to be taken into account. Water should be available at all times for the system of piping which is always at low pressure. There should also be available water for cleaning boiler tubes with turbine cleaners, this service requiring a high pressure. Water for fire lines must always be available at a fairly high pressure, say 125 lb. per sq. in. To permit the continuous use of low-pressure water at about 15 lb. pressure it is necessary to have either a pump on the service at all times or to use a storage tank. A very satisfactory arrangement is had by using two feed pumps arranged so that one can supply the feed main. No water should be taken from this pump for any other service. When not in reserve as a feed pump the second pump should supply water for tube cutting.

With this arrangement the fire pump would be on the fire and the low-pressure systems, maintaining low pressure on all lines, and a tank would supply water for the plumbing fixtures and only such few services as the high pressure would injure. All low-pressure hose lines could be taken from the fire main and the pressure be regulated with hose valves for such rare cases as those when the fire lines would be under heavy pressure. This arrangement will enable the use of the entire fire system for general hose service and give the fire-pump a continuous light duty. The low-pressure system can be made of standard fittings, but some provision should be made to protect this line against the possibility of high pressure such as would be the case when changing the set of the governor on the fire pump. This precautionary measure might be accomplished by using a pressure-reducing valve and relief valve.

Class H2 — Low-Pressure; from Pump. The low-pressure pump should have a governor that can quickly be set for high or low pressure; this can be accomplished by using a weight that can be removed in one piece, so that the high pressure and the low pressure are fixed by the handling of the single weight. The advantage of this arrangement is that when the fire pump is supplying the low-pressure water the simple movement of changing the weight will put the pump on the fire-main service without handling any valves.

Class H3 — Low-Pressure Water; to and from Water-Tank. The most convenient arrangement for a water tank is to place it between the trusses in the engine room and support it as shown in Fig. 231 (H3–1). An iron tank located as shown and open to the engine room is very objectionable on account of its "sweating." The high temperature of the engine room admits of the carrying a large amount of moisture, this being governed by the amount of escaping steam and by weather conditions. The moisture in the air is so readily condensed on the sides of the cool water tank that the outer surfaces of such tanks are usually quite wet. This causes much trouble from dripping. When a tank is not wet and dripping it exposes a badly disfigured surface due to its former sweating. Placing the tank in the boiler room only adds to the difficulties by the water in the tank taking up boiler-room dust.

Another method of supporting the tank is to place it on a division wall over the top of the roof. This is a troublesome arrangement in many ways; the pipes to the tank, also the telltales, etc., must be run through the roof, the openings for which afford opportunities for leaks. With a tank so placed it would be necessary in extremely cold weather to make some provision against freezing.

A wooden tank would be quite as objectionable, if not more so, than an iron one. Such tanks do not sweat, but it is next to impossible to keep them tight in such a hot place as the upper part of an engine room. Probably the most satisfactory tank for such a location as shown in Fig. 231 is a box of matched lumber sufficiently strong to hold the water and lined throughout with sheet copper having well-soldered joints. Such a tank will be found as easy to make tight as an iron one and no difficulty will be experienced from dripping.

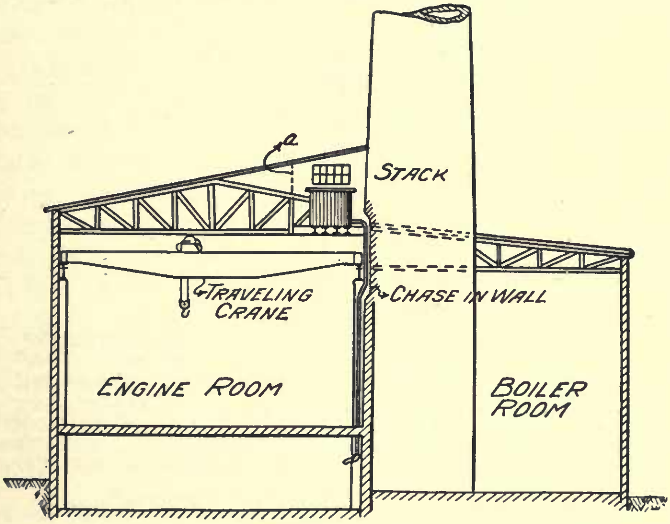

FIG. 231 (H3–1).

Another method of overcoming the trouble from dripping is to enclose the tank in a "room" between the trusses, using, if desired, a metal floor and the partition, *a*, shown dotted in Fig. 231. This room may also have windows opening to the outside of the building. By the use of such a room the engine-room air is prevented from coming in contact with the tank and by manipulating the windows the air around the tank can be kept at a low temperature, thus permitting the use of a plate-iron tank without the difficulties previously mentioned.

There are three methods for supplying such tanks with water.

The first is by the use of a float and lever connected to the steam pipe of the pump (or an electrical controlling device). The second is by the use of a float and lever arranged to operate the water valves in the line discharging into the tank. The third is by means of a float, pulleys and tell-tale placed on the wall so that the operator can see and control the feeding arrangement by hand. There should be an overflow emptying either into a funnel in a conspicuous place or in such a manner as to attract the notice of the operator.

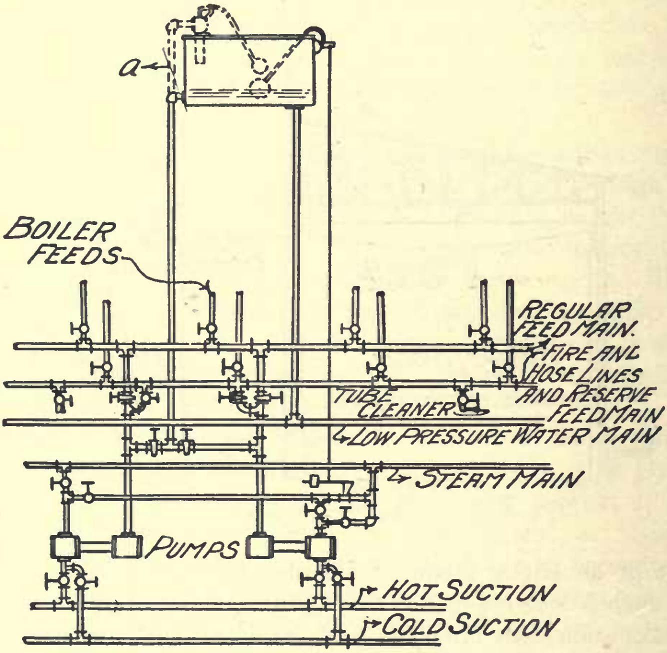

FIG. 232 (H3–2).

The float control of steam valves is the most satisfactory method of regulation, if the pump can be kept constantly in use for this particular service. This requirement can generally be arranged for, as there are only two water services regularly needed for station use; boiler feed and general water supply, as shown in Fig. 232 (H3–2). With the arrangement as shown the auxiliary main would be under low pressure and would be connected with the pump discharging into the tank; in fact it would be supplied from the tank. It will be noted that the low-pressure main is in no way connected with other lines that at times carry high pressures. Thus the arrangement avoids the possibility of water under high pressure being let into the low-pressure system. The pumps are shown with each having similar connections for suction, discharge and steam openings. This allows the use of either pump for boiler feeding, and the selection of the pump which is in the best condition for use in boiler feeding while the other is used for tank work.

The use of a float for operating the water valve offers many desirable features and simplifies operation duties. The pump discharge, *a*, shown dotted in Fig. 232 is carried to the top of the tank and connected with a float which in turn controls the discharge. With the discharge so arranged the steam is carried direct from the main to the pump which has a governor that can be set for a suitable pressure sufficiently in excess of the tank pressure to insure raising the water to the tank level.

As long as the fire main is kept under about the same pressure as that supplied by the tank there will be but little wear at the float valve on the end of the pipe, *a*. However, if the difference in pressure is considerable some special provision should be made so that the float valve will not cut out its faces. The most serviceable arrangement to meet these requirements includes provisions for allowing the float a considerable range of travel, so that when the float is close to the bottom of the tank the valve will be fully open and when the water is near the overflow point the valve will be fully closed, having no intermediate position.

Fig. 233 (H3–3) illustrates a valve so constructed and including in its design a small waste valve attached to the float together with a piston-operated valve for regulating the flow of water to the tank. In this device when the main valve is open the waste valve is also open; the free travel in the valve stem, *a*, allows the float to take the extreme range before the valve is operated.

When the supply tank is fitted with a tell-tale and has a sufficient capacity for many hours' service it is common practice to use a hand-control, either starting or stopping the pump that supplies the tank or by throttling the water supply to the tank if the main from which it is supplied is constantly under pressure.

Another method of storing water and one especially suited for pressures higher than those obtained by the use of a gravity tank, employs an expansion air tank. This tank may be placed in the basement, and if the station is equipped with an air compressor the larger portion of the tank's volume may be utilized for storing water. For example, if, at any time, the tank be three-fourths full of water at 75 lb. pressure and then be emptied of the water, there will be a pressure of 7 lb. per sq. in. when the water has been discharged, these pressures being considered as above atmospheric value.

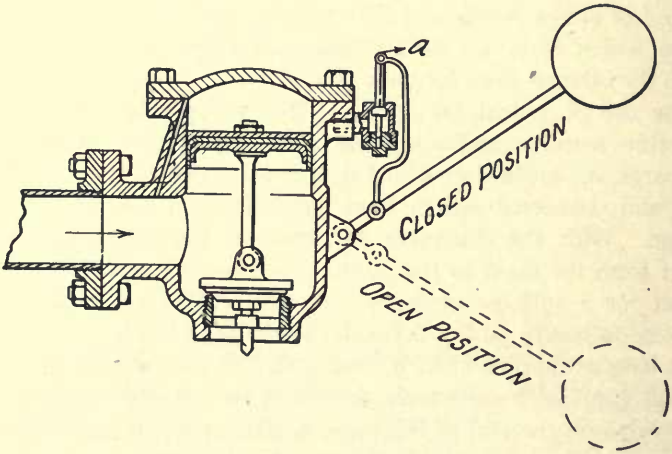

FIG. 233 (H3-3).

To assure the maintenance of a fairly even pressure it is necessary that an expansion tank be quite large, even though the quantity of water to be withdrawn at any one time is relatively small. To obtain an allowable pressure drop of 10 lb. with the tank earlier mentioned as carrying 75 lb. pressure, there would be required a cubical contents of 36 cu. ft. for each cubic foot of water to be withdrawn.

A pressure tank is especially useful in connection with a pump doing constant service and under the control of a governor; the tank allows the pump gradually to increase and decrease its discharge without sudden pressure changes and the consequent shocks. A gravity tank, however, is more satisfactory for power-plant uses than a pressure tank, because the air-pressure tank is under more severe stress than any other part of the water system, while a gravity tank is under the least pressure of any part of its system. The expense of supporting a gravity tank is much less than the original cost for building a larger tank which must withstand higher pressure.

As a gravity tank is quite essential, provision should be made for its accommodation when the structural work is designed. The cost of installation will thus be reduced materially. Ordinarily it will be found the cheaper method to allow the contractor for the structural steel to furnish the tank, tank-room floor, partitions and such ladders as may be required to reach the tank room. In designing the building walls, if a traveling crane is used which will run close to the face of the wall, a chase should be left to accommodate the piping for the water supply to the tank, and for an overflow and possibly a separate discharge pipe.

Class H4 — Low-Pressure Water; to Heater. Ordinarily it will not be found good practice to supply low-pressure water to an open heater since the low-pressure service is generally cold water and at pressures in the neighborhood of 15 lb. If the plant is of the condensing type other means are possibly available. If the plant is of the non-condensing type a loss will be occasioned by pumping the supply water against a 20-lb. pressure and discharging it to atmospheric pressure.

Under these conditions if the plant being considered has 3,000 hp. of boiler capacity there will be about 90,000 lb. of water raised about 40 ft. higher than necessary, or a loss equivalent to 3,600,000 ft. lb. per hr., which equals 60,000 ft. lb. per min., or 2 hp. If the pump uses 100 lb. of steam per hp. hour the loss would then be 200 lb. of steam per hour. This extra work would require about 30 lb. of coal per hr. or 720 lb. per day of 24 hr. and at $2.00 per ton or .1 cent per pound the loss will be 72 cents per day or $262.80 per year; thus an investment of more than $1,500 will be justified to save this loss. Such an amount is more than sufficient to cover the cost of any device necessary for the purpose. If the plant is non-condensing and can use all the exhaust from the pump in the heater, then the steam loss would be much less, but the loss by the use of cold water rather than condenser discharge water, would bring about still another loss.

For a non-condensing plant the arrangement shown in Fig. 230 (G5–1) is simple and economical, using as it does the heater supply pump connected with the feed pump. It is safe to assume that the ordinary float with the float-controlled valve as furnished with open heaters, will require as much attention and cause as much annoyance as the low-duty water cylinders added to the feed pump. If there is but one feed pump with its heater pump attached then it will be advisable to run a branch from the low-pressure main to the heater. This branch can be used in case of repairs such as would necessitate shutting down the heater pump. The saving that may be secured during such short intervals will not pay for the investment in a reserve heater pump.

Class H5 — Low-Pressure Water; to Engine Journals. Many of the large engines are provided with hollow journal shells and arranged for passing water through these chambers to carry off the heat generated by friction. If a large quantity of oil could be circulated through such journals and caused to pass over the hot surfaces, it would accomplish the same result. This procedure, however, is impossible as the weight of the moving parts sliding in the journal prevents more than a film of oil passing over the surface which requires cooling. The water chamber is not similarly restricted, the volume that can be passed over its hot surfaces being determined by the size of the connections and the water pressure. The inability of oil to cool journals, even when fed in a stream, is fully demonstrated in the cases of hot bearings that necessitate shutting down the engine and cooling the journals before again starting. However, these same journals after starting up may continue to run cool with an ordinary supply of oil.

The lower sections of the main journals are the only bearings that ordinarily are water cooled. These bearings lie in close contact with the shaft at all times, thus preventing a free supply of oil to their sliding faces. The side cheeks and caps, also the crank and cross-head pins are in close contact only part of the time, which permits oil to flow between their faces every time the piston reciprocates.

In designing a water-cooling system for journals consideration should be given so that the pipe connections will be free to expand and contract at the connections with the journal. This allowance is not on account of heat, but on account of the movement of the lower shell. If the side cheeks are quite free from the shaft it will move crossways in the bearing and cause the bearing to move also. This movement cannot be taken up completely or the journal will heat, but it should be reduced to the least possible amount, thus retaining the lower bearing in a form that will correspond to that of the shaft. There is sure to be some pounding in the journal and this continual jar will break pipe connections. The nipple and possibly the next piece of pipe away from the journal should be extra heavy and if the opening in the journal is large it will be found advisable to reduce the diameter of the pipe at the first elbow to a size smaller than the regular line to the journal.

Fig. 234 (H5–1) shows a very satisfactory construction with pipe connections entirely outside of the frame, thus avoiding the possibility of their being strained against the frame of the engine. As shown they are also exposed to view which is advantageous in case of leaks. The water can be diverted over the surface of the journal either by means of dividing partitions cast in the journal or by a pipe run into the journal and forming one of the connections. The regulating valve should be on the inlet branch, the outlet being free to atmosphere and discharging into a funnel that may readily be seen and tested by the operator. To allow the greatest possible flexibility the supports for the piping should be well away from the journal. The discharge should be carried to a height slightly above the journal, thus assuring that the bearing will at all times be full of water.

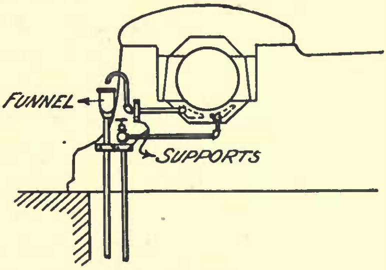

FIG. 234 (H5–1).

Class H6 — Low-Pressure Water; to Dry-Vacuum Pump. For continuous running it is absolutely necessary to cool the air cylinder of the dry-vacuum pump. Low-pressure water is used for this purpose. The temperature of the air pumped is generally about 120° F., and if no air cooler is used and air is compressed from about 2 lb. absolute to 15 lb. it is thus reduced to about one-seventh of its former volume. The dry-vacuum pump will operate under rather high temperatures, thus permitting cooling water to be discharged at a temperature as high as 175° F. The arrangement of pipes for cooling the journal, as shown in Fig. 234, is also suitable for cooling an air-pump cylinder, using only the inlet valve to control the water and an open funnel to observe the quantity and temperature. The amount of cooling water necessary to reduce the temperature of the air cylinder of the dry-vacuum pump is quite small, being only about 1.5 per cent of that used for boiler feeding. The amount of water so used should be determined by observation of the condition of the pump at various temperatures of the cooling water.

One of the most frequent troubles with air cylinders is brought about by the admitting of oil to the cylinder, which, due to the high temperature, becomes burned onto the air-discharge valve.

Class H7 — Low-Pressure Water; to Pump Priming Pipes. A low-pressure water connection should always be provided for priming fire pumps. This connection is not installed because such pumps are not capable of lifting water without priming, but because the pump priming pipes connected with the low-pressure water main enable the fire pump to discharge water and be in service for full duty in the least possible time. As the saving in time in priming feed and ordinary service pumps is not as essential as with fire pumps they are seldom equipped with priming pipes. The piping arrangement shown in Fig. 216 (F1–3) will be found satisfactory for the service pump. A fire pump should have a foot valve, also a priming connection between the suction and discharge valves at both ends of the pump and should also have priming connections to the suction line. By the use of these several details air may be removed from the pump before it is started. If priming water is not easily obtainable from a low-pressure line or from the pump discharge as shown in Fig. 216, then a hose valve should be attached to the pump between the suction and discharge valves at all four ends of a double-acting pump. This detail can be satisfactorily arranged by connecting the four ends with piping and using check valves that open into the ends of the cylinders and a stop valve to control the water from the hose or pipe line.

The usual method of freeing a pump of air is to close the valves in the discharge and open the vent over the discharge pump valve, thus allowing the contents of the cylinder to be discharged to atmosphere at a low pressure. All the air can in this way be discharged from the pump if the priming water is admitted between the suction and the discharge valves. Such an arrangement of valves requires a large air vent, and if a check valve is placed in the discharge line from the pump it will prevent the pressure coming back on the pump valve whenever the air relief is open.

The usual boiler-room operator is not sufficiently skilled to handle these priming arrangements unless they are quite simple. To free a pump of air when it is not fitted with priming pipes requires even more skill. Any operator should quickly learn to open the air vent and admit priming water if that is all that is required. It must not be inferred that priming pipes are mere conveniences, since there are many installations in which they are absolutely essential and with which if priming pipes were not supplied it would be necessary when priming to open the pump and fill it with water by using a hose, pail or similarly crude method, before the pump could be put into operation.

The use of priming connections with centrifugal pumps is indispensable, as has been explained under Class C (F–1). Generally speaking, the priming line to a pump has a diameter of about one-eighth that of the pump suction.

Class H8 — Low-Pressure Water; to Hose Connections. There are generally three distinct hose systems for a power plant, but oftentimes one of these systems is made to serve for another. They are the fire service, the sprinkling and the regular low-pressure service as used for wetting down ashes, washing floors, etc. For the purpose of simplifying piping arrangements these three services should be divided into two systems that may, with safety and without causing serious difficulty, be changed from low to high-pressure systems. Ordinarily one system should supply all the hose connections. The other system should be designed without by-passes or other means by which high pressure could be put on it. The only hose connections that should take their supply from the low-pressure system should be those for wetting down ashes. This class of work is better served by using water under low head, thus avoiding the dust and spattering that would be caused by water of high velocity striking the ashes. As this advantage is too slight to call for a separate pipe line for wetting down ashes it will be advisable, if the fire line passes near the boiler front, to connect with it the hose for this service, controlling the pressure by valves at the hose connections.

If the low-pressure system is supplied from a tank there should be only such connections taken off this system as would be injured by high pressure, but to avoid running special lines and thus complicating the station pipe work it may be found advisable to make occasional hose connections with the high-pressure line.

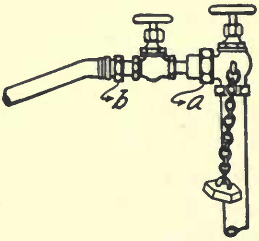

FIG. 235 (H8–1).

A simple arrangement for floor washing is to use a small hose with a large coupling at the end for attaching to the fire connection. To avoid cutting the regular fire-service valves it is quite necessary that a separate valve for controlling the water should be attached to the regular hose valve. If a hose coupling of large size can be tapped out of the fire line and a nipple attached as shown by *a*, in Fig. 235 (H8–1), a very convenient connection is had. An alternate method would be had by screwing a small valve onto the larger valve and connecting the hose with the coupling, *b*.

Class H9 — Low-Pressure Water; to Oil Filter and Tanks. Low-pressure water service for washing purposes supplied with hand control is usually provided for the oil filter and tanks. A very satisfactory piping arrangement is had by running steam and low-pressure water pipes to an "ejector-tee," having a valve in each line and a means for connecting the hose to the tee. With such connections water can be supplied either hot for cleaning tanks or cold for general use. If water is required in any tank it can be supplied by hose or, in the case of precipitating gravity tanks, it may be admitted through pipe connections. Ordinarily the water required for this service does not exceed that which may be delivered through a ½-in. pipe.

Class H10 — Low-Pressure Water; to Grease Extractor. Only a small amount of water is required for grease extractors, the quantity being just sufficient to keep the baffle plate wet and amounting to about 5 per cent of the steam passing through the extractor. A water connection is essential for the successful operation of even the most efficient grease extractors. The water admitted to the separator is discharged together with the condensation, grease, etc., to an entrainer. This entrainer, for a vacuum separator, is designed to receive first, drips under vacuum; then, by a tilting mechanism to close the drip opening and open a steam connection so that the accumulated drips are blown out; it then closes the steam and opens the drip connections in turn, working in a manner somewhat similar to the action of a steam trap.

If the grease extractor is in series with the vacuum line to the condenser the spray water, even though lifting is necessary, may be taken from the condenser circulating water. This supply will be found somewhat more reliable than the low-pressure main and no pumping machinery will be required to insure its continuous operation. If the grease extractor forms a part of an atmospheric exhaust line it will be necessary to supply the spray water under a head greater than the exhaust pressure. In this case the drips would be discharged through a steam trap or a U-shaped drip loop.

Class H11 — Low-Pressure Water; to Cooling Boxes at Furnaces. There are some makes of furnaces that require water cooling to prevent them from being burned. Such devices waste the heat taken up by the water, when it is discharged to the sewer, and they are a source of constant trouble. The manufacturers of station equipments call into use many methods for eliminating this troublesome detail. The reason for this choice is not that they can secure better results, but with a view to avoiding the serious loss and any interruption of operation that would be caused by a failure of the water supply. The customary method of regulating the supply to such devices is by maintaining full water pressure on the parts to be cooled and controlling the water with a discharge valve. If the heat in the furnace increases it is possible to generate steam and drive the water out of the water box unless the discharge opening be increased before the temperature is raised to the steaming point. Thus in the operation of such cooling systems the water must be wasted or a risk run of damaging the water box. By admitting water into a box which has attained a high temperature and driven out the water or in some other manner been without water for a short time, there is not only the danger of burning the water box, but a still greater one of cracking it. As a proof that much greater damage is caused by cracking than by burning many of the builders of this class of apparatus are now making water boxes of riveted boiler plate.

If a considerable supply of water is connected to a water box so arranged that the water can circulate in it relief will be had from much of the danger occasioned by interrupted water supply. The water in the tank, in case of approaching trouble, would become overheated and give a warning. A tank for this purpose, to permit of circulating water being at not less than 210 degrees in temperature, should be placed as high as possible. When the heater used is of the open type and the tank is placed at a high level the overflow may be discharged to the heater.

The arrangement as shown in Fig. 236 (H11–1) has an outside water-circulating tank and an admission valve, *a*, discharging water through a syphon-tee, thus bringing about a forced circulation when the valve is open. It is desirable to place the the storage tank as high as possible, thus increasing the velocity for circulation and raising the overflow, *b*, to a height sufficient for discharging into the open heater. To insure the water passing over the entire surface of the water box, the tube, *c*, is attached to the end of the inlet pipe. To permit free circulation, the connections from the tank to the water box should be of large size and arranged in as direct a line as possible. To prevent the possibility of water wasting away through the supply pipe, if for any reason the pressure on it should drop below that at the inlet pipe, a check valve, *d*, should be placed in the inlet pipe. With connections as shown when the water becomes very hot it will boil in the tank and give sufficient warning to the operator so that he may know when to alter the set of the valve *a*, and prevent any damage. To allow for the boiling away of part of the water without lowering its upper surface below the inlet, the connection, *e*, should be made lower than the outlet, *b*. Unless this precaution is taken when the water level is lowered below *e*, circulation through the water box will be entirely stopped.

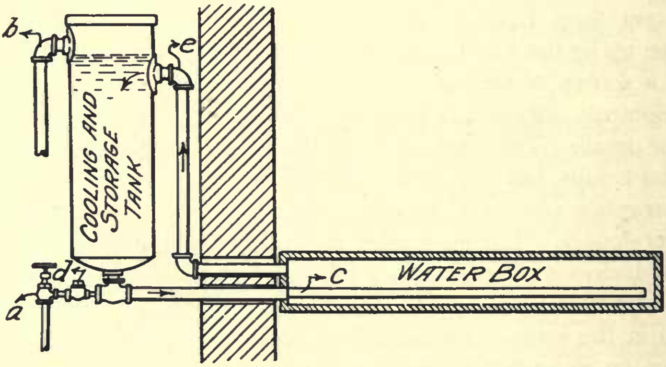

FIG. 236 (H11–1).

It may be advisable to consider the merits of some of the devices using fire tile in place of water-cooled boxes and designed to do the same work. The water-cooled parts are used to save the expense of fire tile destroyed by the high temperatures to which they are subjected. In many cases it costs more to maintain the water-cooled part than to replace the tile.

Class H12 — Low-Pressure Water; from Economizer to Heating System. In many power plants hot water serves best for heating service. If there is available an abundance of exhaust steam it will probably be good practice to use it for heating the water in a large heater. For a condensing plant the heating problem becomes somewhat more difficult. A heating system should be under low pressure, which precludes the use of water taken direct from the boiler.

The higher the pressure carried by a condensing plant the more suitable would be the use of low-pressure economizers; with the lower pressures the strains in the economizers would be comparatively small and a supply of water suitable for heating would be available.

In Fig. 237 (H21–1) is shown an economizer arranged for operation at low pressure. With this arrangement pump No. 1 serves to keep the economizer under pressure and discharge hot water either to feed pump No. 2 or circulating pump No. 3. By closing valves *a* and *b*, the heating system is entirely shut off from the economizer.

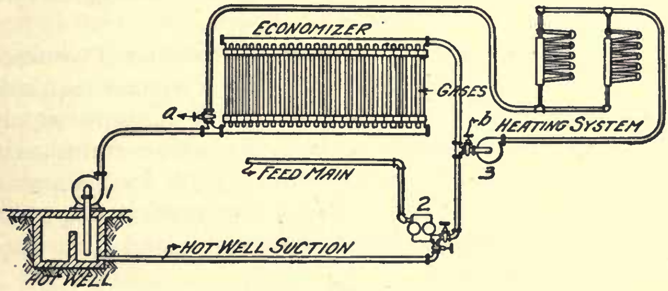

FIG. 237 (H12–1).

If the quantity of water passing through an economizer is considerable the temperature of the flue gases and the water will be lowered. In ordinary practice an economizer delivers to water passing through it about one-sixth as many heat units as the boilers, or, in other words, it has about one-sixth the capacity of the boiler equipment. By increasing the quantity of water passing through the economizer the temperature of the gases is lowered, thus increasing the capacity of the economizer to possibly one-fourth that of the boiler plant. In other words, an economizer equipment for 1,000-hp. boiler capacity will raise the water for heating purposes to a temperature approximating that which would be done with 250-hp. capacity of independent hot-water heaters.

It will not be found advisable to use over 10 per cent of the total capacity of the boilers for heating purposes, as there will be times when only part of the boilers are in operation, and by using water from the economizer for boiler feeding the supply capacity for the heating system will also be decreased. With large power plants, say of 5,000 boiler-hp. capacity, only about 3 per cent of the output will be required for heating, possibly 150 hp., and this duty can readily be performed by the economizer with no perceptible change in water or flue-gas temperatures. The efficiency of a heating system so arranged would even be higher than that of a steam plant not having a heating system in connection with its economizers, since the arrangement as suggested would utilize heat that otherwise would be wasted.

Class H13 — Low-Pressure Water; to Plumbing Fixtures. In nearly all power plants both hot and cold water are required for the plumbing fixtures and, therefore, a low-pressure supply is necessary for this service. The light float valves furnished with water closets, basin cocks, etc., are only suitable for low pressures of about 20 lb. There valves operate well on much lower pressures, but under such conditions for pressures of about 5 lb. require somewhat larger lines.

If a low-pressure water tank forms a part of the power plant piping system the cold-water service should be taken from this supply. Water would then be available for closets and wash-bowls, even though the pumps were in use for other service. If only a small quantity of low-pressure water is required, say 500 gal. per day, it may be advisable to use city water if it is available. It must also be remembered that as the quantity of water required is reduced the size and cost of the necessary storage tank and its supports are also reduced in direct proportion.

For supplying such small tanks the feed pump may be shut off from the boilers long enough to allow the tank to be filled once a day.

The supply of hot water to plumbing fixtures is usually a difficult detail to arrange. This subject is discussed under Class D10, "Branches to Hot-Water Plumbing Fixtures," and in Class A31, "Steam for Heating Purposes."

Class H14 — Low-Pressure Water; to Separate Buildings. If the location of the power plant under consideration is such that it is advisable to furnish warm water to car shops, offices or similar nearby buildings, it will be found quite objectionable to take this supply from the feed mains since they should be left for boiler feeding with the least possible number of unnecessary connections. If a comparatively large quantity of water is required for outside feeding another supply should be arranged, designed for low pressure. If there is an abundance of exhaust steam the simplest way would be to take low-pressure cold water from the regular low-pressure system and allow it to pass through a small exhaust heater used especially for this purpose. If the exhaust steam is less than that condensed by the boiler feedwater heater then this independent heater should be placed ahead of the feedwater heater, thus first raising the temperature of the water in it to about 210 degrees, even though the feedwater heater may not raise the temperature of its water above 150 degrees or less. If all the exhaust steam is condensed in heating the feedwater then the live steam heater shown in Fig. 132 (A32–2) is quite as economical as an exhaust heater.

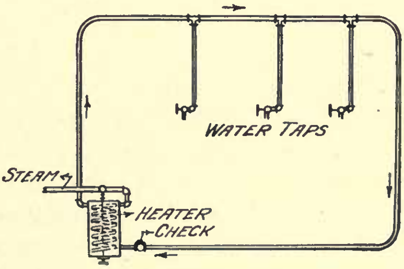

FIG. 238 (H14–1).

If it is necessary to pipe both live steam and low-pressure cold water for a considerable distance to the outside buildings where hot water is also required, and if the steam is always turned on and the exhaust is condensed for feedwater, then the use of a live steam water-heater would be the more economical method of furnishing hot water. Thus less water would be wasted by running off the cold water in the pipes when it is desired to get the warm water. The live steam heater has another advantage in that the temperature can be regulated and that all the condensation may be delivered to the water-heater by taking steam from the bottom of a drip pocket. This practice will save drips which otherwise might be wasted to the sewer.

If the plant is operated with the engines exhausting to atmosphere then all these small savings gained by using a live steam heater are of no consequence because such heat secured from the exhaust is obtained without any expenditure for fuel.

If it is necessary to place the steam water-heater in an outlying building it may be found advisable to lay out the hot-water piping on the loop system. This will keep the water in circulation so that it will be warm throughout all the piping. Fig. 238 (H14–1) shows such an arrangement of piping from which hot water may be instantly drawn without drawing off the water in the main.

CHAPTER XVIII.

CONDENSER COOLING WATER PIPING.

Class I1 — Condenser Cooling Water; Intake from Waterway. The economy secured by the use of condensing machinery is such as to warrant considerable outlay in providing a sufficient supply of water and the apparatus necessary for condensing purposes. Ordinarily a condenser equipment will save from 6 to 8 lb. of steam per hp.-hr. At this rate for a 1,000-hp. unit the saving would be about 10 tons of coal per day which, at $1.50 per ton, would amount to $5,475 per year. If the engine were run only half of the total time the saving would be more than $2,500 per year which, at 12 per cent for interest and depreciation, would justify an expenditure of $20,000 for condensing apparatus In most cases, however, the condensing apparatus would not cost more than the amount that it would save in fuel if it operated one-half of each day for a year's time. In other words, a 100-hp. condensing unit operating under the conditions as stated would save about $2,000 per year after the proper amount for interest and depreciation had been deducted.

If the supply of water for condensing purposes is reliable the initial cost of condensing apparatus may be considered from an entirely different standpoint. The total cost of buildings, boilers, piping, engines, etc., necessary to develop one horsepower may approximate $50; then the cost of condensing apparatus, including waterways, apparatus, etc., would be somewhat less than $4 per horsepower capacity of the total plant, or about $12 for each horsepower furnished by the condenser. It will be noted that the cost per horsepower for any installation is less for a condensing plant than for a non-condensing one, which will permit the use of less boiler and engine horsepower if the plant is built for condensing. It is safe to state that if water is obtainable for condensing from any other source than city waterworks the saving in installation and operation will justify the expenditure necessary for condensing apparatus.

In Fig. 239 (I1–1) a power plant with high and low level of water supply is shown in cross-section. In studying the water-supply problem for such a plant the following points should be be considered: The distance, *a*, should be as short as possible and not over 16 ft.; this is on account of pump suction and expense for deep waterway. The distance, *b*, should be not less than 3 ft., which will allow the suction pipe to be 2 ft. in the water when it is at the low level. By making *b* about 3 ft. it would be possible to operate the plant, even though for any reason the water should drop a foot or so lower than the previous low-water level. The distance, *c*, is the extreme variation between high and low-water levels. The distance, *d*, should be as much more than *c* as possible so as to give ample fall for sewers. If it is necessary to make this but 12 in. more than *c*, then there should be a sewer valve, *e*, that can be used in case of higher water level than that established. The distance to the top of the hot-well, *f*, should be sufficiently greater than *c*, to prevent any unusually high water level (more than *c*) from causing an overflow of water into the building.

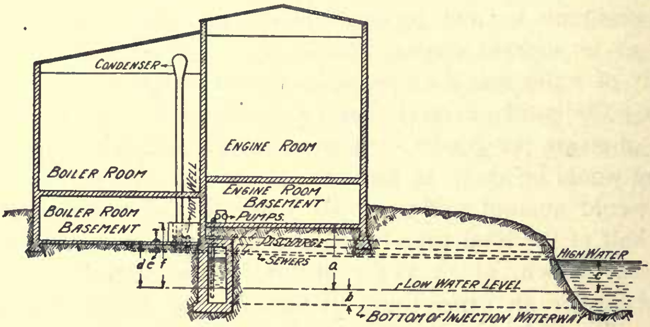

FIG. 239 (I1–1).

A knowledge of the geography of the power plant locality is quite necessary when making plans for obtaining condensing water. The chief requirement in such a situation is "to get water." The amount required may vary, but a sufficient volume must always be available for condensing. Possibly no other feature of station engineering requires so much investigation, study and preparation as this one problem. Evidently there is no ideal condition of condenser water-supply. The nearest approach to the ideal is when the plant stands close to a deep, wide stream having but slight variation in its level. But such supplies are not generally to be had where plants are needed.

On the other hand, the station may be located close to a small stream that flows between narrow banks, overflowing one season and almost dry another. This is a typical situation for condenser water-supply and to overcome its most serious objections it will generally be found necessary to build a dam, thus allowing the water to accumulate in a pond from which the power plant supply may be drawn. This body of water may then be used as a cooling pond if the water supply should become less than that circulated by the condenser pumps. Under such conditions the amount of water necessary to replenish that lost by evaporation would be little or no more than that required for boiler feeding.

In Fig. 240 (I1–2) is shown a pond built in the basin of a stream which formerly flowed between the limits shown by the dotted lines. The banks for such a pond should be raised to a height such that the waste water at overflow times will be confined to its proper channel and not cut through the banks, but pass over a waste waterway dug through firm soil and having sufficient high ground between it and the basin to prevent erosion. A small overflow should be laid in firm soil and located slightly below the overflow into the waste waterway, thus permitting the circulation of water in and out of the basin if there is but a small surplus. Should there be a considerable surplus of water then the condenser can be discharged away from the pond through the line, *A*,

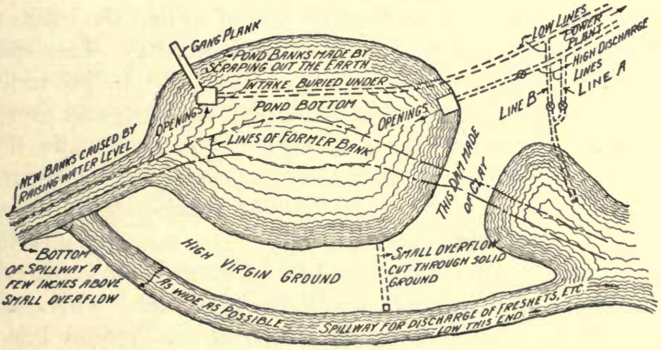

FIG. 240 (I1–2).

and the main supply be kept much cooler. The line, *B*, located lower than the bottom of the pond, provides for complete drainage.

In the design and construction of work of this character no water pipe should be laid in a dam or fill. For instance, it may appear desirable to run a metal drain from the bottom of the pond to the down-side of the steam, laying this pipe in the same place and at the same time as the dam is made. The difficulty that would arise in such a case would not be caused by the pipe carrying water through it, as a long piece of timber would make the same trouble. That is, the water from the pond would form a slight leakage along the surface of the pipe or timber extending through the earth work, and once a channel had been cut through it would only be a short time before the hole would become enlarged and the fill endangered.

The earth fill should not be subjected to having water pass over or through it, but it should be carried to a sufficiently high elevation to force the waste water to flow over firm undisturbed soil and between banks of like character. This can best be accomplished by leveling a large tract of ground so that the waste water will flow over it and into the down-stream side. This spillway should be a sufficient distance from the pond to preclude any possibility of washing away the bank dividing them and protecting the dam. Precautions must be taken to prevent water flowing over or through any made ground or its destruction will occur.

It will be noted in Fig. 240 that the small overflow from the pond is carried through virgin soil. The one difficulty met in building such a line is due to the fact that the pipe is placed in a trench which must be refilled with made ground. This difficulty can be overcome by making the length of the overflow line sufficient to prevent water finding its way through. As the overflow has practically no head of water above the fill which surrounds the pipe, the water has a very slight tendency to leak along the surface. The same precautions should be observed with the condenser discharge trench and the trench for the line, *A*, if the latter is laid at a high level, say 12 in. below the small pond overflow. However, if these lines are at a low elevation, say 6 or 8 ft. below the surface of the pond, it will then be necessary to make the trench of considerable length from the pond to the point of discharge; and to further insure the tightness of the trench and its ability to prevent any appreciable water flow it will be necessary to puddle the fill, using plenty of water to settle the replaced dirt. If clay is obtainable for refilling the trenches, then a short trench may be made tight if care is taken in placing the pipe. In fact, it will be found possible to make a trench when carefully refilled with clay, even more secure from leakage than the surrounding ground, if the latter be of a sandy nature.

Too much importance cannot be placed upon the necessity of carefully making the fill below the pipe, because it is at this point that seepage and trouble occur. Referring to Fig. 241 (I1-3) the space, *a*, would naturally be filled loosely unless special care were taken. It makes no difference how far the earth is dropped when being replaced, it will still pack only at the sides, *b*, and the more firmly it is packed here the less able is the dirt to move sideways and closely fill under the pipe. The weight of the fill has no tendency to force the filling under the pipe and there is no pressure on the earth, *c*, directly under the pipe, unless it is caused by deliberate filling, wetting and ramming. As this is a part of the trench where a channel can be cut without the sides closing in, it is invariably at this point that leakages occur through pipe trenches as such leakage will continue cutting away the earth until a sufficient amount of earth has been removed to allow the pipe to settle into the opening and cause trouble from leakage or possibly breakage.

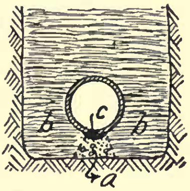

Fig. 241 (I1-3).

Whenever there is a head of water on a trench too much importance cannot be placed upon the details of filling. For such work it is necessary to use metal pipe with perefectly tight joints.

Fig. 242 (I1-4) shows a water supply which is higher than the ground surrounding the building. It would seem that such a condition would, in itself, suggest that the pipe line must be watertight throughout its entire length.

Where tile or other leaky pipes are used the manner of filling a trench does not enter into the seepage problem. There is nothing gained in keeping a trench tight if the pipe passing through it has openings permitting seepage. It is important to lay tile pipe so that it is well supported. This precaution should be taken if for no other reason than to prevent open joints that sand may wash into. Where the water pressure outside the pipe is equal to that inside, tile pipe will be found quite as suitable as metal and will cost much less and last longer.

For a situation such as shown in Fig. 242 some form of a built-in-the-trench reinforced-concrete water conduit would be found suitable as the pressure inside would be slight and but little reinforcing be required. Such a conduit should be built by one familiar with the methods necessary for insuring watertight work, the chief requisite for such work being continuous progress after the concrete placing has been started, thus avoiding joining the fresh work with that which has set.

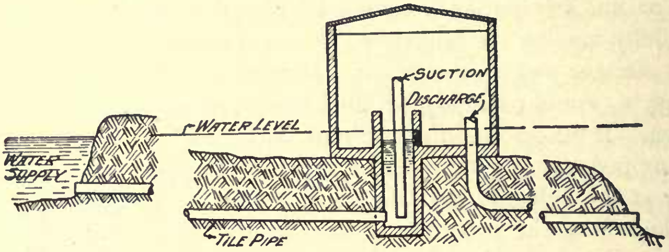

FIG. 242 (I1–4).

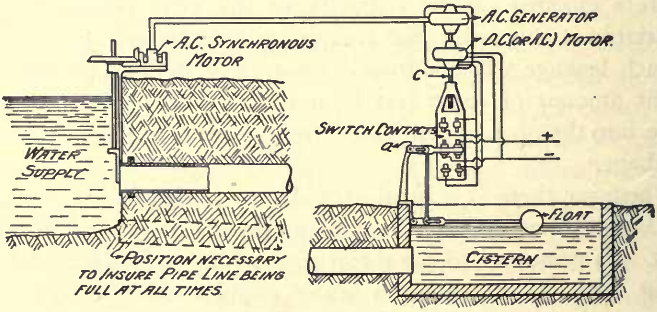

FIG. 243 (I1–5).

Another method of constructing the line shown in Fig. 242, though subject somewhat to interruption through breakdown, would be to use a large cistern at the power house and a float which would electrically operate the admission valve, thus maintaining at all times a constant level in the cistern. This would avoid the rise of water to the surface of the ground and at the same time permit the use of tile pipe. The regulation can be accomplished by using a synchronous moter for operating the admission valve and a small alternating-current generator driven by a motor at the cistern. The current supply to the motor may be controlled by the float as shown in Fig. 243 (I1–5).

Under such conditions the pond-float operates the pair of contacts as shown supported at *a*. These contact points engage with other contacts when a change of water level occurs and complete a circuit through a direct-current motor operating it in either one direction or the other. The motor driving the generator shown also operates the screw, *c*. This withdraws the contact points which the float has caused to engage. The pivot *a* may so be located to obtain any desired travel of the contacts and thus keep the variation of water level within the specified limits. The arrangement as shown in Fig. 243 (I1–5) is set for a variation of 4 ft. in the cistern level and would have the inlet valve entirely open at low level, half way open at midpoint and entirely closed at the high-water mark. The position of the valve at any point is proportional to the water level in the cistern. This system of control is a modification of the electric damper regulator as used in power houses, except that with the damper regulator, instead of the motor driving the generator, it operates a cable connected to the damper. The contacts in the damper system are operated by the gage of the regulator.

This method of regulation by the use of motors can be used for open waterways or for cisterns having a great difference in elevation and where the pipes connecting the source of supply with the cistern cannot be filled entirely with water. The control would be much more sensitive if the supply pipe throughout its entire length were below the water level of the pond. Then the amount of water entering the basin would exactly equal that admitted by the valve. If the demand for water suddenly be cut off, that within the pipe would not be emptied into the basin as would be the case if the pipe were not below the level of the pond.

A considerable reserve capacity must be provided if the pipe discharges above the water level of the cistern because it must then be of sufficient size to receive the contents of the pipe that would flow to it after the admission valve were closed.

So many varying conditions are met in different localities that it is impossible to say which is the most suitable material to use for the construction of large waterways. Much depends upon the soil through which the line must be run. If the line is of considerable length, — say 100 ft. or more, or of such size that a suction 16 in. or more in diameter is required, then the water should be delivered by gravity. In many cases the soil close to the water's edge is unfit for supporting building foundations. This often necessitates the placing of a power-house some distance from the water. The fact that the soil is unsuitable for building purposes makes it quite as unsuitable for building a trench and placing a waterway through it. If the plant is located alongside of a dock much difficulty may be experienced with old piles, dock timbers, etc., and since it is desirable to carry the pipe line under water the entire distance such conditions would hinder careful construction and necessitate installing a pump of sufficiently large capacity to care for the increased amount of seepage through loose ground.

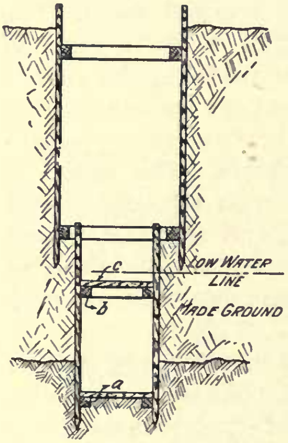

Fig. 244 (I1–6).

Fig. 244 (I1–6) shows an intake constructed of sheet piling. The lower line of plank is driven inside of the upper row. Sheet piling is necessary in soft soil, both to hold back the sides and to confine the water to the desired course. The material between the walls of the trench can be removed while the planks are being driven. Struts and stringers as shown take the thrust of the banks. After the material has been removed between the walls of the trench the lower stringers, *a*, are placed and the bottom secured to them. Before removing the upper row of sheet piling and filling in the trench the plate, *b*, should be set approximately correct when driving the piling and planked over as at *c*.

If placed entirely below the water level, a waterway constructed in this manner will last indefinitely so long as the wood is protected from the atmosphere at all times. The planking can be made double and the waterway made secure against the pressure of the banks and material be prevented from washing through the joints of the plank. To properly carry the tile pipe it would be advisable to use this form of construction as far back from the water as the made ground extends, or at least until firm ground is reached. Tile pipe may be used inside of the sheet piling as far as the water's edge, but where it is necessary to build up a complete enclosure of wood to hold back the banks and seepage water, there is nothing to be gained by placing another conduit inside of the wooden one.

If the intake line is entirely below the water, as would be the case in Fig. 244, or as in the case of a pipe line, there should be wells placed at regular intervals, about 150 ft. apart along the line of the intake, to facilitate the removal of sand or other deposits which may collect in the pipe. Since they are exposed to varying conditions of moisture, these wells should be of masonry. The bottom of the wells should be at least 3 ft. below the bottom of the pipe. This will permit the deposit to collect in the wells along the line, thus acting as small catch-basins. Metal steps should be built in the sides of the wells and the tops should be fitted with iron manhole rings and covers.

There have been intake lines built of 0.25-in. steel or iron plate with flanges at the end for bolting the sections together. The most serious objection to this type of construction is its short life and the fact that the sections are built in lengths of about 16 ft. — which are difficult to handle in the trenches. Such long sections necessitate extreme care in maintaining a perfectly straight line of trench and a special arrangement of struts, etc., must be provided to permit the lowering of the pipe.

If the waterway is of large dimensions and conditions permit, it should be constructed of concrete; this is the best material which can be used and it is probably the cheapest. The shape and method of constructing a concrete pipe will be governed by the condition of the soil through which it is run. If the waterway is cut through shale or rock, vertical sides and a flat bottom will be found the most economical form to construct. Such a conduit is shown in Fig. 245 (I1-7). There is no object in using rounded sides or bottom where the banks are fully able to support the weight on them without exerting a lateral strain on the walls. If

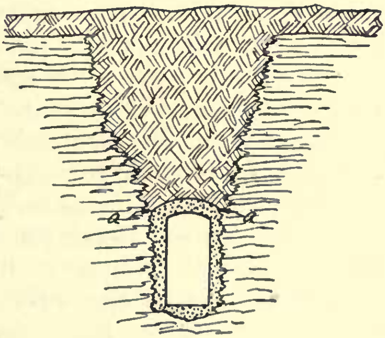

FIG. 245 (I1-7).

the banks at the points, *a–a*, are secure and will permit the concrete being rammed hard, the top may be constructed as an arch. But if the banks are weak, there is no object in making the top arched, as it would not have a solid skewback to resist the thrust. In this case it would be safer and require less material to build a flat top and use metal rods at the lower portion of the top, thus reinforcing the concrete. If the banks are of loose sand, similar to quicksand, then an egg-shaped conduit should be used: in clay, it would be possible to build the waterway of hard brick and require very little forming, the bottom being used as a form to lay the brick.

In whatever form the waterway is constructed it should be so graded in regard to low water and have such a height that a man could walk through it when the water is low. For instance, if the bottom of the waterway is 3 ft. below low water it should not be less than 5 ft. high in the clear, allowing 2 ft. above the water for a man to breathe while cleaning the bottom. The wells which run down to the intake should not be over 150 ft. apart, as the air in the waterway would become stifling if the distance between the manholes is greater than this. The waterway, as stated, may collect sand, etc., and when the water is high and the conduit is full of water a man could not get in to clean it out. This would not cause trouble, as there would be plenty of water available even though there were 2 or 3 ft. of sand on the bottom. The trouble would arise only at times when the water level would be low, in which case, however, it could be easily remedied.

Instead of using forms in the trench for building the concrete walls they can be built on the surface of the ground, in a wooden mold, using light wire mesh for reinforcement. This will permit the use of very light concrete walls, possibly 6 in. for a 3 by 5-ft. conduit, which could be assembled as shown in Fig. 246 (I1–8). Two patterns only are required for the molds, and all the concrete blocks can be made and be ready for use when the trench is opened. By this method of construction the trench would be open only a short time and many of the difficulties occurring from caving in would be avoided. Another advantage of this form of conduit would be that the blocks could be laid in water without injuring the concrete. The loops shown at *a* should be of heavy wire or rods built into the block to facilitate handling them with a crane. Tongue and grooved joints should be used in this construction. The lifting eyes, *a*, in the bottom slabs may be cut off after they are in place or recessed below the surface. With this construction only a small amount of labor would be required for assembling, as the sections could be formed by common laborers. The sections should be put together with cement in the joints and made as tight as tile pipe, which would be quite sufficient for this class of work. The weight of these sections — 4 ft. by 4 ft. by 6 in., taken at 140 lb. per cu. ft. — would be 1,120 lb., which could easily be handled by a crane.

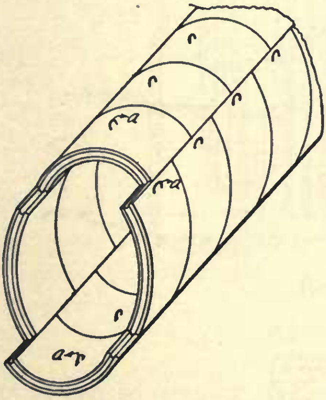

FIG. 246 (I1–8).

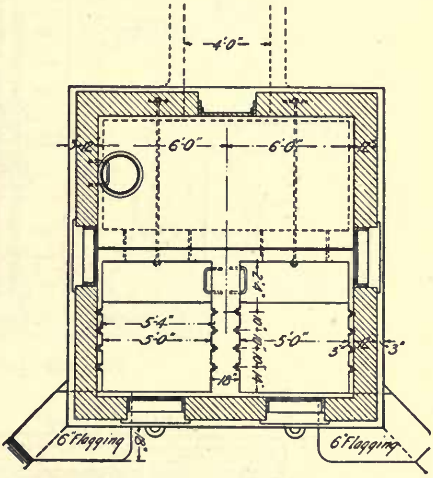

FIG. 247 (I1–9).

Whatever the construction of the intake may be, it is necessary to guard the mouth so as to prevent the entrance of leaves, sticks, fish, ice, logs, etc. If the water supply is liable to freeze around the intake to such an extent that the supply might be endangered, a line with a regulating valve in it should be run from the condenser discharge so that warm water can be delivered at the intake and freezing thus be prevented. The intakes should be fitted with screens of different mesh, arranged so that they can easily be removed for cleaning.

The accompanying figures show a screen house designed by the writer. Fig. 247 (I1–9) is the plan view showing the double-screen compartment with a 3-ft. opening into and out of each compartment. All four of these openings are arranged for

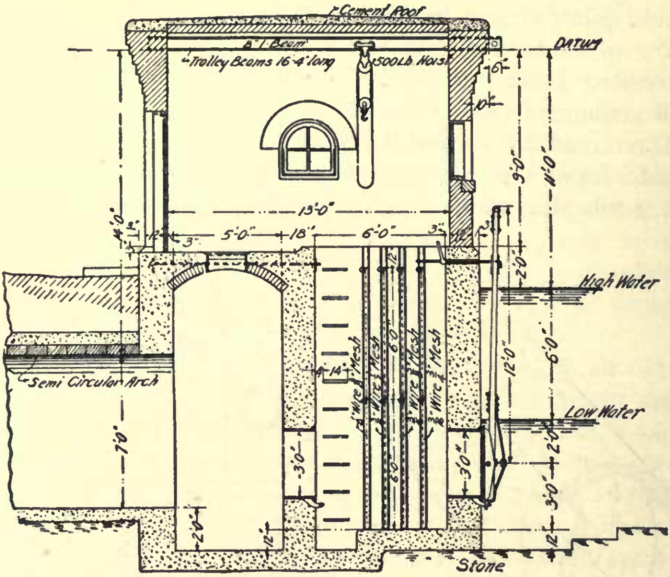

FIG. 248 (I1–10).

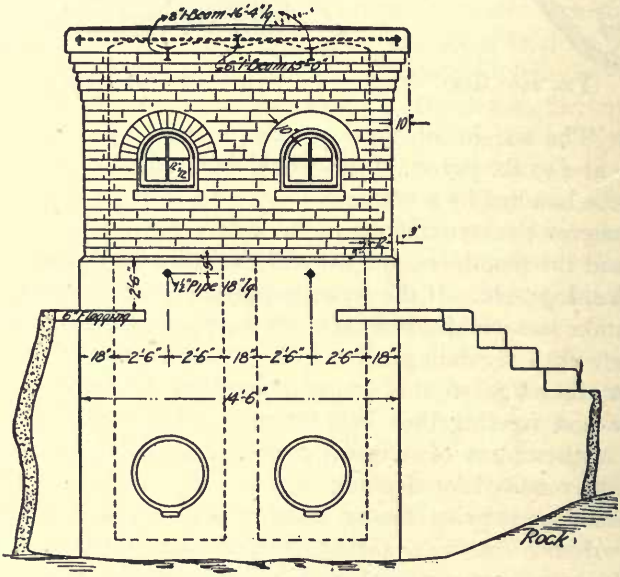

FIG. 249 (I1–11).

the valve shown in Fig. 250 (I1–12) which permits shutting off either of the screen compartments without interfering with the operation of the plant. There are two valves for this screen-house. By placing them on the outside of the opening as shown in elevation, Fig. 249 (I1–11), it is possible to shut off all the openings. The section shown in Fig. 248 (I1–10) shows one of these valves in place. The valves, when not in use, are under cover, and by keeping them well painted they are always in condition ready for use. The lower end of the long lever has a wrought-iron piece which forms a pivot upon a heavy "scrub-brush handle" cast on the iron casing-ring. The upper end and also the lower portion, just above the valve, are each provided with an eye to facilitate raising the valve out of the water; the end of the trolley-beam is extended outside of the building for this purpose.

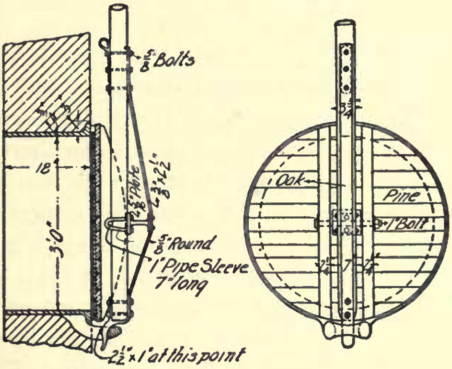

FIG. 250 (I1–12).

The valve shown is made of wood of double thickness with well leaded joints and a soft sponge-rubber ring 1 in. square in section fitted around the space at the edge to make a water-tight joint. The screw-rod which extends through the wall and handle-nut are provided to draw the lever up tight against the valve and force the valve against its seat. The adjusting screw is located inside of the building so that it is out of reach of meddlers. The flagging shown in Figs. 247 and 249 permits a man to get out of the front of the screen-house and for attaching a small chain hoist to the end of the trolley-beam. An 8-in. I-beam is used; not that the weight it is required to carry is so great, but in order to provide room for trolley wheels of ample size.

The screen guides are made of cast iron with lugs to key them into the concrete. The screen frames are made of angle irons of heavy section. Such screens should be made of copper wire, not of brass, as brass wire will not stand the sharp bends necessary in screens of fine mesh. A much cheaper screen can be made of iron wire, but the life of such screens is so short that there is no economy in their use.

It will be seen from the illustration that there is a large settling chamber between the screen compartment and the mouth of the intake to permit sand, etc., to settle. It will also be noted that the height of the waterway is such that at low water there is a space of 3 ft. between the surface of the water and the top of the intake. The floor space over the settling chamber is necessary for the cleaning of screens. Sufficient room has been left between the tiers of screens to permit dropping a brush or rake between them to remove leaves, etc., without removing the screen. The warm water discharge from the condenser is not shown in these illustrations. It consists of a line of 12-in. pipe extended to the intake and carried alongside of the intake waterway and outside of the screen-house, discharging through the bank retaining wall at about low-water level.

Spread footings were not required for this screen-house, as the foundation rested on rock. Had the bottom been of sand, the bottom of the intake foundation would have been concrete of a considerably greater thickness and possibly reinforced with iron bars. In case of fine sand, which is liable to wash, the footing should be protected and anchored to avoid shifting in case of freshets or floating ice. Fig. 251 (I1–13) shows the projected footing loaded with heavy stone carefully piled around the screen-house. The footings should be projected in front as well as at the sides and placed sufficiently low that they can be loaded with stone. By finishing the banks and bottom of the intake in this manner much less difficulty will be experienced from sand, etc., being washed in.

If it is necessary to build the intake house near an old dock, filled-in banks or similar location where a firm bottom for foundations cannot be secured, it may be found advisable to use piles and build the top of the piles into the concrete as shown in Fig. 252

(I1–14). The concrete bottom should be put in at the same time as the walls and the concrete around the piles, thus giving a footing over the entire surface as well as on the piles. To further increase the stability of this structure, the spread footings shown in Fig. 251 may be used, but this necessitates more complicated forms for the concrete. The forms for Fig. 252 can be placed in the water after the ground has been removed around the piles and the concrete built up without pumping the water out. The outside forms rest on the bottom and the inside forms are supported on the piles. Better concrete work can be made in this way than by pumping the water from the center, thus causing it to wash through the fresh concrete.

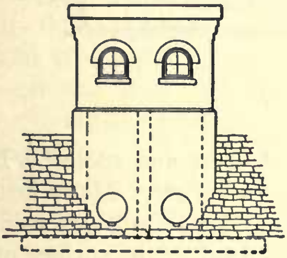

FIG. 251 (I1–13).

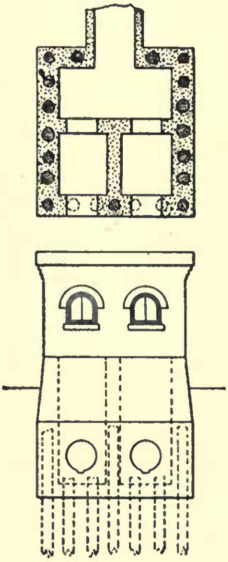

FIG. 252 (I1–14).

In constructing intake waterways there should be no passage between the water supply and the screen chamber which is not easily accessible. This detail, however, is frequently neglected and in nearly every case without good reason. A water conduit from the center of the stream to the screen-box is shown by the full lines in Fig. 253 (I1–15). The waterway shown at *A* is very objectionable as it is sure to clog and cause trouble. If there is not a rapid flow at the intake, then it is advisable to place the screen compartment and intake either at the point shown dotted in the center of the waterway with a runway leading to it or at the screen-box, and cut away the banks so that the water will flow directly into the screen compartment as shown in the illustration. If the source of supply is a stream which carries leaves and floating débris, the screen-house or box should not be set into the banks of the stream unless some provision is made to carry off the floating material. The most desirable location for the screen-house is to place it so that the front face is on the same line as the stream and not recessed in the bank, as ice and logs will then accumulate in the entrance space. Neither should the screen-house project into the stream unless it is well protected, as it is liable to be injured in times of flood by floating ice and logs.

Where cooling ponds are used for reducing the temperature of the condensing water, a screen-house such as that shown dotted in Fig. 253 (I1-15) would be suitable, as it would take water from the center of the pond where it is deepest and coolest. Little difficulty would be experienced from leaves, etc. Many installations such as this are operated without an intake crib or screen, the opening into the crib being located well below the surface of the water.

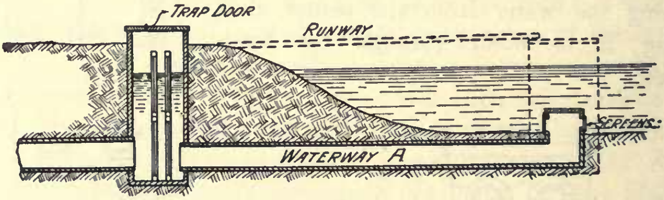

FIG. 253 (I1-15).

There are many suburban power stations being operated non-condensing that could be very readily operated with a cooling pond and condenser. Cooling ponds can ordinarily be constructed for about one dollar per boiler horsepower, not including waterways, etc. This would make the cost of a 1,000-hp. engine plant using 15 lb. of steam per engine horsepower, about $500, or 50 cents per engine horsepower in excess of that where a natural water supply is available.

Cooling towers are frequently used for this service, but these cost at least $3.00 per engine horsepower, including the foundations, fan-drive, etc. Not only are they more expensive to install, but are much more expensive to operate, owing to the fact that the circulating water must be elevated to the top of the tower. This is usually about 30 ft., and the entire head is lost in dripping over the cooling surfaces. To this loss must be added the power required for driving the blast fans in those types which do not have a natural circulation of air. Cooling towers generally have less than one square foot of cooling surface per pound of steam, the average cooling surface being 0.7 sq. ft. per pound of steam. Cooling ponds should be as large as conditions will permit; not that smaller ponds would not be sufficient to maintain the desired vacuum, but because of the quantity of water which must be circulated if the temperature is high. As an increase in the amount of circulating water increases the amount of power lost, the money thus wasted would more than equal the interest on the investment for a pond of larger dimensions.

The fact that a plant is at a considerable elevation above the water supply, whether it is stream or cooling pond, does not prevent installing a condenser plant successfully. An elevated jet-condenser is admirably suited for such a layout as shown in Fig. 254 (I1-16). This is, in many respects, a more plausible arrangement than to run the exhaust up to the condenser bowl located at a higher elevation. The safest arrangement is to have the exhaust drain into the condenser as shown in Fig. 254 (I1–16), but the conditions are generally such that it cannot be so arranged.

The most serious difficulty to be overcome in such installations is the construction of the intake, discharge and condenser well. This will, however, depend upon the condition of the soil and can probably be accomplished by placing the waterway in trenches until the depth becomes excessive and then tunnel the remainder of the distance to the well. The circulating pump and heater pump would be located entirely under water and would therefore not require stuffing boxes where the shaft passes through the case. In fact, the suction may be taken in the center through both the top and the bottom of the impeller case. The only parts requiring attention would be the shaft journals, and as the shaft exerts such a slight pressure on the bearings and would generally be lubricated with grease, the care required would be insignificant. The motors would be placed above the engine-room floor, free from heat, vapor, etc., where they could readily be looked after by the operator.

In case the water supply is below a high steep bluff, the condenser shaft could be cut in the face of the bluff and the screen-

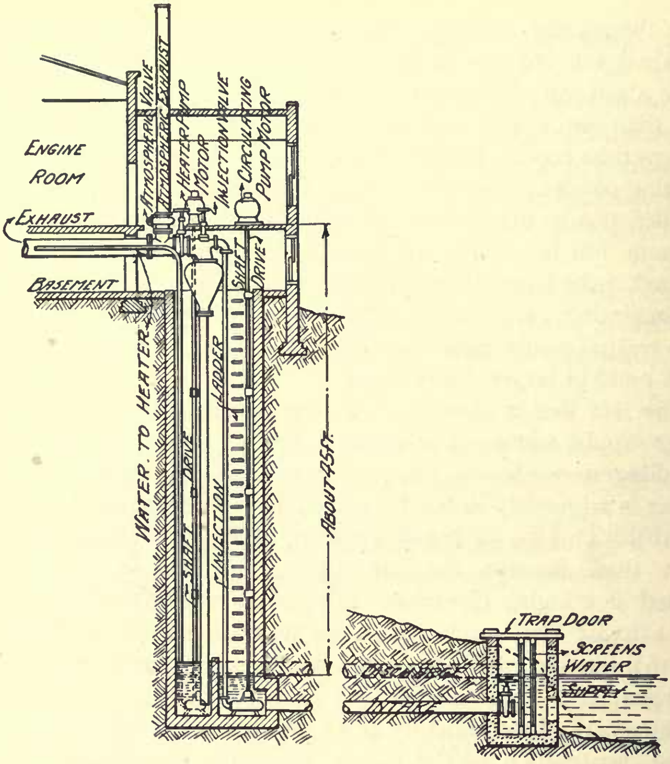

FIG. 254 (I1–16).

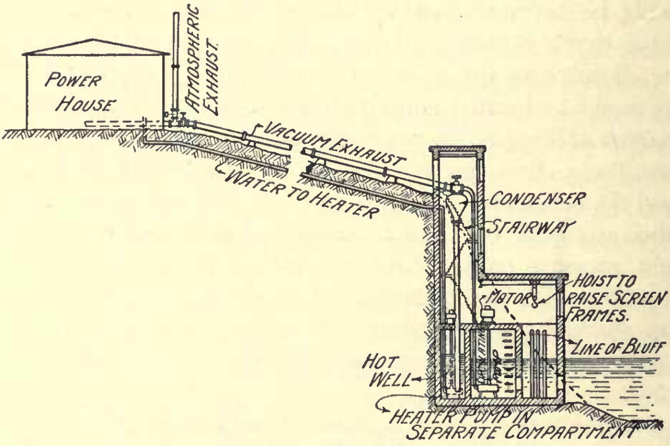

FIG. 255 (I1–17).

house built in the cut as shown in Fig. 255 (I1–17). A rather long exhaust main would then be necessary, the only objection, however, being the increased cost of the line. The fact that the exhaust main would be exposed to the atmosphere would be an advantage, as it then would aid in condensing the steam. The expansion and contraction could easily be cared for by allowing the condenser bowl to move freely with the pipe, the tail-pipe being sufficiently long, so that considerable travel, possibly a foot or more, could be taken care of. The water to the heater would, in this case, require being well insulated to prevent freezing. The condenser building and screen-house, etc., should be built of concrete throughout. A reinforced concrete roof and a metal stairway from the ground down to the screen and motor-floor level should be installed. The motors in this installation should each have a switch at the switchboard, and each motor should have a separate wattmeter or an ammeter so that any variations or unusual conditions could be detected from the power station.

At least once during each watch the engineer on duty should make a careful inspection of the motors, condenser, etc. This duty would in no way be a hardship upon the operator, and with this amount of attention no trouble should arise because of the motors being out of his sight. There are many motors in daily use which may be only a few feet from the operator, but are so situated that they are entirely out of view for possibly a day or more at a time.

The wires from the station to the condenser tower should be carried in some form of insulated underground conduit, thereby avoiding any possibility of trouble from lightning. It will be noted that the power house shown in Fig. 255 may be located at a considerable height above the condenser allowing the exhaust pipe to run down-hill to the condenser. This distance may be 100 ft. or more, in which case this is about the only simple and practical method of installing a condenser where the water lies so far below the power plant.

Another method, one which would be more complex, is to locate the jet condenser or surface condenser in the power house in the usual manner and raise the water to the condenser. The fall of the water from the power house to the level of the source of supply may be utilized by means of a Pelton waterwheel or other similar device. The waterwheel, electric motor and a turbine pump for raising the injection water being all mounted on the same shaft, the motor would only have to supply the power necessary to overcome the friction in the pipes, loss of head in the condenser and the loss due to the inefficiency of the pump and water motor. Instead of running the exhaust and heater supply pipes from the power station to the condenser house, it would then be necessary to run the circulating water line from the source to the power house.

Whichever plan of supplying the water to the condenser is employed, the water used for condensing should not be raised to a high elevation and the available head thus created be allowed to waste. For instance, a surface condenser may be placed, say, 32 ft. above the surface of the water supply, and if all the joints are water tight no loss will be occasioned by raising the water to this elevation and allowing the discharge to fall from this height, provided that the entire section of the pipe from the pump back to the discharge is air-tight. The power required to raise water above 32 ft. would be lost or wasted in this case, as the limit of height of a water column that the atmosphere will support is 32 ft. To utilize any additional head, a device such as a Pelton wheel or turbine waterwheel would be necessary, as previously described.

The most efficient method of supplying circulating water would be to run the exhaust down to the condenser rather than to raise water more than 32 ft. to a surface condenser, or any amount whatever to a jet condenser. The most economical location for a jet condenser of the elevated type is with the overflow as little as possible above the surface of the water supply as it will enable the condenser to discharge its water. This condition is ordinarily obtained by locating the overflow from the condenser at extreme high-water level, allowing the water in the hot-well to raise a foot or so during short intervals.

Class I2 — Condenser Cooling Water; Discharge from Condenser. The elevation of the discharge waterway from an elevated jet condenser should be determined by the location of the hot-well overflow, but for surface condensers the water should be discharged at the same elevation as it is taken, whether the water supply is at high or low water. A surface condenser can and should be operated without perceptible loss of head in the circulating water, other than that caused by the friction of the water in the pipe, condenser tubes, etc.

An elevated jet condenser necessitates two losses of head: First, that due to the difference in weight between the solid cold water in the injection column and that flowing through the condenser and tail pipes. The other loss is due to the fact that the condenser would be located in relation to extreme high water, and would ordinarily be operated at a lower level, necessitating a loss of power due to the quantity of water used and raised from the level of the water supply to the level of the overflow. These combined losses of head will be about 10 ft. in case the water is being pumped from 4 ft. below the high-water level.

A surface condenser would not have these losses, but a loss of head is occasioned which does not exist in the jet condenser. This loss of head is occasioned by the circuitous and restricted path of the cooling water through the small condenser tubes. The loss may be more or less than that of the jet condenser, depending upon the cleanliness of the condenser tubes, but this alone is too slight an advantage to be a deciding factor in selecting the type of condenser to be used.

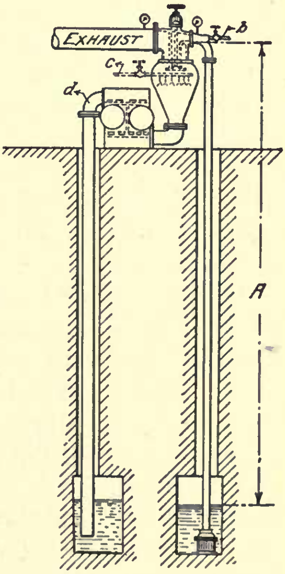

FIG. 256 (I2–1).

The jet type is the most commonly used condenser with suction instead of pressure pumps such as are employed with the elevated types. There are, however, many objectionable features in the suction jet condenser that cannot be eliminated unless the condensing chamber is elevated. Fig. 256 (I2–1) shows a jet condenser of this type arranged to secure the greatest efficiency possible and at the same time to be fairly reliable. The unfortunate feature of this arrangement is that efficiency must be sacrificed to insure uninterrupted operation. To secure the greatest possible efficiency with this device, it is necessary to make the distance, *A*, such that a column of water of that height would be the equivalent of the column of mercury whose height is equal to the vacuum which it is intended to maintain. This would necessitate

A being 28 ft. for a 25-in. vacuum. It would also be necessary for the discharge to be carried down into the discharge waterway, the water in which is as nearly as possible at the same elevation as the intake or supply water. If this type of condenser could be operated and constructed in this manner it would be working under exactly similar conditions, and have the same efficiency as a condenser of the elevated type.

The atmospheric pressure in the type shown in Fig. 256 (21–1) would support the water-leg *A*, and the pump would simply have to overcome the difference in weight of the two columns. The elevated-jet type of condenser has its discharge leg (tail-pipe) of length *A*, and as this is a longer column than the vacuum will support, a pump is used to counterbalance the difference between the injection and discharge legs. To secure the same economy for the condenser shown in Fig. 256 as could be obtained with the elevated-jet type, it is necessary to install it in the manner stated. This, however, is impracticable for two distinct reasons: One because the pump would not be able to lift water 28 ft., and the other because the moment the vacuum drops below 25 in. the water would fail to flow into the condenser and the entire vacuum would be lost. One is a difficulty met in starting the condenser, the other in regular operation. The less the distance *A*, the more certain is the operation. Many condensers of this type are in operation with the lift, *A*, as great as 16 ft. and with a vacuum as low as 14 in.

In order to start a condenser with such a high lift it is necessary to use a "false injection," that is, a water supply delivered to the injection pipe under pressure as shown at *b*, in Fig. 256. In this case a foot-valve must be provided at the lower end of the injection pipe and a gage attached at the top of the line to show when the vacuum has raised the water into the condenser from the intake. The false injection is used only until a sufficient vacuum has been formed in the condenser bowl to raise the water from the intake. Another method of supplying a false injection is through a separate line and sprayer fitted in the bowl as shown by dotted lines at *c*. This avoids the necessity of a foot-valve and the attendant losses by friction in the flow of the water.

This type of condenser, it will be noted, has a much lower efficiency than the elevated type. Even if the lift *A* is made as great as 16 ft. there is a loss of head of 12 ft. over that of the elevated type, making a total of about 18 ft. including the loss through the condenser bowl. This loss would be but 6 ft. in the elevated condenser, or, in other words, only one-third the power would be required for handling the circulating water, assuming the pumps to be of the same type and make. If the discharge connection from the condenser is in any way open to the atmosphere at the upper end as at *d*, in Fig. 256, then the loss of head will be still greater, possibly the full 28 ft. In this case the power required would be four and a half times that of the elevated type. The discharge from the pumps should be kept perfectly air-tight, as this line is carrying air and water from the pump the same as the tail-pipe on the elevated type. If it were possible to discharge the water at a much lower elevation than the intake, then the pump could be entirely dispensed with and the water would flow through the condenser and maintain the vacuum, becoming in operation a device similar to the elevated condenser.

The discharge would in this case have to be at least 34 ft. long, and the distance from the surface of the intake to the surface of the discharge water must not be less than 24 ft. This also is true of the elevated-jet condenser, except that the latter will operate with a smaller difference between the water levels, as far as starting up is concerned, but would require the same difference in the water levels as the suction type if operated without the pump when the vacuum has dropped to 14 in.

Another important advantage in the use of the elevated type of condenser over the suction jet condenser is in the style of pumping machinery which can be used. In the case of the suction jet condenser the pump must handle a much larger volume per horsepower, as it not only has to pump the water, but the air which was contained in it as well. As this air has expanded from atmospheric pressure to the pressure in the condenser, the total volume to be handled by the pump is about eight times the volume of the injection water alone. Further, the class of work which the suction pump must do is very severe, both on the pump and the valves, owing to the shock which is caused when water and air are handled together in one pump. As the pump for the elevated condenser handles only water and that at a low pressure, the centrifugal pump is admirably suited for this class of service. It can be operated very economically either from a pulley on a jack shaft or direct-connected to an electric motor. The power required for the water-ends of the two types of pump is nearly the same when the same work must be done by each.

The steam required to drive a steam pump is generally many times that required by centrifugal pumps if driven by the main engines. The steam pump would require more than 100 lb. of steam per hp.-hr. while the main generating unit would probably use less than 20 lb. per hp.-hr. Hence, the steam required for operating centrifugal pumps would be from one-fifth to one-fourth that required by the steam pump.

If there is an insufficient supply of auxiliary exhaust steam for heating the feed water it would be more economical to run the condenser pump by steam. The reason for this is evident, as a pound of steam for the main engine would contain 1,100 B.t.u., while the pound of steam used in the pump would require but 50 B.t.u. This will be the difference between the heat in a pound of steam at boiler pressure and a pound at atmospheric pressure, as the remainder of the heat is returned to the boiler in the feed water.

In determining the form of drive to be employed for auxiliary machinery, the ability of the plant to utilize the exhaust steam must be considered. In the ideal steam plant the highest economy is obtained when the exhaust from the steam driven auxiliaries is just equal to the steam that the feed water will condense. The efficiency of these machines is then as great as possible, for all the heat which is not converted into work is returned to the boiler.

The hot-well is necessary for the successful operation of the elevated-jet condenser, as it provides a seal to keep the tail-pipe filled and prevent the access of air to it, which otherwise would reduce the vacuum obtainable. In Fig. 220 there was shown a satisfactory method of taking feed water without disturbing the water in the hot-well. Fig. 221 showed a pump box such as would be used with a suction pump jet condenser or a surface condenser. With such apparatus there is no necessity for a hot-well or water seal. A pump box would not be required for a surface condenser, as the feed could be taken from the condenser chamber as shown in Figs. 226 and 228. The most satisfactory arrangement for the pump box shown in Fig. 221 is to place it in the discharge waterway at the lower end of the discharge for such installations as shown in Fig 256, and allow the feed pump to raise the water out of its compartment. As previously stated there should be no opening to the atmosphere at the upper end of the discharge, shown at *d*, in Fig. 256 (I2–1), to accommodate a pump box above the floor.

It is true that the feed pump must raise the water higher when the pump box is placed at the discharge waterway, but it should be remembered that the feed water is only about 3 per cent of the condenser water, and it is therefore more economical to raise 3 per cent the additional height rather than to raise the 97 per cent.

As shown in Fig. 257 (I2–2), the bottom of the discharge waterway should be slightly lower at the point where the thawing-out pipe is run into the intake. The mouth of the discharge should be slightly higher than the intersection marked "low-point" to insure water flowing through the line at times of low water. The discharge of the thawing pipe should be a sufficient distance below the water to protect it against freezing. The entire thawing line should have not less than five feet of earth over it. In case the water is taken from the cooling pond it would be unnecessary to provide a thawing line to the mouth of the intake.

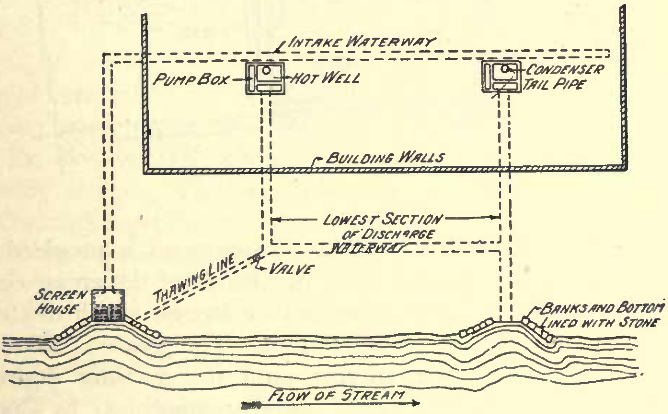

FIG. 257 (I2–2).

The mouth of the discharge into the cooling pond should be provided with an oil or grease catcher to prevent grease from getting into the pond. This is necessary not only to prevent the disfigurement of the banks and surface of the pond, but also to prevent the liability of oil reaching the boilers. A simple grease catcher is shown in Fig. 258 (I2–3). This may be constructed of wood, concrete, brick, or other desirable material. The discharge from this compartment is through an opening located as far as possible below the surface of the water. The opening from the grease-catching compartment is provided with a valve and handle for operating it. Inside of the grease-collecting compartment is an overflow into a trough which discharges into a sewer or grease-catching cistern. The grease is allowed to accumulate in this compartment until the operator desires to draw it off, the latter process being accomplished by opening the trap to observe the overflow, and by closing the valve sufficiently to cause the water level in the compartment to rise to the skimmer edge and overflow into the sewer. An objection to this skimming device is that the sewer will become clogged with the gum and grease discharged into it. To avoid this difficulty and at the same time save the grease it would be profitable to place the grease tank between the overflow and the sewer, as shown in Fig. 259 (I2–4). It may seem at first thought that the arrangements proposed are rather elaborate for the purpose of removing grease, but if some such provision is not made the condition of the pond at the end of five years or so would be unbearable. It should be remembered that all the cylinder oil leaving the engine remains in the pond, and it is very probable that 30 or

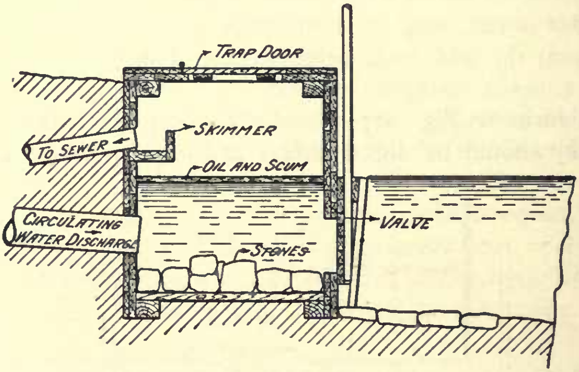

FIG. 258 (I2–3).

40 barrels of cylinder oil would be scattered along the banks, intake, etc., in this period of time.

In reference to the elevated jet condenser discharge, a modification of that shown in Figs. 253 and 254 can be made by placing the condenser bowl at the power house and instead of running the tail-pipe vertically it can be run down the bank in a covered trench, allowing ample means for expansion and contraction as shown in Fig. 260 (I2–5). The hot-well in this case would be made considerably larger. The volume of the hot-well measured from the discharge opening in the tail-pipe to the water level must be greater than the contents of the entire tail-pipe up to the condenser bowl. With this arrangement it would be necessary to run three pipes in the trench — the injection line, tail-pipe and heater supply.

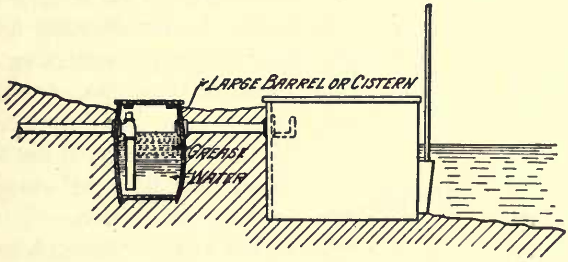

FIG. 259 (I2–4).

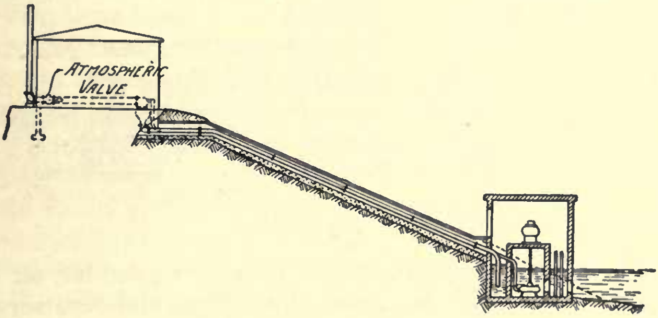

FIG. 260 (I2–5).

To provide for the low-pressure water service in the plant it would be advisable to have two small low-pressure pumps in addition to the motor-driven circulating pump. It would further be advisable to have two centrifugal pumps attached to the motor shaft, one of which should take water from the hot-well and the other from the intake. This arrangement would require four pipe lines from the screen-house to the basement. This condenser system is suitable only where the proper elevations can be secured, the distance from the base of the condenser to the water level being approximately 34 ft. In determining the details of the intake and discharge waterway and the location of the condensers, pumps, etc., the water requirements should also be duly considered. These requirements are for boiler feed, general cold water service and fire protection.

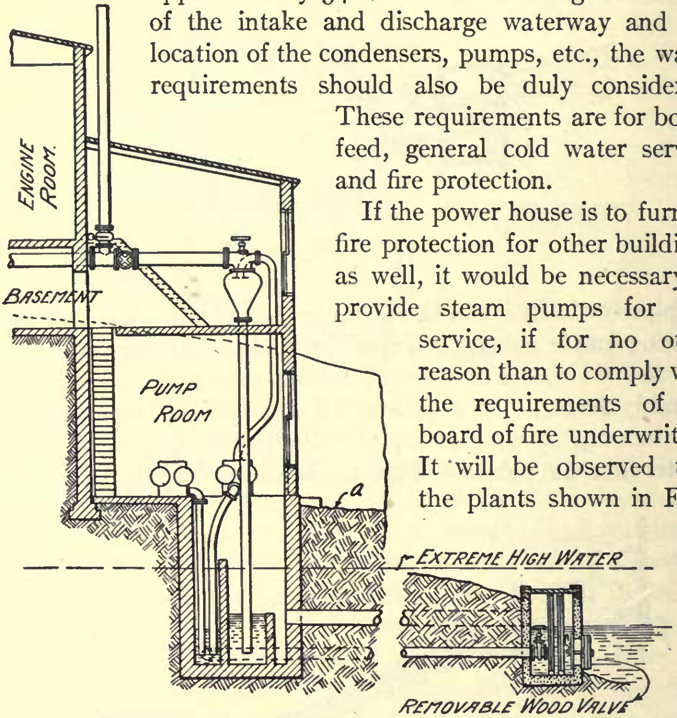

FIG. 261 (I2–6).

If the power house is to furnish fire protection for other buildings as well, it would be necessary to provide steam pumps for this service, if for no other reason than to comply with the requirements of the board of fire underwriters. It will be observed that the plants shown in Figs. 253, 254 and 260 fail to provide suitable equipment for this service. It also will be noted that these different services require electrically-driven pumps as shown, leaving only the exhaust from the feed pumps for heating the feed-water, and a loss of economy follows as previously stated under this class heading, "I–2." To make possible the use of steam-driven pumps it would be necessary to locate the floor of the pump room so low that the pump could lift the water. This can be accomplished as shown in Fig. 261 (I2–6).

The following pumps should be placed in the pump room: The condenser circulating water and underwriter's fire pumps, hot-well pump to the heater and low-pressure pump from the intake. The air pump, if employed, may be located in the room directly over the pump room.

To overcome the difficulty of opening up a trench as deep as shown for the waterway it may be found more economical to use scrapers and lower the section of ground between the condenser and screen-house so that the ground over the waterway lies just below the pump-room floor as shown by the grade lines, *a*. This would make a trench about 16 ft. deep for the intake instead of possibly 30 to 35 ft. deep. By lowering the ground in this manner there could be a door from the pump room and a walk leading down to the screen-house, and this would also provide more room for windows in the pump room, which is very desirable. If a surface condenser is employed practically the same arrangement would be adopted for a circulating pump and fire pump in the pump room, but the condenser and wet-vacuum pump would be located as close to the engines as possible. The pump room and the well to the waterway can be made considerably smaller, in fact the waterways may be run directly under the pump and be fitted with a manhole opening and ladder leading down to the water. The floor of the pump room shown in Fig. 261 may also be run over the intake and hot-well, there being no serious objection to this arrangement, as there is no machinery located in the well, as would be the case in Figs. 253 and 254. Fig. 261 unquestionably is the most practical system for plants located at a considerable distance above the water supply, as it is possible to start the pump and obtain the full vacuum before the engines are started, and thus avoid interruption caused by the opening of circuit-breakers and the stopping of the pump motors.

The system is more economical from an operating standpoint, and it would be in most cases as economical to construct as any of the other systems described, due to the fact that only standard apparatus is employed. It would be necessary in such a system to have an elevated water tank and priming lines connected to all the pumps in the pump room so that they can be started with a 14 or 16-ft. suction.

Class I3, 4 and 5 — Condenser Cooling Water; Main and Branches to Pumps and Condensers. If the plant is fitted with more than one condenser or more than one pump, a main should be provided into which all the pumps discharge and one from which all the condensers receive their water. This arrangement enables the operation of any of the pumps with any of the different condensers. Such an arrangement is particularly essential in the case of motor-driven pumps, as it permits the use of as many pumps as may be required. The pressure on these lines would be very slight, in fact they may be under vacuum, this being determined by the style of the condensers and the relative elevations of the line with respect to the condensers. Light cast-iron pipe is very suitable for this service, but special provision must be made for the expansion and contraction with changes of temperature. Valves should be placed in each branch and should also be located along the main so that each condenser unit may be isolated, together with its pumps, as shown in Fig. 262 (I3–1).

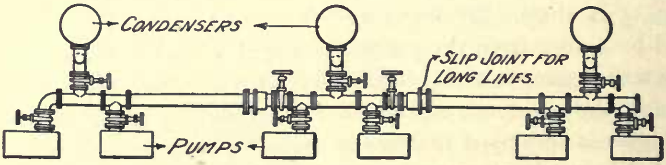

FIG. 262 (I3–1).

By arranging lines in this manner, it is possible to shut down any portion of the main to make repairs and permit the remaining portion to operate without interruption. The size of the main required is only that required for one condenser or two pumps, and for three condensers would simply be the size of the branch pipe to the condenser. This main is also desirable if the pumps are steam driven, as it makes the injection water more easy to control. A pressure gage should be placed on the main to indicate whether the pumps are delivering more water than required, which would cause the pressure to increase, or whether the supply is insufficient, which would result in a decrease. The injection valves (or admission valves to a surface condenser) are generally controlled by hand, and as they are opened or closed to meet the demand of the condensers, the capacity of the pumps is also changed, due to the increased or decreased pressure against which they are delivering. It is therefore quite impossible to keep the quantity of cooling water properly regulated, as the conditions constantly change, so that if the water supply is adjusted at a sufficiently large amount to insure the maximum vacuum obtainable, then the tail water is for the greater portion of the time at a very low temperature. If the quantity of water is reduced to raise the temperature of the discharge water, then the vacuum will be less than that which is obtainable, except when the load may be temporarily light.

The ideal method of controlling the circulating of cooling water would be by means of a thermostatic regulator operated by the temperature of the tail water, opening or closing the inlet valve as quickly and as often as the temperature of the discharge changes. Controlling the quantity of injection by the vacuum is very uncertain and undesirable, as it is evident that if leaks should occur or for any other reason, such as the condenser becoming air-bound, and the vacuum drop, the quantity of injection would be abnormally increased, resulting in too low a temperature of the tail water and a waste of power in the circulating pump, as the extra supply of injection is useless. A thermostatic regulator for controlling the quantity of the injection water is shown in Fig. 263 (I3–2). The regulator, as will be seen, consists of an expansion tube which is permanently attached to a point near the lower end of the tail-pipe and attached to the injection valve by an adjusting screw which permits the regulator to be adjusted. The length of the tube is so chosen that it will give the desired travel to the valve. As copper has a higher coefficient of expansion than cast-iron, as the temperature of the injection water becomes too high, the lengthening of the copper tube increases the opening through the injection valve, which admits more water and constantly lowers the temperature of the injection. Should the temperature of the tail water become too low, it is evident that the reverse process occurs. The shaft, sprocket, etc., shown by dotted lines on the diagram, are for a valve extension so that the valve can be operated from the floor if desired. A thermometer placed in the tail-pipe and

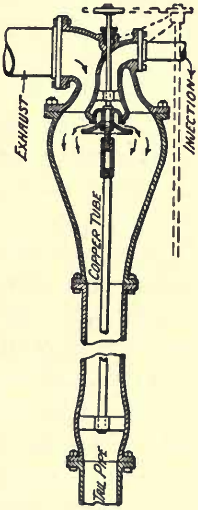

Fig. 263 (I3–2).

a vacuum gage connected to the exhaust pipe should be placed near the operating handle of the injection valve so that the attendant may observe the vacuum and temperature of the discharge when adjusting the amount of injection water supplied to the condenser.

In reading the vacuum gage a correction must be made to allow for the column of water in the pipe if there is a long drop or rise in the gage connection. Each foot of pipe filled with condensation is equal to about an inch on the vacuum gage. It is seldom that two or more vacuum gages will read the same, due to the difference in the length of their water columns. The pointer on a gauge is set to show the pressure at the gage connection, and if the pipe runs from either above or below the gage and water collects in the pipe, the gage will read incorrectly. To determine the extent of this inaccuracy, the gage should be read and the line then quickly blown out and the gage re-read, at the same time noting the pressure on some other gage to ascertain whether the pressure remained constant while the gage connection was being blown out.

Class I6, 7 and 8 — Condenser Cooling Water; Connections for Other Service than Condensing. In regular operation, the feed pump would draw water directly from the hot-well or from the hot-well pump which would deliver the warm water to an open heater, from which the feed pump would deliver it to the boiler. The fire pump would draw its water from the intake line only, regardless of whether it is supplying low-pressure main or the high-pressure lines in a case of a fire. The pump that is used for tube-drilling should have an intake connection, and the feed pump should also have a connection to the intake for use when the condenser is not in operation. To facilitate the arrangement of these different connections with the circulating water lines it is generally found that the best arrangement is to run both the intake and discharge waterways under the building in such a way that all the pumps can take their suction directly from the waterways without the necessity of using a long suction main to which the different pumps are attached, with their numerous pipe joints, valves, etc.

When laying out waterways for condensing machinery it should be remembered that there are other uses for the water which if not properly provided for at the start will lead into complicated and troublesome pump suctions. If the intake is laid out as a part of the building construction and the portion under the building is completed before making a connection to the water supply, there should be no particularly difficult features met in its construction. The location of the waterways that is best adapted for all the various connections is parallel with the dividing wall between the engine and the boiler room, the various pumping machinery being set along the wall and over or just to one side of the waterway. To avoid the possibility of loosening the soil alongside of the waterway and provide a safe footing for the division wall, crane columns, etc., it would be found both a safer and more economical construction to support the walls on the masonry of the waterway as shown in Fig. 264 (I6–1). The top and bottom of the waterway may be reinforced as shown. Sleeves should be placed in the concrete for the suction pipe to pass through, and manholes provided with ladders built into the concrete should be placed in the waterway to facilitate entrance for cleaning or inspection.

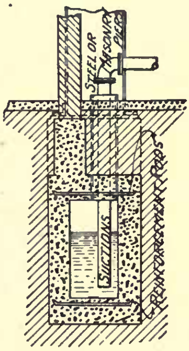

FIG. 264 (I6–1).

In nearly every case the condenser discharge line would be located at a higher elevation than the intake, owing to the variation in the level of the water supply at different seasons. If this variation is only four feet, and there is two feet of water in the intake when the water is at its lowest level, then the overflow from the hot-well should be 6 ft. from the bottom of the intake, thus making it possible for the discharge waterway to cross the intake waterway and leave at least 4 ft. under the discharge waterway for the intake. Many plants are arranged with the intake and discharge waterway next to each other, a practice the ultimate economy of which is doubtful, there being a slight saving in construction cost which is counterbalanced by loss in operation owing to the rise of temperature of the intake. If a surface condenser is to be installed both waterways should be kept at the same level regardless of the variation in the height of the water supply, and in this case a considerable saving in the cost of construction would result if the two waterways are placed in the same trench.

Class I9 — Condenser Cooling Water; Branches to and from the Cooling Tower. The various makes of cooling tower are all quite similar in their general construction and operation. Details shown in Fig. 265 (I9–1) are common to all makes. The water is distributed over the tower filling at the top and allowed to percolate through the filling downward against the rising current of air. The different forms of filling furnished by the manufacturers of water towers are ordinarily rated at 1 to 1.125 sq. ft. of cooling surface per pound of steam condensed, and the cost of the cooling tower materials, not including the foundations, brick lining, motor to drive the fan nor cost of erection, is generally from 10 to 14 cents per square foot of cooling surface. The height of the tower is generally about 32 or 33 ft., measured from the top to the bottom of the metal casing. The metal casing is lapped so that the water will not leak through the seams.

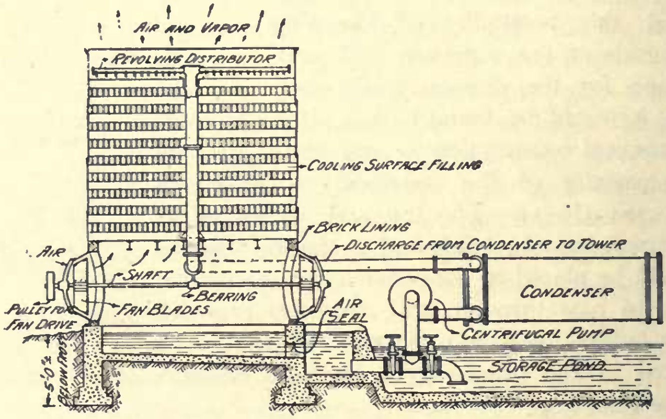

FIG. 265.

The lowest section of the casing would ordinarily be not less than 0.25 in. and the top section not less than 0.125 in. thick. The distributor is supported on hollow brass balls, and the bearing surfaces of the sleeves at the end of the discharge pipe are of brass to insure that the distributor will revolve with but very slight pressure at the nozzles. The I-beams shown to support the filling, rest on the brick lining. The air at the base of the tower being under a slight pressure, the water seal shown is required where the water is discharged from the tower to a storage basin, as it prevents air from passing through this opening. The size of fan required does not appear to be standardized among the different manufacturers, as those supplied vary from two 8-ft. to two 10-ft. fans to supply the draft for a tower for 30,000 lb. of steam per hour.

Different manufacturers employ different materials for the cooling surfaces. The most commonly used material is wood, the most satisfactory wood for this purpose being swamp cypress, in surfaced boards 1 in. by 8 in. set on edge about 1.5 in. apart. Each layer is laid at right angles to the one below it. Glazed tile is also used, unglazed tile being very unsatisfactory due to its moisture absorbing capacity. This causes the unglazed tile to freeze and crumble in cold weather when the tower is not in operation.

Another material which is quite satisfactory for filling is galvanized wire screening. These are hung from the top in such a manner that they can be easily removed and replaced when they are eaten out. The chief advantage of the wire screen construction is that it offers the least possible resistance to the flow of air through it, making it possible to cool the water by natural air draft instead of by the use of a fan. This, in itself, is quite a saving, as it requires 1 hp. for each 1,000 lb. of steam per hour which is condensed, or about 2 per cent of the power developed by the main engine. For instance, about 35 hp. is required to drive the fan for a 2,000-hp. engine. To avoid the expenditure of this power it would be economy to invest $125 for each horsepower saved, or, in other words, for a plant as stated, an expenditure of $4,375 additional for a natural draft tower would be justified. This would be five times the outlay required to pay the difference in cost of the two systems. The saving in power would unquestionably pay the difference in yearly cost of maintaining wire screens in good order. In considering natural draft cooling towers, it should be especially noted what duty would be required of the circulating pumps to determine whether they would require more or less power owing to the elevation to which the water must be pumped.

The ideal system is, of course, to raise the water the least possible distance and, at the same time, use natural draft. Fig. 266 (I9–2) shows the cooling tower arranged for natural draft and the distance, *a*, reduced to the least possible amount. This tower is shown of rectangular construction instead of round, as in Fig. 265, as the rectangular form would be more suitable where it is necessary to support it on the roof. The reason for placing this form of tower on the roof is to insure a better circulation of the air and also because the air farther from the ground is somewhat cooler.

If a surface condenser is used, the relative height of the tower with respect to the condenser is of no importance in determining the power required to handle the circulating water, as the high suction and discharge columns balance each other, and the power required for circulating the water is simply determined by the distance *a*. A surface condenser, using water thus cooled, would require about 40 lb. of circulating water per pound of steam condensed, and if a centrifugal pump belted to the main engine shaft were employed its efficiency would be about 40 per cent. Hence 100 ft.-lb. would be expended in raising the required volume of water 1 ft. Assuming the engine to be using 18 lb. of steam per horsepower per hour, the power needed to circulate the cooling water would be 1,800 ft.-lb. per hr., or 30 ft.-lb. per min. approximately, or 0.001 hp. for each engine horsepower, for each foot the water is lifted in the distance *a*. This would justify an expenditure of $0.125 per hp. for each foot of *a*. If the plant had a 1,000-hp. unit, the expenditure of $125 for the reduction of each foot of the distance *a* would be justified.

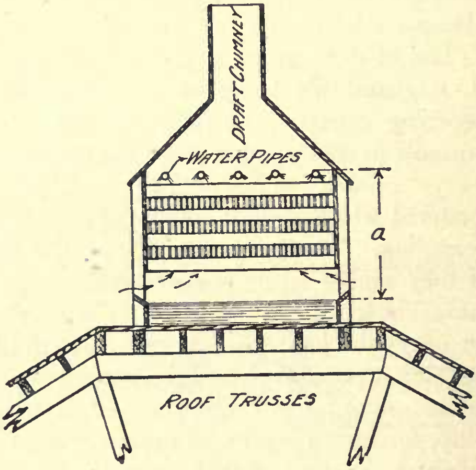

FIG. 266.

A jet condenser can be used with economy in conjunction with a cooling tower only when the tower is located so that the hot-well discharge will flow without any appreciable loss of head directly on to the cooling surface filling, and the circulating pump raises the water from the basin of the cooling tower up and into the injection pipe to the lower end of the column of water which the vacuum will support.

The design shown in Fig. 265 would require about a 30-ft. lift and the jet condenser about 7 ft., making a total of 37 ft. which the water would have to be raised. This would require approximately 0.037 hp. per horsepower of the main engine. If the water could be taken from the cooling pond the loss of head through the tower would be eliminated, thus making the power required for the condenser but 0.7 hp. per 100 hp. of the engine.

The surface condenser is better suited for operation with the cooling tower, as it can be located at almost any elevation and avoid any head loss other than that required at the cooling tower and the friction head of the piping system. There are many installations, however, using elevated cooling towers and the suction type of jet condenser, as shown in Fig. 267 (I9–3). This makes a very inefficient installation. The head on the injection pipe is entirely wasted, being resisted by closing the injection valve at the condenser. The distance from the pump to the outlet at the top of the cooling tower is frequently as much as 60 ft. Assuming 18 lb. steam per hp.-hr. of the main engine and 40 lb. of circulating water per pound of steam condensed, and a pump requiring 120 lb. of steam per hp.-hr. and having an efficiency of 60 per cent, we find that the circulating pump requires 24.2 lb. of steam for each 100 lb. of steam delivered to the main engine. In other words, the condenser pump requires as much steam to operate it as is saved by operating the engine condensing. It may be that a slight economy is secured in such an instance, due to the auxiliary exhaust steam being delivered to the feed water heater, but the question is, why is not apparatus which is suited to each particular installation

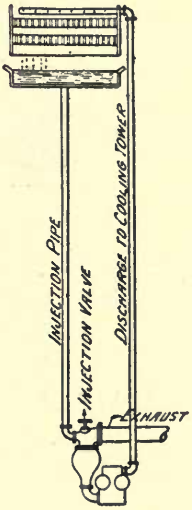

FIG. 267 (I9–3).

employed? By using a surface condenser and the distance *a*, 10 ft., the steam consumption of the condenser pump would be but one-sixth as great as in the preceding case, or about 4 lb. of steam for each 100 hp. delivered to the engine. This steam, however, would be condensed in the heater and the heat returned to the boiler, thus a very good return on the investment in the cooling tower, condenser, etc., would be secured.

The heat required to operate the pump would be about four times 46 B.t.u. and the engine 100 lb. at 913 B.t.u., or, $\frac{184}{913} = 0.2$ B.t.u. for the condenser for each 100 B.t.u. required by the main engine.

The most conspicuous loss in the operation of condensing machinery in conjunction with cooling towers is that occasioned by the long water line between the cooling tower and the condenser, these lines invariably having a large number of turns and restricted passages. In fact, this difficulty is also conspicuous in the condenser; in receiving bids on the condenser this point should be given careful consideration, as the difference in cost of different apparatus may be deceiving, the higher price being oftentimes the cheaper when the cost of operation is considered. If the lines between the cooling tower and the condenser are long, it is always good practice to increase their size, as the fixed yearly cost on the difference on the investment is less than that saved in the operation. Pipe bends should be used in place of elbows, as each elbow in a 12-in. line, for instance, is equivalent to about 40 ft. of pipe. The piping is oftentimes made more compact by using elbows of short radius, etc., as shown in Fig. 268 (I9–4) for condenser No. 1, but the resistance in the line of piping is thereby increased. The loss by friction of water flowing through the system shown in

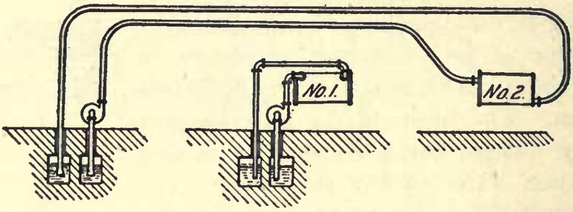

Fig. 268 (I9–4).

No. 2 is no greater than that shown in No. 1. The losses occasioned by short radius ells and square ends at the pipe inlets and outlets makes the avoidable losses of No. 1 amount to about 300 ft. of pipe if it is 12 in. in diameter. This saving is sufficient in itself to permit running the line to the top of the roof or an outdoor cooling tower and not show so great a friction loss as that of the short connected system shown in No. 1.

The amount of water lost by evaporation in the cooling operation varies; systems using cooling trays with air circulating under them require less than that necessary for boiler feeding, being as low as 0.5 lb. loss by evaporation for each pound of steam condensed. This system requires a very large tray surface, as its operation is dependent upon radiation only. Systems in which the air is passed through the water require much less surface, as the heat is taken up by evaporation as well as by radiation. This style of water-cooling will lower the temperature as much as 15 degrees below that of the surrounding atmosphere, a reduction in the temperature of the water of as much as 50 degrees. With 50 degrees difference in temperature the amount of cooling water required would only be about 20 lb. per lb. of steam condensed. If the loss is 7 per cent, then 1.4 pounds of cooling water would be evaporated for each pound of steam condensed. In regular practice it has been found that the water fed to the boiler is sufficient at all times to provide for the evaporation, this being due possibly to the fact that when the load is very light the fans would not be used, thus reducing the loss by evaporation, the cooling by radiation to the air passing through the tower by its natural draft being then sufficient to cool the water. In cold weather it is generally necessary to draw off a portion of the cooling water, as the evaporation is then less than the water fed to the boiler; this being the case where the cooling water is not used for boiler feeding.

CHAPTER XIX.

CONDENSATION, AIR AND VACUUM LINES.

Class J1 — Condensation and Air Line from Condenser. Surface condensers and elevated jet condensers can easily be arranged to remove the air separately by what is termed a dry vacuum pump. Such a pump is designed to handle air only, and the usual construction is similar to the crank and fly wheel type of air compressors. The piston speed of this type of pump is generally high, 400 ft. per min. being approximately the normal speed. The clearance is reduced to the least possible amount and in many other ways the pump is designed especially for compressing air, and if by accident even a small amount of water is drawn into the pump, it is liable to be damaged. The total piston displacement of a dry vacuum pump is generally greater than the total displacement of the water circulating pumps, but seldom exceed it by more than 50 per cent. The amount of air discharged by a dry vacuum pump is only a small portion of the piston displacement, and because of the expansion of the air contained in the clearance spaces, compression, resistance of the valves, ports, etc., the quantity discharged varies from 10 to 15 per cent of the piston displacement.

The different types of condensers either permit of or require a different method of handling the air or, more correctly speaking, the non-condensable vapor. In a jet condenser, these vapors are mingled with the circulating water and if the water contains organic matters, the volume to be handled would be very much greater than in a surface condenser. Though the elevated jet type of condenser would have the greater amount of air to remove it requires less special provision for removing the air than the surface condenser.

There are many elevated jet condensers which are maintaining a vacuum of 25 and 26 in. which have no provision made for the removal of air other than that of the downward flowing column of cooling water, having only centrifugal pumps to maintain the vacuum. Condensers of this type are generally constructed the same as an ejector with the water and the steam meeting in a restricted passage, both having a downward flow at the point of meeting. Owing to the velocity of the mixture of steam and water through the restricted passage, the air which reaches a condensing chamber is carried downward through the tail pipe together with the circulating water and is discharged into the hot well.

The velocity of the water in the tail pipe varies from 250 ft. to 500 ft. per min. being greater in large than in small condensers. By using a dry vacuum pump on large size condensers, it is possible to maintain a high vacuum, say, 26 or 27 in. and requires only sufficient water to condense the steam, thus increasing the temperature of the hot well water, which is desirable if it is to be used for boiler feeding.

Though this saving is conspicuous in the larger sizes, it is doubtful whether there are any advantages attending the use of dry vacuum pumps on condensers smaller than 16 in. diameter of exhaust.

There is a special design of elevated jet condenser which employs two tail pipes, one being restricted in size and designed for a high water velocity to eject the air and discharge it into the hot well. The other tail pipe, which is of sufficient size to carry away all the water which the ejection pipe will not discharge, has its opening from the condenser bowl at a higher elevation than the ejection pipe opening. A condenser designed on this principle is shown in Fig. 269 (J1–1) and it has been claimed that a vacuum of 26 and 27 in. has been maintained with a high temperature of the water in the hot well, and no other means provided for removing the air other than the air ejection tail pipe. This being the case, but very little additional machinery and apparatus is required with this condensing arrangement, the circulating pump being any one of the standard low pressure designs, the one which is most flexible and efficient being a direct connected engine type centrifugal pump, the exhaust of which is piped to the feed water heater.

The dry vacuum pump is not wholly necessary with surface condensers, but unlike the elevated jet condenser some provision must be made for removing the air with a pump, either of the wet or dry vacuum type. Air that accumulates in a surface condenser is in the compartment together with the condensation and in no way comes in contact with the circulating water. The movements of the condensations are comparatively slow and not sufficient to remove the air. The air may be taken together with the water, or separately, as shown in Figs. 28 and 29. The wet vacuum pump is that most generally used and is so termed because it handles the air together with the condensation. This class of pump is also used for the suction type jet condensers to remove the air and condensation, and when so used is generally styled an "air pump." The class of service is practically the same for both condensers, the jet condenser having approximately thirty times as much water to handle and a correspondingly greater amount of air. The action of this combined air and water vacuum pump is somewhat peculiar, its jerky motion not being generally understood. Fig. 270 (J1–2) shows the wet vacuum pump attached to a condenser. When the pump is in regular operation, but little condensation is being handled, and that is well down in the suction pipe. When the pump is discharging the contents of the water end, one side is under pressure marked + and the other side is at the same pressure as the condenser and is marked –. The pressure behind the steam cylinder is also under pressure marked +, this pressure being maintained sufficiently high to overcome the pressure on the water end marked +. The work performed in compressing the contents in the water cylinder

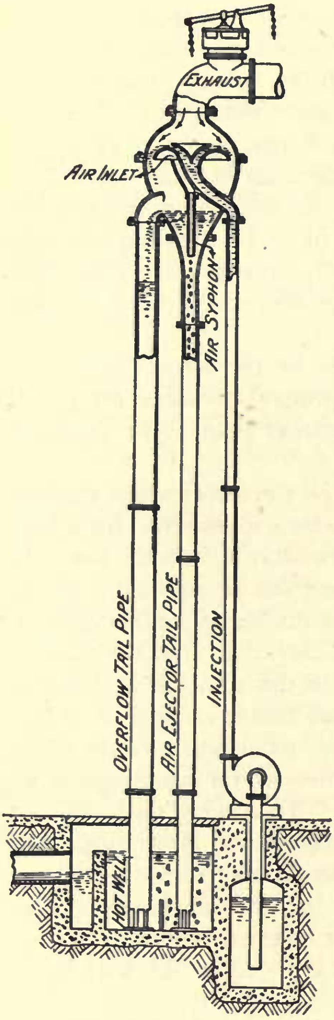

FIG. 269 (J1–1).

marked + is similar to compressing a spring. The air contained in the water cylinder being the elastic body, as soon as the steam valve has crossed over the port and allowed the exhaust port to communicate with the end of the cylinder that has been under compression, the support in the steam cylinder is taken from the end of the piston rod, and the compressed air in the water end marked + is free to expand, thus causing the quick recoil so conspicuous in this class of machinery. The recoil movement will reach almost the full stroke when the pump is running above speed, and when there is no recoil the pump is taking only water, the air in this case accumulating in the condenser and by keeping the steam from the condensing surfaces, reduces its capacity and as the capacity becomes less than that required to condense the steam delivered to the condenser, the vacuum drops.

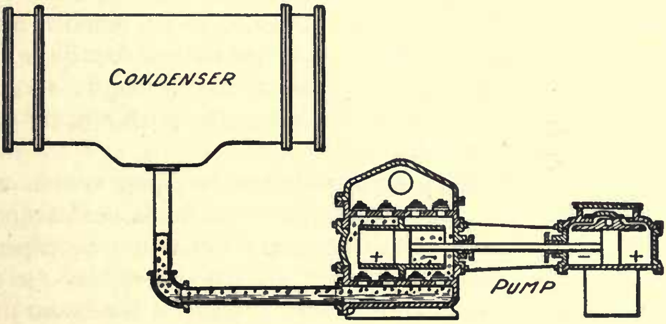

FIG. 270 (J1–2).

The amount of air that is being handled can easily be judged by the amount of recoil. The amount of recoil necessary for successful operation can only be determined by observing the vacuum, as the volume of air is largely dependent upon the tightness of the piping, stuffing boxes, etc. When the amount of recoil of the pump piston reaches nearly the full stroke, it is an indication that there are air leaks which should be located at once and made air tight. This is in many cases a very difficult operation, both the locating of the leak as well as to close them after they have been found. One of the most positive methods of showing up the leaks is to fill the vacuum system with water and put a slight pressure on it, about 10 pounds to the square inch, and while the pipes are filled with water make a careful inspection oi the entire system, marking, or drawing up all joints and stuffing boxes where leaks are found. In case the exhaust pipes are large, it may be necessary to place posts under the pipe to support the additional weight, as 10 ft. of 24-in. pipe will contain about 3,000 lb. of water. Another method of locating leaks in the system is to create a low vacuum on the system, say five pounds, and with a small pointed brush, shellac the joints, observing carefully where the shellac is drawn in. Many of the small leaks can be closed in this manner, but where large leaks are found it may be necessary to make a new joint. Another method, but quite crude, is to give all the joints a heavy coat of pitch, while the vacuum is maintained on the system, trusting that the pitch will fill up the cracks and stop the leaks.

If gas is obtainable at the plant the entire piping system can be filled with gas and leaks located by a candle passed around the joints. The quantity of gas necessary would not be expensive, 1,000 cu. ft. being sufficient to fill a large system, say 140 ft. of pipe 3 ft. in diameter. To fill a line with gas, it is necessary to fill it with steam and then close up the system, and as the steam condenses allow gas to fill the pipe.

Considerable trouble is experienced with the use of metallic packing for piston rods, valve stems, etc., on account of the air leaking past them. The piston rod packing can be improved by carefully removing it from the stuffing box and marking the parts so they will go back in place. The high spots should then be carefully scraped so that they exactly fit the rod and thus assist the packing to wear down to a perfect bearing. The motion of the parts of the packing is quite slight, and as they are made to wear slowly an air-tight fit may not be secured for a considerable time if the operator waits for it to wear to a perfect fit, and if the leak is very serious, it would probably never wear tight, as the wear caused by the leakage would exceed that of the rod and therefore the leak would become larger instead of smaller. The low-pressure cylinders are subjected to such low temperatures that almost any form of fibrous packing may be used for them successfully. Fibrous packing may require more frequent attention and renewal and may eventually cost more than metallic packing, but since the loss of vacuum is often 2 in. in the case of metallic packings, which are apparently in good condition, the fibrous packing will probably be the most economical unless the packing manufacturers will guarantee to install and maintain the packing so that it will remain as tight as fibrous packing.

Each inch of vacuum loss is equivalent to about 1 per cent increase in the cost of operation, which would amount to about $440 a year in the case of 1,000-hp. engine operating 12 hr. a day. The cost of packing and expense of keeping it in good condition is small compared to the loss caused by a drop in the vacuum. Stuffing boxes should be, if possible, arranged so that either fibrous or metallic packing can be used, and the engine should preferably be so arranged that the change from metallic to fibrous packing and the renewal of packing can be made without dismantling the engine or interfering with its regular hours of service.

Class J2, 3, 4 and 5 — Dry Vacuum Mains and Branches. A dry vacuum main is necessary where there is more than one condenser and more than one dry vacuum pump, as it permits the use of one pump on one or both condensers. The mains should be tapped at the top for branches from the condenser and the pump connection should be taken from the bottom. This detail is quite important to insure the draining of all condensation to be removed from the main through the air pumps in a small continuous volume. There is no objection to passing the condensation through the pump if it is in the form of mist, as it aids in reduction of the compression temperature in the air pump cylinder, but it is unsafe to allow the condensation to enter the air pump in slugs, for the air pump would undoubtedly be seriously damaged, as the piston speed is high and the clearances small. The probable result would be a broken cylinder head, valves, connecting rod or other part.

The dry vacuum main should have a slight uniform pitch toward the air pump opening to prevent the accumulation of condensation in pockets and a valve on the pump suction should be located directly below the main as shown in Fig. 271 (J2–1). This arrangement avoids the possibility of the branch filling with condensation down to the valve, a detail which will not permit of draining on account of the line being under less pressure than the atmosphere. The valve between the pump branches is necessary so that repairs can be made to the main while the condenser on the other side of the valve is in operation. The valves, *a*, located close to the air pump, should not be less than one-fourth the diameter of the pump suction, and they should be of the globe form to insure tightness. These valves are necessary in starting the pump, to permit it being brought up to speed before the full vacuum is put on it. After the pump is in operation the branch line valves should be opened slowly so as to permit the water which has accumulated above them to leak slowly past and through the pump. The temperature of the air entering the pump is generally about 120 degrees, which is increased considerably by the compression in the pump cylinder, so that water jackets are necessary to keep the cylinder cool, as previously stated, under the heading Class H6. The discharge from the pump is quite dry, due to the heating in the cylinder, and may be discharged over an open sewer or the like, with some provision for getting rid of the oil and grease carried over by the air. If this air is objectionable in the engine room, it can be discharged into the atmospheric exhaust line, as there would be practically no saving in heat units, the temperature of the feed water in the heater being nearly as high as the air.

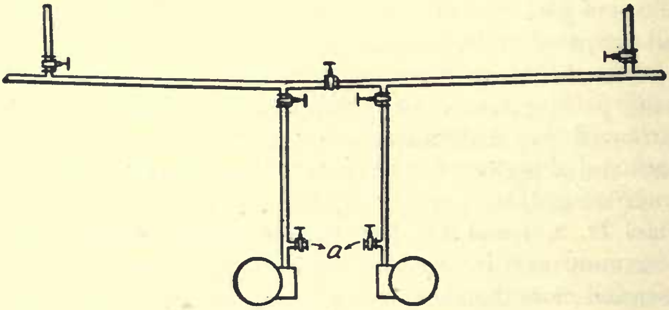

FIG. 271 (J2–1).

The dry vacuum main and branches, as illustrated in Fig. 271, may be used for either an elevated jet or a surface condenser, the details being the same in either case. The elevated jet condenser discharges air together with the tail water whether a dry vacuum pump is used or not, the dry vacuum pump simply being more effective, keeps the condensing chamber freer from air and thus permits a higher vacuum to be maintained. The air which is discharged through the tail pipe into the hot well tends to form vapor, hence if the hot well is located in the engine room it should be ventilated, as this hot vapor is generally very foul, being largely the gas liberated by the decomposed matter carried in the injection water. Fig. 272 (J2–2) shows a well ventilated by an air duct which is carried to the outside of the building above the grade line. The manhole cover and the tail pipe should have an air-tight fit at the top of the well to prevent the discharge of gases and vapor into the engine room.

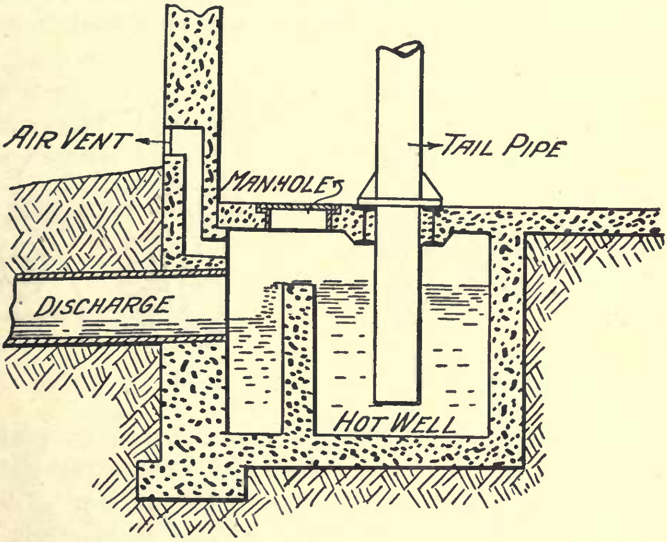

FIG. 272 (J2–2).

As previously stated the dry vacuum pump is a much more efficient device for removing the air from the condenser than the wet vacuum pump because of the small clearance spaces which are permissible at the cylinder ends. In addition to this they have mechanically operated suction valves, usually of the form shown in Fig. 273 (J 2–3). This valve has a "flash port" passing through it. The object of this port is to reduce the pressure of the air which remains in the clearance space immediately after the completion of the compression stroke and by communicating with the opposite end of the cylinder increase the pressure on the other side of the piston shown at *b*, which is about to be compressed, so that the air can be discharged into the atmosphere through the poppet valves shown in detail in Fig. 274 (J2–4).

These poppet valves should be securely held in place, but in such a manner that they will not be burned in, as would be the case if threaded and screwed into the cylinder. The valve proper should be as light and as strong as possible. The best material to use for the valves is bar steel or steel castings machined so as to reduce the weight, the shell of the moving part being about one-sixteenth of an inch thick. The bridges shown in the section *AB*, Fig. 274, should have at least 0.25 in. bearing to guide the steel poppet valve. By making the poppet of steel the valve faces will wear better than if both parts of the valve are made of brass. The set screw in the cap should be set firmly against the valve and secured from movement by a lock-nut set up tight, this construction taking the strains without endangering the small bridges in the air port. The usual construction is to place the valve at the side of the cylinder lying horizontally. A better construction is to place the valve at the bottom of the cylinder in a vertical position, thereby reducing the wear of the valves and also insuring the pump against injury from water, as the valves located in this position will keep the cylinder drained of water. The admission valve shown in Fig. 273 is mechanically operated to avoid the resistance offered by the poppet valve. The area of of this type of valve must be about 6.5 times that of the discharge poppet valves to avoid throttling on the suction stroke. A back pressure of one pound would hardly be noticed in the discharge, but such a drop through the suction valves would materially reduce the capacity of the pump. The capacity of the pump would be reduced fully one-half and would necessitate a 2-in. higher vacuum in the pump than in the condenser to overcome the resistance through the valves. By employing mechanically operated valves the area of the ports can be made sufficiently

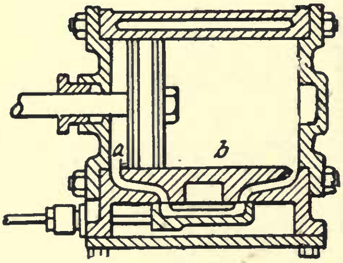

FIG. 273 (J2–3).

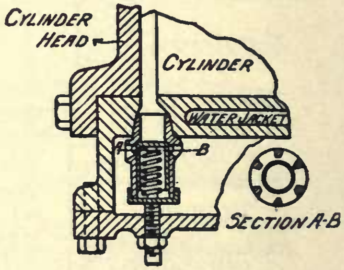

FIG. 274 (J2–4).

large and tight to avoid slippage, which would occur in large poppet valves closing slowly when lightly loaded. If a high vacuum, say 28 in., is desired, it is necessary to use a dry vacuum pump or at least a pump with mechanically operated suction valves.

A type of pump which is now being quite extensively installed for high vacuum service, which is designed to handle air and water mixed, is that termed the suction valveless pump as shown in Fig. 275 (J2-5). In this design the piston is pointed so that it strikes the water without shock and drives the water of condensation under the piston out through the ports of the cylinder at a high velocity, which carries the air with it on the same principle as an injector. The movement of the piston closes the ports and the air and water are discharged through the head valves after compression. On the downward stroke of the pump a higher vacuum is formed in the cylinder, *a*, than exists in the condenser at the same instant, and the air therefore rushes into the cylinder as soon as the ports are uncovered by the piston, and this is further assisted by the injector action of the water which follows immediately, and as the piston is moving very rapidly the ports would probably be covered before any backflow from the cylinder had a chance to occur. Be that as it may, however, the high efficiency and successful operation of this type

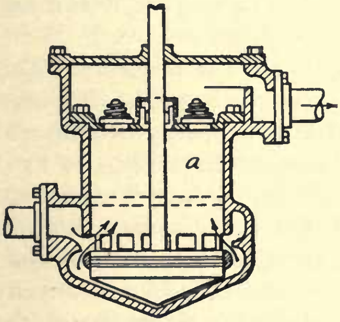

FIG. 275 (J2-5).

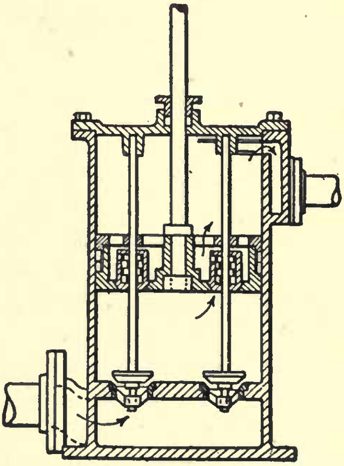

FIG. 276 (J2-6).

of pump is fully established and demonstrates its ability to remove air and condensation under a vacuum of 28 in.

The special advantages of the suction valveless pump are that it has no bucket or foot valves, which constantly need care and renewal, and are generally very difficult to get at for repair.

It is possible to use poppet suction valves, but in such cases they should be mechanically operated, as shown in Fig. 276 (J2-6). Both suction and discharge valves are mechanically operated in this pump, the operation of the valves being accomplished by the friction packing rings inside of the discharge valves. In the accompanying illustration the suction valves are shown open on the upstroke, the valve rods being drawn upward by the friction, which likewise closes the discharge valves when the piston is on the upstroke. On the downstroke the friction of the packing pushes the valve rods down, thus closing the suction valves and opening the discharge valves. The friction of the packing rings must always be maintained sufficient to sustain the weight of the valves and valve rod. This arrangement of valves permits the air and water to be discharged and drawn into the pump without any appreciable loss of head.

Class J6–7–8 and 9 — Condensation Main and Branches. This class of service pertains to surface condensers only. The condensation alone or with the air contained in it may be delivered to an open heater by the pump running continuously at a fixed speed, or the pump may be regulated by a float if the pump handles the condensation only. If the condensation pump is governed by a float it cannot handle air mixed with condensation. In this case the water of condensation may be delivered directly to the boilers, as shown in Fig. 226, through a closed heater, the condensation pump in this case being that employed for feeding the boiler. With this arrangement, though extremely simple, it is necessary that the pump be located at a sufficient distance below the condenser discharge, so that the weight of the column of water in the pump suction pipe will be sufficient to raise the valves of the pump and completely fill the pump cylinder without the necessity of maintaining a greater vacuum in the pump cylinder than in the condenser.

The details shown in Fig. 276 would not be suitable for high pressure such as would be required in boiler feeding, and furthermore this detail could not be employed, as the diameter of the pump necessary for boiler feeding would be far less than is necessary for the type of valve construction there shown. For high pressures the outside packed plunger pump is better suited, as it is at all times possible to ascertain exactly what the leakage is and the condition of the packing. In Fig. 277 (J2–7) is shown an outside packed plunger pump, which is packed by removing the cover plate over the suction chamber, *a*. The suction valves in this pump, as will be seen from an examination of the drawing, are mechanically operated by the movement of the plunger rod, upon which the valves are mounted. The discharge valves are of the usual heavy type employed for boiler feed pumps. The two brass plungers, which are free to slip on the rod within the limit set by the collars, *bb*, have valve seats turned on them at their outside ends. In operation the motion of the pump rod is transmitted to the plunger through the suction valve, which causes the valve to be firmly seated and kept tight by the pressure against the end of the hollow rams, and being mechanically opened, give free access for the water through the suction end. A feature which will be evident from an examination of the drawing is the large suction valve area presented by this type of construction. This type of pump is especially suited for direct steam drive with the steam cylinder at the other end of the piston rod. From its construction it will be easily seen that this pump is well adapted to handle air and water together, but is not suitable for use as a dry vacuum pump on account of the large clearances.

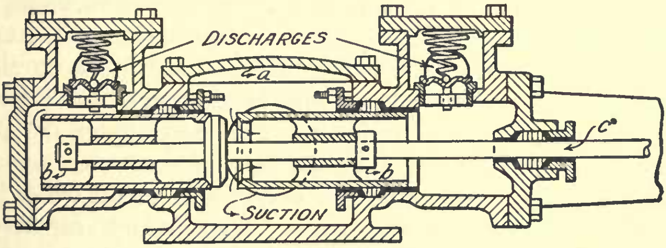

FIG. 277 (J2–7).

To insure a high efficiency the design of a dry vacuum pump should be of the crank and fly wheel type, so that the clearances may be reduced to the least possible amount, as shown in Figs. 275 and 276. This type of pump shown in Fig. 277 would be more efficient for handling air and water combined if the valves on the piston rod closed against the other end of the ram, closing against the ram from the same side as shown, the valves being located inside of the ram. The air pumps shown in Figs. 275, 276 or 277 cannot be used if located a considerable distance below the condenser, as shown in Fig. 226. For these types of pump the suction lines should be carried from the bottom of the condenser to the suction chamber of the pump along practically a level line, giving the air a free path to the air pump over the surface of the water in the suction line. If it is necessary to place a wet vacuum pump a considerable distance below the condenser, owing to the use of spring loaded suction valves, it is then necessary to keep all the water pumped out of the suction pipe in order to permit the air to flow freely to the pump cylinder. This necessitates the pump being run at a higher speed, and by keeping the water out of the pump its capacity for handling air is decreased as the water is not present to fill the clearance spaces. The greatest capacity for handling air is obtained when the water taken at each stroke is just sufficient to fill the clearance spaces.

The condensation pump is oftentimes located in an out of the way place owing to the position of the condenser, and, in fact, it is sometimes necessary to set other pumps in positions where it is impossible to provide ready means for observing their operation. The most necessary operating condition to be observed is the speed at which the pump is running. This can be easily ascertained by arranging an indicator at a point readily observed by the operator. A simple detail for such an indicator and one which permits the indicator to be placed in almost any location is shown in Fig. 278 (J2–8). The indicator piping is attached to one end of the steam cylinder or water cylinder and the change of pressure is noted by the rise and fall of the water in the gage glass, there being one movement for each stroke. The upper valve, *a*, is kept closed while in operation, the lower one being open. The quantity of air in the glass can be increased by manipulating the different valves, closing *c*, opening *b*, closing *b*, opening *a*, and drawing off the water through *e*. To

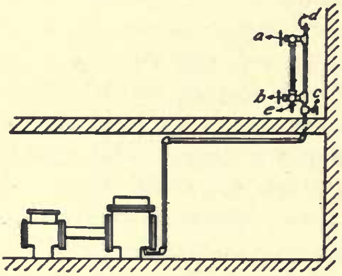

FIG. 278 (J2–8).

raise the water line have *c* open, draw air at *d* and close *b*, open *a* and discharge contents of glass as much as required through *e*. The operation of this device is due to the air confined in the upper part of the gage glass, the volume changing as the pressure on it changes. Not only can the speed be observed with this gage but also the regularity of motion. The liquid in the glass may be colored, but for continuous service it is better to use clear water, as nearly all colored liquids mark the glass where the liquid and air come in contact. It will be better to use galvanized iron or brass pipe and fittings, as they would reduce the danger of the glass becoming soiled and therefore make it possible to observe the motion of the water more easily.

CHAPTER XX.

CITY WATER PIPING.

Class K1 — City Water Main. Plants that are provided with their own water supply soon become very careful in the distribution and use of city water. It is only a plant in which no other than city water is obtainable in which the employees of the plant become wasteful in its use.

In laying out the piping system of the plant which is to be operated entirely with city water many different methods can be introduced which will reduce or avoid the use of water. For example, instead of using hydraulic turbine tube cleaners, power cleaners should be employed, as they are successful in any plant and especially so in plants which use only city water. Instead of using furnaces having water cooled parts some other type should be used to save the continuous loss of water. Instead of the bearings being water cooled they should be made sufficiently large to run cool without water. Instead of ashes being dropped into metal hoppers or other receptacles which necessitates their being wetted they should discharge into a masonry hopper, allowing air to the grate to carry off the heat.

If the water contains a considerable quantity of scale-forming salts it should be treated chemically in a purifier in order to reduce to a minimum the quantity of water wasted in blowing off. Little has been accomplished in the design of an exhaust condenser, a device which would save practically all the water fed to the boilers by condensing. Such a condenser would in all probability be constructed on the same general principles as an ejector, the ejector, however, having the greater amount of work to perform, as it takes water from a state of rest and at a lower pressure.

An exhaust ejector would take air at practically the same pressure as the air it would discharge against. One cubic foot of air requires 0.0686 heat unit to increase its temperature 1° F., or, if air is taken at 65 degrees and delivered at 205 degrees, the increase in temperature would be 140 degrees, which would require 9.6 heat units per cubic foot. Exhaust steam would have 965.7 latent heat units per pound, and as the volume at atmospheric pressure is 26.36 cubic feet per pound the exhaust steam would contain 36.6 latent heat units per cubic foot. To condense 1 cu. ft. of steam therefore would require 3.8 cu. ft. of air.

A system of condensing the exhaust steam by means of atmospheric air is shown in Fig. 279 (K1–1). The exhaust pipe is shown in the center of the air flue, the object being to increase the temperature of the air to create a draught. The air would, however, be drawn through the flue by the flow of steam through the ejector flights. The upper section is shown as a water and air separator.

In the arrangement of a condenser of this character, it must be noted that the exhaust travels at a high velocity, possibly 5,000 ft. per min., and the air at 1,000 ft. per min., which is quite rapid, about that obtainable by a high stack. To what extent the air would be accelerated by the exhaust ejector is quite problematical and to secure the greatest difference in weight of air in the chimney, and that without, it may be advisable to place the condenser at the base of the chimney, causing the entire column of air to be at the highest possible temperature. If the capacity of the chimney is less than the exhaust blower or ejector, then the increased length of stack would simply offer resistance to the flow of air, as is the case of a high smokestack placed

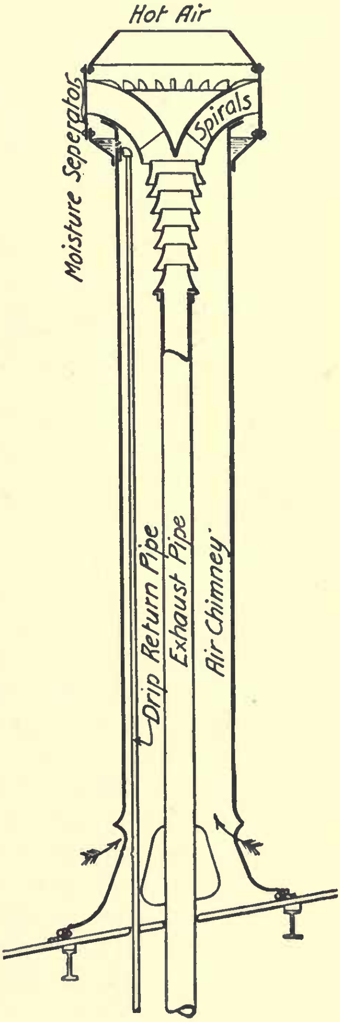

FIG. 279 (K1–1).

over the fan of an induced draught plant. It is quite probable that the air chimney would have to be fully twenty times the area of the exhaust, or about four and one-half times the diameter of the exhaust pipe. The air can be supplied from a blower, but it is very doubtful if the saving in water expense would justify or equal the interest depreciation and operating cost of such an arrangement. A plant equipped with an exhaust condenser would not require an exhaust heater, as it is possible to feed the cold make-up water into the exhaust condensing chamber, thereby aiding the process of condensation and heating the water. To use more water for the purpose of condensing would be just so much water wasted, as there would be no use for it, and it would therefore be discharged into the sewer. The amount of water added to take the place of that lost in the form of vapor would be close to 10 per cent of that fed into the boilers. To prevent an excess of air passing through the chimney, shown in Fig. 279, it is possible to provide a thermostat in the return drip pipe, which could operate a damper or series of dampers, controlling the quantity of air passing through the chimney. This would be necessary to maintain the condensation at a high temperature for boiler feeding.

One objection to such a condenser is the increase of difficulties arising from cylinder oil, as all the oil is returned to the boiler feeding system, but it has the advantage of materially decreasing the amount of scale-forming salts admitted to the boiler. A saving of fuel and water in electrical plants using city water can easily be obtained by using motor driven auxiliaries instead of steam driven auxiliaries. The greatest difficulty experienced with motors for this service has been that only one speed was obtainable, but there are now a large number of different types of variable speed motors on the market, which have a wide range of speed with nearly a constant efficiency. These motors are principally used to drive machine tools, some of them having a range of 5 to 1, that is, the speed is variable from full speed to one-fifth the full speed.

Plants which have their own water supply and are within reach of city waterworks should have a connection to the city main of sufficient size to supply the boilers. Invariably the city connection is so made that it is a source of loss to the waterworks. The most common method is to connect the city water to fire hydrants and install a meter at the point where the city water enters the building, as shown in Fig. 280 (K1–2). The system as shown is primarily laid out for station convenience and reliability. The fire hydrants are taken from a fire system located on the outside of the building, fitted with a valve *A*, which admits the city water to it. There is no meter placed between the city mains and the hydrants, partly on account of the liability of the meter becoming damaged under severe working speeds and thus shutting off the flow of water. As the hydrants

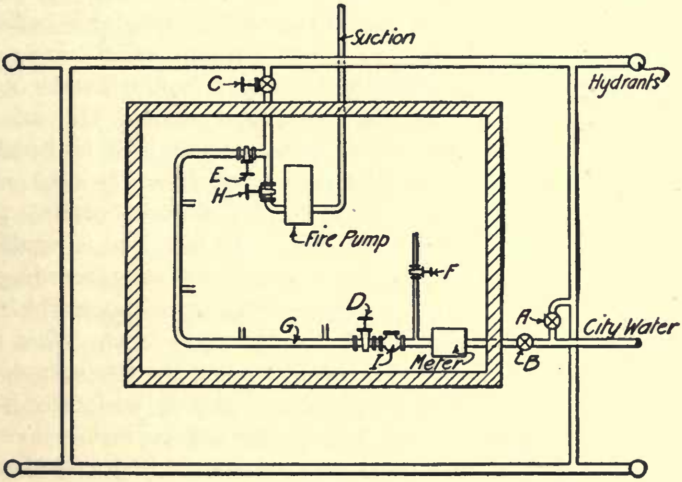

FIG. 280 (K1–2).

are a protection against fire the city is expected to furnish water for this service. The valves *B* and *C* close all connections into the building to prevent loss of pressure in case of fire and damage to the inside piping. In regular operation it is assumed that the valve *A* is closed, *B* open, *C* open, *D* closed and *H* and *F* open. This places the outside fire lines and inside boiler and miscellaneous service line *G* on the station water system and its fire pump shown in the illustration, the only city water being that taken for drinking purposes and wash basins through the valve *F*. The assumption is that the city water would be used for fire service only, in case the fire pump is thrown out of service, or, if the water supply of the power plant fails, city water could be run into the lines through the valve *D*. The plan looks honest, and if used as stated it would be. The chief engineer of the plant knows how much water has been used, and if at any time it becomes necessary to stop the fire pump and use city water, the assistant is liable to be reprimanded, and consequently to obviate this he would open valve *A* and cut off the pump at *H*, thus allowing the city water to flow around through the fire mains back to the general main to supply the boilers without registering on the meter. From the operator's standpoint there can be no objection to this plan except that it makes possible the presentation of an excessive water bill in case the waterworks inspector should find the valve *A* open. If the station operator is perfectly honest and does not want to place a means of obtaining city water without passing through the meter in the hands of his employees, he can employ the following system: The valve *A* should be sealed to prevent its being moved without breaking the seal. The valve *B* should be open and valve *D* closed under ordinary conditions. The check valve *I* prevents station pressure from backing into the city lines. In this case it would be necessary to make arrangements with the waterworks regarding the valve *A*, some predetermined damage being agreed upon which can be collected in case the valve *A* is found open at any other time than immediately after a fire, the seal being the property of the waterworks. The valves *A*, *B* and *C* should be located sufficiently distant from the building to permit operating them in case of a fire, and if against a wall they should be a considerable distance from windows or door openings to permit access to them. An excellent arrangement for placing valves *A* and *B* would be to have a hose at the fire department house about 50 ft. from the building with the valve posts inside, or along the side of the building. Fire service is seldom or never needed, and to familiarize the employees with its location and operation it is generally a good plan to have the parts of the fire system exposed so that they are constantly in sight of the employees.

Ordinarily but one meter is placed in a station, one that is large enough for the ultimate emergency requirement, as shown in Fig. 280. If the city waterworks is satisfied with this arrangement it should be satisfactory to the station operator. The small line *F* is oftentimes but one-half or three-fourths-in. piping and the meter a 3 or a 4-in., with nothing flowing through it except the water passing through the small line. The leakage past a large meter is sufficient to supply all or a large part of that used from the small line, and to get the correct reading a smaller meter should be installed for ordinary use and the large one for emergency service.

Class K2 — City Water Connections to and from the Meter. A suitable location for the water meter is sometimes difficult to find. The meter in any case should be properly protected from frost. If located in the basement of the building it is liable to be subjected to low temperatures which injure the meter, and in such cases the meter should be placed in a brick well outside of the building with a tight cover over it, and a small drain run from the bottom of the well to a sewer or to low ground. To further protect the meter from extremely low temperatures straw should be placed over it to prevent air from circulating in the well. These meter pits are objectionable, as they are generally damp and cause the iron parts of the meter to become rust eaten, and are in inconvenient places to get into to read or make repairs. Ordinarily a well-constructed wooden box around the meter would protect it from the lowest temperatures found in the basement, and if arranged so that the box can readily be removed repairs are more easily made. To prevent freezing it is first necessary to confine the air surrounding the part to be protected, and, second, to prevent the air from circulating as far as possible.

If the meter is placed inside of a building, proper means should be provided for shutting it off and all other inside piping to prevent waste of water in case of fire. Such an arrangement is illustrated in Fig. 280, in which a valve is shown outside of the building. If the water lines from the meter carry only city water and have no connection with any other water supply system, then the check valve and stop valve on the discharge side of the meter is unnecessary. If the meter is constantly in service there should be a by-pass around it with a valve in it which can be sealed by the water department to prevent water being drawn from the system without registering on the meter. A by-pass is necessary to permit uninterrupted service while repairs or adjustments are being made to the meter. Before making such provisions, however, the details of the arrangement with a sketch should be submitted to the city water department for approval.

Class K3 — City Water to Plumbing Fixtures. Ordinarily this service presents no unusual features, the most conspicuous feature being that the city water enters the building quite cool, and, if the lines pass through warm basements, the course of the pipe line is generally outlined along the floor by the constant dripping from the cold pipe. This difficulty can be overcome by burying the pipe line, but in power plant work the pipe lines are wherever possible kept out of the ground to facilitate repairs, etc. By encasing the pipe with a cheap wool felt covering, the annoyance of sweating is overcome and at the same time the water is thus kept at a lower temperature. The different wrought-iron pipe lines used for conveying water to and from the plumbing fixtures should be galvanized to avoid as far as possible the stain caused by rust from black pipes, which gives the plumbing fixtures a very untidy appearance. This point should be observed both for cold and hot water lines to the plumbing fixtures.

Before determining what faucets are to be used for the city cold water it would be advisable to ascertain what water is to be used for hot water service, since it may be found simpler to use high pressure valves and take hot water from the feed main under boiler pressure. This point is more fully explained under Class D10. The washstands in power plants would become exceedingly dirty if some care were not exercised over the men using them, and although white enamel basins are difficult to keep clean they are the only kind that should be used. Their untidy appearance assures that greater care will be taken in keeping them clean.

Class K4 — City Water to Low Pressure Water System. This service is shown in Fig. 280 and would ordinarily only be an emergency connection, the regular service being taken from the station water supply. Such connections as this are quite necessary to insure continuous operation, and how to avoid the abuse of these provisions is oftentimes a serious problem. It is a well-known fact in station operation that systems having two or more means supplied for meeting an emergency are not as carefully looked after as those having no reserve supplied. The result is that where city water is connected to the station system for emergency service it is generally quite extensively used, even though it be at a loss to the company and could to a great extent be avoided.

Possibly as effective a method as can be followed for reducing the waste of city water is to have the water meter reading placed on the daily station log, showing from day to day the amount of water used; also a line from the operator to state the reason why the valve, *D*, in Fig. 280, was open. The most satisfactory method of taking these readings is to print the dials on the record sheet and let the operator mark the position of the pointers, from which the chief engineer can figure the water consumption instead of intrusting it to an assistant. Mistakes are easily made in reading meters, and if the chart were used it would reduce the possibility of error to a minimum.

Class K5 — City Water Connections to Boiler Feed Main. If the power station has its own water supply the city water supply should not be connected with the boiler feed main. The pressure carried on a city main is not sufficient for boiler feeding. This necessitates joining the city water connection to the auxiliary feed main. Here the supply can be used under a low pressure without interfering with the regular boiler feeding. If the plant is run with city water only then this latter connection should be used, since it enables the operator to wash or fill boilers without running any pump.

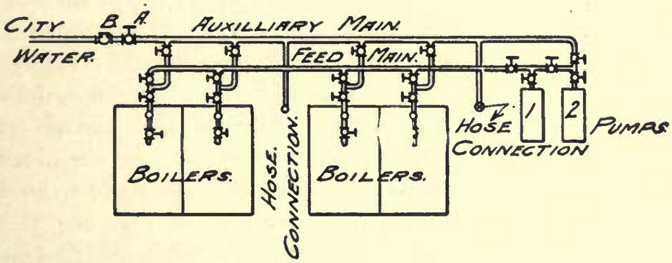

FIG. 281 (K5–1).

Fig. 281 (K5–1) shows an auxiliary main arranged so that under ordinary conditions it will be supplied with city pressure as far as the pumps, thus making this water available for wetting down ashes, etc. When pump No. 2 is supplying the auxiliary main with water under high pressure for operating turbine tube cleaners there will be no water at low pressure available as far as valve *A*. This, however, would not be a serious objection in most boiler rooms. To avoid damage to the low-pressure city lines, if an operator should start the pump without closing the valve, *A*, a check valve, *B*, should be fitted in the low-pressure main, as shown.

Feed water can in an emergency be obtained by means of a fire hose if the city fire plugs are properly located. This would make the use of city water more troublesome to the operator and would be an evidence readily seen of his neglect in caring for the system that should be in operative order.

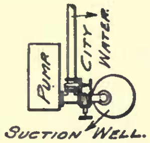

Fig. 282 (K6–1).

Class K6 — City Water to Pump Suctions. Plants which have city water available should have the city service connection of sufficient size to feed all the boilers. All continuously operated plants should have two separate feed pump suctions, whether there are two different sources of water supply or only one. Plants having both their own and a city water supply should have the city water delivered directly to the pump suctions, as shown in Fig. 282 (K6–1). It is not best to deliver the water into the suction well, since it may be found necessary to empty this well for making repairs.

The city connection may be made quite small, possibly one-third the diameter of the regular suction pipe. Water is delivered through the city lines under pressure, and such lines are too seldom used to justify a reduction of pipe line losses by the use of a large pipe. If a plant is operated entirely on city water there should be two separate city connections, as shown in Fig. 283 (K6–2). To provide this arrangement it may be necessary to use two meters. If two taps are not provided the plant might be without water if the city main to which it was connected should be shut off for repairs, or for any other cause. Fig. 283 shows a power plant located at the intersection of two streets and connections made to two mains with two valves in the city mains between the connections. If there were but one valve, either *A* or *B*, then it would be necessary to connect with the city mains beyond another valve, as shown by the dotted lines in Fig. 283. This would necessitate the use of another meter, also shown dotted. By connecting to the mains in this manner water is obtainable whenever it is necessary to shut off the water on both sides of a city valve. The use of two meters permits a more accessible piping layout. It also affords means for repairing any part of the main and yet have one pump in service.

The most satisfactory piping layout is one with two separate suction lines from the pump to the water supply. A valve should be placed between these two suction mains to separate them whether water is obtained from two city or two private sources of supply.

If the suctions are taken from two private sources, such as a pond and its tributary stream, they should be from two points which are as far from each other as possible. Thus, if the stream is muddy the suction can be taken from the pond, or, if the pond should be empty, the suction can be taken from the stream. If water is available from only one source, such as a small stream, which is not continuously available either because of too little or too much water, which would oftentimes cause it to be very muddy, then another reserve supply is necessary, either in the form of a pond or an artesian well.

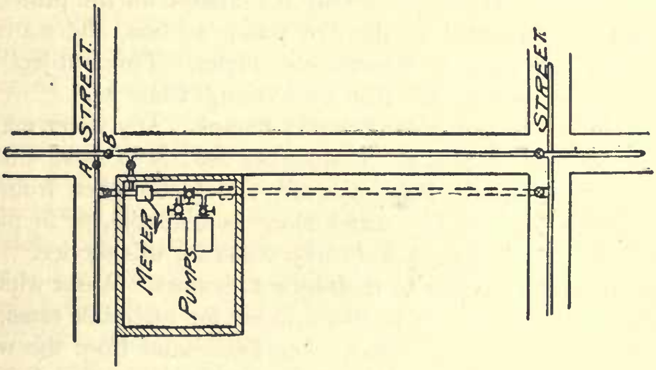

FIG. 283 (K6–2).

Class K7 — City Water to the Heater. A plant operated entirely on city water would have a connection to the float controlling-valve if an open heater is used, in which case this would be a regular service connection. If the plant has its own water supply it will also have a low-pressure water service and a connection from this low-pressure service to the heater. To supply city water for emergency purposes it is ordinarily delivered to the low-pressure water mains which are connected to the heater.

If these mains are not properly laid out, necessitating their being entirely out of service when repairs are made, it will be more satisfactory as regards reliability to connect the city water directly to the heater. This connection can be a permanent pipe line, or a temporary hose connection may be employed if a hose valve is attached to the heater. If the valve is of the proper size to fit fire hose, the water supply during periods of repairs can be taken from a fire hydrant.

Class K8 — City Water to Fire System. The pressure carried on city water mains is generally low, about 20 to 30 lb. per sq. in., and consequently when a large number of streams are taken from a fire hydrant this pressure is almost entirely lost in overcoming the friction in the pipes. Power stations are generally large and high buildings, necessitating the use of high pressure on the fire lines. If city water only is available for fire protection it should be connected to the fire pump suction, the water at such times not passing through the meter. This subject will be taken up more fully in "Fire Protection," Class M.

Class K9 — City Water for Priming Pumps. Any water may be used for priming pumps, as the quantity used is so small that its quality is immaterial. Priming water should be taken from the city mains only where city water alone is available, or in plants which have no storage tank to furnish water for this service.

Class K10—City Water to Hydraulic Elevators. Water which is suitable for boiler feeding is also suitable for hydraulic rams, etc. It would be necessary to remove any loose sand from the water for either service. If the plant is run with city water then the ram should be of such area that the lowest city pressure would operate it. The resistance of the ram stuffing box and the loss of head due to the velocity of flow are usually so great that the theoretical pressure under the ram should be twice that which is actually necessary to operate it. This subject will be taken up more fully in "Hydraulic Elevators — Class O."

Class K11 — City Water to Engine Journals. City water instead of the regular station water would be used for cooling journals if the latter supply were too warm to be effective. Rather than use city water it would be more economical to use a greater quantity of the station water. If city water has a temperature of fifty degrees F. and the station water is fifteen degrees warmer and the discharge from the journals has a temperature of 150 degrees F., then the city water is raised 100 degrees, whereas the station water is raised 85 degrees. This difference in practically all such cases is too slight to justify the use of city water.

If city water is used exclusively then it should be discharged into a drip main located so that the water will drain into the heater. Funnels should be fitted so that the drip flow may be observed. If the heater is located too high to permit the use of a gravity discharge, the sights may be made air-tight, as shown in Fig. 284

(K11-1), permitting a back pressure on the engine journals, sights, etc. To avoid the loss of the air confined in the glass body such sights should be placed where there is the least pressure.

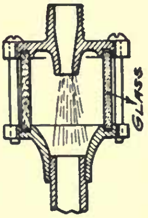

FIG. 284 (K11-1).

Another method of determining the flow is to use in addition to the regulating valve a three-way valve, one discharge being into the heater and the other into an open funnel connected to the sewer. To determine the amount of water flowing the valve can be turned to discharge into the funnel, and again placed in its normal position, thus turning the discharge into the heater.

Class K12 — City Water to the Damper Regulators. If no other water of constant pressure is available to operate the damper regulators, city water may be used for this service. Especially is this true if the pressure is low, say about thirty lb. per sq. in. The use of boiler feed water or steam condensation is extremely objectionable due to the destructive effect on the controller valves.

The working piston of a regulator should be of sufficient diameter and stroke to operate the dampers while under low pressure. The work of moving the damper must be done by one stroke, the return of the damper being effected by a counterweight. Therefore the capacity of the regulator cylinder must be twice that necessary to move the damper alone. If a force of forty lb. is required to move the damper when in any position, then the effective capacity of the regulator cylinder should be eighty lb., or twice this, which would be about 150 lb. pressure on the piston rod. If the lowest pressure on the water main from an overhead tank is fifteen lb., the regulator would require a piston about 3.5 in. in diameter, a much larger size than the manufacturers of regulators care to furnish. However, if constant and satisfactory service is desired low pressure must be used.

Class K13 — City Water to Pressure Oil Tanks. Water is frequently used to raise cylinder oil from its storage tank through pipe lines into the lubricators. Almost any supply will perform this duty satisfactorily. If engine oil is being put under pressure by means of water it is quite essential that a fairly uniform pressure be maintained. If the station has a gravity water storage tank, then a more uniform pressure is obtainable by connection to the storage tank than can be had by using city water.

Class K14 — City Water for Drinking Purposes. Drinking water supply is a service that cannot be dispensed with, and though every other service is supplied from the station pumping system it is generally necessary to use the city water for drinking. It may be that the station water is cleaner and, in fact, may "sparkle," but yet it may have properties which affect the employees of the power house, more particularly if they are accustomed to city water. Considerable time would be saved if a drinking place were located near the firemen and another convenient for the engineers.

These pipe lines should be of galvanized iron carried underground and exposed to the heat of the building as little as possible. In all probability this piping connection can be installed without passing the water through the large station meter. This will require paying the regular water rate. By making proper provision in this regard but little time and water are lost when an operator goes for a drink. If a pipe runs 100 ft. or more through a hot room the station employees are apt to let the water run for a considerable time until sufficient cold water has been wasted to cool the hot pipes. Drinking water is as important in a power plant as the feed water for the boilers, and should be given the fullest consideration.

Class K15 — City Water to Other Buildings. Whether the water for the different shops, barns, etc., is to be taken through the power station meter depends largely upon how complete an accounting system is employed. Ordinarily it is much more satisfactory to have a separate record of the water used in the power station and that used in the shops, and if sprinkling cars are operated possibly a separate record also of the water used for this service. If the city water department will not install so many small meters they can be installed by the consumer and placed in separate buildings. This permits calibrating them and using them as a check on the main meter.

CHAPTER XXI.

ARTESIAN WATER PIPING.

Class L1 and 2 — Artesian Water to Pumps and Water Tanks. The use of artesian wells is not as general as the advantages accompanying their use warrant. The question of water supply should be the first to receive consideration in deciding upon a site for a power station. The coaling facilities can, as a rule, be more easily provided than a suitable water supply. A surface water supply, such as a creek or stream which gives ample water for 9 or 10 months and runs dry a month or two, is of little use as a source of water, since it is necessary to provide some other source of supply for the remaining portion of the year.

The cost of raising water, say 100 feet, from a driven well is not excessive if the pump is motor-driven. In this case the pump discharges against a 50-lb. head. Allowing for friction, each theoretical horsepower costs but approximately one-half cent per hour if the plant is equipped with compound condensing engines. One thousand horsepower of capacity, assuming a steam consumption of 20 lb. of steam per hp. per hr., would require 20,000 lb. of water per hour, or 333 lb. per min. If this is raised 100 ft., the theoretical work done is at a rate of approximately 33,300 ft.-lb. per min., or 1 horsepower. If the efficiency of the pumping plant is 50 per cent the actual horsepower delivered to the pumps will have to be twice the theoretical, thus making the cost of pumping the water required by 1,000-hp. plant for one hour about one cent. This is assuming that the water is allowed to discharge into a cooling pond in which the loss by evaporation is equal to the water required for feeding the boiler.

At the cost just estimated for the 1,000-hp. plant the cost of pumping 1,000 gal. of water would be 0.004166 cent, a cost which is much lower than that for which any waterworks system can sell water. The cost of repairs and depreciation must be added to these figures. Regarding the capacity of a deep-well pump, it should be borne in mind that it should be at least twice the normal load capacity; that is, if 333 pounds of water are required per minute, the pumps should not have a capacity of less than 666 pounds per minute. This additional capacity is required to permit the storing of water for emergency purposes or to supply the plant while repairs are being made. Motor-driven pumps can have a stroke of 24 in., but to have a long life they should not make over 35 strokes per minute, which would require a 5-in. water cylinder to supply the 1,000-hp. capacity as stated.

In determining the size of the deep-well pumps required, the capacity of the plant upon which the capacity of the pump is based should not be the average horsepower as determined from the horsepower-hours daily output of the plant. For, a plant may have engines of 2,000-hp. capacity, but develop only 20,000 hp.-hr. in 20 hours; in which case the pump should have an hourly capacity sufficient for 2,000 hp., this being twice the average output. Ordinarily the pump should have a capacity equal to the steam machinery installed, and some system of water storage should be provided — one of considerable capacity, so that if the deep-well pump should be out of service for two or three days no shortage of water will be encountered.

If the condensers discharge into a cooling pond this pond would be of ample capacity, since it would ordinarily have 10 sq. ft. of cooling surface for each pound of steam condensed per hour. A drop in the water level of 1 foot would therefore furnish sufficient water to supply the plant for 62 hr. or three days. This does not include seepage losses, a waste which must be considered when determining the capacity of pumping machinery. If the pond is built in clay or lined with clay, the seepage loss will be quite slight. There are many storage ponds constructed on ground 20 feet or more above that surrounding them, which are used to store the rain and melted snow which fills them during the early spring for use during the summer months. Water stands in these ponds with but little drop of level, this drop being caused more by evaporation than by seepage.

It may be desirable to put in an overhead tank to supply the low-pressure mains, but this is of no practical use for a reserve water supply for boiler feeding unless the plant is exceedingly small. For instance, a plant of 1,000 boiler hp. would require a tank of about 40,000 gal. capacity to run 10 hr. Forty thousand gallons is equivalent to 5,000 cu. ft. or a tank would be required

10 by 20 by 25 ft., weighing 65 tons when filled with water. If there is no cooling or other pond where water can be stored, then a cistern may be constructed in the ground, the sides and bottom being finished with cement concrete, much the same as a cement floor or sidewalk.

If water from the city waterworks is available a large storage tank is not so essential, but if in any case a storage tank must be provided it should be in connection with the deep-well pump, so that the latter can be discharged continuously for a long period without being compelled to work in unison with the other pumps. The deep well is generally located a considerable distance from the plant, and by using storage tanks of five hours' capacity of the deep-well pump, it will avoid starting or stopping the pump except at long intervals. If an induction motor is used, started by a switch in the engine room, and the storage tank is located where it can be seen from the power house, a telltale must be provided so the operator can ascertain when the reservoir is filled. The device shown in Fig. 285 (L1-1) permits the deep well and storage tank to be located at some distance from power house. The standpipe in the power station has a telltale attached, which can, if desired, be fitted with an electric high and low water alarm, brought into contact by the telltale. The automatic high and low water alarm should require little or no attention. This form of telltale is the most approved automatic indicator, since it has no work to do but make and break the bell circuit, which notifies the attendant to open or close the pump motor switch. This requires possibly one-half minute of the attendant's time every five hours or so. The connection from the storage system to the power house should be of ample size, say twice the size of the pump suction, in order to insure the water level in the telltale being approximately the same as that in the cistern. As there would be no appreciable pressure on it,

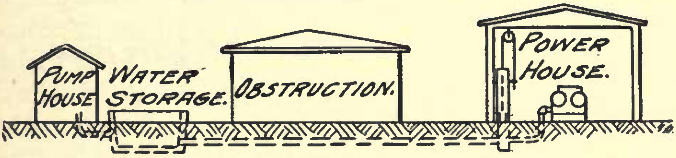

FIG. 285 (L1-1).

such a line of piping could, in almost every case, be constructed of sewer tile. Tile pipe would not be desirable if the cistern water level were above the ground level.

To insure the telltale showing correctly, a small pipe, say one inch, may be laid in the same trench with the pump suction and be used merely to operate the telltale, thus permitting the use of a smaller metal suction pipe. An ideal power station arrangement is secured if the storage cistern or pond is built upon a hill high enough so that the water from the cistern will be under sufficient head to serve the low-pressure water service in the power house, shops, etc. The feed pumps taking this water under pressure would avoid the difficulties caused by air, etc. The pressure corresponding to an elevation of from 20 to 25 ft. is generally sufficient for any service other than boiler feeding.

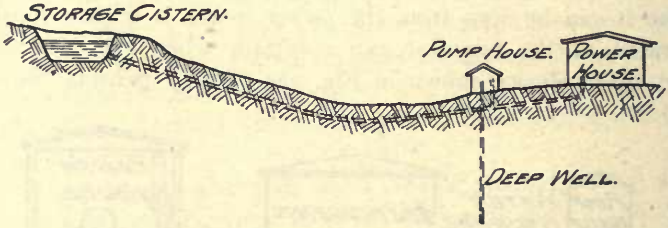

FIG. 286 (L1–2).

It is quite immaterial where the storage tank is located. If the desired head is obtainable by placing the storage tank 500 ft. or perhaps more from the power house, it would be better practice than to maintain a pump in operation simply for supplying the low-pressure system. A power station which has its storage cistern located on a hill is shown in Fig. 286 (L1–2).

The artesian well is very seldom found within the power station, though there is no reason why it should not be, and there are many good reasons why it should be in the main building, as the cost of the pump house would be dispensed with. Further, being in a high-roofed room it would be very easy to remove the pump rods from the casing or raise the casing itself if necessary. The reason that artesian wells are generally located in separate buildings is that designs for the power house are completed, decided upon, and work on the power house started before work on the deep well is undertaken. If a deep well and its driven head are to be located in the main building, it is necessary to decide this point long before work is started on the buildings in order that the well drillers may complete their work and remove their drilling derrick before work on the buildings is started.

In order to avoid having the well interfere with the location of some other machinery, it is absolutely necessary that its location be very carefully considered before the well drilling is started. Such is, however, not the general method of doing things.

In most cases the well is not located and the contract is not let until the water is absolutely needed. It is because of the order of doing things that the artesian well is located outside the power house, not that it is not wanted inside, but simply because it would seriously delay the construction work. When drilling a well a steam line should be run from the power house to the driller's outfit, rather than rely upon the small vertical boiler of the latter's apparatus. Much time and money can be thus saved by avoiding delays, etc.

In sinking wells, it is found perfectly practicable to use outside connected couplings, when casing is driven through the loose earth only. When rock is reached the casing is allowed to set upon it, and the drilled hole is made the size of the bore of the casing pipe, no casing being used through the rock unless a great depth is to be reached. In this event the casing pipe is reduced in size and is passed through the rock, as shown in Fig. 287 (L1–3). The joints in the lower casing are made as shown in detail in this figure. The purpose of the casing through the rock is to prevent loose pieces of rock from falling into the drilled hole. In many instances the rock can be drilled, leaving a clean hole without the use of the casing.

Whenever it is possible to place the pumping cylinder in the upper or larger casing, this is done, since it permits the use of a larger cylinder. To be able to reach water of a lower elevation and not to be compelled to reduce the working cylinder to suit the size of the smaller casing pipe, the pump suction with a strainer at its lower end is carried down a full length of the pipe, about 20 ft. There is no danger of this strainer striking the bottom of the well, since it is invariably sunk considerably deeper than absolutely necessary, possibly 50 ft. or so below the pump cylinder. How much deeper it is sunk than necessary to obtain water depends upon the performance of the well and the judgment of the well driller, whose judgment is generally accepted.

The pump cylinder is attached to the drop pipe, as shown in Fig. 288 (L1–4), the bore of the cylinder being about 0.25 in. less than the bore of the drop pipe, to permit removal of the pump piston or foot valve. Cup leather packings are universally used for these pumps. The drop pipe does not rest on its lower end, the pipe being fixed at its upper end and left hanging free from this upper support. Fig. 289 (L1–5) shows a drop pipe supported from the pump head. The cap *A* is removable to permit the removal of the sucker rod, piston or valves when necessary without disturbing the pipe connections. If the drop pipe is to be removed it can be done by disconnecting the bearing *B* and the joint *C* without unscrewing any pipe work. Ordinarily the base of the pump head is fixed at the top of its foundation and the upper portion is arranged to slide back out of the way. The

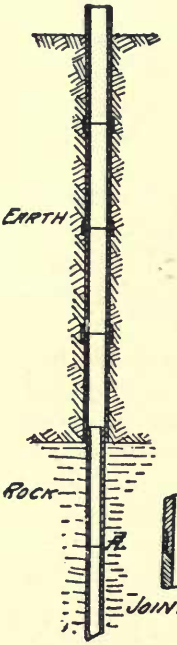

FIG. 287 (L1–3).

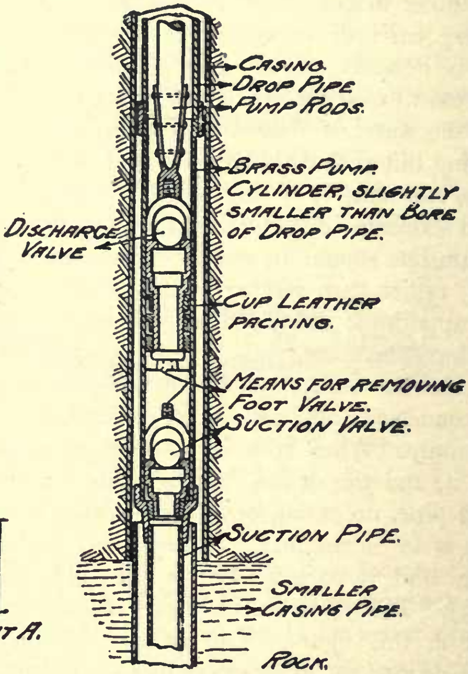

FIG. 288 (L1–4).

use of a drop pipe is the most approved practice for the construction of artesian wells, and only in emergency cases should the locked cylinder be used.

If a well having an abundant supply of water is fitted with a pump of insufficient capacity, there are two methods of increasing the capacity of the pump. The stroke may be increased or the diameter of the pump may be increased. The best method is to increase the stroke. A 16-in. stroke pump is ordinarily run at 30 strokes per minute or at a plunger speed of 480 in. per min., and a pump with a 36-in. stroke would ordinarily operate at 20 strokes or 720 in. per minute, a gain in capacity of 50 per cent. If an 8-in. casing is used a 5.75-in. cylinder would be used with a drop pipe, and if it is of the locked form about a 7.25-in. cylinder would be used, giving about 60 per cent increased capacity. By increasing the stroke as well as the diameter the capacity of the pump can be increased nearly two and one-half times.

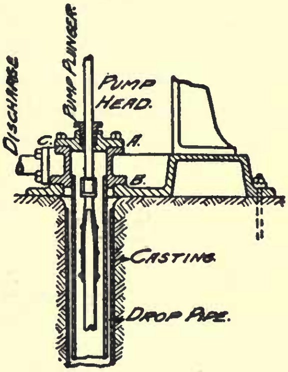

FIG. 289 (L1–5).

There are numerous types of locked cylinders which, if they become too securely locked, would probably have to stay whether or not they leaked between the cylinder and the casing. Such makeshifts may be justified in the case of an emergency, but should be avoided in designing new work. The locked cylinder is lowered into the casing and locked or packed to the driven casing, no drop pipe being used in this case. The cylinder in this case is made as large as can be lowered through the driven casing.

For power station use motor-driven artesian well pumps are far superior to steam-driven pumps, as they are more economical to operate and are in many ways less troublesome.

Class L3 — Artesian Water to Power House. If the artesian well water is the only available water for the power house, some means should be provided for a double supply. This is necessary not only to make repairs but to insure water for operation in case some part of the system should give out and require being thrown out of service. Fig. 290 (L3–1) shows a storage cistern and well connected to opposite ends of the suction main. If it became necessary to shut off the main from the well to the pump or from the storage cistern to the pump, it could be done without interfering with the other supply.

A relief valve should be placed in the discharge line from the deep-well pump without any valve between it and the pump. This relief valve would ordinarily protect the deep-well pump and permit the excess water to return to the well when the storage tank is shut off from the feed pump, and the latter necessarily takes water from the deep-well pump direct. Provided the storage cistern is sufficiently elevated to give the desired head, the low-pressure system should be piped as shown, so that its service will not be interrupted if either the pump or tank should be shut off. If the storage cistern is at a low elevation so that the feed pumps take water by suction, then one of the feed pumps could provide the low-pressure water using the auxiliary feed main for the low-pressure supply.

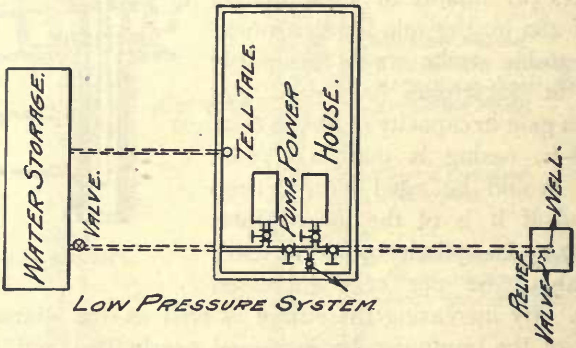

FIG. 290 (L3-1).

Pump suction lines are essential for continuous operation, and the plant in no case should be made wholly dependent upon any one pipe connection for its continuous operation. The underground pipes should be of cast iron the same as that used for city water pipes. A telltale pipe can be run from the storage reservoir to the power station, as shown in Fig. 290 and also in Fig. 285, the pipe being laid in the same trench as the supply pipe instead of independently, as shown.

Class L4 — Artesian Water to Other Buildings. Ordinarily the buildings located near the power plant are supplied with water from the low-pressure general service main or the fire main if the latter is intended to serve for both the general and the fire service. The water for the plumbing fixtures in the power house and other buildings when taken from the general low-pressure main should not be considered to be in any particular class of water supply if there is more than one. For instance, the low-pressure system may be supplied with deep well water to-day, storage cistern water to-morrow, and perhaps with city water the next day.

The distribution of water from its original source should be considered only with respect to the systems served and not by the apparatus itself. For example, Fig. 290 shows a system of supplying artesian water to the storage tanks, the pumps and the low-pressure main. The services supplied from these sources do not belong to the artesian water system, but solely to the system which takes artesian water when it can get it and other water when artesian water is not obtainable.

Class L5 — Artesian Water to Fire Mains. If a plant is wholly dependent upon artesian water for its water supply, or if there is a possibility of too small a supply of water being obtained from a stream, it will be found necessary to hold water in storage for use in case of a fire. An artesian well may have a capacity of but 60 gal. per min. and take 16 hr. to fill a storage pond or cistern, yet together they may make a reliable water supply for fire protection. There are cases where large pumps are not available for fire service, and it is safer to elevate water to a high tank, say 125 ft. from the ground, using a deep well pump for this service. For power stations a better arrangement is to provide a storage tank on the ground, of much greater capacity, not less than 100,000 gal., and use a fire pump of large capacity. This storage tank may be arranged as shown in Fig. 290, and in case of fire both feed pumps could be used for fire service.

In this arrangement the pumps installed should be such that one is especially suited for fire service, but applicable for boiler feeding, and the other designed for boiler feeding, but suitable for fire service as well.

Class L6 — Artesian Water to Condensers. There are difficulties encountered in the use of most artesian well water which appear conspicuously in the boiler. The use of such water in the condensers tends to diminish these difficulties because the temperature of the water is increased, and it is delivered to a large pond where the solid matter contained in it can settle. If the jet type of condenser is to be used, the piping system can be simplified by placing the water storage tank, shown in Fig. 290, so that its extreme high water level will be 12 or 18 in. below the top of the hot-well, this ordinarily being the basement floor line. If an elevated pond were employed to supply the low-pressure service, the hot-well would likewise have to be elevated, which would thus necessitate the use of an unsatisfactory construction.

Ordinarily the reserve feed pump will likewise serve as a fire pump, and if the low-pressure service is taken from the fire mains the pumps will always be ready for fire service. In this installation a double system of suction lines to the feed pumps must be provided, and also means must be afforded for the feed pumps to take water from the hot-well and the fire pump to take its water from the pond, or, better still, from the deep well discharge, the latter arrangement being shown in Fig. 291 (L6–1).

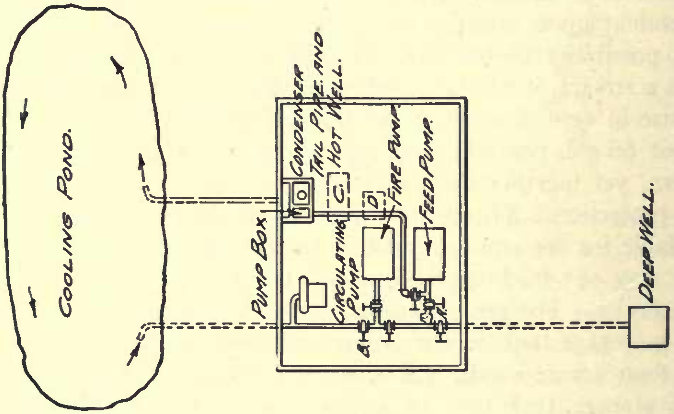

Fig. 291 (L6–1).

In regular operation all the valves shown in Fig. 291 will be left open and the check valve, *a*, will be closed. This is because the overflow of the hot-well will be higher than the surface of the pond (say 12 in.), and, besides, the weight of the valve will also tend to close it.

The pump box from which the suction is taken should not be less than four feet deep, making a distance of 3 ft. from the pond level to this suction, thus insuring water in the suction line and feed pumps at all times. If water does not flow to the feed pump from the condenser it will flow to it through the check valve, *A*. The deep well water will not regularly flow to the feed pump, but will pass by it, part being taken by the fire pump working on the low-pressure service, the remainder going to the circulating pump. This will be seen by examining Fig. 291. By closing the valve, *B*, either half of the suction system may be shut off. If the deep well pump is operated together with the feed pump, the excess water will overflow at the pump box. In the latter case the condenser would not be in operation. It would be possible to connect the hot-well to the fire pump, but this would not be used enough to justify the expense and increased complication resulting from these connections.

Emergency connections should insure reliability, and not necessarily the highest economy. The system shown in Fig. 291 will operate more satisfactorily if some form of variable speed drive is provided which will permit running the pump at different speeds.

To obtain drinking water a small centrifugal pump can be placed either on the end of the motor shaft or belted from it. This is more advisable than to take the drinking water from the low-pressure system shown in Fig. 291, as a low-pressure line would be constructed of black pipe large in size, and the water would be warm, and there would also be danger of pond water getting into the low-pressure service. This pump would take water from the deep-well pump-discharge and would maintain a pressure of 5 or 10 lb. Centrifugal pumps have the advantage that they do not require relief valves. The capacity of such a pump need not be over 10 gal. per min. and will require less than 0.25 hp. to drive it.

If the artesian water is to be used for cooling a surface condenser the piping system would be similar to that shown for the elevated jet type of condenser illustrated in Fig. 291. The condensation then will flow from the hot-well or base of the condenser to the vacuum feed pump, as in Fig. 291, but the check valve, *a*, will be omitted. If an open heater is to be installed there must be another pump to take water from the hot-well and deliver it to the heater; in Fig. 291 the latter is indicated by *d* and the pump by *c*. This statement applies equally to surface and elevated jet condensers.

Class L7 — Air Lift for Artesian Water. An air outfit consists of an air compressor, a pipe for conveying the air to the bottom of the well and a device for atomizing the water by air and forcing the water upward, together with the air used for atomizing. The water is raised in the same manner as a hat or piece of paper is by a high wind, the ability of the air to support or carry the water in reality depending simply upon the skin friction of the air on the exposed surfaces of the finely divided water. By reducing the size of a globule of water by one-half, its area becomes one-fourth the original, but its weight only one-eighth of what it was previously. It is therefore evident that, the smaller each particle of water is, the greater will be its frictional resistance in proportion to its weight. Consequently, with finely divided water in an air lift a smaller volume of air of lower velocity is required to create a lifting friction greater than the weight of the particles of water.

The air lift can be constructed in many different forms, but the principle of any design depends upon the high frictional resistance of the air on the surfaces of the particles of water. The heavier the particles of water may be, the greater will be the air velocity required to give the necessary lifting power. Hence, the capacity of the air compressor serving the lift will depend upon how effectively the atomizer operates. Further, as the skin friction of air increases approximately as the square of the velocity, the higher the velocity of the air required the greater will be the frictional losses in the pipe; and for this reason few air lifts show even a fair efficiency.

Obviously, the size of the air discharge or water lift pipe must be made sufficiently small to secure the velocity necessary to support the water. An air compressor having a capacity of 30 cu. ft. of free air per min. would give a velocity of 5,000 ft. per min. if the air were discharged at atmospheric pressure through a 1-in. lift pipe, or a velocity of 2,500 ft. per min. if the air is at a pressure of 15 lb. per sq. in.

There are two different methods of delivering air to a well. It may be discharged through the drop pipe or it may be discharged through the annular space surrounding this pipe. Fig. 292 (L7–1) shows the air discharge taken from the large drop pipe. This generally is the better construction, since it enables the use of a small pipe through which to discharge the water and a large cross section to furnish the air to the lower end of this pipe. By using the drop pipe for the discharge a clear straight bore is obtained, thus maintaining more uniform conditions during the discharge of the water.

It is necessary to overcome the resistance of the piping and the ejector; if 15 lb. air pressure is to be carried, the distance, *b*, in Fig. 292 should be made not less than 35 ft., since the air pressure in the casing will lower the water level by that amount. The level, *c*, is the working level of the water with the pressure removed. This will be somewhat lower while the water is being pumped than while it is standing at rest. The distance, *a*, may be small or it may be found better if the ejector is dropped below the standing water level. By using a hose connection at the upper end of the drop pipe, and making the distance, *a*, a few inches, *b*, about 35 ft., and *d*, the length of a pipe, the best position for the ejector is readily ascertained while the compressor is in operation. This can be done by moving the drop pipe up and down until the most satisfactory results are obtained. The most efficient pressure at which to operate the lift can then be easily determined.

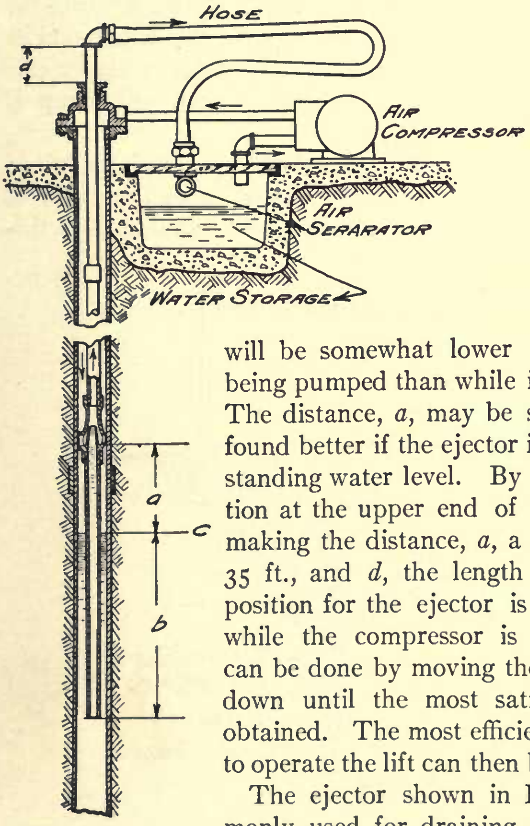

FIG. 292 (L7-1).

The ejector shown in Fig. 292 is one commonly used for draining cisterns, etc., and to further reduce the frictional resistance of the air flowing into it holes may be drilled in it. To obtain the best results from air lifts, the ejector should be ordered from a firm which makes a specialty of such devices, and in ordering, the exact use to which it is to be put should be stated, as the application of the ejector for this service is different from that for which ejectors are commonly employed. The air in this case enters around the nozzle instead of passing through the nozzle, as in regular service.

If air is available in the plant for water lifting and a special compressor is not needed for this service the air lift presents some very desirable features, the most important of which is that there is no mechanism whatever in the well, and, further, it is possible to handle very large quantities of water with it. These advantages, however, are not ordinarily sufficient to warrant the installation of an air compressor especially for this work, because a higher efficiency is obtainable if the common form of deep-well pump is employed.

Class L8 — Artesian Water for High Buildings. In large hotels and office buildings there is ordinarily a large enough quantity of water used to make it profitable to sink a well. Buildings of this class are especially well adapted to artesian well work, because they have high open elevator shafts which permit of raising pump rods and drop pipes. With an elevator in the shaft no other apparatus is necessary to lift the parts out of the well. Fig. 293 (L8–1) shows such a well with the driving machinery set to one side of the well. In this case it would be better to sink a false casing, say 20 ft. long and of large diameter, to secure the soil under the elevator shaft

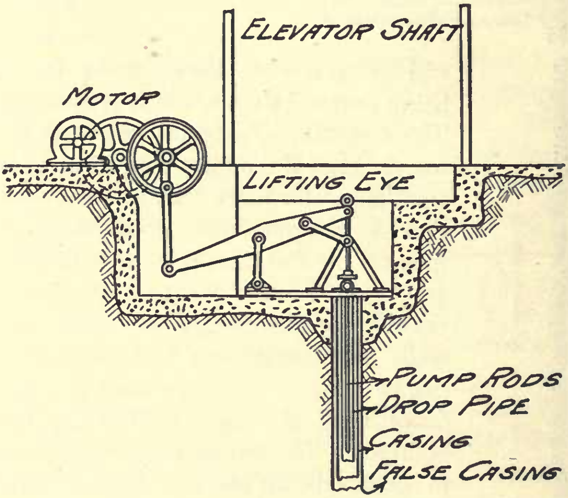

Fig. 293 (L8–1).

footings. The regular well casing should be driven inside of the false casing after the latter has been sunk. The end of the walking beam can be formed in the shape of a Y with a cross-head pin passing through the upper section of the pump-rod head. The removal of this pin and stuffing-box cap only are required to draw out the sucker rod.

CHAPTER XXII.

FIRE SERVICE PIPING.

Class M1 — Fire-Service Mains. There are two distinctly different systems of fire protection, one being an installation conforming to the rules of the fire insurance underwriters, so that no difficulty will be experienced in collecting insurance, and the other an arrangement especially adapted to putting out fires which might start in the particular building considered, no attention being paid to the underwriters' rules. Which of the two systems is to be installed depends upon whether insurance is to be carried.

Ordinarily the roof of a power station is far removed from any inflammable material liable to set fire to it, but in nearly every case there is no protection for the roof, though the latter is the most common fire loss. The roof is quite as liable to be set afire from the top as from the under side, and to provide the best protection, a system such as shown in Fig. 294 (M1–2) would be found valuable and more particularly so if the power house be located close to some other building or combustible material. The perforated spray fittings should be so arranged that the trap door will be protected with water. Then, if necessary, an operator can get on to the runway in case of fire around the hatch. A hose connec-

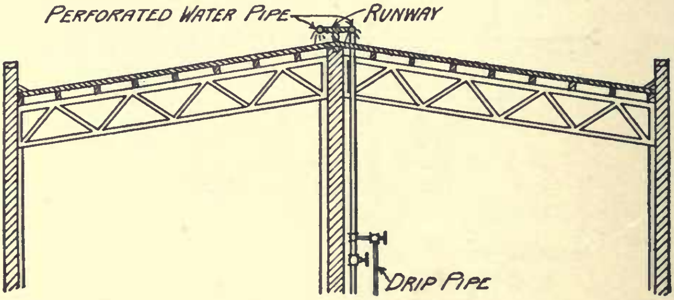

FIG. 294 (M1–2).

tion should be provided on the roof, the latter detail being shown later under "fire service."

In considering fire protection, it is first necessary to determine whether it is simply to be for the power station or for buildings in its immediate vicinity. If there are other buildings to protect, it would be more than possible that they would be insured, and to secure the best protection and insurance rate it probably would be necessary to install an underwriters' fire pump in the power station so connected that it would be always ready for fire service and so arranged that all other services taken from the fire main could quickly be shut off. In this case it is quite probable that the fire pump would not be connected to serve as a reserve feed pump, thus requiring two feed pumps in addition to the fire pump.

Further to insure the reliability of fire service it would be advisable to install one of the feed pumps so that it could be used for fire service if necessary, thus maintain the fire water supply whenever the regular fire pump is being repacked or repaired. The regular feed pumps should be of the outside packed-plunger type, the fire pump of the underwriters' type and the second feed pump of the center-packed plunger type with extremely light rams to permit its being operated at the high speed necessary for fire service. A fairly good arrangement is to use one feed pump and two fire pumps of smaller size. The latter plan is, however, objectionable if an open feed-water heater is used, since the hot water from the heater will soon destroy the inside packing of the fire pump, which must be of the piston pattern in order to operate under the high speed necessary. If the power station is isolated, little water is required for its protection, and ordinarily two pumps will be ample. Both pumps could be of the outside-packed plunger type, and, as all other machinery would be stopped in case of fire, these pumps could be operated instead of one fire pump.

In many plants the steam and feed lines are supported from the roof trusses. The only reason for such an inconsistent construction is that it is the easiest available method of support. Not only should the lines be carried independently of the roof trusses, but they should be supported so firmly that they will remain intact, even if the roof falls on them. The feed main should lie far enough below the tops of the boilers to be protected from anything falling on it. The safety-valve pipe through the roof should have the lightest obtainable cast-iron elbow at its lower end to protect the safety valve.

Unless the boiler room is protected against the breaking of steam lines in case of fire, there should be some special provision made to insure the continuous operation of the fire pump. The smoke breaching is generally an easily destroyed object in case of fire, and if the fire pump is to be kept running the longest possible time, it would be a more certain arrangement to have a separate underground fire pump connection to, say, two different boilers, one always being in service. In case of fire over the boilers the connections to these would be opened and all others, including those of the boiler feed, water columns, etc., closed. The fire pump in this case should be in a separate building outside the power house, or walls should be built around it so that it could be operated even though the boiler room were completely destroyed or filled with steam and smoke.

The steam contained in the boiler connected to the fire pump would be its "store" to draw from, assuming that it would then be impossible to feed more water or coal to the boiler. This supply, however, would run the fire pumps for a long period, and unless some such provision were made, the fire service would end with the first damage to the piping. It is no uncommon thing to find a fire pump placed in the basement or back of the boilers and in other locations that would compel the operator to leave the pump to itself as soon as a little steam or smoke reached him.

If the outside risk is great, the fire-pump service should be guarded in every possible way. The insurance companies demand a specific construction, but, their rules being general, expert judgment is not always used for each individual risk. Their rules oftentimes demand things wholly useless in some cases, and in others neglect to make demands that are absolutely essential for protection against fire. This is a feature of their business that cannot well be otherwise.

The fire protection and fire fighting arrangements demanded by the insurance companies are as good as can be stated for general use, but the engineer must locate the unprotected risks about his plant and make the necessary provisions against fire. The fact that the plant is equipped so that it can collect its insurance is of but little or no value, for it encourages a feeling of indifference to fire, and though a dollar of insurance may be collected, possibly ten would be lost indirectly on account of the fire. The fire and low pressure service in a power house can both be supplied from the fire pump, but they should be separate lines, with a valve at the fire pump to shut off all indoor piping. The low-pressure main would ordinarily be a separate line, the other low-pressure lines being supplied from the fire main with an outside valve. If it is necessary to open certain valves and close others in case of fire some established system should be followed, such as yellow valves closed and red valves opened in case of fire. These valves should lie as close in a group as possible, and a chart should be hung up near them, showing all the valves to be operated, as it is quite easy for any operator to forget when he becomes excited. If there are indoor fire taps at other buildings they may be supplied from the fire main, with the valves left open until the line becomes damaged or the men are driven from the interior of the building. This layout is shown in Fig. 295 (M1–3.) No. 1 shows the fire pump, No. 2 the auxiliary or reserve pump, and No. 3 the boiler feed pump.

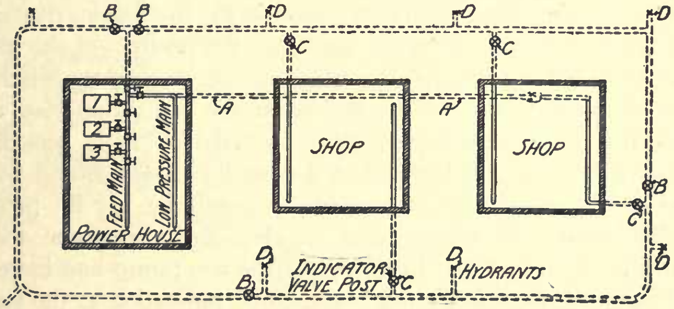

FIG. 295 (M1–3).

The fire main is in the form of a loop, thus permitting any portion to be shut off and still have fire protection. The valves, *B*, are the shut-off valves and do not require indicator posts, as they should not be operated in case of fire. The valves, *C*, shut off water from the inside of shop buildings, and these should be fitted with indicator posts. The fire hydrants are indicated by the letter *D*. If the lines running into the shops, shown with the shut-off valve, *C*, are used for plumbing fixtures only, it would be advisable to supply them from the separate main indicated at *A*, so that they would be shut off before running the fire mains under high pressure. By thus arranging the piping there would be no valves, *C*, to handle, the only valves to be opened or closed being at the fire pump.

The main, *A*, could have a reducing valve fitted in it so that it would always be full open when the fire pump was working on low pressure and closed whenever the fire lines are operated under high pressure. This arrangement would protect the low pressure line and simplify the operation of the system in case of fire, as practically the only operation necessary would be to increase the water pressure by changing the position of the weight on the pump governor. An automatic device can be used for shifting the weight on the governor and shut off the low-pressure service. This can be done by a loosely fitting piston in the fire service discharge, which would operate the valve and shift the position of the weight previously mentioned, the operating piston leaving the discharge from the fire pump unobstructed while the fire pump was operating under high pressure. With this device it is possible to attach a hose to any hydrant under 20 lb. pressure, and by the time the hydrant valve is opened there will be 125 lb. pressure on the entire fire system, and the low-pressure system will be shut off. The fact that the speed of the fire pump had increased and the pressure raised would be the first indication to the station operator that the fire service was being used.

With this device in operation the fire line could not be used for any other service, as the flow in the pipe line would trip the valve. The construction of such an automatic valve is shown in Fig. 296 (M1–4). The piston fits the body of this special valve so closely that the flow of water to one hose is sufficient to trip the weighted lever and draw out the counterweight on the pump governor. The special valve is illustrated, showing the low-pressure main shut-off and the piston out of the flow of the water. The final travel of the piston is given to it by the weighted lever. To place the pump on low pressure after it has been used for fire service, the lever is returned to its former position. This returns the piston to its original position and shifts the counterweight on the pump governor, so that the diaphragm does not have to raise so great a weight in closing the balanced steam valve.

It will be noted that normally the lever is nearly in a vertical position, thus requiring but little pressure under the piston to tip it over. If all the piping is tight and the piston fits its bore closely, this pressure controller can be used in connection with the automatic sprinklers. The standard underwriter pump has a water relief valve at *D*, and this should be provided in all cases where the pump is to be used for fire service. Priming pipes and a hand-operated cylinder oil pump should be fitted to the pump. All makes of underwriters' fire pumps are designed to conform to the same specification, but there are so many details pertaining to pump construction not mentioned in the underwriters' specifications that no two makes of pumps can be considered equal.

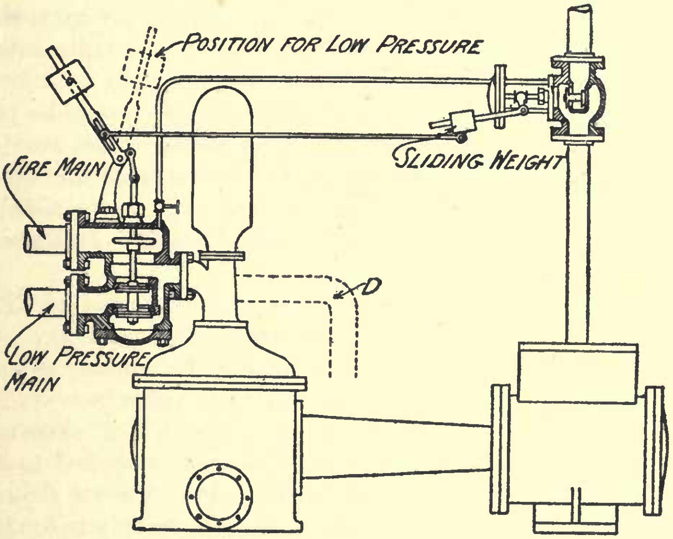

FIG. 296 (M1-4).

Possibly no other feature in the design of a pump governs its value so much as its weight. Though metal can be wastefully used in the design of a pump, it is quite unlikely that a manufacturer would add weight needlessly. Strength and large port openings, liberal wearing surfaces, etc., are secured only by increased weight, and it is quite impossible to design a light pump having the same merits as a heavier one. When securing prices, the weights of the pumps should be compared.

Referring to Fig. 295 it will be seen that water is supplied to each hydrant from both directions, that is, each side of the loop is supplying water to those hydrants being used. A system designed in this manner supplied from a pump with an 8-in. discharge would require loop piping of 6-in. pipe. The loop system is practically equivalent to running a double pipe line of this size to each hydrant. The lineal feet of pipe in the loop main is but slightly greater than in a single main system, and the area of the pipe can be reduced to just one-half that of a single main. Not only is a more reliable system secured in this manner, but also one which is no more expensive to install. The fire main should be placed at the same depth as the city water pipe in the same locality, thus avoiding the possibility of freezing.

For buildings of ordinary height the hydrants should be placed at a distance from a building equal to its height. This avoids the possibility of the walls falling on the hydrants or the firemen. Hydrants or indicator valves posts placed too close to a wall are liable to become unapproachable in case of fire, and cause a serious loss of pressure and a waste of water.

Fire protection for power stations, shops, etc., can be divided into two separate classes: interior and exterior service. The conditions encountered in each case should be thoroughly studied and understood before attempting to design either service. The interior service is the proverbial "stitch in time" which "saves nine." It is the quick use of water in small quantities applied to a fire at its beginning that makes the well-provided interior protection so valuable. A room 50 by 100 ft. may have only two 1½-inch hose reels on the wall, but if they can be put into use without delay and are so located that they can be readily reached and will cover the entire room, there will be but little chance of a fire getting beyond the control of the interior fire protection.

A study of the necessities in fire fighting, by those who make this their sole occupation, are: First, a system of water supply adequately covering the territory to be protected. Second, an alarm system covering the territory to be protected. Third, an organization of men who have been trained and understand their duty in case of fire. Fourth, apparatus for pumping water to the highest and most remote parts of a building. Fifth, means of egress when the building is no longer tenable. Sixth, auxiliary apparatus for extinguishing smaller fires without using large quantities of water, and thus causing serious losses through damage by water.

A point which requires the most careful consideration is the selection of fire hose, a subject which has caused the city fire departments unlimited trouble. Any article containing rubber depreciates with age, and still rubber is essential in the manufacture of water-tight hose. It certainly seems wasteful to buy high-grade hose and allow it to lie until it is useless, but there is no method of avoiding this. It has in many instances been the unfortunate experience of fire departments that it is impossible to put out fires with old weak hose. Fire departments cannot afford to take chances with old hose past its useful life, and companies and individuals cannot better afford to take such chances. The hose question is too often entirely or seriously neglected, although it is one of the most important parts of fire protection system, as firemen can do nothing with rotten hose. Insurance companies realize this point and for this reason recommend tanks and pails, and preferable to all other methods, a regular piped sprinkler system, as they know that the hose is frequently unfit for use when it is required, or the men are not at hand to use it.

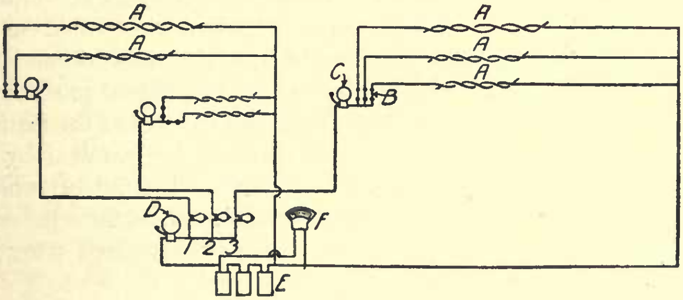

Fig. 297 (M1–5).

Alarm systems receive little or no attention, fires usually being first reported when some one discovers smoke or flames coming from a window and reports it to the engineer. Buildings should be fitted with a fire alarm in each room. This can be accomplished in a very simple manner, as shown in Fig. 297 (M1–5). The alarm consists essentially of two wires twisted together and insulated from each other by a compound which melts at a comparatively low temperature. These twisted wires are run under benches, around walls, along the ceiling, at stairways and any other exposed point. The number of circuits which can be thus connected is unlimited. There can be any number of circuits in a room, each having a marker at *B*, which becomes discolored as soon as the circuit is completed and rings the bell, *C*, in that particular room, and also operates the light or annunciator and sends in an alarm to the fire station. The batteries may be placed at *E* and the entire system operated on low voltage. The lamps or the voltmeter, *F*, show the voltage of the batteries at all times. The fireman (or the engineer, if he is in charge of the fire system) then sees where the wires *A* have been heated, and if the location is not easily found he can look at the markers, *B*, to locate the short-circuit, and, if caused by an accident, it can easily be repaired by rewaxing. This device has the advantage that it can be set low down and in dangerous locations without the dangers accompanying the use of automatic sprinklers. This device would set off the alarm before the sprinklers would have time to work, and firemen would be on hand long before the fire had gained much headway. The wires would be quite small and the cost of the installation would be very slight, as it could easily be installed by the resident electrician or one of the engineers. Instead of running separate positive and negative leads, double conductor wire could be used, the wires being separated where the twisted wires are attached.

The inside fire service should be a branch from the fire main, as shown in Fig. 295, with an indicator valve, *C*, for each building, as it is desirable that the inside fire service be used in each building until it is no longer tenable. The main shown at *A* would be used to supply all services other than the fire service.

With such an alarm system and the pump pressure device shown in Fig. 296, it would be good practice to give an alarm whenever both are caused to operate together, showing that heat has made the wires, *A*, come in contact, and that water is being drawn from the fire system. In each room at the alarm, *C*, there should be a spring-closed switch, which should be opened or closed, giving an alarm for the city fire department or for additional help, without necessitating leaving the room where the fire is found. This general fire system, if arranged in similar manner to that of the city fire department and adaptable to private institutions, would be installed as follows:

1. Fire mains installed on the loop plan as shown in Fig. 295.
2. Fire pumps installed and isolated with door and windows opening outside.

3. Fire pumps having an individual indestructible steam line from not less than two boilers.

4. Fire pump having pressure raising device, shown in Fig. 296.

5. Fire lines to individual buildings with valve at *C*, as shown in Fig. 295.

6. Hose provided for all rooms and connected ready for instantaneous use.

7. Hose tested at regular intervals.

8. Alarm system as shown in Fig. 297.

9. Employees drilled at least once a month.

10. Chemical extinguishers in locations where water would cause considerable damage, but hose also installed in these locations.

11. Fire escapes placed so that a man with a fire hose can remain the longest possible time and know that he can get out.

12. Standpipes extending to the roofs of all buildings.

Class M2 — Fire Service to Hydrants. The hydrants, *D*, shown in Fig. 295 would ordinarily have two openings for 2½-in. hose, and have an inlet not smaller than the size of the main. In determining the depth to bury the fire main, the length of the hydrant that will be used should be known. The standard depth is 5 ft. from the pavement to the bottom of the pipes. In placing the hydrant a flat stone well rammed down should be put under it to prevent settling. Old bricks, stone, etc., should be placed around the drain hole to permit the water to seep away and also to prevent sand and gravel from entering the hydrant. The hose connection should point toward the building.

Standard hydrants require a special wrench to open the valve, and as these wrenches are also necessary to remove the hose caps and also to attach the hose, little would be gained by having a handwheel fixed to the hydrant, even though it were in a position where it would not be tampered with. In some installations the hose and fire tools are kept in a house surrounding the hydrant. A better plan, however, is to have a central fire station where all hose for the hydrants is kept, and have hose carts to carry it. By having a central station it serves as a meeting point in case of fire, and the chief has therefore better control of the men.

A convenient form of cart is shown in Fig. 298 (M2–1). Each 50-ft. length of hose should be laid in the top of the cart and the lower shelf used for tools, etc. For use around power stations and shops it is quite inconvenient to have all the hose on one reel.

The house in which the cart is kept should have a glass-closed opening over a spring lock, with a notice above the glass: "In case of fire break glass and unlock the door." Another method is to have a sliding bolt lock with a conspicuous sign: "Slide this bolt to open door and give alarm," there being another door which could be used without setting off the alarm. In many respects the latter form is preferable, as there is less liability of its being molested. It also would bring additional help more readily.

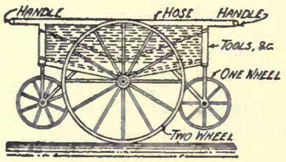

FIG. 298 (M2–1).

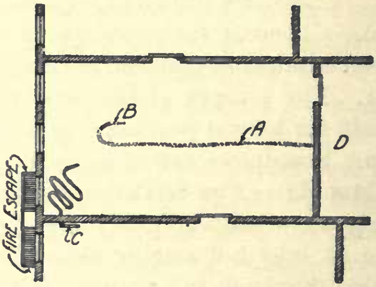

FIG. 299 (M3–1).

Class M3 — Fire Service to Interior Connections. A branch of the fire main with its indicator post is shown in Fig. 295. The indicator simply consists of a slide showing a sign, "Open" or "Closed," according to the position of the valve. Indicator posts avoid uncertainty and confusion, as few men can tell by the movement of a valve wheel whether it is open or closed. In case of fire the few who know would probably become confused and think a valve was open when in reality it was closed. If an indicator post must necessarily be placed close to the building it should be located at one of the corners, so that it could be operated from either side, permitting the operator to avoid the heat and smoke.

The interior fire lines should be supported on brick walls or in such a manner that they will remain serviceable for the longest possible period. The placing of the hose reels should receive the most careful consideration, since much depends upon where a man is located when using the hose, and to what extent the hose is exposed to danger. Fig. 299 (M3–1) shows the plan of a large room with one outside wall.

The hose shown by the dotted line, *A*, is connected to a reel mounted on the inside division wall. Although all the objectionable features of such an arrangement are evident there are probably more hose reels installed in this manner than in any other. The possible reason for this is that the designers wish to keep all the hose and pipe lines near the center of the building to protect them from freezing. The economy of such an arrangement is extremely doubtful, as the efficiency of the fire service is greatly reduced.

If a fire were discovered in a room having the reel and hose attached as at *A*, in Fig. 299, it would be necessary to pass through the greater part of the room to get at the hose, and there would be danger of the man taking down the hose and trying to put out the fire being blinded and overcome by the smoke. Even though the operator had the hose down from the reel and nozzle as at *B*, there would be serious danger of being overcome by smoke long before the fire had done any serious damage. There is in reality only one correct position for a hose reel or rack, and that is close to windows where air can be obtained, and where safe exit is possible. This permits a man to get to the hose in case a fire has made considerable headway. He can also protect his hose from the fire as long as he is able to use it. The fire escape shown permits the hose *C* to be used in the next room by running the line out of the window and across the fire escape.

It is quite common practice to place hose racks in hallways back of the workrooms as shown at *D*, and expect men to work from the center of the building. It may be an ideal place from which to suppress a fire, but in laying out fire systems the safety of the fire fighters should receive the first consideration, and the fire service should be designed to insure their safety, otherwise the money invested in fire protection will be useless for want of men to use it. There are many designs of hose racks, reels, valves, etc., used. The following conditions should be fulfilled by satisfactory hose racks and reels, but they are difficult to combine in one device.

1. The device must permit the hose to be quickly and easily removed.

2. Leakage past the hose valve must not be discharged into the hose, causing it to be injured.

3. The hose should not lie with short-radius bends in it, as the material of which hose is made will in time assume the forms

in which it has been held for any length of time and is easily broken when straightened out.

4. The hose should lie so that it will drain itself.
5. The hose should be inclosed where oil is extensively used.

These conditions are quite exacting, and the nearest approach to them is shown in Fig. 300 (M3-2). This arrangement consists of a shelf or shelves each large enough to hold fifty ft. of hose laid straight, one or more lengths on a shelf and the hose supported preferably in a U-shaped trough. The hose is detached from the hose valve, and the supports are pitched to permit water to drain from the hose. To further protect the hose there should be a sectional drop door protecting the shelves from the circulation of air. This is an ideal support, and like most ideal arrangements, as a rule, it does not fit into the place where it is wanted.

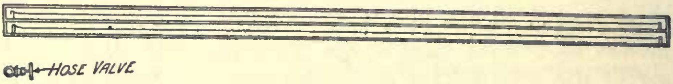

FIG. 300 (M3-2).

One of the most practical forms of hose support is that shown in Fig. 301 (M3-3). This form of hose reel can be used in almost any location. As shown by the illustration, it is placed in a vertical position, the hose being wound in the form of a spiral, the nozzle being at the top. The hose is supported over its entire length. The shortest curve in the hose is that of the drum. The hose is attached to the swivel joint. A check valve is placed at *A*, which remains open as long as there is no water passing through the valve *B*. Water which may be in the hose, or which leaks past the valve *B*, would be discharged through this open check valve. If the hose is kept in a room where oil is extensively used, a sheet of heavy wrapping paper may be put around the outside to protect the hose. This can readily be torn away when the hose is required.

The form of support shown in Fig. 301 (M3-3) has all the desirable features except that the hose is held in a curved position. The radius of the drum is, however, so great compared with that of other supports used, that the injury resulting from this curvature must be very slight. The hose may be permanently attached to the service line in the arrangement of Fig. 299 and nearly all other forms, provided a check valve is fitted, as shown at *A* in Fig. 301.

There are hose reels in use with a central water connection as shown in Fig. 301, the drum, however, revolving on a horizontal axis.

Such an arrangement is open to the same objections as the style of hose support shown in Fig. 302 (M3–4). The entire weight of the hose is carried on only a portion of its length, and the weight of the hose thus tends to flatten it. If there is any water in the hose in such forms it drains to the lower loops and remains there, this being the difficulty in practically all forms of hose support. It is a very difficult detail to remedy. Another form of hose support is shown in Fig. 303 (M3–5). This support is objectionable on account of the sharp bends necessary in piling the hose and the weight resting on the bottom layers tending to flatten them. Further there is no method of draining a hose piled in this manner, and in this respect it is even worse than that shown in Fig. 302. This form of hose support is very largely used, and the only excuse for it is that it is cheap and can be folded back against the wall and thus occupies very little space. The form of support shown in Fig. 304 (M3–6) could be made quite cheaply and would avoid the sharp bend in the hose, would drain properly, and is supported throughout its entire length.

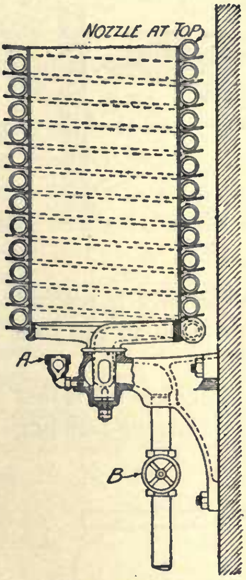

FIG. 301 (M3–3).

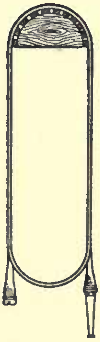

FIG. 302 (M3–4).

Class M4 — Fire Service on Roof. Though this class of fire protection is very efficient, it is generally neglected. A power house, with the exception of the roof, is quite easily constructed in a fireproof manner. This is equally true of many shops. If a power plant is located where it is in danger from surrounding buildings, it may be advisable to use the roof-wetting pipes shown in Fig. 294. But ordinarily a hose and standpipe at each end of the building are sufficient.

A very efficient manner in which to install a roof standpipe is shown in Fig. 305 (M4–1). The hose and valve are on a shelf or rack on the inside of the building, the heat of the room preventing the water pipe and parts from freezing. The cast-iron doors and frames are built in the wall, and the doors open out on to a platform, which is set sufficiently low so that a man will be protected somewhat from the heat of the fire. The ladder which reaches this platform and is continued on and over the wall to the roof permits easy access to the hose and the roof.

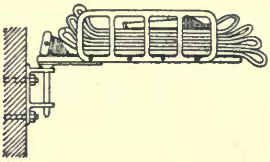

Fig. 303 (M3–5).

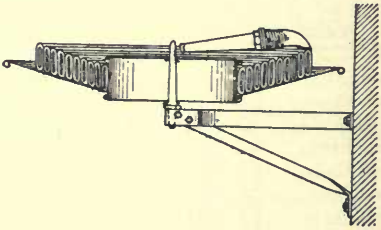

Fig. 304 (M3–6).

Men working on top of a burning roof would soon leave it rather than run the risk of being dropped into the burning building because of the roof sheathing giving way or the trusses buckling. The most secure point at which to locate the platform shown in Fig. 305 is at the outside end of the power plant and at a division wall, as is shown by the dotted lines. This location gives a better range of both the boiler and engine room roof, and is the safest position along the end wall, as it is braced by the division wall.

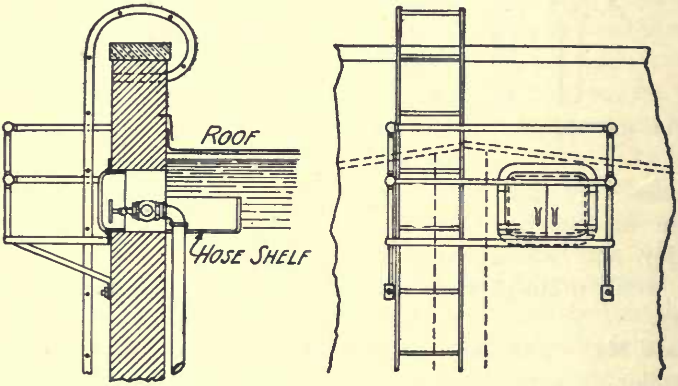

Fig. 305 (M4–1).

Another method of supplying water to the roof is by means of an outdoor standpipe, ladder and platform, as shown in Fig. 305, but without the hose and the hose valve located inside the wall. The standpipe in this case would have an underground connection and a valve fitted with a drain which could be opened when the line is shut off. Such a line would be fitted with an indicator post. With the latter arrangement it would be necessary to carry a hose up the ladder whenever it was needed.

The outdoor standpipe would ordinarily be placed alongside the fire escape if used for factory protection, and there would be one or two hose connections with valves at each floor, and possibly two hose connections at the roof. This standpipe would be made of large diameter, as all water used for fire protection might be taken from this pipe. For power plant protection the system shown in Fig. 305 can more easily and quickly be put into service, and it is also somewhat cheaper to install. In attempting to economize, however, the utility and reliability of operation must not be overlooked, as the value of fire protection depends largely upon what provisions have been made to prevent serious loss of pressure in case the interior pipe lines should be broken, as may happen in the system shown in Fig. 305. There should be some means provided to permit shutting off all pipe lines which may be accidentally broken, and it should further be provided that all such lines can be shut off from the exterior of the building, even though the walls of the building have fallen. If such means cannot be provided for, the arrangement in Fig. 305, an outside standpipe with an underground valve located some distance from the building, should be used.

Class M5 — Fire Service from the City Supply. The extent to which city pressure can be applied in fire protection depends upon the available pressure and the extent of the fire protection intended by the system. In the larger cities comparatively low pressure is maintained, and the necessary pressure for fire service is obtained by means of a fire engine or pumps. Smaller cities and towns resort to a system of fire alarm and increase the pressure on the main during times of fire. This increase of pressure is generally quite small compared with that obtainable from fire pumps, a pressure of 150 lb. per sq. in. being quite general in the latter. The usual pressure in towns is 20 lb. per sq. in., and this is seldom increased above 60 lb. The plumbing and water lines would be strained if a higher pressure were carried.

If a pressure of 60 lb. is quickly available on the city water system, there would be no real necessity for an independent fire pump, provided the building were not more than 30 ft. high or about 50 ft. wide. A pressure of 60 lb. at the hydrant will give a discharge of about 122 gal. per min. through a 0.75-in. nozzle at the end of a 100-ft. 2.5 inch hose line. The stream of water will rise vertically to a height of about 70 ft. and reach horizontally to a distance of about 50 ft. under these conditions. A 1⅛-in. nozzle will deliver about twice the amount of water that a 0.75-in. nozzle will deliver, and, though it will not project it to the same height, it will project it a greater horizontal distance.

Plants located within the district of fire engine service should have their own inside fire service, and for this purpose the city pressure would in most cases be sufficient, as the height and general dimensions of the rooms would not be too great to permit water to be delivered to any part of the room. If the building is high it will be necessary to place a tank on the roof, using an ordinary house pump to fill the tank if the city pressure is not sufficient to deliver the water to that height.

Class M6 — Fire Service to Low-Pressure Service. If a fire pump were connected to the fire mains only, it would require special attention to keep it in working order, so that it might be used at any moment. Should the plant and its surrounding buildings require water at low pressure and the plant have its own water supply, it will be a good plan to use the fire pump for this service. By using the fire pump for the low-pressure service it is kept in constant use and its condition is thus known at all times.

The low-pressure service should be connected to the fire mains or pump discharge in such a manner that it can be shut off quickly in case of fire, the means for shutting off the pump being so arranged that the pump can be turned off outside of the building which is to be protected. Ordinarily, the best arrangement would be to start the low-pressure piping system at the fire pump discharge, a valve being inserted in the line so that the latter could be cut off. By taking all the general service connections from this main, only one main would have to be shut off in case of fire.

This one valve would shut off the water service from all plumbing fixtures, wash water for the car barns, and the water service to the journals, etc., and in many cases also the water to the open heaters. In most instances no serious result or inconvenience would be experienced if such services were shut off during a fire, but if it is absolutely essential to maintain some portion of the low-pressure water service it would be advisable to run a separate main from the fire pump discharge, the latter line then being fitted with a reducing valve. The main line, however, should be arranged so that it can be shut off, since there will be many minor connections taken from it which might be broken in case of fire, and thus cause a loss of pressure and a waste of water.

If three pumps, a feed pump, fire pump and reserve pump, are employed, the reserve pump can be used to supply the low-pressure service. The principal point to consider is how to reduce to a minimum the amount of water used for purposes other than fire. The use of a reducing valve in a branch from the fire line is liable to cause trouble if the low-pressure pipe is damaged and considerable water would then be lost, even though the pressure were reduced.

A positive and safe method is to shut off all the lines to the low-pressure service by gate valves, as previously mentioned, and if necessary permit the feed pump to supply the boilers with cold water in times of fire. If an overhead tank is installed it can be used to supply water for the engine journals or as much of the low pressure system as is unlikely to be injured by fire.

Class M7 — Fire Service to Oil Room. All oils, grease, benzine, etc., kept in barrels should be stored in a separate room for two reasons, one being to avoid leakage due to the prevailing heat of the power station, and the other to confine this material so that it will be less exposed to fire, and thus not liable to endanger other parts of the building in case a fire should start from the point where such inflammable material is stored. The oil room should have a double metal-faced door, one inside of the room, and the other outside of the room or wall. The room should be located at an outside wall, with sufficient windows opening away from the building to act as a vent in case of an explosion of vapor inside of the oil room and also to allow the fire to be suppressed from the outside. The ceiling should be of masonry, designed to withstand intense heat. The door which opens into the oil room should have a masonry sill at 8 inches or more above the floor, so that if oil should escape it would not run under the door and spread the fire to the rest of the building. A sewer and catch basin should be connected to the oil room floor to carry off any water delivered to the room, otherwise both water and oil would spread to other parts of the building by leaking through the crack under the door.

If compressed air is at all times available in the power plant, a very efficient system of fire protection can be provided for the oil room by using one of the many "kill fire" powders. Such powder can be stored outside of the oil room and can be thrown on the fire by means of compressed air. The use of water in an oil room tends to spread fire, but the chemical powders merely produce a non-combustible gas, which smothers. It must be borne in mind, however, that fire extinguishers which produce non-combustible gases are only successful in a closed space. The necessity for keeping the doors closed when these powders are used will therefore be evident. A closed room such as has been suggested for the storage of oil is ideally suited for the use of chemical fire extinguishers, since the air is confined in the room, and the non-combustible gas is easily retained and accomplishes results with a small amount of chemical.

Instead of using dry powder it might be better to use bottles of the chemical in liquid form, supported by fuse wire or strings, so that in case of fire the bottles would drop to the floor, break, and extinguish the blaze.

If compressed air is not available in the plant two or three pipe sleeves can be built in the oil room wall, and if chemical extinguishers are available their contents can be discharged into the oil room through the sleeves.

Engine and cylinder oil contained in metal tanks would be but a slight fire risk if kept between the masonry foundations if there is masonry floor in the engine room basement.

Where a return-drip oil system is used it is quite objectionable to place any part of this system in the oil room. It is seldom a difficult problem to place the various parts of the return-drip system so that they are protected from the fire. If the engine room floor is made of wooden joists and wooden boards there will be little additional risk if oil in metal tanks is placed below it. The fire would have to be far beyond control before there would be any additional danger from the oil tanks.

CHAPTER XXIII.

WATER TREATMENT APPARATUS AND PIPING.

Class N1 — Water Treatment — Water Supply. If a water treatment plant is necessary it is quite evident that there is little or no choice in regard to the water which is to be used for the steam plant. Regardless of the system of chemical treatment which is used, it is advisable, if not absolutely necessary, that the temperature of the water be raised to facilitate the treatment. Nearly all chemicals soluble in water dissolve more easily as the temperature of the water is increased, and chemical action also takes place more readily in warm than in cold solutions. The efficiency of the treating apparatus is therefore increased if it is kept sufficiently warm. If the plant is run condensing, then the water should be taken from the hot-well.

Three different chemical treatment systems are shown in Figs. 63, 64, 65 and 66. Fig. 63 shows the water being taken from the condenser discharge (this being the regularly used connection), and this discharge should be trapped so that it will retain the water, even in case there is little or no flow through it. Ordinarily it is the best practice to fill the precipitation tanks with warm water when the condenser is running.

A chemical-treating plant is a source of economy, and if its operation is interfered with, the loss will be proportional to the time it is out of service, but in no case should the continuous operation of the power plant be dependent upon the treating system. If it is possible to deliver sufficient steam for 20 hr. a day to raise the temperature of the feed water to 200 degrees, it would be poor judgment to install a treating system sufficiently large to treat cold water.

It requires careful consideration, however, in deciding upon the use of exhaust steam for warming the purification tank. If there is but a limited amount of exhaust steam, special precautions should be taken to save the heat units in the exhaust, and it would be a mistake to use exhaust steam in such cases for heating the treating tank in order to permit the use of a less expensive installation than would be possible if the water were treated cold. Far more money would be lost in heat radiation from the tanks than would be required to pay the interest and depreciation charges on a treating plant sufficiently large to treat cold water which would not give rise to the loss by radiation.

A very efficient plan of raising the temperature of the mixing tank is that shown in Fig. 306 (N1–1). In the arrangement shown there is not so great a heating surface exposed to the flue gases as there would be in an economizer, but this is not objectionable, because it would be quite undesirable to raise the temperature of the water above about 200 degrees, otherwise vapor would be given off. In the plant shown in Fig. 306 there are two tanks side by side, with flue dampers which can be opened and closed to shut off the gases from either tank.

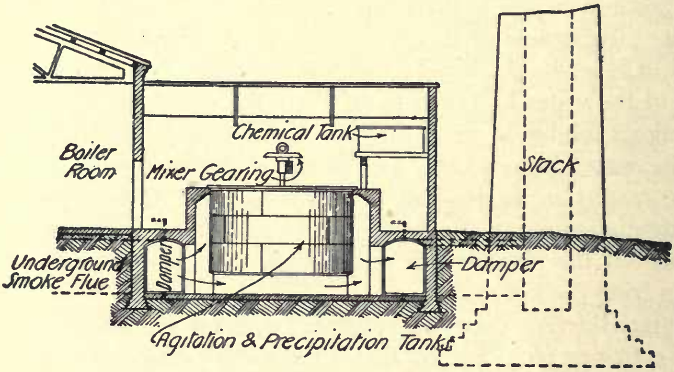

FIG. 306 (N1–1).

Ample space should be left around the tank for cleaning out and making repairs. When the heat is applied it may be found necessary to use the three tanks so that the circulation of the water may be stopped to allow the material to precipitate.

When a tank is filled with water, the chemicals are run into it and the mixer is started. The mixer should run as long as the flue gases are passing around the tank to keep the water in circulation. The flue gases should pass around but one tank at a time. One of the other tanks, just previously agitated, should be shut down to settle, ready for supplying water. There would be three operations to be carried out by each shift of operators — agitation, precipitation, and supply.

The time required to change the tanks is a very small item if the necessity for watching it be eliminated. This difficulty can be overcome quite readily by attaching an alarm to the suction pipe in the tank having a float at its movable end, as shown in Fig. 63. The alarm will notify the operator when the tank is pumped full and also when the tank being drawn from is empty. Such a system of water treatment is very efficient because the water is at rest for so long periods of time. When the tanks are changed every 8 hours it will be necessary to make them 20 ft. in diameter and 14 ft. high for a 1,000-boiler hp. plant. If the continuous system shown in Fig. 65 were to be heated by waste flue gases it would be necessary to use a separate tank for mixing and agitation, otherwise but little heat would be taken up by the water.

When the feed water is heated as shown in Fig. 306 there will be but little use for exhaust steam, and it will be found to be a more economical arrangement to run the air and circulating pumps for the condenser from the engine shafting or use a motor-driven centrifugal pump. The feed pump should be compounded and a small closed heater used to condense its steam. The pump used to fill the heating tanks may be of the motor-driven centrifugal type. A plant equipped in this manner will show very good economy, the tanks located in the smoke flue effecting a saving the same as economizers would, but without offering an equal obstruction to the draft. The saving in chemicals alone is a great advantage with the heating tanks, and whatever heat is transferred from the flue gases to the water there would be as much of a saving as from economizers.

Class N2 — Water Treatment Boiler Supply. The water from the treating tank or apparatus should only be connected to feed pump suctions which can readily be shut off without interfering in the least with the running of the pump. The treating pump should be arranged the same as though it were merely a convenience, the loss occasioned by shutting it down being too slight to justify any expense in providing emergency arrangements to insure its continuous operation.

The feed pump should have a suction direct from the hot-well and also one from the intake. These different connections are clearly shown in Figs. 64 and 65. The discharge from the feed pump to the boiler is the same as for any other water supply. It is only in the pressure system shown in Fig. 66 that the water treatment apparatus is located between the pumps and boilers. In this case the treating system is operated in much the same manner as a closed heater.

There is one point which must constantly be borne in mind in considering chemical treatment, and that is how to remove the impurities from the water before it is taken into the pump suction. The velocity of the water in a pressure system is quite rapid because of the smaller size of the water tanks which must be used in order to withstand the boiler pressure. To accomplish the same results as are obtained with larger precipitation tanks a filter bed must be used. To facilitate a precipitation it is necessary that no water flow in or out of the tank, and that no mixer or other device be in motion while the process of settling is taking place.

There is still another condition which will prevent the successful operation of a precipitation plant and that is caused by varying temperatures of the water. Circulation of the water prevents the precipitate from settling. In a steam boiler circulation serves a useful purpose and partially prevents exactly what is desired in a precipitating tank. For instance, if heat is applied to the under side of the tank shown in Fig. 306, circulation of the water will be set up. Also, if the surface of the water is exposed to a cold atmosphere circulation of the water will likewise take place. For these reasons the gases must be shut off from the tank while precipitation and settling are taking place. By permitting the bottom of the tank to become cooler than the top circulation is also prevented.

It is desirable to have water in the boiler circulating at all times to prevent the fine impurity from settling. There are times, however, when the circulation in the boiler is sluggish, and then the finely divided precipitate settles on the tubes and other parts of the boiler. The amount of precipitation which will settle depends upon the length of time the circulation is retarded. The amount of scale which is formed each time the circulation in the boiler is retarded is easily seen by counting the number of laminations in the scale and noting the thickness of each. Scale 0.5 in. thick may be made up of a number of equal laminations, or it may be composed of one lamina 0.25 in. thick and a number of thinner ones ^{1} in. or less in thickness. A piece of scale thus laminated would indicate that the boiler had been banked for one long period and a number of shorter ones, or it may indicate that more scale-forming material entered the boiler during one period than at another.

The precipitation of the impurities in feed-water is much the same whether the process is carried out in a settling tank or in a boiler. The heat or chemicals will liberate the gas which is necessary to hold the impurities in the solution, and the problem at all times resolves itself into that of freeing the material of this gas and precipitating the impurities before the water enters the boiler. The use of compounds or chemicals which precipitate the impurities in the boiler is extremely objectionable, because all the impurities are thus delivered into the boiler and in addition the chemicals which are used to throw down the scale-forming salts.

In order to operate a boiler with such mud in it, it is necessary to constantly throw away part of the boiler water by blowing off and to thin down the salts left in the boiler by the addition of fresh water. This is necessary to prevent foaming and priming, which would make the quality of the steam very poor and might cause serious injury to the engines.

Exhaust and live steam purifiers are troublesome devices to operate and are generally of such small dimensions that the water flows through them at a relatively high rate and therefore does not permit the suspended material to be completely settled. Though live steam purifiers may liberate the gas which holds the salts in solution, they have not sufficient volume to permit so complete a separation of the suspended material as is obtained in two 20-ft. tanks.

Live steam purifiers are really only continuous heaters, and as insufficient time is allowed for settling, it is necessary to use a filter in conjunction with them, the same as for the high-pressure closed continuous chemical treatment system. Precipitation, however, will remove impurities more effectively than is possible by any other means. Water and oil will pass through a filter bed of the finest material without any sign of one being separated from the other, and this is likewise true of water carrying an impalpable powder in suspension, since the latter will pass through any filter or screen through which water will pass.

A filter is merely a screen which removes the larger particles and permits the smaller ones to pass. Precipitation, however, separates the heavier from the lighter material, regardless of its ability to pass through a mesh of a certain gage. The separation in this case is due to the difference in the specific gravities of the water and suspended materials. Oil and water will quickly separate if permitted to precipitate, though a filter would have no effect whatever. If sufficient time is allowed material suspended in water will precipitate regardless of how finely it may be divided, but if sufficient time is not given for precipitation, then there is no means for separating it from the water other than by filtration or by attraction. The latter means of separation is the one principally used in live steam purifiers.

A steam purifier of the tray type is shown in Fig. 307 (N2–1). These trays are so arranged that they can be drawn from the purifier lengthwise, thus permitting the scale which has been deposited on them to be easily removed. Each tray is supported the same as a drawer, by two guides. The water flows into the top tray and overflows at the edges. Instead of dripping over the edge, it runs along the bottom and drips into the next lower tray, and thus discharges from one to another. A part of the soluble salts is precipitated in the trays, though the largest amount of precipitate is found just under the edges of the trays. That which is caught is dried and baked on to the pan, the same as boiler scale forms in a boiler, only it is deposited in a far less uniform manner. The scale which forms on the under side of the tray is caught neither by precipitation nor by filtration, but simply by attraction, there evidently being a strong affinity between the scale which has formed and that suspended in the water. The temperature in the purifier is generally much greater than that at which the sulphates remain in solution, i.e., 270° F., the result being that the scale which collects is very solid.

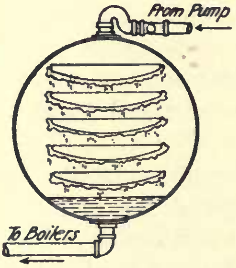

Fig. 307 (N2–1).

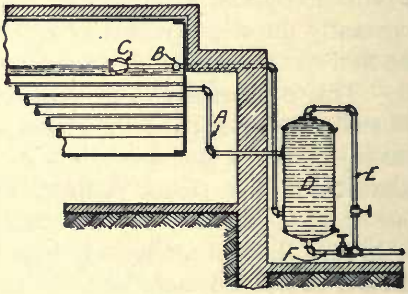

Fig. 308 (N3–1).

Class N3 — Water Treatment after Reaching the Boiler. There are numerous forms of boiler water purifiers, most of which are of the general type shown in Fig. 308 (N3-1). The water is taken from the boiler and discharged into a small settling tank and returned to the boiler, the circulation being maintained by running a hot pipe inside the furnace, as shown at *A*.

There are various forms of pipe connections used, in all of which are arranged cold and hot legs, thus making one column of water heavier than the other. There is a swivel at *B*, and float, *C*, to move the skimmer up and down as the water level changes. The skimmer serves to remove some of the lighter impurities that are on the surface of the water. These impurities generally make the thickest scale, but the scale formed by them is soft and spongy and easily broken. By removing this material and leaving the heavier sulphates the scale that forms on the boiler is extremely hard. It frequently requires more time to remove this hard scale than it would to remove the heavier scale which would have formed had the lighter material not been removed.

Not only does it require more time to remove the hard scale, but the wear and tear on the tube cleaners is of serious importance. Water which does not contain the sulphates which form hard scale is rarely found, but water which contains little else than carbonate of lime and magnesia may be greatly improved by the use of such devices. The fine impurities which are constantly being carried around by the circulation of the water are not removed by surface skimmers, the only method of removing these being to permit the water to come to absolute rest and give it sufficient time to settle. The tank, *D*, is designed for this purpose, and its efficiency is dependent wholly upon its size. The blow-off, *E*, is intended to discharge the scum or light impurities, and the precipitate is drawn off through the valve, *F*. The principle involved in the operation of this device shown in Fig. 308 is identical with the action taking place in all boilers. The circulation of a small portion of the water is retarded, and this permits a partial separation to take place.

Where the circulation is thus retarded the greatest amount of scale is formed in the boiler. These settling places or mud drums are practically the same as the tank shown in Fig. 308. They are far too small to insure any appreciable good. A 500-hp.

boiler would be provided with a tank about 2 ft. in diameter and 5 ft. high, thus holding about 1,000 lb. of water, the latter being equal to that which is evaporated in 4 min. To permit these fine impurities to precipitate, the flow through the tank, *D*, should be very slow, the most satisfactory result being obtained when there is no flow whatever. Chemical treating plants are able to show good results because of this fact alone, and as the velocity is increased the amount of impurities which are precipitated decreases and thus a filter bed becomes necessary.

If the system shown in Fig. 308 were carried out on a sufficiently large scale to accomplish the desired result of removing a sufficient amount of scale-forming impurities, it would be a far superior arrangement to any which is in use. It would then accomplish the desired results without the addition of any chemicals to the water in the boiler.

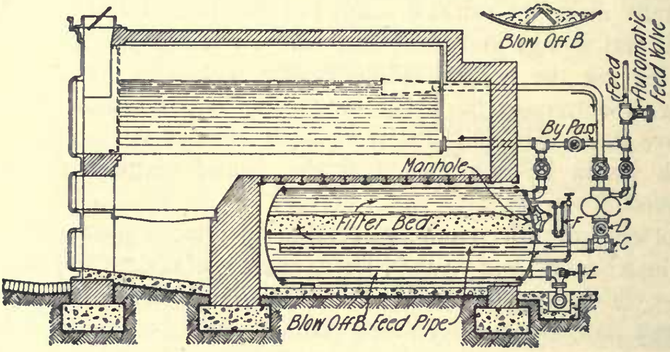

FIG. 309 (N3-2).

In Fig. 309 (N3-2) a precipitating tank is shown placed beneath the boiler. Water is taken from the surface of the boiler. This removes the impurities carried by the water which is in circulation. The feed water drives the circulator and thus causes all the water in the boiler to circulate through the settling tank and back to the boiler. For each gallon of water fed into the boiler an equal amount of water from the boiler circulates through the tank. The enlarged detail shows how the blow-off is taken from along the entire length of the tank bottom. As considerable scale will form where the feed water enters, a cap, *C*, closes the end of the brass distribution pipe and facilitates the removal of scale.

If the boiler pressure is 140 lb., the temperature of the water in the boiler is 350 degrees, and if the temperature of the incoming feed water is 200 degrees the temperature of the feed water will be raised to 280 degrees. This is sufficient to throw down the sulphates. The latter calculation is based on the assumption that for each gallon of water fed to the boiler one gallon of the water in the boiler is circulated through the treating tank.

It should be remembered that the smaller the amount of boiler water which is circulated, the more efficient the filter bed becomes. The circulating device shown would not be fitted with stuffing boxes. It would deliver its water under a slightly greater head than its suction. The parts of this device would be fitted loosely and its service would be very light. Manholes should be fitted in the outside end of the tank and a valve, *D*, provided to shut off the water to the under side of the filter bed. Hence by opening the blow-off valve, *E*, the deposit in the filter bed would be easily discharged into the sewer. The gage, *F*, shows a difference in pressure above and below the filter bed, and thus as the filter bed becomes fouled the pressure gage enables the operator to know definitely when it is necessary to blow it out. As little or no heat is applied to the tank there will be no tendency to form scale, the impurities settling in the form of mud.

The covering over the tank should be supported either on an arch or on T-bars, as shown in Fig. 309. When the tank extends to the back wall the wall should have the form of an arch about an inch distant from the tank. The space between the tank and the wall should be closed with asbestos to prevent any air leaking into the furnace. The tank shown in Fig. 309 has fully ten times the capacity of that shown in Fig. 308, and in addition it also has a filter across its widest section where the velocity of the water is the least.

To apply such a purifier to a Babcock & Wilcox type of boiler, it may be necessary to place it transversely instead of longitudinally as shown, or it may be placed outside of the setting. The only object in placing it inside the setting is to reduce the radiation from it. The purifier shown is a part of the boiler, being out of service whenever the boiler is not being used, and there would thus be ample opportunity at such times to examine or clean the purifier. This precipitation tank would require frequent blowing out, but the time required for this operation would be very slight. It does not become a repository for scale as in the case of live steam purifier.

The velocity through the filter shown in Fig. 309 would be about 3 feet per hour if none of the area were occupied by filtering material, but as the area through a filter bed is only about 25 per cent of the total area of the filter, the velocity through the filtering material will be about 12 ft. per hour. A filter bed used, as shown in Fig. 309, is not subjected to the same exacting requirements as the one used in the chemical system shown in Fig. 66. In the filter shown in Fig. 309 the water is constantly being repassed through the filter, and if the filter bed does not remove the extremely fine particles but little harm will result from their presence, since the water must be practically at rest before they will settle.

Filters such as shown in Fig. 66 ordinarily have about 1 square foot of filter bed for each 30-hp. capacity. That shown in Fig. 309 has about $\frac{1}{3}$ sq. ft. per hp., but as it must pass boiler water as well as the feed water, the area may be anywhere from 0.08 to 0.166 sq. ft. per hp.

Class N4 — Water Treatment Minor Connection. Intermittent chemical treating systems require a considerable amount of piping for their installation, due largely to the fact that separate pumps and heaters are generally required. In the water treating plant the pump is used solely in forcing water into the large tank. Steam may be brought from the main station to the chemical building, and instead of exhausting the pump into the main heater, the steam from the pump may be fed to a heater to be used for raising the temperature of the water before it is delivered into the treating tank.

In addition to the steam line to the treating plant there would be a line from the condenser discharge and a line from the intake. A pipe also would be required for delivering treated water to the boiler feed pump in the power house. If the treating tanks are placed more than 14 ft. below the feed pump and an open heater is used, the discharge from the tank should be run at a low elevation to a pump located as shown in Fig. 310 (N4–1). The steam supply to this pump is controlled by a ball float operated valve located at the heater, as shown.

If an open heater is used, this system of controlling the water to the heater is very satisfactory, and in most cases permits the use of a standard pump with the water cylinder on the level of the boiler room floor. Only in exceptional cases would the water supply be so far below the boiler room floor that it would necessitate placing the water end in the well, as shown in Fig. 310.

The bottom of the precipitation tank should be far enough above the supply water line to insure an ample drop for the wash-out line which is used for discharging the precipitate. There should be hose connections to the pump in the chemical house, as it is necessary to wash out the settling tanks. These tanks should not be washed out very often, since it is found in practice that the agitation of the old sludge aids in carrying down the finer precipitate when it is first formed, and it therefore is beneficial to keep some of the old mud in the tanks at all times.

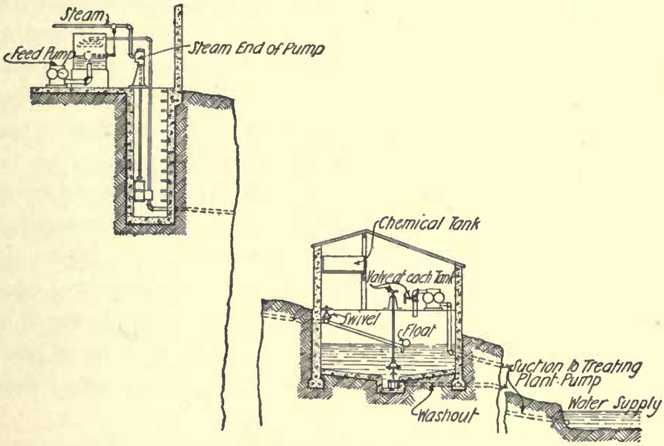

FIG. 310 (N4–1).

Fig. 310 shows a water tank constructed of concrete. Before deciding upon the use of concrete for this purpose it would be well to submit the concrete materials to a chemist, together with a sample of the water. The decision to use such materials would depend upon the character of the water and the reagents necessary to treat it. Wood is very extensively used for chemical treating tanks, as iron deteriorates rapidly. In any case the tanks should be round in shape with a mechanically driven agitator (motor-driven or otherwise).

Cold water must be agitated longer than warm water. Water at 35 degrees must be agitated for about three hours to complete the chemical reactions and about 1.5 hr. at 90 degrees and about one hour at 170 degrees. If the tanks are not continuously agitated while chemical action is taking place, the chemicals fall to the bottom and thus a large proportion of the chemicals is wasted. If the water is brought to a state of rest the precipitation is quite rapid, 15 min. generally being sufficient.

A complete plant for treating 600,000 gal. of water per day costs about $10,000. Ordinarily the total cost, including interest on the investment, depreciation, labor, materials, etc., is from two to five cents per 1,000 gal. of water treated, depending upon the character of the water, chemicals required and the amount of labor needed to operate the plant. Assuming a cost of four cents per 1,000 gal. for treating the water and that the plant is run at its full capacity 16 hr. a day for 30 days, the total cost of treating the water (1,920,000 gal.) would be about $75, provided that special employees were not needed to operate the treating plant.

A chemical treating plant for 1,000 hp. capacity would be much smaller than the 600,000-gal. plant previously mentioned, and therefore the cost of installation per gallon of capacity would be somewhat greater. Boilers of 1,000 hp. capacity require 4,000 gal. of water per hr. Consequently, if the tanks are changed every 8 hr. they must have a capacity of 32,000 gal. each or 96,000 gal. per day. The portion of the tanks holding water would then be about 20 ft. in diameter and 14 ft. high.

These tanks would have double the capacity if the water were changed every 4 hr. instead of every 8 hr. The chemical holding tank should be round, as the circular form of tank is best suited to use in conjunction with an agitator. If a tank is required for mixing the chemicals before they are fed into the precipitating tank, the water fed into the precipitating tank should be passed through the chemical measuring device and from there into the large tank, thus insuring that all the chemicals weighed out are emptied into the precipitating tank.

Instead of using a steam pump to fill the tank a centrifugal pump driven from a line shaft connected to a small engine may be used. This line shaft may also drive the agitators. The exhaust from this engine may be delivered directly into the water at the side of the tank, the heat thus being taken up during the entire time the water is being agitated as well as when the tanks are being filled. The pump and agitators should be fitted with clutches or tight and loose pulleys so that either can be run without the other.

If a station operator has trouble with boilers on account of the impure feedwater, it is advisable that he learn all he can about chemical treatment before making any definite decisions or letting contracts. The manufacturing chemists should analyze the water, state its properties, the reagents to use, quantity of each which are necessary, and submit a price for the reagents. From time to time after a treating plant has been installed it will be advisable to send a sample of untreated and a sample of treated water to the chemist's works to determine if the proper kind and quantity of reagents are being used and to determine if the reagents being used are giving the best results.

The successful operation of any water treating plant is dependent almost wholly upon the chief operator, and if it is necessary for him to become thoroughly familiar with this subject why should not this information be secured before planning the installation of a plant? If the chief operator has no other means of obtaining the information desired, it would no doubt prove to be a good investment to install a small vertical internally fired boiler in the boiler room within easy reach of the firemen. This small boiler need not be over 10 hp. and should be connected to one of the regular steam mains. A separate pump should be installed for feeding this boiler with treated water prepared in a small experimental treating plant consisting of a couple of temporary tanks.

The expense of such an experimental plant would be very slight, as the boiler could probably be rented and one of the spare pumps piped temporarily for feeding the small boiler. It is highly probable that after using the experimental plant for a month or two the employees operating it would be familiar with chemical treatment and any decision which might then be made regarding a permanent installation would be based on a definite knowledge of the conditions and would undoubtedly be correct.

CHAPTER XXIV.

HIGH PRESSURE WATER PIPING.

Classes O1 to O3 — Water to Hydraulic Elevators. If elevators are installed in a power house they are generally of the hydraulic ram construction termed "lifts," generally low lifts only, such as from the boiler room basement to boiler room floor level, a height of 10 to 20 ft. The elevator platform is placed on the end of a plunger and the cylinder is dropped into a well or casing. The valve used to admit and discharge water from the ram is generally of the balanced piston type with cup leather washers such as are used on heavy hydraulic rams. This valve is quite easily operated and permits the use of large port openings.

For boiler room service the pipe connection from the operating valve to the elevator cylinder and the discharge line from the elevated cylinder should each be about one-fourth the diameter of the plunger if the pressure carried at the pump is 60 lb. If high-pressure water is available, say at 120 lb., it can be used very satisfactorily. The use of warm water at 125 degrees or over should be avoided if possible, as the stuffing box packing and cup leather in the operating valve deteriorate rapidly when warm water is used. The reason for this is that the heat removes the lubricant from the packing. A standard three-way valve can be used for an operating valve, but is much more difficult to move and will leak considerably if it is used frequently.

In the construction of a hydraulic ram it is the best practice to fit a brass sleeve on the ram which passes through the stuffing box, but unless the brass sleeve is properly fitted considerable difficulty and annoyance will be occasioned by leakage. In no case should the joint between the brass tube and the ram be made tight at its outer or upper end. The inner end should be made tight and the outer end should be left free to move and discharge any water that may have leaked by the inner end, thereby avoiding the possibility of the pressure inside the tube causing a rupture. Considerable difficulty is experienced if the upper end of the brass sleeve is rigidly attached to the iron ram, because the expansion and contraction of iron and brass are not the same. This unequal expansion and contraction causes the joint at the inner or bottom end of the ram to leak and make trouble. The same difficulty is experienced if the brass sleeve bears against a shoulder on the ram at its upper end. A much better construction is obtained if the upper end of the brass tube is free to expand and contract, and to secure this the upper end of the ram, where the brass tube ends, should have a slight groove turned in it, as shown in Fig. 311 (O1–1). The tube can be placed on the ram and the lower end "spun" into the shape as shown.

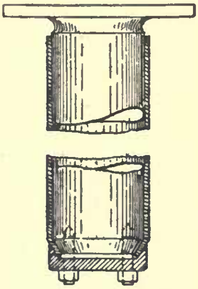

Fig. 311 (O1–1).

One of the most useful applications of the plunger hydraulic elevator is for coal and ash lifts in small stations. The general plan for installing a plunger elevator in a small power house is shown in Fig. 312 (O1–2). In such an installation the hydraulic elevator would lift the coal car about seven feet. The weight of the car would be about 1,000 lb. and the car would be loaded with from 1,000 to 1,500 lb. of coal.

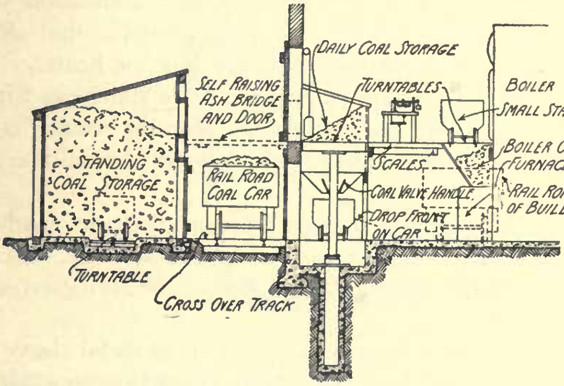

Fig. 312 (O1–2).

For a boiler plant averaging 1000 hp. about 100 trips per day would be required for handling the coal used in a 20-hr. day, and about 20 trips would be required to remove the ashes. The total number of trips per day would therefore be about 120 in 20 hr., or about 6 trips per hr.

In practice it has been found that one man on each shift can handle coal and ashes of the quantity stated and also weigh each car of coal. Ordinarily the coal is shoveled but once — from the car to the overhead bin. The storage space, which requires additional shoveling to load the coal into the small cars, is used only in case of shortage. The ash car can be placed either on a coal track or, if the conditions will permit, at the end of the overhead track that runs over the furnace hopper. This track is extended over the railroad ash car which is left standing on a stub switch.

The capacity of the daily storage bin should be slightly greater per foot of length than that of a railroad coal car. The small cars have a drop front, which facilitates loading them with ashes from the floor, and they are also fitted with dump bottoms. Scales are provided so that tests of a certain coal or boiler can readily be made. Ashes are delivered to the small car while it is on the boiler room floor level. The only power device required for this entire system is therefore the hydraulic lift, and the best practice is to use low-pressure water service for the ram if the station has its own water supply or has a storage tank into which the ram can discharge if city water is used.

If an open heater is used, fitted with a float admission valve to carry low water in the heater, it is quite probable that all the ram water would be saved by discharging it into the heater. The elevator as shown would require about 500 lb. of water per trip, or 60,000 lb. per day. The coal which the elevator would handle would evaporate about eight times as much water as would be used by the elevator.

Unless some forethought is given and preparations are made for sinking the cylinder casings considerable trouble may be experienced. It is difficult to dig a small deep hole and even more so to keep it plumb.

The most usual construction is to drop a sheet metal sleeve into a hole and fill in around it. This sleeve should be considerably larger than the cylinder.

Care must be taken in setting the sleeve to see that it is not out of place more than the clearance between it and the cylinder. This sheet metal sleeve will not last long in such a location, and to prevent the banks from closing in on the ram cylinder it is advisable to fill in around the sleeve with a sand and cement grout up to the point where the concrete floor of the elevator pit begins. If the casing leaks so badly that the grout runs into it, the interior of the sleeve can be kept from filling with cement by filling it with water. The water should be poured in so that its level is about the same as the level of the grout around the exterior.

Fig. 313 (O1–3) shows a hydraulic lift with the sleeve in place and a turntable on top of the platform. Ordinarily the pit for the platform would not be over 18 in. deep. A catch basin should be placed at the bottom of the pit to discharge any water getting into it. The bottom end of the ram should be closed air tight, for if it is left open the inside of the ram will fill with air, become "air bound" and cause the elevator to bounce up and down. If the air is discharged at the top, and the center of the ram is filled with water, the pressure on the bottom of the ram will be reduced by an

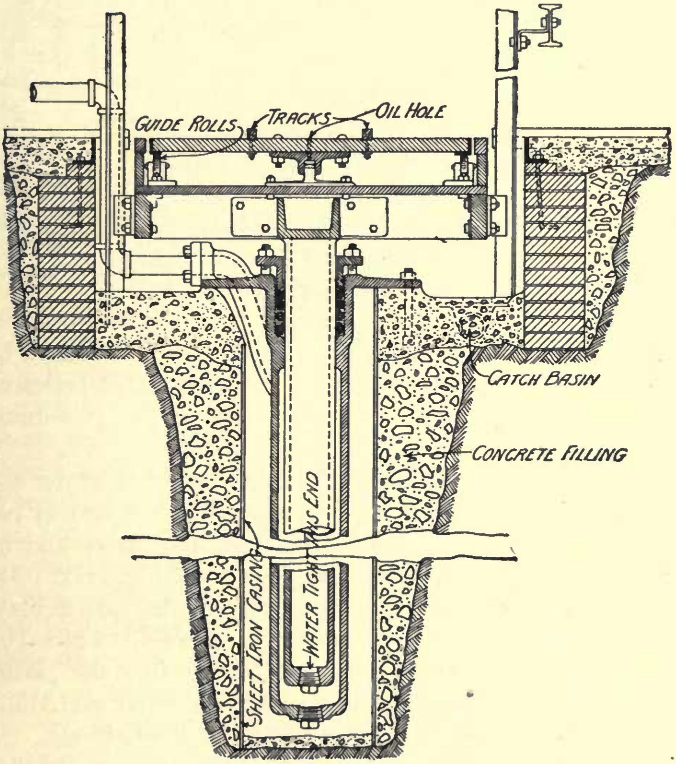

FIG. 313 (O1–3).

amount equal to the area of the head times the weight of a column of water as high as the length of the ram. Two guides for the platform are generally fitted at diagonally opposite corners of the elevator shaft. This is necessary if a turntable is used on the elevator platform. For small power houses this type of the elevator is in many ways better than a high-speed electric elevator, being less easily damaged by careless handling and less liable to accident. If the lift were 16 ft. or over it would be quite an undertaking to sink the casing plumb for such a distance and in such cases an outside cylinder with overhead sheaves and cable would be simpler to install and would be somewhat less expensive. Such a lift is shown in Fig. 314 (O1–4), the hydraulic ram in this case having one-half the travel of the elevator platform. A sufficient counterweight must be loaded on the ram to permit it to discharge the water and raise the platform when loaded. This construction is quite similar to the standard high-lift elevator construction. For high lifts an electrically operated elevator may be found more economical to operate.

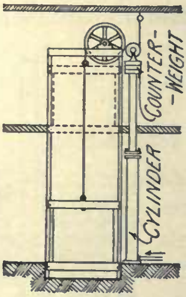

FIG. 314 (O1–4).

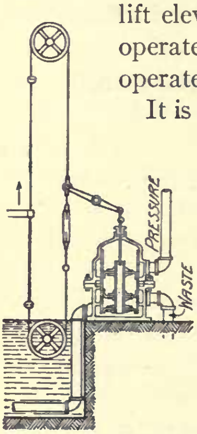

FIG. 315 (O1–5).

It is only for a low lift that the type of elevator shown in Fig. 313 is particularly adapted in power station work. An operating valve and operating cable are shown in Fig. 315 (O1–5). Automatic stops (top and bottom limits) are clamped to the operating cable, which, being struck by an arm extending from the platform, automatically shut off the water and stop the elevator at the upper and lower levels.

The pressure pipe for such an installation should be carried above ground, but the waste pipe may be run underground, especially if it discharges into a sewer. Unfortunately the location of the operating valve is generally such that it precludes the possibility of using pipe bends instead of elbows, but if it were possible to use them, the hoist would operate more quickly without requiring any greater power from the pump.

CHAPTER XXV.

AIR LINES.

Class P1 — Air Lines — Main. The use of compressed air in power stations is quite general, but for some classes of work it is used because it is available rather than because it is especially suitable. Ordinarily a motor-driven compressor of the type used on electric railway cars having an automatic governor is used. Air in many plants is used for blowing out dust and cleaning electrical machinery. These requirements are sufficiently urgent to make the installation of a compressor necessary. An air tank about 18 in. in diameter and 5 ft. high should be used to provide for sudden demands for air beyond the capacity of the compressor. For ordinary station use a steam-driven air compressor will be found to be more expensive and more troublesome to operate than the regular air compressor.

The air main and its branches may be made of black iron pipe with cast-iron fittings. The heating of the air as it is compressed is not sufficient to require any special consideration other than in the compressor itself. For stationary service, compressors are usually water jacketed, for the reason that water is available and can be circulated without the difficulties to be met with in water jacketing a compressor in car service. If a small compressor with a water jacket is obtainable it should be used. To avoid the neglect of opening the jacket lines when the compressor is started it may be well to use a tank, as shown in Fig. 316 (P1–1). Whenever heat is delivered to the cylinder the water will start to circulate and keep the cylinder cool until all the water in the tank becomes heated. A compressor thus fitted will show less wear on the

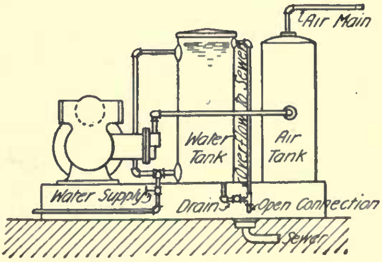

FIG. 316 (P1–1).

piston, cylinder and valves and will require less oil for internal lubrication. The motor would not have as heavy a load and a greater quantity of air would be delivered than otherwise.

Class P2 — Air Lines for Blowing Out Electrical Apparatus. The earlier method of blowing dirt out of electrical windings was by use of hand bellows, but as the size of electrical apparatus increased and as higher voltages were used, the necessity for a more efficient air supply made the use of air compressors necessary. The cleaning of the electrical machinery is not merely a matter of appearance, but it is absolutely necessary to prevent short circuits. The higher the air pressure, the more thoroughly is it possible to remove the dirt. By making this cleaning operation simple and convenient, the attendant takes much better care of his apparatus.

The air pipe lines are generally 1-in. mains and ¾-in. branches to hose valves. It is good practice to install a large number of hose connections, making the use of a long line of hose unnecessary. The hose should be ½ in. in size with a small opening nozzle provided with a valve. The hose should be able to stand 60 lb. pressure. The union that connects with the hose valves should have two projecting handles so that the hose can be attached and detached without a wrench. The hose connection valves should be ¾ in. with a hose nipple reduced for the ½-in. hose. Ordinarily it will be necessary to have hose connections at each generator, converter, or other apparatus; also at oil switches, back of the switchboard and other places where dirt and dust accumulate.

Plants that use air-cooled transformers should be provided against picking up dust through the fan suction. If some form of a vacuum cleaner could be used on floors around electrical apparatus, many of the cleaning troubles would be solved.

Class P3 — Air Lines for Oiling Systems. The use of air as applied to oiling systems is shown in Figs. 56, 58 and 60. The oiling system that is dependent upon air for its operation is a constant source of trouble, as it is then necessary to have an air pump always in service. When using compressed air for the oiling system, compressors should be installed that are adapted to continuous operation. The use of both air and oiling systems should be considered in the nature of conveniences and not a necessity. Nevertheless one frequently finds plants operating that have no other means of supplying oil to the engine than by an oiling system, which in turn depends on air to supply the necessary pressure.

Air may be used quite successfully to raise oil from a receiving tank to a gravity tank, but to do this requires a closed tank, which in itself is an objectionable detail. If tanks are to have air pressure upon them, they should be arranged as shown in Fig. 317 (P3–1). Tank No. 1 is shown ready to go under pressure and tank No. 2 ready to go out of service. The position, *A*, is that of the valve previous to changing over, with pressure on No. 2 and No. 1 open to the atmosphere. The position, *B*, is intermediate with all openings closed. Position, *C*, is an equalizing position; that is, tanks No. 1 and No. 2 open to each other. This position is retained until both tanks are under the same pressure. Then the handle of the valve is moved over to the position shown as *D*, this being with pressure on No. 1, and No. 2 open to the atmosphere. Before changing over tanks, it will be necessary to close drip valve, *E*; also open valve, *G*. Then, when the air valve is in the position *C*, valve *H* can be closed and the air valve then thrown over to position *D*. As soon as pressure is off of tank No. 2, the tank is opened to take the oil drips.

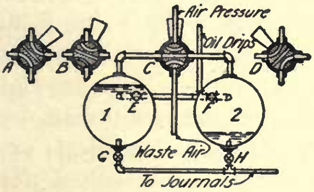

FIG. 317 (P3–1).

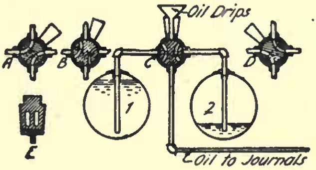

FIG. 318 (P3–2).

It will be noted that by having separate valves *E*, *F*, *G* and *H* there is considerable manipulation required. The operation of these tanks can be simplified by using another 4-way valve connected to the same handle as the air valve shown in Fig. 317. The handle when toward either single tank indicates that tank to be under pressure and when in the middle position as equalized, there being but three positions assumed by the one operating handle. Fig. 318 (P3–2) shows the position of the oil valve when placed in unison with the air valve. The same letters in Figs. 317 and 318 show a like position of the handle. The small port crossing the larger one may be obtained by drilling through the plug valve and placing a tube in the opening. Ordinarily a small port can be obtained by drilling and chipping, as shown at *e* in Fig. 318.

To further secure the oiling system against trouble in case the air compressor is out of service, also to avoid fluctuating pressure, it will be necessary to use an air storage tank and check valve in the supply pipe.

Class P4 — Air Lines for Fire Protection. Rooms containing inflammable material, such as benzine, paints, oils, etc., can best be protected with an air blower connected to a receptacle holding a fire extinguishing powder, as shown in Fig. 319 (P4–1). The syphon can be an ejector tee or a standard reduced tee, say 1 by $\frac{3}{8}$ by $\frac{1}{2}$ in. The extinguishing chemical may be either dry or liquid. The amount discharged can be controlled by the valve, *A*. The chemical extinguisher is especially suited for such fires as flame up, as oil, paint, etc.

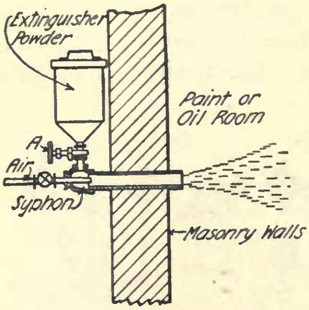

FIG. 319 (P4–1).

Class P5 — Air Lines for Signal Whistles. The air system can often be used very satisfactorily to signal from engineer to switchboard operator, as the air lines run to practically all the machines and is easily reached for whistle branches. There should be a whistle at the switchboard so that the operator can give a signal; also a whistle at the engine so the engineer may call the attention of the board operator. The whistles should be shrill so that they can be heard above other noises. Whistle signals are far-reaching and can be used more effectively than a bell and are very easily maintained. Air is much preferable to steam for all whistles, as air whistles can be located anywhere, are free from water and are ready to blow the moment the whistle valve is opened.

CHAPTER XXVI.

STEAM DRIPS.

Class Q1 — Steam Drips from Mains. While removing the condensation from pipe lines is important, it is not this that causes so much destruction to engines, but the water carried over in large quantities with the steam that must be given the chief consideration. Different systems for removing drips from pipe lines were shown in Figs. 36 to 44. In designing a drip system it is necessary to consider these "slugs" and make such provision as will protect the machinery from damage.

The arrangement shown in Fig. 320 (Q1–1) is satisfactory for handling condensation, but is not adapted for handling large quantities of water. The header as shown would with the flow of steam drain into the separator, and if this were of the ordinary size much water would be carried through to the engine. A safer plan is to take the steam from the top of the header and place the receiver separator at the engine throttle. The header would then hold back a large quantity of this water and discharge it through its own drip. Further to insure the discharge of this water from the header, it would be advisable to take the steam connection for the reheater coil from the bottom of the header and allow any water to work its way through the coil to the drain. This is a very desirable way for safeguarding against the flooding of engine cylinders because the velocity of the steam passing through the reheater is high, the capacity of the coil is large, and there is no mechanism to be injured by the water. As the heating capacity of the high temperature water is nearly equal to that of the steam there will be but little difference in the reheating temperature.

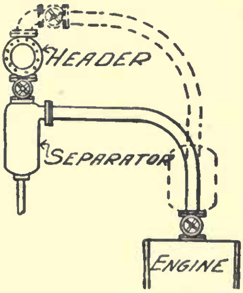

FIG. 320 (Q1–1).

Unfortunately the details that insure engine cylinders against flooding increase the condensation loss. This is true except for those steam lines that may be taken from the bottom of steam mains and feed the auxiliary service where water is not dangerous. Large headers or separators are a source of constant radiation loss, and if used with superheated steam the losses from radiation in these become greater than the loss from friction. If superheated steam is to be used it will materially affect the design of the pipe work, the steam supply and drip system.

No one feature of station operation causes so much water to be carried into steam lines as high water in the boilers. As soon as engineers realize that feed regulators do more than save trouble for the fireman, they will use them as they would a damper regulator, to save cost of operation, and then the ever-repeating difficulties arising from high and low water will almost entirely be eliminated. Regulators are now in the market which do not require floats and have an excess of power available to handle feed valves. The amount of attention required to keep them in good order is small compared with the labor of constantly watching the water level and regulating the feed valves. By using feed regulators it is possible to carry a much lower water level, thus insuring drier steam and imposing less work on the drip line. With a uniformly low water level it is nearly impossible for boilers to throw any great quantity of water. Where the boiler water is bad, carrying the water level low considerably reduces the danger of water being carried over into the steam line.

It is well to remember that superheat will remain in the steam only when the steam is handled at high velocity—6,000 to 10,000 ft. per min. If the steam velocity is low, even with a superheat of 200 degrees, all or part of this will be lost before the engine cylinder is reached. This condition calls for special consideration in the design of steam lines, as follows:

1. The steam lines should be as short as possible.
2. The size of the pipe should be small to reduce the radiation losses so that they will be approximately the same as frictional heat losses.
3. The line from the boiler to the engine should be free from abrupt turns.
4. Such portions of the steam lines as carry steam moving at a low velocity, should be provided with drip connections.
5. Large receivers, separators, etc., should not be used.

Where drip connections are necessary, the best method is to have small pockets in the Y-fittings and take the steam from these pockets to a drip separator and from the drip separator to the auxiliaries, as shown in Fig. 321 (Q1–2). Ordinarily Y-fittings are objectionable, but as they offer much less resistance to steam flow their use is desirable for superheated steam. The boiler branches should have long bends and no elbows because the friction of one 5-in., 90-degree elbow is about the same as that of a full length of a 5-in. pipe. In Fig. 321 it will be noted that water cannot lie in the end of a steam main, as shown at *A*, when boilers *B* alone are in operation, because steam is flowing to the auxiliaries at all times.

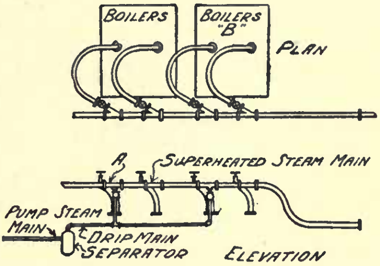

FIG. 321 (Q1–2).

In regular operation there will be little or no drip to care for in the arrangement shown in Fig. 321, but when starting a plant with no steam flowing to its steam machines there will be as much drip as though superheaters were not used.

Class Q2 — Steam Drips from Separators. Nearly all separators include some method of diverting the flow of the steam and rely for separation upon the inertia of the heavy particles to cause them to leave the steam at the point where flow is diverted. This form of separator is shown in Fig. 322 (Q2–1) as No. 1 and No. 2. The area of discharge is maintained practically the same through the separator as in the pipe itself. Another method for obtaining like result is to decrease the flow in the separator and allow the condensation to drop out, as shown in No. 3, Fig. 322. This requires an extremely large device. A very efficient separator is one in which the principles of these two are combined. No. 4 and No. 5 show different types embodying this idea. No. 4 takes up about three times the space of No. 5, and the velocity of the steam at the turn is one-third greater. The area of the steam passage in No. 5 is 14 times the area of the pipe. No. 5 has the advantage that the resistance of the separator is immeasurable on account of its large port area. The steam is divided into thin films as it makes the turn, and the condensation has the least possible distance to travel to get out of the flow. As the separator is relatively small in size, it can be very easily and favorably located.

In laying out a drip system some method should be provided so that this pure water of high temperature will not be wasted to the sewer. The usual method of discharging this condensation into the heater is not generally economical. If an economizer is used it will be best to discharge the drips directly into the boilers, as was shown in Fig. 36.

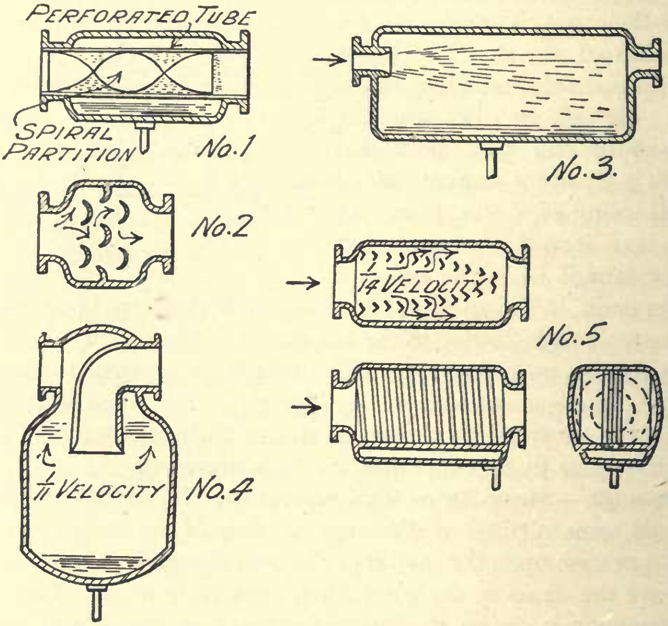

FIG. 322 (Q2–1).

Class Q3 — Steam Drips from Boiler and Engine Branches. Various forms of boiler branches are shown — Figs. 78 to 88. The different engine branches as shown in Figs. 74 to 77 usually require drains. These drains can nearly always be connected with the sewer and should be closed except when starting up.

Class Q4 — Steam Drips from Auxiliary Steam Main and Gravity Return. If the auxiliaries are placed far from the main steam line it is necessary to put in an auxiliary steam main. In some installations auxiliaries are operated at a lower pressure, making use of a reducing valve necessary. A usual method is to locate auxiliary main in such a way that the drips from the main steam header will flow to the auxiliary main and thus work through the pumps and other devices where water can do no particular harm. Figs. 40, 41, 42 and 44 show these different systems. In Fig. 40 all the drips are shown as collected in a drip main and delivered to an elevated receiver or separator, which discharges its drip back to the boiler and by gravity and the steam to the auxiliary steam main. Figs. 41 and 42 show a large-sized auxiliary main, which takes the steam from the various drip pockets to the steam header. The auxiliaries take their steam from the top of the auxiliary main, and the condensation flows into an automatic drip receiver and pump, which returns the drips to the boilers. In Fig. 44 an overhead receiver-separator is used. Fig. 323 (Q4–1) shows the general arrangement of this overhead receiver-separator. The connection to this separator is made at a low point in the drip main to insure regular working conditions. It is necessary to take a small amount of steam from this overhead separator, which may be used for a heating system, or, if economy is to be disregarded, may be discharged to the atmosphere. A large flow, however, would maintain the pressure in various parts of the system that would somewhat simplify operation.

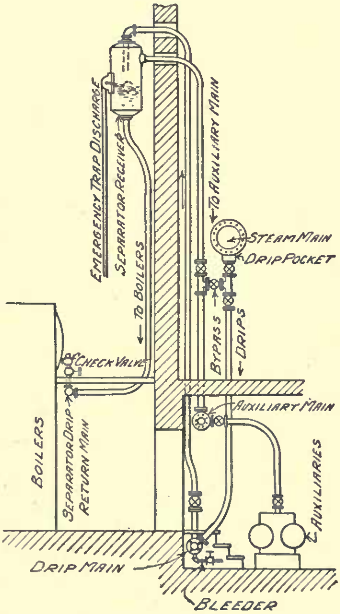

FIG. 323 (Q4–1).

Where there are numerous drip pockets which drain into a common drip main they are likely to be of different heights, producing different pressures. The pockets which are under lower pressure must have sufficient head in the drip branch so that the weight of the column of condensation will exceed this pressure difference, thus insuring a discharge even with the lower pressure branches. For instance, the reheating coil in the low-pressure receiver may have five pounds less pressure at its drip discharge and it may be located within a foot of the basement floor; there are two means of removing such drips, the simplest being to pass the highest pressure drips through the coils and in this manner make them all low-pressure drips. The other method is to use a float-operated resistance in the high-pressure drip pockets, thus causing a decrease in pressure in the drip branch as soon as condensation is discharged, and permitting the low-pressure drips to discharge.

Referring to Fig. 323 it will be noted that a trap discharge is provided for receiver-separator, this trap operating only when the water in the receiver rises above a certain level. This water line can rise, when all boilers are shut off from the return drip system and also when there is no flow of steam to the auxiliary main. Whenever the riser to receiver-separator fills with water the weight is increased until it becomes heavier than the column to the boiler; then the water ceases to return to the boiler, the steam condenses in the overhead receiver, the water level rises and discharges water from the trap. No water passes the boiler check valves until steam again flows to the auxiliary main.

In practice there is always a feed pump running and this alone is sufficient to operate the drip return system. The amount of steam required for the feed pump is about the same as the amount of condensation. Many drip return systems are operated by allowing the steam to waste to the atmosphere at the drip receiver, the amount required being about one-twentieth of 1 per cent of the steam generated. In practice a greater loss is necessary to insure the successful handling of drips when the boilers are throwing over water. It is to insure an abundance of steam to raise the drips without an accompanying loss that steam from the drip receiver is delivered to some piece of steam apparatus in constant operation. Instead of using the trap to discharge from an overhead receiver, a pressure relief valve can be used, opening and relieving the steam pressure whenever there is no machinery using steam. This type of drip return is more satisfactory than any pump return drip system and is being extensively employed.

Class Q5 — Steam Drips from Pump Branches. In long pump branches the considerable condensation makes some device for removing the steam from the water absolutely necessary. For this purpose a receiver-separator is often located at the pump close to the throttle valve. By connecting this receiver to the drip system, or by using a hand-operated bleeder, it is possible to get dry steam for the pump, even if the distance from the steam main is great.

The use of a receiver-separator is advisable for all classes of steam machines that are located at the end of long steam lines, the principal advantages being better lubrication and a drier steam. Where the steam machines are comparatively small and placed close together it will be much better to run a steam line from machine to machine than to put in an auxiliary main with branches. By taking steam from the top of the pipe and slightly sloping the pipe and placing a drip receiver at the lower end, dry steam for the auxiliaries will be insured.

Class Q6 — Drips from Pump Steam Cylinders. The drips from pump steam cylinders are present, even though the steam branch to the pump be well drained or free from condensation. Such cylinder drains are often the only means of discharging the condensation from the branch line. The best arrangement that can be provided for pump cylinder drains is shown in Fig. 324 (Q6–1). The operation of but one valve is required to open the four drains of the duplex pump. An arrangement of check valves prevents water being blown back into the cylinder which is exhausting to the atmosphere. If the steam to the pump is fairly free from moisture these drains are closed while the pump is in operation, and for the short time they are open in starting no difficulty will be encountered in discharging to an open drain.

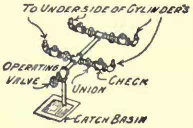

FIG. 324 (Q6–1).

Class Q7 — Steam Drips from Engine Cylinders and Reliefs. All engines require cylinder drains, either as a part of the engine or pipe separator. With Corliss engines, having a release device at the eccentric rods, drips can be discharged first from steam branch to cylinder, then from cylinder to exhaust by moving the valves by hand. Engines that are not equipped with the releasing gear require drips to free them from condensation when starting up. Pipe drips should have valves worked by hand, and to provide against water while the engine is running it is customary to connect at each end of a cylinder an automatic relief valve set at a pressure slightly higher than the steam pressure. On a Corliss type of engine it is customary to place the relief valve horizontally and above the cap of the exhaust valve, as shown in Fig. 157.

Class Q8 — Steam Drips from Engine Receiver and Reheater. In an installation having compound engines, reheating receiver, steam separator, condenser, etc., as shown in Fig. 325 (Q7–1), there would be a large amount of drips. This figure also shows the cylinder drip connections which would be used in case a release device on the valve gear were not provided. The by-pass from steam separator and drip line would be used only in an emergency when the reheating coil was out of service or when the drain would not pass the water fast enough. In case of high water or bad water the use of this waste would be necessary to prevent injury to the engine.

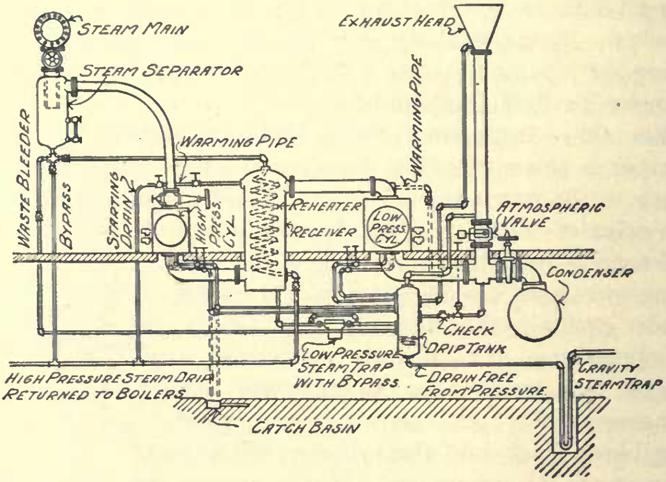

FIG. 325 (Q7–1).

The object in passing all drips through the reheater coil is, as previously noted, to insure quick removal and to eliminate handling drips of different pressures. The warming pipe is used before starting up and should be installed regardless of whether the valves can be hand operated or not, as it allows steam to be put on both sides of the piston. By the use of these warming pipes the different parts of the engine may be heated and expand to their normal size and form before moving over the wearing surfaces. It is well known that a perfect, dense and glossy surface is secured in the cylinder, on the piston and valves only after considerable time and care have been expended to secure it. These surfaces can easily be destroyed by moving one part over another when they are not at their normal running temperature, in which case, instead of the pressure being low, it is sufficiently high to preclude the possibility of oil reaching the sliding surfaces. When an engine groans in starting up, it is unmistakable evidence that the smooth surface gained by normal operation is being injured.

The starting drain at the top of the throttle is not a universal detail, as it is possible to pass this condensation through the engine by opening the throttle. By the use of the starting drain the oil is not so completely washed out of the cylinder. The cylinder drains should be piped to one side so that an extension valve stem and hand wheel placed above the floor can be used. Special care must be observed in running cylinder drips to avoid the possibility of water being drawn back into the cylinders when under a partial vacuum, as will be the case when the engine is being started and the little steam admitted expands below atmospheric pressure. Ordinarily each drain is run separately to the exhaust. The safety of this arrangement is contingent upon the certainty of the exhaust being free from water. The arrangement recommended by the engine builders is to run each drain separately to a catch basin in the basement floor, with the end of the drip pipe above the floor level, so that it is impossible to draw water back into it. In no case should the drain from one end of the cylinder be connected with the drain from the other end; each drain should be separately piped to the point of discharge, so that when one pipe is discharging water and the other one sucking air there will be no danger of water being drawn back into the cylinder. Where escaping steam is objectionable a drip tank can be used, but it should always be open to the atmosphere and to the sewer.

Class Q9 — Drips from Steam Loop. In Fig. 326 (Q9–1) condensation is being taken by the gravity return loop from an elevation lower than the boiler into which it is discharged. To maintain this system in operation it is necessary that the weight of the column, *A*, shall be less than the weight of column *B*. The riser leg, *A*, will contain, when working, water at a temperature of the steam — say, 140 lb. pressure — which will make the weight of the water 55.16 lb. per cu. ft. The drop leg must be sufficiently exposed to lower the temperature of the water 100 degrees, say, to 250 degrees. At this temperature the water would weigh 58.81 lb. per cu. ft. With these temperatures, if riser, *A*, were 50 ft. and distance, *C*, one foot, *B* plus *C* would have to be 47 ft. and distance, *D*, 3 ft. to make the system operative when full of water. This, however, is not the usual method of operation. The distance, *D*, is generally 15 or 20 ft. In order to maintain water in the leg, *B*, continuously heavier than leg, *A*, it will be necessary that the contents of leg, *A*, be steam and water, the steam flowing at sufficient velocity to carry the condensation upward and into the condensation pipe. The riser, *A*, must be sufficiently small to produce this velocity and the condenser pipe sufficiently large to condense the steam that passes through riser, *A*. The difference in water temperatures of the two legs is quite a negligible quantity, the system being operative with water and drip legs practically at the same temperature as the steam.

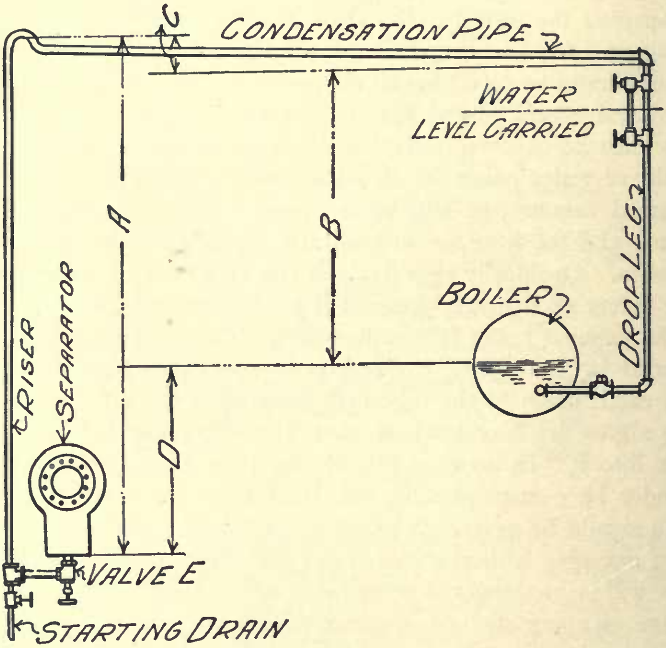

FIG. 326 (Q9–1).

There are many features to be considered in connection with this type of drip return which require extra judgment to determine. With a small size of riser pipe a greater pressure drop is necessary, and to permit this greater pressure drop the drop leg, *B*, must be increased accordingly. If riser, *A*, is made very large, then the riser, *B*, can be short, but the condenser pipe must be increased to condense the increased amount of steam. If the system is laid out in a comprehensive manner to do certain work, it is possible to operate this loop very satisfactorily. The valve, *E*, controls the flow through the loop and is set by observing the water level in the gage glass at the top of the drop leg. The closing of the valve, *E*, decreases the pressure accordingly for the entire loop, and the water in the gage glass rises until its head equals all the losses.

In comparing this drip system with that shown in Fig. 323 it will be noted that the two systems are very similar in that they both carry condensation to an elevation so that it will flow to the boiler — one condensing steam to effect this result, the other using the steam. The system shown in Fig. 326 could go out of service without any ready means of showing it; but the system in Fig. 323 would show quite plainly by the water passing through the feed pump.

Class Q10 — Steam Drips from Automatic Pump. In the best station practice moving parts are eliminated wherever it is possible to obtain desirable results in other ways. The automatic drip pump generally possesses some detail that requires considerable attention. If the float is air tight and sealed, it is liable to become water logged or collapse. If it is an open bucket with a counterbalance, it is liable to become filled with mud and cease to operate. The open bucket is the most reliable, and to overcome the difficulties arising from the collection of mud a blow-off should be attached to clean out both the receiver and the bucket, as shown in Fig. 327 (Q10–1). The register type of balance valve is often used on a pump for this service, an automatic lubricator being placed above the throttle to lubricate the sliding parts.

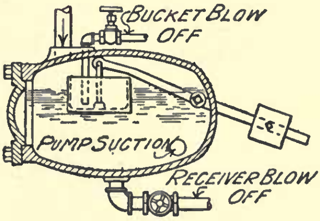

FIG. 327 (Q10–1).

The work for an automatic pump is much like a low-pressure service. The difference in pressure is very slight, but the pressure to which the pump may sometimes be subjected is three or four times the boiler pressure. For this work the outside-packed plunger pump is objectionable for two distinct reasons, one being that the plunger packing is difficult to maintain for high temperatures, and the other that plungers must be packed to stand high pressure, while the pump is only doing low-pressure service. In the latter event the power required to move the plunger in the packing is much greater than the power required to pump the water.

The pump shown in Fig. 277 is suited for this service, as it has a 1-piece brass lining in place of the packing and gland, the slight loss by slippage being much less than the frictional loss in a packed piston. In the pump shown water can flow from the reservoir into the cylinder without lowering the pressure on opening the suction valves. The lowering of pressure on high temperature water is accompanied by re-evaporation, causing the pump to become steam bound, and unless the valves are mechanically operated the receiver should be placed not less than 18 to 24 in. above the pump.

Class Q11 — Steam Drips from Exhaust Main and Branches. The collection of drips from the exhaust main is a low-pressure service, and, unless the cost of water is excessive and an oil separator used, it is desirable to let them go to waste. Exhaust mains under atmospheric pressure are quite readily drained by a U-shaped water seal, as shown in Figs. 161 and 162. A very simple drain trap can be used for this service, consisting of a buoyant exhaust valve, as shown in Fig. 328 (Q11–1). The water fills the trap body, and the partial vacuum causes the valve to rise to the surface of the water and return to its seat when the water is discharged. This trap is operative under a more limited range than that shown in Figs. 161 and 162. When possible the branches and main should be laid out so the drips will be delivered to one point.

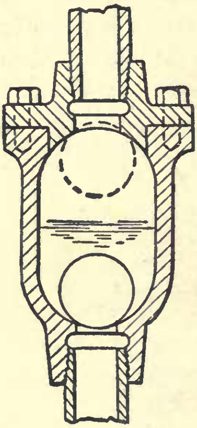

FIG. 328 (Q11–1).

Class Q12 — Steam Drips from Vacuum Separator and Steam Traps. The ordinary form of grease extractor is shown in Fig. 154. The drips from a vacuum line require a special trap or entrainer, which part of the time may be under the same pressure as the vacuum line, then again under sufficient pressure to discharge against the atmosphere. This is accomplished by having a steam line running to trap and valves in both the drip line and steam line, one of which is closed when the other is open, a float device being used to operate the valves. Fig. 329 (Q12–1) shows one form of the device in which the steam line is closed when the drain is open. When the float rises the line to the vacuum drip is closed and the steam valve is open, forcing the water in the trap through the spring-closed discharge. In some types the float operates a pilot valve which admits pressure to and operates a multiported piston, there being but two working combinations of port openings. The pilot valve control is very successfully used for steam traps of the type shown in Fig. 330 (Q12–2). A very small float, with but a fraction of an inch travel, will control a large discharge valve.

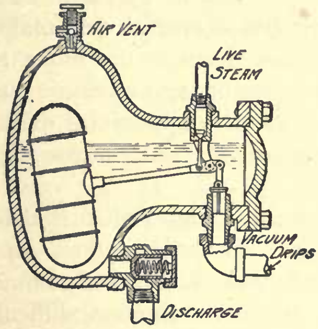

FIG. 329 (Q12–1).

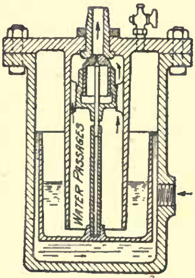

FIG. 330 (Q12–2).

Two steam traps of the same resistance are able to discharge the same quantity of water against the same head. The capacity of a steam trap can be intelligently stated by giving its head loss when discharging a given quantity of water. The size of pipe connections have little bearing on the capacity of a trap. The head loss should be the loss in pressure as measured at the inlet and the outlet pipes close to the traps, being the loss occasioned by resistance. In specifying for a trap it should be stated that the trap shall have not less than a given number of gallons capacity, with a loss of pressure not to exceed a certain number of pounds, when passing through the trap.

Class Q13 — Steam Drips from Outside Buildings. This service is in nearly every case of a complex nature. The collection of drips from different parts of the various buildings invariably offers many obstacles to systematic or reliable arrangement. Some drains may be delivered at high elevation, others at a lower one. The pressure may be high at times, and at other times very low. A system for this purpose must be able to take drips at any temperature, elevation or pressure and in almost any quantity.

Steam lines can be carried long distances, first to a high elevation, then to a lower one, and then up, and so on, without any other limitation than to care for the expansion and the drips. The high-pressure line can generally be drained by steam traps at the different low points, delivering into a special drip main, the pressure being sufficient to return the drips to the boiler room. In places that have drips of a lower pressure an automatic receiver pump would be used. Such buildings or points having drips of a pressure higher than the drip main would require steam traps to discharge drips into the drip main.

When the pressure of the drip main is higher than that of the line drained a pump must be used. These limitations must be observed in all the drains provided; that is, the drips cannot be handled if below the drip main pressure. Another difficulty is in the maintenance of a constant drip main pressure. This is necessary if return drip pumps are used, and the pressure can generally be maintained by using a relief valve set at some desired pressure and allow drips to pass from the drip main through this relief valve.

When drips are returned from many points in large quantities it is customary to use a drip storage tank, and feed the water to the boilers. A plant having many mains and a great variety of steam condensing devices can reduce radiation loss and insure better results in general by using boiler feed regulators that will increase feed to boilers at the same time the quantity of returning drips is increased. There are so many governing features in drip returns that each separate feature must be considered. The following points must be considered and each condition safeguarded.

1. The drips have approximately the same temperature as the steam, and on discharging into a lower pressure, much steam is formed.

2. Steam traps invariably discharge some steam before they close.

3. Water moving in "slugs" separated by steam will strike the fittings much the same as if it were a solid bar.

4. The velocity that water will travel and strike fittings is governed more by the rapidity of steam condensing in the drip lines than the normal flow of the drips.

5. High velocity drips prevent water and steam separating into large volumes of each, the entire mass being broken up and water hammer practically eliminated.

6. The lower the drip line pressure the greater will be the volume of vapor.

7. To carry a partial vacuum on drip lines serves to lower the temperature, the action of water, steam and air in the lines being the same as at any other pressure.

8. The less the pressure difference between a drip main and that drained, the less will be the difficulties from water hammer.

9. Drips can be carried to a high elevation with very slight head loss, the steam and water being intermingled in the riser pipe.

10. Whenever possible the steam pressure should be reduced so that the drips are but slightly greater in pressure than the drip main.

11. The discharge from an automatic pump must be of higher pressure than its suction.

12. The high condenser pipe of a steam return loop must have its air removed with a vacuum pump if its pressure be below atmosphere.

In laying out a system the drip line can vary in elevation if at all times there is sufficient steam carried to sufficiently reduce the weight of the total mass. Fig. 331 (Q13–1) shows a drip return with two risers, the difference in the pressure at the two ends being slight and depending upon the ability of the horizontal lines to condense the steam. The vaporizer delivers steam only when an insufficient amount is passing through with the drips. The efficiency of this device is greater than that of the steam loop shown in Fig. 326, as it rarely uses live steam, while the loop requires live steam at all times. When water rises in the vaporizer live steam is added, but as long as water is carried up from the riser with the steam, no live steam is necessary. If the drip system is delivering at about atmospheric pressure, one cubic foot of water will make about 1,600 cu. ft. of steam. If the total height of risers, *C*, *D* and *E*, is 50 ft. and the drop leg, *F*, is 20 ft., then 30 ft. of the 50 ft. in the riser must be steam and not require additional head to carry the water up the riser. Ordinarily, much more than one-half the volume of the drip is steam, and live steam will not be required to lighten the riser columns. If live steam were required it would take but one pound of boiler water generated into steam to lighten 1,000 lb. of drip return water.

The riser should be sufficiently small to insure high velocity, and to suit variable conditions risers may be in pairs, each pair being of two sizes of pipe, say $\frac{3}{4}$-in. and 1-in., which will permit either being used separately or both in unison, giving capacity in the proportion of 9 to 16 to 25. If the drip system shown in Fig. 331 is used to remove drips from pressure steam mains, these drips can be returned against boiler pressure even if the drips are at 10 lb. below the boiler pressure, in which event, however, it will be necessary that sufficient length of drop leg be used to overcome this difference in pressure. If the drips are solid water it will be necessary to use the vaporizer shown in Fig. 331 to raise them to the high horizontal condenser pipe.

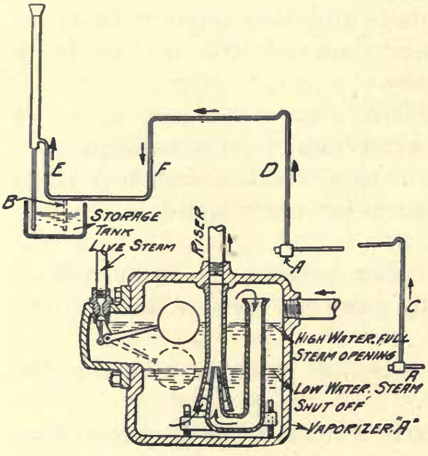

FIG. 331 (Q13-1).

The greatest objection to the loop drip system is that the principle governing its operation is not well understood by those who usually have it in charge.

A simpler form, although possessing more parts, is that shown in Fig. 332 (Q13-2). On the score of simplicity it is largely used in collecting drips from surrounding buildings. Each building has a drip tank provided with a vaporizer pipe. The water flows by gravity from these tanks to the main station. Such buildings as *A*, which have tanks located at a high elevation, may have a low level tank to catch all the building drains and a pump to raise these drips to an overhead tank. This would be strictly a gravity system, and if grease were removed from the exhaust drips they could be returned in this way. Another method is to use the drip tanks, as shown in Fig. 332, with each tank located to suit the requirements. In a small float-controlled pump the discharge from the different buildings is taken from a low-pressure main to an elevated tank in the power house, then to an open heater. The drip mains from building to building can be placed on different elevations, since the entire system is one of pressure return. The boiler room tank is of necessity higher than any of the drip lines. This system as well as that shown in Fig. 332 would be free from water hammer and other difficulties arising from steam and water in drip lines. To avoid trouble from steam in drip pipes, it would be advisable to discharge traps, etc., into a large standpipe vented through the roof. This will give storage for trap discharge and at the same time permit vapors to escape or condense. The standpipe should have about twice the diameter of the trap discharge. The method shown in Fig. 331 is good, and modifications can be made that will permit its use in many places.

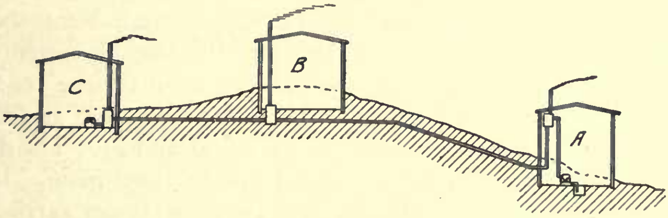

FIG. 332 (Q13-2).

If live steam lines, water lines and electric wires also run between buildings, then some form of tunnel will be advisable. The pipe lines should be located over each other and at one side, while the wires should be placed at the top. If the expense of such a tunnel bars its use, the next best plan is to use a masonry trench, the sides and bottom having a cover that is a slow conductor of heat and waterproof. A concrete trench with a wooden top is shown in Fig. 333 (Q13-3). A top having single boards is a poor construction. With heat on one side, and the outside exposed to the rain and sun, the boards soon warp so that they will leak air

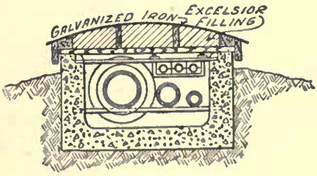

FIG. 333 (Q13-3).

and water, damaging the pipe covering. Each cover section should be one sheet of galvanized iron with the ends lapped to protect the joints. The excelsior filling improves the insulating properties, but this type of trench cover being double thickness with an air space makes a good non-conductor without the filling.

Class Q14 — Steam Drips Miscellaneous. The safety valve should have a drain to discharge such condensation as may be caused by steam leakage past the valve, this detail being shown in Figs. 128 and 129. The drains from the heating system are shown in Figs. 178, 179 and 180. Drains from surface condensers are shown in Figs. 226 and 228. The drip main returning drips to boilers is shown in Figs. 36, 37, 40, 41 and 44. The drips should not in any case be discharged into the feed main. High temperature drips have more or less vapor or steam carried in them and only when conditions are regularly maintained can these high temperature drips be delivered to a feed main without causing serious water hammer. The branches from drip mains to boiler should have stop valves next to the boiler, a check valve and another stop valve next to the drip main.

It is quite safe to state that in nearly every case it is a saving to return drips to the boiler in some manner. If but 1 per cent of the steam generated in a 1,000-hp. plant is discharged in drips then $360 can be invested to save the heat units and show 10 per cent on the investment. The value of returning pure water is in many cases even greater than the gain in saving heat units.

CHAPTER XXVII.

OIL PIPING.

Class R1 — Oil and Drip Mains. There are three classes of oil mains to provide for: engine oil supply, cylinder oil supply and oil drip mains. The engine oil mains, continually under pressure, are used in connection with a drip return system. The oil passing through will be free flowing, and the cooler this oil can be kept the more suitable it is for reducing friction and the temperature of engine bearings. In making up the joints for the oiling system, a thread filler should not be used. The most perfect joints are made by using clean oil and clean threads on iron pipe, the fittings being of rough brass. The use of brass pipe should be avoided, as it increases the cost of installation, and all brass joints are difficult to make tight. Galvanized pipe is suitable, as this pipe must be of a good grade to be galvanized, and in the process the pipe is pickled, which removes most of its scale. Malleable iron fittings should not be used, as they are not stiff enough ordinarily to make up oil-tight joints. Heavy cast-iron fittings and galvanized pipe or drawn steel tubing and brass fittings make the best combinations.

The joint shown in Fig. 334 (R1–1) permits the pipe being screwed up to the shoulder. The round joint nuts or rings of steel are screwed up when the pipes are all in place; this compresses the brass fitting, making the joint tight. A strong connection results, offering a smooth bore, free from shoulders and projections that collect sediment and block the pipe. The valves should be smooth-bore cocks, with ends made up the same as the fitting shown. The inside of the pipe should have its ends reamed concentric with the fittings. A sediment pocket with a plug at its bottom for cleaning should be provided. Crosses are often

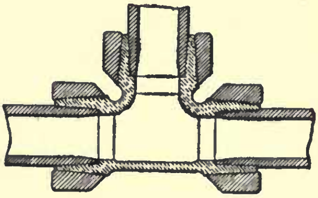

FIG. 334 (R1–1).

used for this purpose, but are objectionable, as the pockets are small.

The drip mains are the main sewer, with no head, and running part full, carrying all the impurities washed into them. Much trouble is experienced with these drip lines if made with standard pipe and fittings. The details essential for sewer connections are clearly shown for the drip main:

1. The bottom of the drain must be a smooth, unbroken surface free from pockets or projections.
2. In case it is necessary to make a drop, means should be provided for cleaning out the trap thus formed.
3. A gradual fall should be given the line.
4. A means for cleaning the line should be available.

If the length of the drip main is not more than one length of pipe, then a large pipe of, say, 2½ in. can be used. The drains are taken in at the top of the pipe, through drilled and tapped holes. Where more than one length of pipe is required the joint should be free from pockets or shoulders. About the only practical method of accomplishing this is as shown in Fig. 335 (R1–2). A lead ring is squeezed into the joint between the flange and pipe at the threads. The bore of the flange is machined the same for both flanges and if this varies slightly the lead ring is trimmed with a slight bevel from the end of pipe to the flange. When this flange joint is made up the bore is smooth, leaving no projections to cause precipitation. Connections can be made by means of a T placed between the flanges shown in Fig. 335, but this will be more expensive than to use a larger main, drilled and tapped on its upper side to receive the branch. The pipe main shuts out the dust from the basement and also permits steam being blown through to clean it out, as shown in Fig. 114.

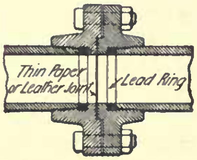

FIG. 335 (R1–2).

An open main, similar to a roof gutter, can be made of galvanized sheet iron, or a wooden trough covered with tin can be used. A flat open trough would retain many of the impurities and relieve the filter to this extent. Considering the use of a device carrying oil, and open to the atmosphere, it must be expected that oil will creep over the entire outside surface. Drip lines should be run in warm places. The warmer the line is kept the less liable is precipitate to lodge.

Class R2 — Oil and Drip Lines to Cups and Machines. The following few essentials in these drip connections should be provided for.

1. The connections to main journals, eccentrics and crank-pins should be arranged so that the journal caps or oil guards can be removed while running and without shutting off the oil supply.
2. Different lines and branches should have a gradual uphill construction, there being a low point which all the branches will drain.
3. Pipes should be supported a sufficient distance from the machine to permit cleaning.
4. The oiling system for each machine should be a unit in itself operative without the general oiling system and capable of being changed over while the machine is running.

The first requirement is shown in Fig. 336 (R2–1), the pipes swinging on their threaded joints. If valves were used in each of the swing connections they would be placed at *A*, this being necessary in order to disconnect the cups from the journals. Valve *B* is the throttle and the tee shown at *C* is pointed down, with a valve or plug at its lower end. For the third requirement some post form of support of the type used for plumbing fixtures, as shown in Fig. 337 (R2–2), is very desirable. Fig. 338 (R2–3) is objectionable unless the post has a right-and-left thread. The screw holes for the support shown in Fig. 337 can be drilled with a breast drill, but for Fig. 338 a ratchet drill must be used. The distance from the pipe to the engine frame need not be great — 1½ in. on small pipe and 2 in. on larger ones, this distance being quite convenient to allow passing a piece of waste through.

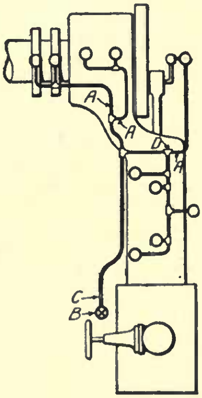

FIG. 336 (R2–1).

The fourth requirement is quite essential as its non-observance affects continuous operation. It requires an emergency tank, located between the oil throttle and the journals, permitting engine oil to be supplied in large quantities. Emergency tanks can be kept away from the engine, the valves placed at a high point and the tanks attached when required, using the oil in the combined cup until the emergency tank can be attached and filled, thereby making a very reliable arrangement.

The different drains may be attached to a drip pot located in the main. This avoids the necessity of running many branches. The joining of drips with a tee is a very crude detail. It should be an invariable rule that no drip branch shall be run that cannot be cleaned from end to end by passing a wire through it. The drip pot, Fig. 339 (R2–4), is especially suited for basements where the drips are located close to the ceiling. That shown in Fig. 340 (R2–5) is suited for drip lines built in the cement floor. These drip pots are of size to take six or eight drains, one pot to take three or four drains at one point and discharge into the next pot, the next pot to take four or five more and discharge into another, one engine having possibly three pots, including the one located in the main. When pots are used there is no occasion for using valves in the branches or other means for cleaning except by wire from pot to pot.

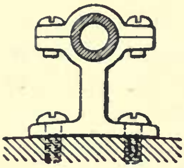

FIG. 337 (R2–2).

FIG. 338 (R2–3).

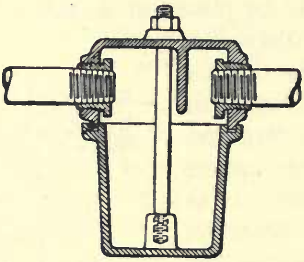

FIG. 339 (R2–4).

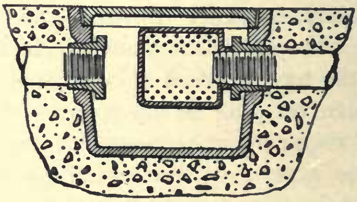

FIG. 340 (R2–5).

The ordinary method of draining the engine bed and pans is to drill and tap a small opening with which the drip pipes are connected from below. Some engine beds have drains carried to one side, possibly half in and half out of the floor, the details employed being insufficient to provide for the proper flow of the oil and likely to become damaged. The drip pot shown in

Fig. 341 (R2–6) should be provided, there being hardly any other detail that can be employed to keep vibration strains from the pipe and also make renewals possible.

Modern practice requires but little piping for cylinder lubricators other than that furnished with the engine. Force feed lubricators are used almost exclusively. They are economic and positive in operation. There is chance for considerable loss due to careless use of cylinder oil when it is supplied from a pipe line. When the drop, sight feed lubricator was extensively used, there were various methods of piping the lubricators, as shown in Figs. 54 to 57. For large power plants the cylinder oil supply system, shown in Fig. 58, may be found convenient and clean. The saving in oil and labor will be slight, but as the piping for such a system is inexpensive, it may, in an indirect way, be a profitable investment, as it aids in securing cleanliness in the plant.

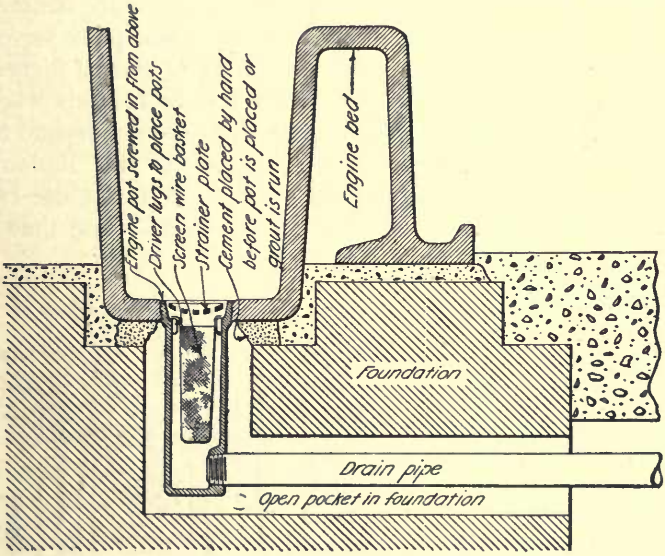

FIG. 341 (R2–6).

The method of feeding cylinder oil to the steam valves and the cylinder has much to do with the economical use of the oil, it often being possible to reduce the consumption fully one-half. Oil should be fed to the valves as close to the cylinder as possible. The quantity of animal fat required in an oil is determined by the amount of condensation in the cylinders. The animal fats should have the least possible exposure to high temperature steam. Animal fats are the only lubricants that will adhere to the wet walls of cylinders, therefore the drier the cylinder walls the less animal fat will be required, thus permitting the use of a much heavier mineral oil. This will require atomizing at a considerable distance from the cylinder. Such heavy oil is a permanent lubricant and will stand coming in contact with high temperature steam.

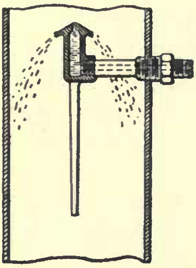

FIG. 342 (R2–7).

Atomizers for use in steam pipes serve the same purpose as feeding in the oil higher up in the pipe. The oil is broken up when it leaves the atomizer and does not depend upon the heat of the steam to be thoroughly vaporized. A vaporizer is particularly valuable in the use of oil containing animal fats, as it shortens the distance and time that these fats are exposed to steam before precipitation on cylinder walls.

One form of atomizer is shown in Fig. 342 (R2–7). The chief requirement of this device is that no part can become loosened and carried into the engine. The long foot or stem projecting downward from the atomizer prevents the head from unscrewing. Another method of use is to have the atomizer head smaller than the opening in the pipe, made in one piece and screwed in from the outside. A most satisfactory lubricator is shown in Fig. 343 (R2–8). As the oil receptacle incloses the entire pump mechanism the receptacle is free from all working parts, being held in place by two winged nuts on the end of two eyebolts. The receptacle can be removed while the pump is in operation and oil fed to the pump suction direct. A stroke adjuster, which moves with the plunger, shows the movement of each of the plungers.

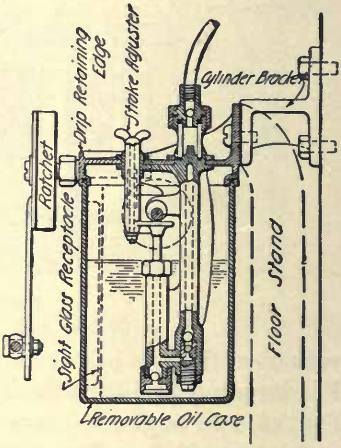

FIG. 343 (R2–8).

Some Corliss engines have lubricators with five feeds, but this is not the best practice for the economical use of oil. There would be in this case one feed at each end of the two admission valves, and the other feed into the packing rings. The latter feed is desirable if fed between the inner and outer ends of packing, requiring in this case as much pressure to deliver oil to packing as will be required to deliver it into steam space. The lubricator ordinarily should have three feeds — one to the rod as noted and one a short distance above the throttle valve with an atomizer, as shown in Fig. 342. There should be another feed higher up in the steam pipe for emergency use.

With four lubricator feeds in use, it is difficult to get men accustomed to proper feeding. The general tendency is to use too much oil, which is detrimental to proper lubrication — it is more difficult to break up a large drop of oil than a small one.

The oil cup shown in Fig. 344 (R2–9) has many commendable features. Oil from the pipe line can be discharged to a journal or cup and oil from the cup can be discharged to the journal. The cup can be filled by rotating the cock shown. The handle of the cock is balanced and shows the position of the parts. The ends of the cock are packed, affording sufficient friction to hold it in any position in which it may be placed, without leakage. The needle valve utilizes its packing, more to retain set than to prevent leaks, as there is no pressure past the valve. In regular operation the line is shut off with the cock and the needle valve left undisturbed ready to feed the desired amount when the engine is again started. If the oiling system is under pressure before the engine starts, the oil cups at the top of the oil regulator are left off. Instead of using glass body storage cups, they may be made of light sheet metal, as shown in Fig. 345 (R2–10), and shaped to stack up in close quarters and be ready for use if required.

Another type of oil feeder is the automatic oil cup or valve arranged to close when the oil throttle is closed and open with the throttle. This type of valve is shown in Fig. 346 (R2–11) and to make the system reliable an emergency tank must be used, as shown in Fig. 59. This automatic valve consists, primarily, of a free moving piston with a valve at its lower end. The pressure moves the piston from the valve seat as far as the set of the regulating screw will permit and a spring closes the valve when the oil pressure is off. Any leakage that may pass the piston will flow over its edge and be discharged through a port in the center of the regulating valve. When the piston closes the regulating valve it also closes the valve in the open end of the piston, shutting off any oil that otherwise would leak past the piston. The union connection to the sight post is the same as shown in Fig. 344. This permits a pipe connection and a position of sights to suit the requirements. The valve in this cup remains at the end of the pipe when the cup is disconnected from the journal, the same as in Fig. 344. When it is necessary to change over to the low-pressure gravity system the adjusting screw is run out and the valve mechanically lifted from its seat. The spring used for low-pressure cups is light, so that the pressure will force back the piston and open the valve. The high pressure requires a spring that will close more firmly but not so accurately as with fitted valve faces. The parts of this cup are few in number and as each is heavy there is practically no danger of the parts becoming damaged.

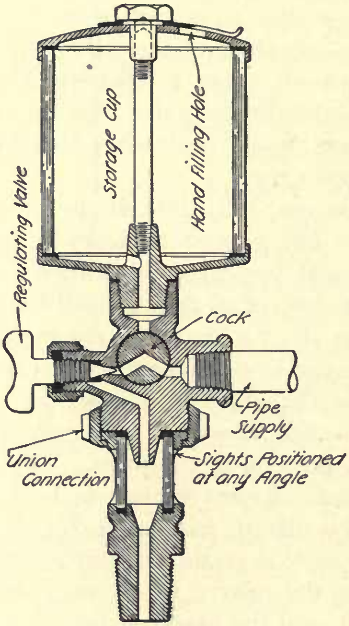

FIG. 344 (R2–9).

FIG. 345 (R2–10).

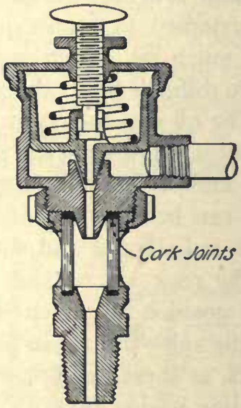

FIG. 346 (R2–11).

Class R3 — Oil and Drip Lines for Oil Pumps. Any of the pumps ordinarily used for water can be used to pump oil if the oil can be kept free from water. The animal fats have an affinity for both oil and water and if the oil contains or takes up animal fats it is then in condition to absorb water. Oil in this condition cannot be agitated without foaming and where the oil is used many times these fats are sure to be taken on and considerable water be absorbed by the oil.

The duty of an oil pump is generally so light that the greatest difficulty is encountered in handling small quantities of oil; for instance, if a 3 by 2 by 3 in. steam pump be used, pumping half a barrel of oil each hour, then the pump would make but 10 strokes per minute or a total piston travel of but 2.5 ft. per min. If the steam line to the pump were only ordinarily exposed to radiation, the condensation would almost stop the pump. For handling so small a quantity of oil at a pressure of 15 lb. per sq. in. a drive equal to 0.004 hp. will be required to operate the pump.

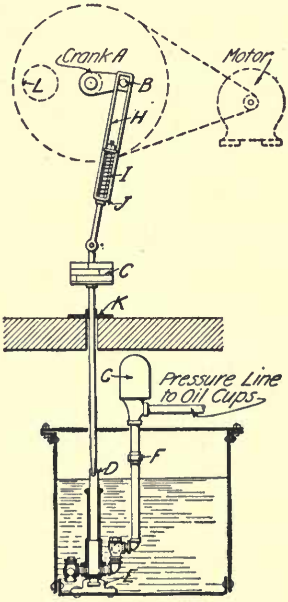

FIG. 347 (R3-1).

The pump arrangement shown in Fig. 347 (R3-1) is specially suited for oil systems. The speed of crank *A* can be kept constant, power being taken from a small motor as shown. The wear and tear on the motor is much less by allowing it to run continuously. The pin and slide box, *B*, require a vertical travel, whether it completes a circle in its travel, or but a segment, as would be the case if attached to a rocker arm. Pressure on the oil is exerted by the weight, *C*, the driving mechanism simply raising the weight of each stroke. If no oil is used, the weight will remain elevated. The pump should be located in the oil tank for the reason that any leakage past the piston will then flow directly back to the tank. The plunger should have a long bearing in the cylinder, not less than four inches in any part of the stroke. The connection to the rod at the top of the plunger, *D*, should be of the ball form, so that it may be free to turn. The anchor block, *E*, receives the T end, which is a part of the pump cylinder. The air chamber, *G*, is not absolutely necessary, but serves to minimize variations in the pressure. The slot in the connecting rod, *H*, must be of sufficient length to permit a complete revolution of the crank without moving the connecting rod. The spring cushions the shock of the slide box, *B*, striking the open end of the connecting rod and compressing as weight *C* obtains speed. The guide, *K*, takes the side thrust of the pump rod. If a small motor is used, it will be advisable to use a counterweight opposite the pin, *B*, as shown at *L*. This counterweight should have about half the weight of that lifted by the pin, *B*. The pump can make as high as 100 strokes per minute with a 0.75 in. plunger and 3-in. stroke and work satisfactorily.

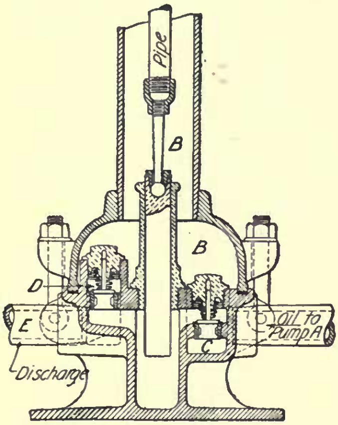

FIG. 348 (R3-2).

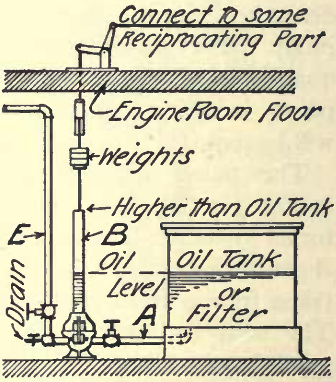

FIG. 349 (R3-3).

Instead of the oil pump being located inside of the tank, it may be located elsewhere with pipe connections as shown in Figs. 348 (R3-2) and 349 (R3-3). The oil supply pipe, *A*, standpipe, *B*, and port to suction valve, *C*, are at all times open to each other, a port running from chamber *B* to port *C*, with pipe *A* connecting them. A discharge port, *D*, is carried down to one side past the discharge valve and connects with discharge pipe, *E*. It will be noted that this pump is quite free from friction and there is no chance of oil slopping around it. The valve and plunger stand vertically. Fig. 349 shows the pump operated from a bell crank. The pump shown in Fig. 348

is well adapted to deliver oil to an overhead tank, the bell-crank working full stroke all the time, and if desired the escapement shown in Fig. 347 may be omitted. However, this detail is so simple and has so little wear that its use would be advisable if for no other purpose than to be able to maintain oil pressure without the gravity tank when this tank is being cleaned or repaired. If the engine has an emergency oil supply, as shown in Figs. 344 and 345, it will be safe to operate without the gravity tank, using simply the filter, pump and oil storage, shown in Fig. 349, to which all the drains are run, and deliver oil by hand to the oil cups during such time that any portion of the system is out of service.

Placing all the engines on one oiling system is not the best practice, as a slight trouble will affect the entire station. An advantage in having a separate system for each engine is that different oils can be used for different engines, according to the needs.

Class R4 — Oil and Drip Lines for Filters and Purifiers. There are many types of apparatus for removing undesirable properties from the oil. The following are the impurities, so called, that must be removed to keep the oil in the best condition:

1. Solid substances of measurable size, removed by filtration.
2. Solid substances of very small size, removed by precipitation.
3. Fats and heavy oils, removed by allowing oil to stand perfectly still and precipitate.
4. Free water, removed by precipitation.
5. Water incorporated and held in suspension by the oil, removed by evaporating the water from the oil.

The ordinary commercial filter accomplishes the first and to a slight extent the second, but little attempt is made to meet the third, fourth and fifth requirements. To properly perform the second and third requirements, it is necessary to remove the oil entirely from circulation for a considerable time, say from four to six weeks. The fourth requirement can quickly be accomplished with an automatic water discharge placed between the drip main and the filter, preventing the free water from reaching the filter. The fifth requirement requires a special device which should be used occasionally, say once a month, all the oil passing through it at that time.

There are two general types of filters, one having a small filtering area and great depth, the other having a large area and slight depth. Wire screen trays are easily cleaned and a large part of the filtering can be done with them, the final filtration to be carried on through some fine mesh material such as felt or bone charcoal. The screens should be so placed that they may be removed one at a time and the deposits blown out with steam.

The fourth requirement should be cared for before the oil reaches the filter, as oil and water make a wet, greasy surface which is repellent, making the movement through the filter very slow. Water can readily be removed from the oil by the use of an automatic separator, as shown in Fig. 350 (R4–1). The operation of this separator depends upon the difference in gravity of oil and water. The column of oil above line *A* is maintained at the same weight as a column of water above the same line. If an increase in the amount of oil lowers the line *A-A* slightly, then the oil column will weigh less than the water column and the top surface of the water will fall below the edge of overflow and cause the oil surface to be relatively higher. The oil and water overflows should be long so that the discharge will not rise over them sufficiently to greatly disturb the line between the oil and water. For each inch difference in the height of the overflows a column of 10 in. of oil can be carried. One and one-half inches difference will permit 15 in. of oil above the water. The inlet pipe crosses the separating tank and has holes along the bottom and sides, the water tending to discharge through the lower and oil out of the side holes. The inlet is shown in the oil space as it is preferable to bring the oil in contact with as little water as possible and

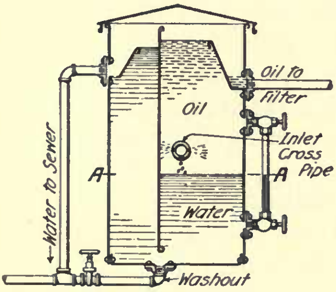

FIG. 350 (R4–1).

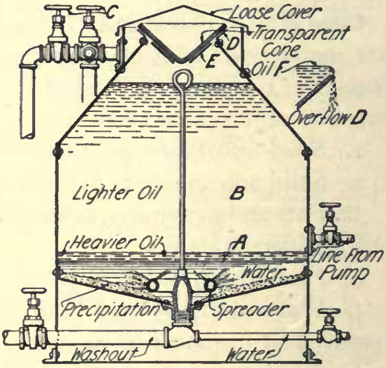

FIG. 351 (R4–2).

thus avoid increasing the quantity of water incorporated. This separator will become very dirty and to facilitate cleaning there should be a wash-out valve located at the bottom.

The second and third requirements necessitate putting the used oil out of service; the method of doing this is shown in Figs. 61 and 62. This precipitating tank should be located in the basement and used for no other purpose. The contents of a filter should be discharged into an overhead gravity tank, the filter being cleaned and filled with settled oil. The precipitation tank should have its contents entirely out of circulation and be as free from vibration as possible. For successful precipitation, the following requirements should be provided for:

1. In removing the clear settled oil from precipitation tank the contents should not be agitated.
2. The clean oil should be passed over only clean surfaces.
3. The discharge should readily be apparent, showing clearly if it is top oil, bottom oil or water.
4. Means should be provided for saving the bottom oil, to be used elsewhere.
5. Means should be provided for the thorough cleaning of the tank.

The above requirements are well provided for in the precipitation tank shown in Fig. 351 (R4–2). The contents of the tank are raised by admitting water from the "spreader" at the bottom of the tank. This spreader is constructed similar to a gas burner, with many small openings so arranged that the current of the water is broken up and discharged into the bottom of the tank without causing agitation. The thin layer, *A*, is the heavy oil which has precipitated out of the upper light oil. It is easy to raise oil and water and not cause them to mix; but to keep the oil, *A*, at the bottom and not have it mix with the oil, *B*, requires a spreader well designed and water fed slowly into the tank. The three valves at *C* control the overflow, one line leading to the filter, another to an oil barrel and a third to the sewer, used only in washing out. The cone at the top of the tank is made of glass, the line between light and heavy oil, also the line between heavy oil and water, being readily noted as it rises and passes the cone. The overflow ring, *D*, and reflector bar, *E*, are nickel plated and polished. The distance between the glass and the reflector bar is $\frac{1}{8}$ in. and shows clearly the line between dark and light oil. If the overflow, *D*, were only used as shown in the enlarged view, the oil would lie on the top surface as at *F* and water would continue to flow from under it.

After the oil is raised from the tank then the spreader is removed by means of an extension handle and the inside of the tank is ready to be cleaned. A very satisfactory style of cleaner is shown in Figs. 111 and 112. The tank has a cone-shaped shell, both to facilitate cleaning and also to reduce agitation of the oil when it is being raised with the water. Instead of the cone being entirely of glass it may be of metal with a slit covered with a narrow strip of glass and the reflectors, *D* and *E*, attached to the cone. A loose inverted cone top must in any case weigh more than the oil it displaces, to prevent it from floating. Fig. 352 (R4-3) shows a metal top and section *A-B* shows glass set in a frame of stiff metal. The reflector is set $\frac{1}{8}$ in. away from the glass and has a sufficient number of holes in it to permit oil to reach the glass at all points from the bottom to the top. The glass alone is not sufficient to indicate the contents. It is necessary for light to pass through the oil to enable the operator to determine the contents of the tank. A cone top permits drawing off practically all of each grade of oil, as there will be but a narrow ring remaining at the overflow, the entire center being taken up by the cone. Instead of oil $\frac{1}{8}$ in. deep covering a 16-in. round section there is only a ring $\frac{1}{8}$ in. deep and $\frac{1}{4}$ in. wide of the same size section.

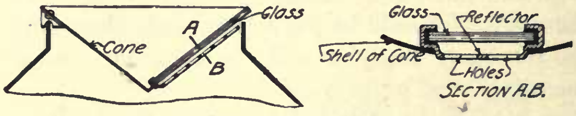

FIG. 352 (R4-3).

In considering the use of a precipitating tank the storage space in the filter permits but a partial precipitation and the most conclusive evidence that something more than a filter is required can be found in the oil as used. When the oil is new it will run through the filter freely, but when it has been used for some time it is necessary to heat it in order to force it through the filter. The longer the oil is used the more sluggish it becomes and the more heat is required. If the filter were removing all the undesirable properties, it would not be necessary to heat the oil to enable it to pass the filter. The filter does the rough work in purifying the oil, but a precipitation tank is needed to complete the process. By the use of a precipitation tank immeasurably fine impurities and the heavy oil and animal fats are separated and the oil deprived of the means of conveying water in suspension. Only by allowing the mixture to remain perfectly still for about a month can the heavier oils and incorporated water be made to precipitate.

Another method for removing water from oil utilizes a heater and a blower for passing air at a temperature of 140 degrees through the oil. This method is unsatisfactory because it does not remove the fats which again take up water.

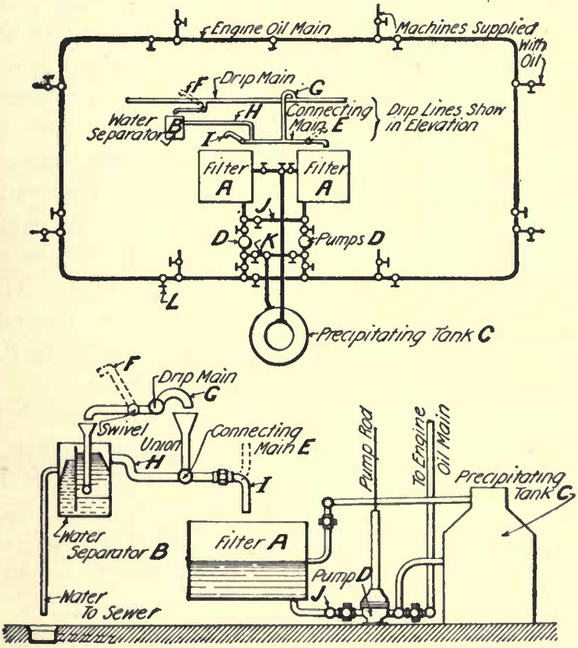

FIG. 353 (R4-4).

In the piping system in Fig. 353 (R4-4) the filters are shown half full, it being possible at any time to empty either by discharging the drips into the other.

A water separator is shown so arranged that when being cleaned its filter connection, *F*, can be raised. The water in such filters can be discharged through the washouts. The trap in drip main, *G*, prevents any drips from passing the water separator when connection, *F*, is down. Trap, *H*, likewise prevents drips from backing into the water separator when it is being cleaned. A swivel connection, *I*, permits the use of either or both of the filters. The precipitating tank, *C*, is shown in Fig. 351, with the oil overflow sufficiently high so that oil will discharge by gravity into the filter. The pumps, *D*, are like those shown in Fig. 348 and preferably motor driven as shown in Fig. 347. It is necessary that two pumps be used to enable repairs to be made to the pumps and to permit filling the precipitating tank with dirty oil from one of the filters while the other pump is supplying the bearings. The crossover connection, *J*, enables both filters to be in use with but one pump in operation. The crossover, *K*, is necessary to permit the contents of either filter to be discharged into the precipitating tank. The numerous valves, *L*, in the oil mains insure that only one machine will be shut down if there is any trouble with an oil main.

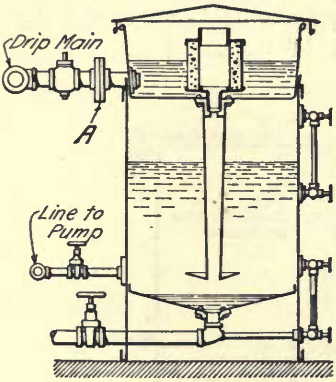

Fig. 354 (R4-5).

If two or more filters were used, connections as shown in Fig. 353 would be unsatisfactory, because the drips would then flow to the lowest connection. In the arrangement shown in Fig. 354 (R4-5) the oil flows from one filter into another, the clean filters doing the larger amount of work. This method is objectionable because it requires that the joint, *A*, be broken whenever the storage tank is cleaned.

The water gage and the line to the pump are located at the lowest possible point. The levels in the different filters are maintained alike with the construction such as will permit oil to flow from one tank to another. The center of the filtering cylinder is open, and through this central opening at the bottom the filtering tube can be plugged. In this manner the cylinders can be removed one at a time without interfering with the operation of the other cylinders.

Class R5—Oil and Drip Lines for Oil Storage. In making proper provision for oil storage it is necessary to consider the following questions:

1. Has the power plant owner a sufficiently large oil storage house?
2. Can a saving be effected by receiving oil in carload lots?
3. Must other than the power station draw on the stock?

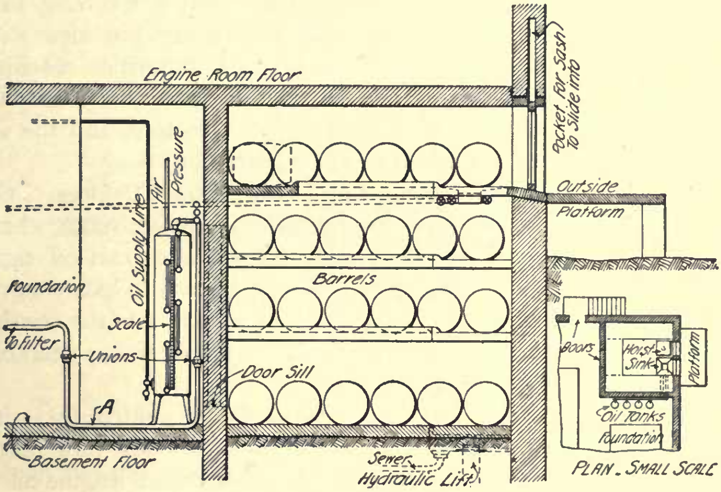

FIG. 355 (R5–1).

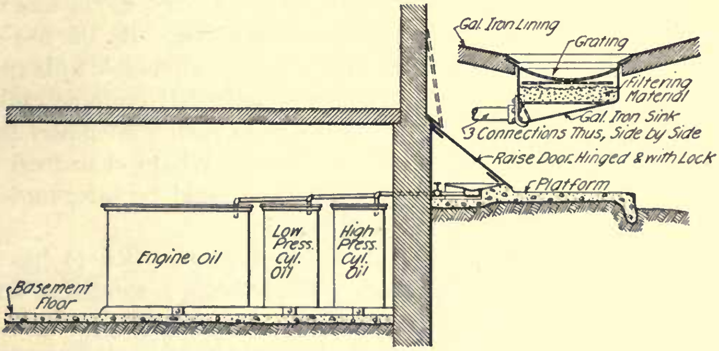

FIG. 356 (R5–2).

Fig. 355 (R5–1) shows an oilroom with a hydraulic lift for raising or lowering barrels. A room 14 ft. square is of sufficient size to store a carload of oil in barrels. An emptying sink is located next to the window and close to the hoist. From this sink a number of lines run to the filters and stock tanks. These stock tanks are similar to those shown in Fig. 58, with the tanks outside of the barrel room, as it is desirable to keep the tanks warm and also easier to arrange a scale to show the amount of oil used by each shift.

Another arrangement for oil storage is that shown in Fig. 356 (R5–2), which shows three storage tanks with a receiving sink located outside of the building, this sink being provided with waste or other filtering material to prevent impurities reaching the storage tank. If air pressure is available, then the cylinder oil tanks may have dished heads, both top and bottom, and the air pressure be used to deliver oil to the engine room floor.

Class R6 — Oil and Drip Lines for Hand Devices. On account of the numerous places around the engine room where engine oil is required it is necessary to provide several oil taps. If the plant consists of large units, it would be well to locate an oil tap at each machine. Such taps could be attached to the regular piping system of the unit, in some easily accessible spot, preferably over some drip pan of the machine.

The quantity of oil used daily is easily accounted for with the system as shown in Fig. 355; the records show just how much cylinder oil has been used, also how often a barrel of engine oil is added to the oiling system. With the system shown in Fig. 356 it is not so easy to keep the record from day to day, as the size of the oil tanks makes accurate readings impossible. By the use of one or two small tanks, as shown in Fig. 355, it is possible to keep a very accurate record of the oil consumption by having these tanks filled to a certain level each day and having each shift report the oil level at beginning and end of the watch. Whatever method is employed to supply the measuring tanks should be safeguarded against the possibilities of any manipulation.

The small measuring tank shown in Fig. 357 (R6–1) has a float tell-tale instead of gage glass. The tell-tale is somewhat less liable to injury and derangement, as there is neither a packing nor glass tube to keep in order. The tank should be of small diameter, say 8 in., and 5 ft. long if not over 8 gal. of oil is used each day. In considering the use of air and water to raise oil, it must be noted that the storage tank may require a large volume of air to raise possibly one cubic foot of oil into the measuring tank. Water would be quicker to act, but if water were used special care would have to be taken to avoid the possibility of destructive pressure being put on the storage tank. The use of water introduces a feature which might cause serious oil loss due to the fact that water used to raise the oil must be run to the sewer whenever the storage tank is to be filled. Unless closely watched the water might all run out and considerable oil waste to the sewer. The use of air eliminates the possibility of oil losses from this cause.

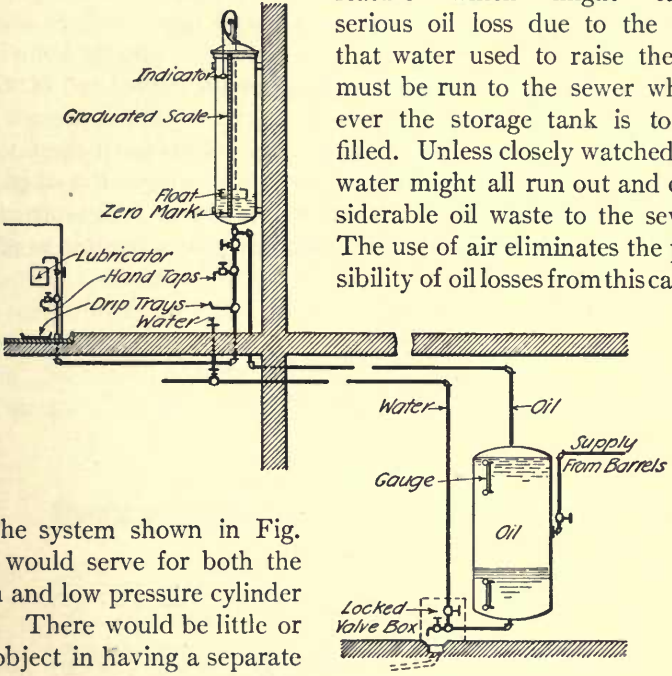

FIG. 357 (R6–1).

The system shown in Fig. 357 would serve for both the high and low pressure cylinder oils. There would be little or no object in having a separate tank for new engine oil. The operators would not use it if their shift were to be charged with it—they could get oil from the return drip system. The use of oil in the boiler room for feed pumps, stoker engines, etc., can be best accounted for by making the engineer in charge of the shift accountable. The usual method of recording at the end of a shift is for the engineer quitting and the one coming on to go to all the lubricators and other devices that hold a quantity of oil and see that the oil is brought up to the established "quitting line." When tanks are restocked the engineer in charge and

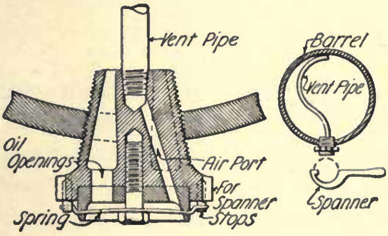

FIG. 358 (R6–2).

the stockkeeper take readings together and the tank is then filled.

To facilitate the emptying of the barrels and to avoid putting vent holes in them there should be a barrel valve used, as shown in Fig. 358 (R6–2). This barrel valve is screwed into the bung hole by a spanner wrench. The vent pipe is made curved and of small pipe so that if it strikes the side of the barrel it will not prevent the valve from being screwed in. The valve is of the register type, with two or three oil openings and one air opening. Pin stops are quite necessary to insure that the valve will be fully opened or closed. By turning the spring upside down it is possible to grind the valve to its face.

CHAPTER XXVIII.

BLOW-OFF PIPING.

Class S1 — Blow-Off Main. The service performed by a blow-off main is exacting. The pressure and temperature variations are such as to cause much movement of the lines. It is neither customary nor necessary to install two blow-off mains. In Fig. 45 is shown a duplicate blow-off main which is arranged more to suit the requirements of condenser discharge than for any other service.

Fig. 359 (S1–1) is a sectional view of the blow-off basin shown in Fig. 45. The blow-off pipes and the pipe hangers are of cast iron, made necessary on account of the moisture in the waterway. The gratings at the top of the basin are made very open to allow steam to escape freely. The volume of water that this basin should hold is dependent upon the amount passing through from the condensers. A basin 5 feet square will be found of sufficient size in almost any case. If the blow-off main is open to the free circulation of air and is hot constantly, it should be of standard wrought-iron pipe.

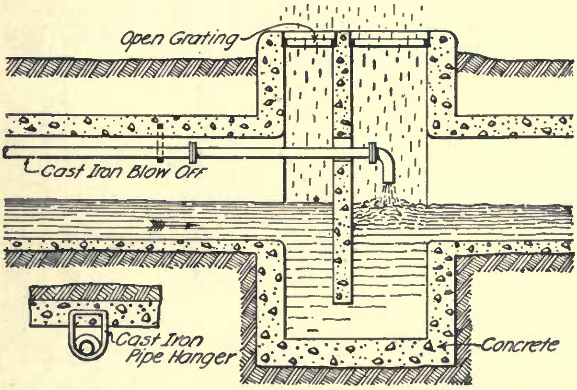

FIG. 359 (S1–1).

The main, back of the boilers, should be in an open trench. The portion of the trench between the boilers should have a cover plate to make the floor continuous. The form of cast plate shown in Fig. 360 (S1–2) is suitable for such work, as it does not require a frame. The round corner support does not let the plate damage the cement work. The plate is secured on the forms and the cement finished against it. The pipe line should be completed before the cement work is finished, thus saving time and insuring a better location of the pipe and less damage to the concrete. A brick trench can, in many cases, be constructed more quickly, but concrete is better for this work, as it is more permanent.

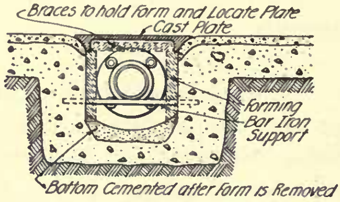

Fig. 360 (S1–2).

The cover for the trench is in some cases of plank or it may be of flagging. In laying out the trench care should be taken that sufficient room is provided so that the lower bolts of the main shown in Fig. 360 may be reached. Fig. 361 (S1–3) shows a wide, open trench back of the boiler which gives ample room around the fittings. Fig. 362 (S1–4) shows a similar space back of the boiler made into a pit with a plank covering. These planks should be of oak and surfaced, possibly 4 in. wide with a 1-in. space between and all the planks fastened to angle irons placed at the ends. The pits back of the boilers should have a sewer drain, and the wide trench, Fig. 362, may be pitched to the center and one catch basin serve many boilers. If the main is of considerable length and there are short, stiff branches connected to it, it may be necessary to use a U-bend to provide the necessary elasticity. The importance of elasticity should constantly be

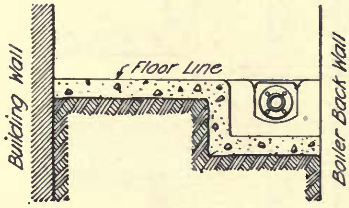

Fig. 361 (S1–3).

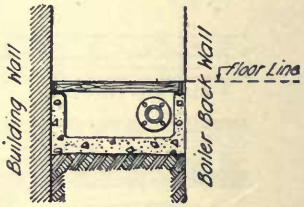

Fig. 362 (S1–4).

kept in mind in laying out blow-off connections. If cast iron is used for the main it may be necessary to allow for the movement in the boiler branches. Rather than strain boiler connections it would be better to use a slip-joint in the main and anchor the two parts of main at about their center.

Class S2 — Blow-Off Branches from Boilers. It may be necessary to place the blow-off main close to the wall to secure elasticity. As shown in Fig. 363 (S2-1) the pipe, *A*, provides practically all the elasticity between the boiler and the main and should be made of standard weight pipe. The space shown back of the boiler is wider than that usually found, and if the passage is narrow, similar to that shown in Fig. 362, then all the connections would be very stiff. The connections shown in Fig. 364 (S2-2) require a rather elaborate bend, but by making it in the form shown the necessary elasticity is obtained. It will be noted that the valves in Fig. 363 close against the pressure and the valves shown in Fig. 364 close with the pressure. These are the two principal types of blow-off valves.

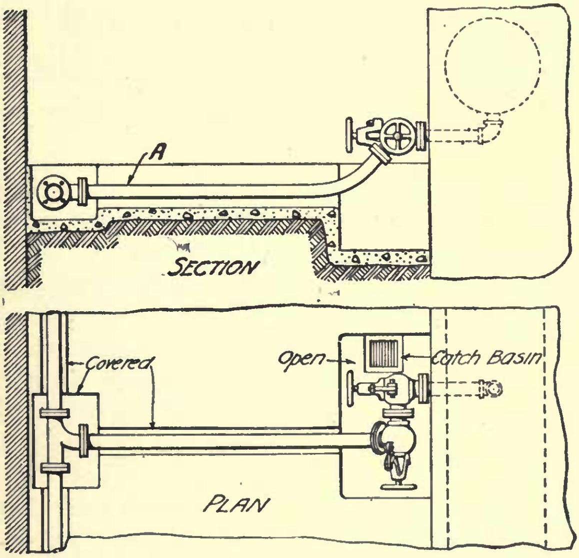

FIG. 363 (S2-1).

One of the best forms of blow-off connections is shown in Fig. 365 (S2-3). The blow-off main is shown as being in the engine room basement, an excellent arrangement when it can be so placed, as it requires no trench work, is always open to inspection and may easily be repaired. The branches to the boiler are long and provide the necessary elasticity. The only trench that is required is for the connection to the boiler. The trench can be quite narrow — just wide enough to allow for the movement of the pipe. Y-fittings should be used in the main, as they offer the least resistance and cause the least water hammer. The valve next to the boiler should be left open while the boiler is in operation, using the second valve as the regular operating valve. Any scale that may pass the valve plug will drop away from the seat and fall out.

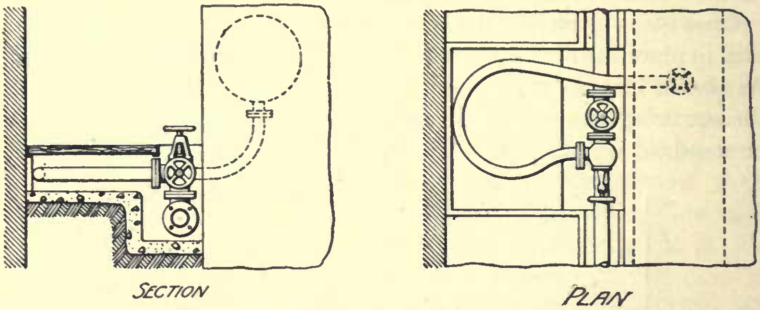

FIG. 364 (S2-2).

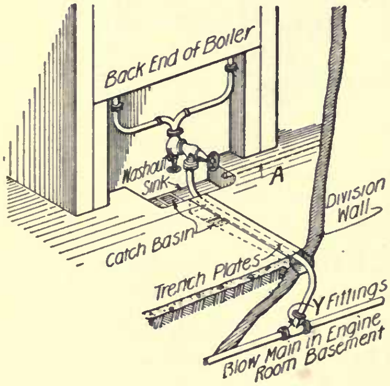

FIG. 365 (S2-3).

Duplicate valves are necessary in the blow-off connection. The second one permits of the operating valve being shut off from the boiler whenever a leak occurs, affording an opportunity for repairs while the boiler is under pressure. A second reason is to insure the safety of a man at work inside of the boiler. When washing the boiler the second valve should be shut and the bonnet or center piece of the first valve next to boiler removed to allow water to discharge into the pit under the valves.

The wash-out sink as shown in Fig. 365 should be deep enough to hold the scale that will accumulate. The pit shown in Fig. 361 is well adapted to keep scale out of the sewer, and with two or more catch basins a considerable distance apart it is possible to shut off the catch basin close to the boiler and allow the scale to accumulate in the pit. The pit can be made as shown in Fig. 364, four feet wide and full depth to the wall, covered as shown in same figure. The pit should be about 18 in. deep and the trenches 10 in., allowing 8 in. for the accumulation of scale at the end of the pit.

Instead of the first valve many boilers are fitted with a "washout tee" and but one blow-off valve, with the blind flange or cap removable. This provides one advantage sought in the use of two valves, but fails to provide means of insuring a tight valve at all times. A small leak of but one-half pint a minute would, in a year's time, pay for an extra valve.

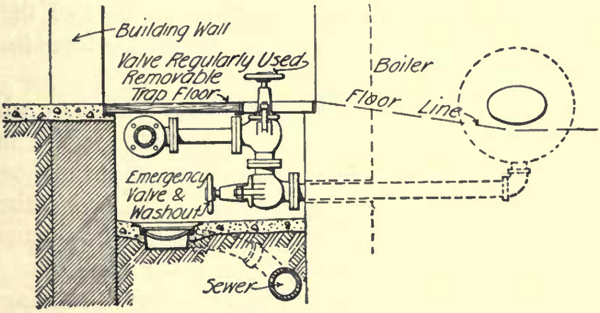

FIG. 366 (S2-4).

If the boiler sets low and the blow-off runs out below the floor line, the blow-off connections may satisfactorily be arranged as shown in Fig. 366 (S2-4). The blow-off connection shown would be quite impracticable if the wash water had to be discharged into the blow-off line, because the drum would not drain freely and the lower connection would soon fill with scale. This trouble, however, would not present itself when blowing out under pressure. If the bonnet of the valve next to the boiler were removed there would be no pocket to fill with scale, nor would it be difficult to drain the drum.

Class S3 — Blow-Off Branches from Economizers. As with boiler blow-off connections, there should be two valves used for the economizer blow-off. The valve next to the economizer should be so located that its bonnet might be removed to allow washings to accumulate and water to pass to the sewer. If the boiler room floor has ample drainage, then the valve may be so located that any washings will fall on the floor, allowing the water to run to the sewer. The first blow-off valve should not be located at a high level, as the water discharged through the bonnet opening would spatter most objectionably.

Located at the economizer blow-off valve there should be a pressure gage to show how much the pressure is being reduced in the economizer. The valve can be so manipulated that the pressure will not be sufficiently low to let steam be generated. In order to discharge water from an economizer it is necessary for the pump to speed up and supply water as fast as it is blown out, or steam will be formed as a result of the drop in pressure and the economizer be partially emptied of water. The amount of steam formed is about the same quantity as that of the water discharged. This caution should be observed, otherwise water hammer may occur.

A pressure gage located near the blow-off will show when the pump has maintained the pressure. In closing the valve the gage will show whether or not the pump slows down to prevent excessive pressure in the economizer. Fig. 203 shows an economizer with the feed entering, in one case at the end of the upper manifold, then passing through two sections to the lower manifold. It also shows in dotted lines the usual and more correct form, having the feed enter at one end of the lower manifold, with the blow-off at the other end. As the lower portion of the economizer is much cooler than the tubes and upper headers, it is much better that the cool water enter at the bottom, thereby avoiding the extreme changes in temperature which cause trouble.

Class S4 — Blow-Off Branches from Heaters, Purifiers, Etc. A closed heater requires a blow-off at the lowest point in the water space, the precipitation being in the form of mud and not likely to injure the valve. However, it is best to use two blow-off valves, as with boilers. If only one valve were used it would be necessary to have a wash-out tee next to the heater. Live steam purifiers should have similar protection and means for washing out. The washings from any station device should be in plain view, so that the operator can see exactly what is being accomplished.

It is essential that the station operator be able to know what he is doing and be able to protect himself against accident. Double blow-off valves and sewer wash-outs are necessary to care for these requirements. Small economies effected by saving a few valves will be insignificant compared to the payment of damages in cases of injury.

Class S5 — Blow-Offs from Steam Traps and Bleeders. Steam trap drips which contain grease should be discharged through a blow-off, if practicable, to avoid vapor in the sewer. Traps discharging water from the intermediate receiver discharge at low pressures and should be provided with check valves to prevent the possibility of water backing through them if a trap were open while a boiler was being blown.

Check valves in blow-off lines are liable to cause trouble, first appearing, with possibly destructive results, when water reaches a low-pressure cylinder. Bleeders for removing condensation from boilers and engine branches should be run to the heaters, if such connections can be made without piping complications.

Steam traps either are furnished with gage glasses, or have tapped openings for them. As it is impossible to maintain a glass where the temperature is constantly changing, a better plan is to arrange for an audible discharge from the trap. The operator, becoming accustomed to this sound, is warned immediately upon its ceasing. Fig. 367 (S5–1) shows a trap having two different sound-making devices in its discharge. One has an air chamber which fills with vapor and air after the trap has discharged. When the trap again discharges the vapor and air are blown out, sounding the whistle. The other device consists of a vibrator placed in the path of the discharge, the impact of the water causing a vibration similar to that of a tuning fork.

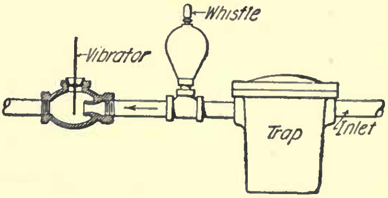

Fig. 367 (S5–1).

Bleeders are generally small, and if much used should have two valves placed together, the valve next to the pressure being used as a controlling valve, the second one only as a stop valve.

Class S6 — Blow-Off Tanks. A blow-off tank is intended to protect the sewer against high temperature water and steam.

Its use is compelled by ordinance in many cities. That these tanks are often made and used in a manner unfit for the service is shown by steam escaping from many sewer gratings in the streets. The problem is far from simple, and the arrangements necessary to overcome the existence of vapor and hot water in sewers are very extensive.

With a blow-off tank as sometimes designed the steam is allowed to escape through a vent pipe carried to a high elevation. This tank is all that is provided in many cases to care for the boiler blow-off, and the vent often is too small, not only allowing steam to be carried into the sewers, but, since it also fails to relieve the pressure, allowing water to be discharged through the vent. High temperature water from the boiler will expand to about 200 cu. ft. of steam for each cubic foot of water discharged.

The exhaust can be carried off with a large vapor pipe run to a high elevation so that the air will flow into the sewer openings and out through the vent pipe, as shown in Fig. 368 (S6–1). As shown, the discharge from the blow-off main is pointed upward to break up the boiler water and allow the greatest possible amount of steam to escape, this being the only point for discharging the heat from the water other than into the sewer. The baffle in the blow-off system prevents the hot water from going directly to the sewer. The vent pipe should be very large, say 18 to 24 in. in diameter, and may be made of materials similar to those used in a smokestack. The joints should be lapped so that the water will run from the outside to the inside. A circulation down the sewer manhole, through the main sewer and blow-off to the cistern, then up the vent pipe, would prevent leakage at the sewer manholes. In such blow-off equipments the sewer leading from the cistern to the main sewer should be large, thus enabling

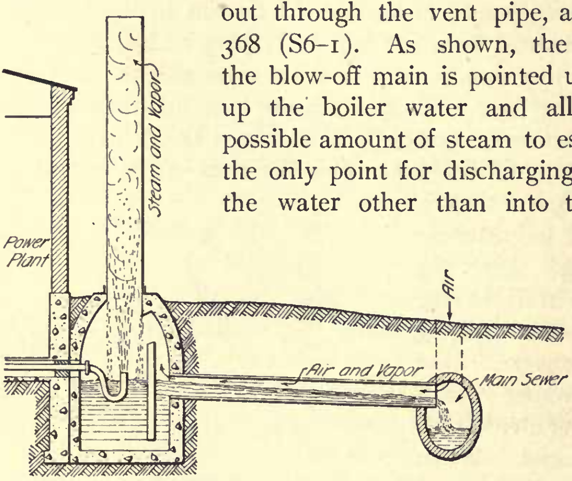

FIG. 368 (S6–1).

air and vapor to pass the water which would be discharged into the sewer.

The heat units in the blow-off water are ordinarily wasted, but it would be practicable to blow off into a settling chamber, thus allowing the impurities and the scale to settle and then returning the water to the boilers. As the blowing off of a boiler takes place, ordinarily, but once or twice a day, the gain by thus saving the water blown from the boilers would necessarily be slight.

The blow-off cistern shown in Fig. 369 (S6–2) is located at about 50 ft. from the building and has an open grating to permit the escape of steam. This cistern is constructed as a storage for the blow-off of water with its discharge valves set so that the rate of discharge into the sewer will be small. Such a cistern should have a storage capacity of not less than 70 cu. ft. The pipe from the building to the cistern should be inclosed in a tile sewer pipe, which will permit its removal. The opening, *A*, in the building wall should have a clear space in front of it to permit removing a full length of pipe, thus allowing the entire blow-off main to be removed. The slip-joint at the cistern end would afford a ready means for closing the opening in the cistern, at the same time permitting free movement of the pipe line in the boiler room. The regulating valve in the cistern should not be over 2½ in. in diameter and should be of brass. An old valve can be used for this purpose, as it will neither be under pressure nor closed tightly. The check valve in the boiler room should not be less than one inch in opening, as the discharge end of the blow-off will be under water and any vacuum formed in the blow-off main should be broken without drawing cistern water back into the line. The blow-off main back of the boilers should be located above the high-water level of the cistern to avoid water hammer.

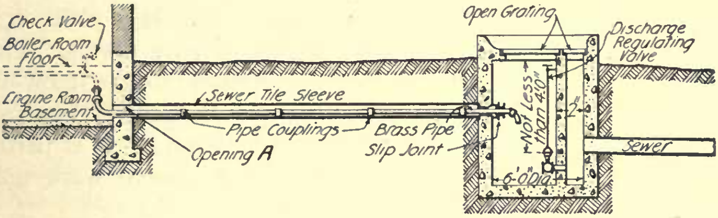

FIG. 369 (S6–2).

CHAPTER XXIX.

GREASE SEWERS.

Class T1 — Grease Sewer Main. Grease sewers are not generally dignified as systems; in fact, they are usually given but little consideration. Instead of well planned systems being installed, one finds that greasy discharges are run into the blow-off. Fig. 46 shows in a general way the cold sewers and the hot sewers, each as a separate line. There are many greasy wastes in a plant that should not be discharged into the regular gravity sewers. The grease sewers should be constructed similarly to the blow-off systems, but if free from pressure they may be built of iron soil pipe with calked lead joints and run underground. It is partly due to the fact that these greasy drips ruin cement work that separate lines are necessary.

The various locations of hot sewer inlets make it quite impossible to use standard wrought pipe and to place the grease lines above ground. In Fig. 46 the pipe is shown resting on loose packing sand and provided with a sleeve through the cement floor, which latter detail allows for the movement of the pipe. If screwed wrought-iron pipe were used for the hot sewer, it would last indefinitely if the sewer were not subjected to pressure in blowing off, as oil would also be discharged through the blow-off cistern. Fig. 370 (T1–1) shows good construction for a separate blow-off or grease separating tank with a small vapor pipe. As built

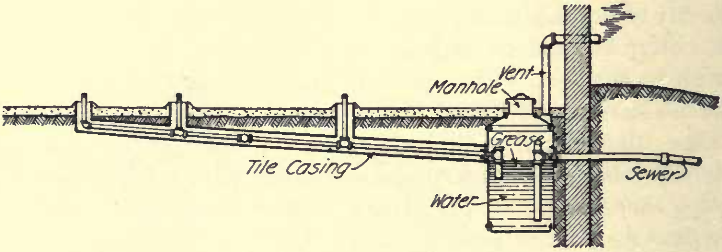

Fig. 370 (T1–1).

the grease would remain in this tank until removed, and as a comparatively large amount of oily drips would reach this tank a considerable amount of grease would be collected. The drip line is carried through a tile pipe, the purpose of which is to hold the soil away from the line. Each branch of the drip line should have a tight connection at its upper end to prevent steam from escaping. The drip line should run down into the tank sufficiently far to prevent much agitation of the grease at the top. The discharge is shown with a tee at the upper opening, thus preventing the contents of the tank from siphoning down to the sewer level. The drop pipe allows water to be discharged without losing the grease.

Some form of tin pump might be used to remove the grease, which could be used for various purposes. In considering the saving of oil and grease, no arrangements should be made to discharge this kind of grease into an oiling system, as it is wholly unfit for journals; in fact, an oiling system to work most satisfactorily must be able to rid itself of this class of grease if once it has taken it up. It will be necessary to give the line considerable pitch to avoid the possibility of drawing back water standing in the line.

Class T2 — Grease Sewer from Engines. Practically all of the cylinder oil that gets into the oiling system is discharged from the piston and valve rod stuffing boxes. Some engine builders provide a grease compartment between the front head of the cylinder and the cross-head guide, with a stuffing box to isolate this compartment. If pockets to catch oil drips are also provided in valve bonnets then little cylinder oil will be discharged into the oiling system. Ordinarily these drips are run to the sewer, but with the grease sewer system, as shown in Fig. 370, much oil can be saved and used. Ordinarily a pocket can be put on the front head to catch drips from the piston rod, as shown in Fig. 371 (T2-1).

If there are bleeders at the ends of the cylinders, also from the steam chest, it will be found safer to discharge them into the exhaust at the highest point possible rather than into the grease sewer. Then the drain from the exhaust line or receiver could be run to the grease sewer. If a trap is used to carry away drips from the intermediate receiver, it should discharge into the grease sewer, and if the line is well pitched there will be but little water for it to suck back in case pressure on the receiver falls below that of the atmosphere. To further protect engines against water being drawn in, it is advisable to place a check valve at a tee in the trap discharge, the check falling closed, but free to open when under a partial vacuum. The exhaust that runs to the condenser should also have a check in its drip line, but the reverse of that for the intermediate receiver trap. The exhaust should close with a vacuum and be open when under pressure.

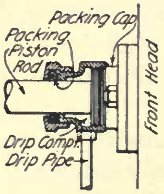

FIG. 371 (T2–1).

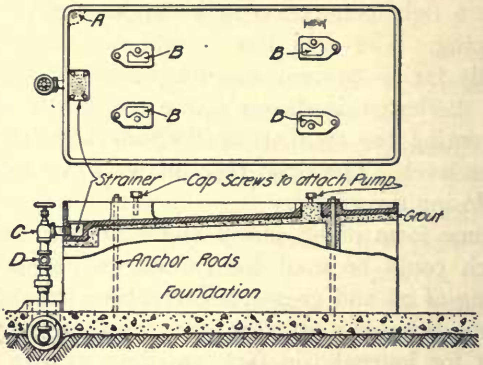

FIG. 372 (T3–1).

These different oily steam drip lines are shown, in Fig. 325, as running to a drip tank. The drain from this tank is run to a grease sewer. A drip tank should be of generous capacity, say, for a 2,000-hp. engine, 12 in. diameter by 4 ft. high. The vent from the top to the atmospheric pipe should be amply large to discharge the steam blown into it, say about 2½ in. in diameter. With such a drip tank but one underground connection to the grease sewer will be required.

Class T3 — Grease Sewer from Pumps. All pumps should be provided with a lipped cast-iron pan the full size of the pump. This pan should have raised spots for the pump feet and a strainer for the pipe discharge. The pan shown in Fig. 372 (T3–1) is simple in design and effective. The tops of the bosses are set level and the pan pitched toward the drain. A strainer should be placed over the drip opening.

A possible error in pan construction is to place the anchor rods close to the edge of the pan, thus making a good job of masonry of either brick or concrete impossible, since there will be too little material outside of the rod. The rod bosses should be projected from the pump feet bosses, making the fewest possible corners to wipe around. Another error is to use these anchor rods for securing the pump to the pan. The anchor rods are more or less elastic and do not hold the pump firmly. To obtain a rigid job the pump should be anchored to the pan and the pan then anchored to the foundation. The holes, *B*, are quite essential for securing a good job of grouting when the pan is placed on the foundation. The lip around the edge of the pan should not be less than 1½ in. high. The top of the pump bosses and the outer rim also should be on one level to prevent oil from getting into the foundation.

The drain valve, *C*, should be used if the pan drips are run into the grease sewer. The tee, *D*, is to connect the blow-offs from the steam cylinder as shown in Fig. 324. The pan drips will carry away much grease and oil which can ordinarily be discharged to the grease sewer by leaving the valve, *C*, slightly open. The drain from the exhaust pipe may also be connected to opening, *D*.

Class T4 — Grease Sewer from Grease Extractors. If there is a grease extractor in the exhaust line, then the drips should be discharged directly to the grease sewer; but if considerable back pressure is carried, then a trap such as shown in Figs. 161 and 162 should be used to keep the steam from blowing through to the grease sewer. Any drains taken from the bottom of exhaust lines should be run to this sewer. If a grease extractor is used in a vacuum line, then the drips should be run to a vacuum trap and this trap should discharge into the grease sewer. If the heater overflow is used to discharge oil from the surface, then this discharge should also be run to the grease sewer. It is poor station management, after the grease has been caught, to discharge it into the regular sewer, thus not only losing this valuable material but injuring the sewers as well.

Class T5 —Grease Sewers to Precipitating Tanks. The precipitating tanks are used to remove from the engine oil system such oil and grease as may be found in the grease trap shown in Fig. 370. If considerable light oil reaches this trap it also should be discharged into the precipitating tank. After heavy oil has stood in the precipitating tank, it becomes of a more uniform grade and can be drawn off. This detail requires some kind of a pump that can be started and run until the grease has been removed from the grease trap.

CHAPTER XXX.

TILE SEWERS.

Class U1 — Tile Sewers — Main. Power plant sewers fulfill so many different services that it may be found better not to join them all. The wash water and rain water sewers can be joined, but the grease discharges and soil pipe wastes should be kept independent. In a condensing plant the wash and rain water can be run into the discharge waterway. The sewers under a high head should not be connected with those of low head or they will flood the basement floors. The requirements of each service must determine which branches shall be united into one main.

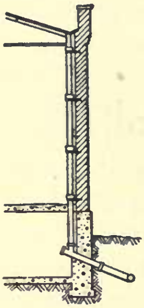

FIG. 373 (U2-1).

If grease and water of extremely high temperature are kept out of the sewers the main may be built of the pipe with cement joints. Oil carried in a drain serves to preserve the iron pipe, but it will destroy the cement joints of tile pipe. The choice of material for sewers depends upon how much grease is to be handled and how much water will flow with the grease.

Class U2 — Tile Sewers from Roof Conductors. The main branches that carry the roof water are subject during a heavy rain to sufficient pressure to raise water out of the basement catch basin. If possible the roof should be divided so that a small surface will drain into the closet sewers and flush out the soil pipe.

The conductors from high or hot roofs should be run on the inside of the building in a warm place. The heat of the roof often will melt the snow in cold weather and therefore the conductor should be protected from low temperatures. Fig. 373 (U2-1) shows a conductor arranged for flashing joined to a section of copper spout which is run down into the iron conductor. The iron conductor may be of light cast-iron soil pipe with calked joints and a cast-iron Y built into the wall to receive the lower end of the down spout. The different pipe sections should have substantial wall anchors, and the Y at the bottom should have a cap with a cemented joint, so that it can be removed if it becomes necessary to clean out the conductor or branch to the sewer.

The outside sewer connections should be of tile pipe, as there is no advantage in the use of metal pipes unless they pass under walls or foundations. In establishing the depth at which sewers are to be placed it must be remembered that water may pass from the roof, even though the temperature of the ground be very low. Also the heat of the power plant and water passing in sewers raises the temperature. Waterworks lines are generally located 5 ft. below the surface. Sewers close to the buildings laid 3 ft. below the surface would be quite as safe as the water lines. If the plant is large it may be necessary to use large sewers with a slight pitch, so that the highest connection will not be less than 3 ft. from the ground surface and the discharge of sewer above normal water level.

It is not necessary that the entire sewer system discharging to the river lie above extreme high water. As high water conditions are of short duration water may be allowed to back into the main as long as it does not overflow any of the floor drains. The fall, however, must be given careful consideration if paper is to be discharged into the sewer, as a slight obstruction where the flow is very slow will cause the paper to block the line completely. The sewers from soil pipes should not be retarded by water rising and filling the discharge end of the sewer.

Class U3 — Tile Sewers from Plumbing Fixtures. Sewers from the lavatories are generally difficult to lay out. If the condenser discharge waterway is built of concrete then a separate soil pipe may be carried in the concrete, as shown in Fig. 374 (U3–1). Sewer tile or a collapsible wood frame could be used to form the soil pipe opening. Probably it will be found cheaper to lay the soil pipe in the fill over the concrete; or if this brings it too close to the surface of the ground it might be laid alongside, as dotted at *A*, in Fig. 374. This separate sewer pipe should extend beyond the blow-off cistern in the waterway, otherwise it will contaminate the condenser discharge waterways. By this method there will be no fumes rising from the waterway into the station.

The lavatory should be located in the basement at the outside wall, as shown in Fig. 375 (U3–2). If the conductor should be at a corner, as *A*, then it can be run back along the wall, or the sewer can make a loop to include the conductor. Plumbing fixtures should be so arranged that the water from the wash basins, shower bath and a small roof conductor is made to pass through the line that leads from the closets. This will insure that the line will be well flushed.

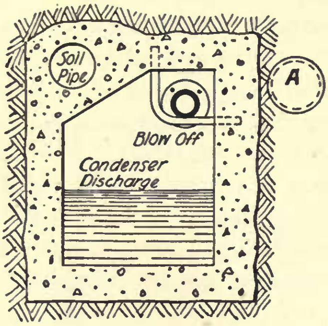

FIG. 374 (U3–1).

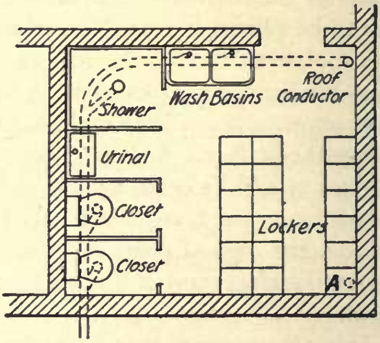

FIG. 375 (U3–2).

Another detail in connection with the sewers from water closets is that as they are liable to become blocked they should not be run under engine foundations, boiler rooms, or with many branches and bends in places where they cannot readily be taken up.

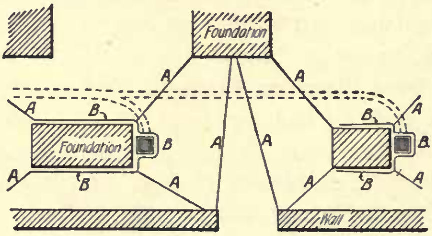

FIG. 376 (U4–1).

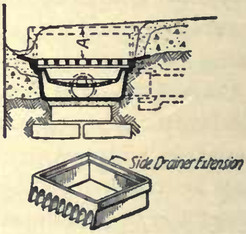

FIG. 377 (U4–2).

Class U4 — Tile Sewers from Floor Drains. The boiler room and basement floors should be so arranged that they can be cleaned with a hose. To do this satisfactorily it is necessary to have a large number of catch basins and ample pitch to the floor. Fig. 376 (U4–1) shows a floor with the pitch run to suit the catch basins. The pitch boards should be set on the lines *A* and the gutter strips placed at *B*, both strips to be removed after the concrete and cement top is in place, previous to finishing the surface. The slots, *A*, are to be filled with cement and sand. The gutters, *B*, should be about two inches deep, with the corners well rounded. The pitch of the gutters and floors should be about 0.25 in. to the foot, which makes it necessary to place the top of the catch basin below the surrounding floor level, as shown in Fig. 377 (U4–2). The distance, *A*, in many cases is as much as four inches, and with the catch basin set low a bad hole in the floor is made. If an extension side drainer is used as shown, then the grating can be placed in the top and the floor concrete floated to the top of this extension piece, thus making the floor level. Water will discharge between the fingers at the side of the extension piece and above the fine sieve grating. The catch basin has a side outlet, and no trap. This allows the connection to the basin to lie high and also be entered easily with a rod or hose when being flushed.

These floor drains should not empty into the lavatory sewers, unless a trap is used, with means available for cleaning out sand or other material that may be washed in from the floor. If the floor drains in the basement are on practically the same level as the sewer, it may be necessary to use a non-return sewer check valve, as shown in Fig. 378 (U4–3). The check discharges into a cistern which has its sides carried above the floor to prevent overflowing in case of the sewer running full under a slight back pressure. This check is always open to inspection, and should it fail to close it might be closed by hand. Floor drain outlets should be placed in this well just above the bottom of the main sewer, so that the well will drain itself as soon as the sewer becomes empty.

Sewer checks are so made that they can be placed in a line outside of the well, but when so placed their operation cannot be observed. A trap similar to that in Fig. 378 would be suitable for use if the floor drains discharged into the lavatory sewer, the check being omitted and some form of manhole plate and frame placed at the floor line.

Wherever ashes are wet down in front of boilers a cistern is useful if located in a central position so that the different catch basins may be separately drained into it. In a large plant it may be necessary to use a number of these cisterns, having a small well at each sewer grating and carrying the discharge from one to the next, and so on, as shown in Fig. 379 (U4–4), with the iron gratings carried in a square frame. The runs from basin to basin should be short and straight. The last cistern in the series should be much larger and deeper than the others, to protect the sewer from that point on. If necessary, a fine wire cylindrical screen can be placed at the last discharge.

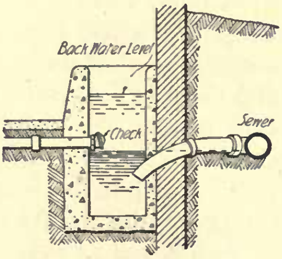

FIG. 378 (U4-3).

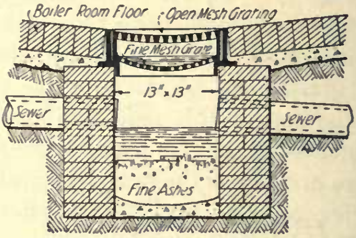

FIG. 379 (U4-4).

If the engine room floor is of cement or tile the drain would be over a level surface because in washing the floor but little water would be used. The drains then might be small and located under the hose valves. A small catch basin should be placed below the surface of the floor, as shown in Fig. 380 (U4-5), with the water connection as passing through a raised boss in the small drip sink. This boss prevents the drips from running down the water pipe. If the floor is marble or tile then the body of the sink should be galvanized

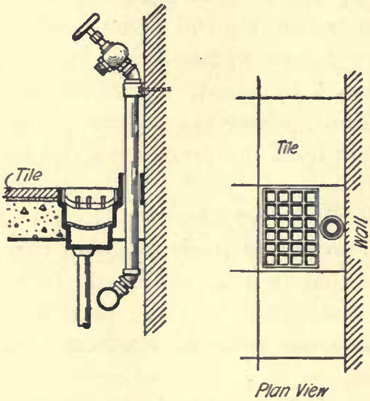

FIG. 380 (U4-5).

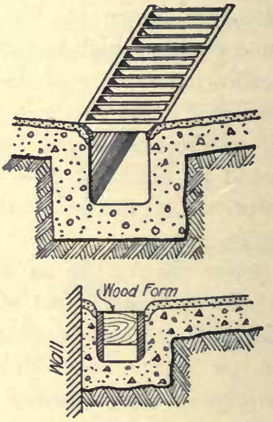

FIG. 381 (U4-6).

to prevent its rusting and staining the floor. The shape and size of these sinks should correspond with the size of the tile to be used. The water valve should be attached to a 45-degree elbow so that the hand wheel will clear the wall.

In many plants where the basements have practically no fall, an open sewer can be used. Fig. 381 (U4-6) shows two open sewers, one covered with a grating so it may be stepped on, and the other next to a wall and without a cover. The wooden form as shown in the uncovered sewer is required for placing the concrete flooring. An advantage of this type of sewer is that but little pitch is required. Tile sewers should not be used if the pitch be less than 0.25 in. per ft.

Class U5 — Tile Sewers from Ash Wetting Floor. The catch basin which receives ash laden water should be so designed that the tendency will be for heavy cinders to fall away from the sewer pipe discharges while fine particles rise and are carried by the slow movement of water in the catch basin to the more rapid current in the sewer pipe. These requirements are well provided for by the catch basin shown in Fig. 379.

Ordinary sewer details as employed for carrying away water will not handle ashes without becoming blocked. A sufficient flow to carry away the precipitation is impossible. Heavy materials such as ashes should be stored in the sewerage system where they can be reached and not forced into the main line.

Class U6 — Tile Sewers from Boiler Washouts. Tile sewers leading from boiler washouts are shown in Figs. 365 and 366. These have catch basins similar to that shown in Fig. 376. If water and scale were discharged on to a floor or the bottom of pit as shown in Fig. 366, and if the drain from this discharge were allowed to flow over a wide surface to a sewer a considerable distance away, then the velocity of the water passing over the floor would be less than through the sewer, and the fine particles carried by the slow-moving water would not be carried with sufficient force to pass them through the sewers.

An illustration of this principle is shown in Fig. 382 (U6-1). The middle boiler is shown discharging water and scale into the pit, the heavy particles falling and water overflowing through the blow-off trenches at *A*. In operation the catch basin, *b*, is shut off before the workman begins to clean the boiler. Thus the pit becomes a precipitation chamber. The light material rises to the surface and passes the overflow, *A*, reaching the sewer in a flow of high velocity. The catch basins here shown have the same design as those shown in Fig. 379. If the cleaning of the catch basin shown in Fig. 379 is neglected, it fills up to the level of the discharge sewer and the particles will work into the main line.

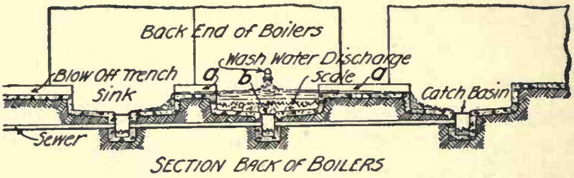

FIG. 382 (U6-1).

Another form of catch basin, and one that shuts off the water discharge whenever it becomes choked with deposits, is shown in Fig. 383 (U6-2). This design is similar to that shown in Fig. 379, but it has a central cone-shaped feeder which will become choked when the lower end comes in contact with the deposits at the bottom of the catch basin. The basin shown in Fig. 383 can be used as shown in Figs. 379 and 382, with the sewer passing through it, or all the branches can be run to a sewer line with Y fittings, thus offering little or no chance for anything getting into the line that will not pass through it. The cone-shaped feeder is similar in operation to the coal feeders used in hard coal stoves, the amount of material in the cone having no effect in raising the deposits in the cistern above the bottom of the cone. The inside

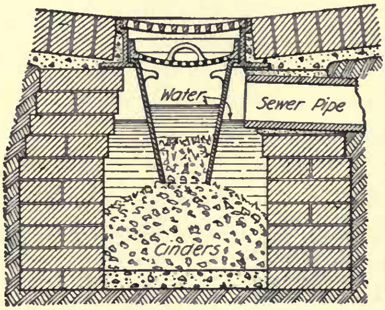

FIG. 383 (U6-2).

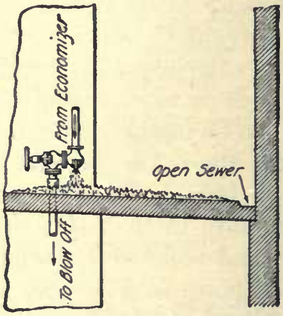

FIG. 384 (U7-1).

grating has a handle and can be taken out quickly to allow the removal of cinders.

Class U7 — Tile Sewers from Economizers and Heaters. Since loose scale is discharged with the wash water, the sewer arrangement for economizers and heaters should be much the same as for boilers. Rather than build complicated catch basins to keep scale out of sewers, it may be found cheaper to use some portable separating device which may be placed at any washout outlet and the discharge from this separator allowed to flow to a simple form of catch basin. If the washout outlets are two feet or more above the floor line, then it will be possible to have such a separator mounted on wheels so that the scale collected can be removed to a convenient place for dumping. The simplest device for this purpose, however, would be a long, narrow box, say 3 ft. wide, 12 in. high and 8 ft. long, designed to allow the water to overflow its edges. Any material washed away with the water would be carried through the sewers. This box should be made of metal, and if made of No. 12 plate could be readily handled, if not mounted on wheels. A practical arrangement is shown in Fig. 384 (U7–1). The discharge from the washout which drops on to the pitched floor will run to an open drain connected to a catch basin.

Class U8 — Tile Sewers from Blow-off and Grease Tank. The sewer from the blow-off tank should be arranged as shown in Fig. 369, so that steam may escape and the water be discharged under control of a valve. Floor drains from catch basins, as shown in Figs. 377 and 379, should not be run into a line that carries the blow-off water unless a trap is used to prevent the steam from passing back into the building.

Class U9 — Tile Sewers from Pumps. Steam cylinder and pan drips should be led to a grease trap through the grease sewer, as shown in Fig. 379. The catch basins can then be used as floor drains. If two pumps stand close together it is generally possible to make one catch basin serve both. The relief valves of such pumps should be piped to a point about three inches above the grating of the catch basin. Pumps having outside packed plungers should have a pan, as shown in Fig. 372. Instead of water and oil being allowed to drip into the pan and mix, there should be a dividing partition, the drips from the water end discharging into the catch basin, and the drips from the steam end running into the grease sewer. This division allows the water drips to discharge at all times.

Class U10 — Tile Sewers from Filters. The cold water filters can be drained to the sewer if the waste water is discharged into a well or basin open to the air. A sealed connection should not be used if the discharge is under pressure, because a pressure of one or two pounds would be sufficient to cause damage to the ordinary sewer. If the filter is to discharge under pressure, then it should be connected to the blow-off system. Oil filters and tanks should discharge their grease, together with the hot wash water, into the grease sewer. The automatic water discharge shown in Fig. 350 should discharge to the tile sewer. There will be no grease in this water and the connection can be open to the atmosphere at all times.

The washings from the precipitating tank, Fig. 351, should also be run to the grease sewer. It may seem at first that it is poor operation to discharge the contents of a grease trap into a precipitation tank, then wash the grease that hangs to the side of the precipitation tank back into the grease trap. This clinging grease, however, is no more refuse than that which is drawn off to be used, and if it is not reclaimed at one time it will be at another if returned again to the grease trap.

Class U11 — Drain Tile Sewers. The tendency of drain tile is to produce a uniform moisture condition of the soil by draining water from wet to dry soil. To prevent damp walls the following features should be considered: (1) As much water as possible must be removed from the soil lying against wall. (2) The wall must be made impervious to water. (3) The inside face of the wall should be sufficiently well ventilated to carry off the moisture.

The first requirement is the only one that can be improved by use of drain tile, and the more open the soil the more essential becomes the use of tile. With regard to the second requirement, a wall may be watertight through certain portions and yet afford regular channels at frequent intervals. Concrete laid at different times offers fissures through which water can flow. Brick work and stone work have enough open joints to keep moist the entire surface of a wall. Plastering the outside of the wall, if done all at one time, will serve best to make the wall watertight. If drain tile is used at the bottom of the wall, as shown in Fig. 385 (U11–1), then the different sections of ground would have varied amounts of moisture. The different days' work of concrete are shown by the lines at *B*. If a course must be stopped before finishing it should be run down at an angle as shown and the step maintained as though it were longitudinal. The drain will prevent water from filling the soil and the joints are "weathered" so that water cannot flow through.

The drain tile at the bottom of the wall will drain only the ground above it, so it is necessary to place the drain well below the floor line. If the sewer that the drain tile empties into lies high, necessitating placing the drain at *A*, then all the concrete below the joint, *B*, should be laid at one time.

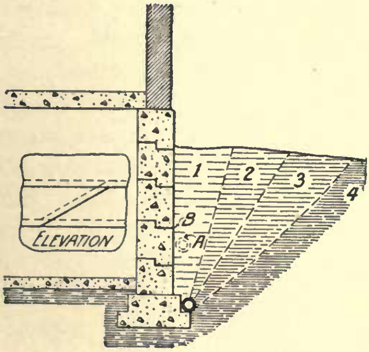

FIG. 385 (U11–1).

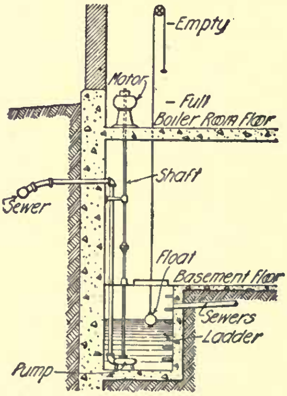

FIG. 386 (U12–1).

Class U12 — Tile Sewers — Sumps. It is sometimes impossible to drain parts of a building by gravity, and to remove such water a sump is provided with some form of pump or ejector. In locating a sump it should be remembered that (1) as a sump must be placed lower than the entire drainage system, it is unavoidably in a damp place; (2) through oversight or accident a sump may overflow; (3) being located in a remote part of the building, it will receive but little attention. These conditions make the use of belts and electrical machinery very unreliable unless placed with care. A centrifugal pump is well suited for this service because it will handle any sand, ashes and grit that may be carried to it from the drains.

A satisfactory arrangement for this service is that shown in Fig. 386 (U12–1). The pump is located at the bottom of the sump and the motor where it can have good care. The motor runs only when there is work to be done. The high or low water alarm will relieve the necessity of watching the pump. If the operation of the plant is dependent upon keeping water out of the sump, then a steam ejector of ample size to take care of extreme conditions should also be installed. The steam line to the ejector should include a stop valve to permit of shutting off steam to the sump during the normal working of the plant.

CHAPTER XXXI.

GAGE PIPING.

Class VI — Sundry Gage Connections. The general requirements for gages on steam lines are described in connection with Figs. 125 and 127. A gage should be provided for each section of the following mains, separated by a valve: Steam header, feed, auxiliary, atmospheric exhaust, vacuum exhaust, dry vacuum, circulating water, fire, low pressure, oil, compressed air and city water. Provision should also be made for installing gages for each boiler, and if an automatic feed valve is used one should be placed between the pilot and the feed valve; each engine to show steam, intermediate and vacuum pressure; each feed pump between the governor and the steam cylinder and between the stop valve and water cylinder at discharge; fire pump, to show steam and water pressure, and in some instances to show vacuum on the suction; condenser circulating pump to show discharge pressure (also provide attachment for vacuum gage on suction); dry vacuum pump between stop valve and pump and to show air suction; automatic pumps to show condition of discharge valve; oil pumps to show pressure on discharge; engine oil piping; each condenser between a stop valve and the condensing space; economizers, to be placed near blow-off to aid in handling valve properly. Gages thus installed serve two purposes: they show whether or not pressure exists and also indicate the amount of that pressure.

In addition to these gages it would be well to install a pressure recording gage and a feed-water temperature recording gage, a permanent draft gage showing chimney draft and another between boiler and economizers. If a specially sensitive draft gage is used it can be made to serve two or more points by having a shut-off valve for each branch.

A simple and sensitive draft gage is shown in Fig. 387 (VI–1). Water is placed in one of the glass cups and oil in the other. Instead of the draft being measured from one surface to another in these glasses, the draft is measured in the smaller tubes. A column of oil 10 in. high has approximately the same weight as 9 in. of water and for every tenth of an inch draft the gage shows one inch. If 0.7 in. draft were observed on the gage about seven inches would be indicated on the scale attached to gage. A movement of 10 in. in the small glasses with $\frac{1}{8}$-in. bore would cause a movement in the large glasses (difference in levels) of 0.1 in., so if properly scaled the gage may show 1.1 in. draft when a movement of 10 in. has occurred in the 0.5-in. glasses. This gage can be readily made by any engineer having a lathe. The pattern work is extremely simple and rods and glasses are standard.

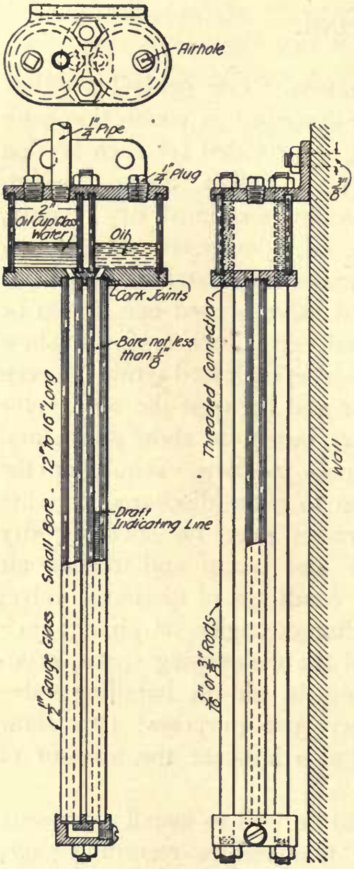

FIG. 387 (V1–1).

Class V2 — Sundry Water Column Connections and Feed Regulators. Water columns and connections are shown in Figs. 115 to 124. Boiler feed regulators are shown in Figs. 194 to 199. These illustrations show the steam, water and feed valve connections. In addition to the usual water column connections there should be a blow-off connection from the bottom of the column to the blow-off line. In many plants the columns are blown into the ash pit: a satisfactory practice unless too much water is blown into the pit. If an ash hopper is provided to retain ashes ready for discharging into an ash conveyor, it will be found best to keep water out of the pit. Water in the pit causes the slide grates to rust, and washes in grit, making them troublesome to operate. If an open funnel is used to receive the blow-off from gage cocks it should be drained to the ash pit. As but little water will be discharged from the funnel, and as it will always be open to atmosphere, the blow-off water may blow back through it. This will necessitate a check valve at the bottom of funnel branch to make it a safe connection. The blow-off lines from the bottoms of the column and water gage should run separately down to a point within reach from the floor and a valve be placed in each connection before it connects into a common discharge.

Steam gages are sometimes placed at the top of a column. A gage should not thus be subjected to the sudden pressure changes and the liability of becoming shut with scale from the repeated blowing of the water column. The boiler feed regulator should not be a part of the water column, but independent, having separate steam and water connections, so that any scaling in one will not affect the other. When so connected, if a water column does not agree with the working of the feed valve, it will be evident that something is wrong; but if both connections were taken off of the same steam and water connections they might both show a false water level.

Class V3 — Sundry Connections for Damper Regulators. In general the hydraulic damper regulator requires a pressure line from the bottom of the steam header, a water line to the controlling valve that admits water to the plunger, and a waste water line from this controlling valve to relieve pressure on the ram. There are two general classes of regulators. One type causes the damper to be opened or closed completely when the pressure for which it is set is reached and to remain so until the other extreme pressure is reached. The other type is designed to open and close the damper gradually, the position of the damper at all times corresponding with the various pressures. Regulators of the latter class do not maintain the steam at a definite pressure, but control the fire purely from a commercial standpoint. They obtain from the coal the greatest possible number of heat units that are obtainable by damper control. Fig. 388 (V3-1) shows a regulator of this type; the pressure from the steam line is connected to the under side of the diaphragm and the pressure on diaphragm is counterbalanced by a weight on a lever. Some types use a weight to load the lever, others use springs; that shown is provided with both. Either one alone will not give the desired adjustment for the regulator.

It is generally found most economical to allow about five pounds variation in pressure from the time the damper starts to move until it is full open or closed. When two springs are used the full range of pressure variation is adjustable as follows: If the upper spring is loaded to 10 lb. in tension and no load is put on the bottom spring, then the balance level will move from one stop screw to the other with a very slight added pressure. If top spring is loaded to 40 lb. and lower one to 30 lb., it will then require a very considerable pressure variation to carry the lever from one stop to the other.

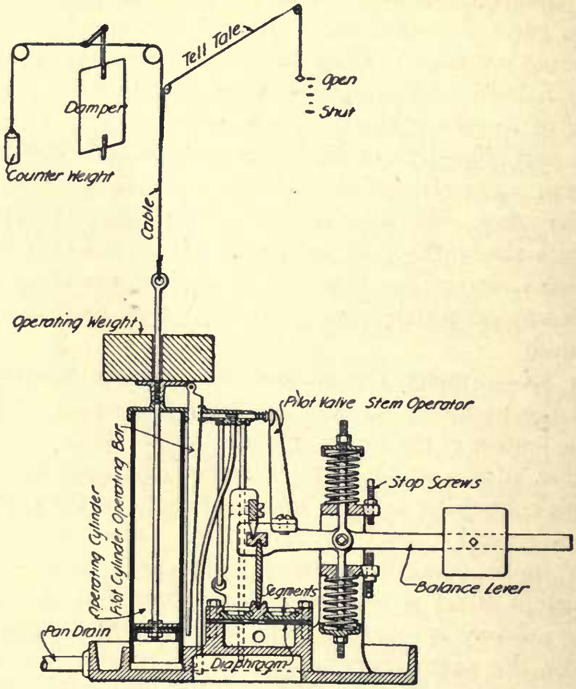

FIG. 388 (V3-1).

The most satisfactory operation is obtained by setting the spring load on the balance lever for the lowest pressure to be carried, say 100 lb., and either slide weight out or hang on weights for the higher pressures. It will be noted that the diaphragm has but little travel and that it is supported over its entire surface. The strain caused by the pressure is transmitted to the segment jointed blocks shown.

If ample provision is made to catch the drips and leaks from the regulator it should be placed in engine room in charge of the engineers, and to aid the firemen in handling the boilers there should be some form of telltale carried to the front of the boilers where the firemen can observe the working of the regulator. (See Fig. 388.) The economy effected with an efficient regulator is sufficient to pay for one of the most approved types in a very short time.

Class V4 — Sundry Relief Valve Connections. There are many types of relief valves, as previously illustrated and described, as follows: Saftey valves, on boilers, Figs. 128, 129 and 130; cylinder reliefs, Fig. 159; intermediate receiver reliefs, Figs. 43 and 134; heater reliefs, Figs. 206 and 226; pump reliefs, Fig. 216; and special types of relief valves, Figs. 182, 183 and 184. Relief valves are also required on economizers and air compressors.

The boiler safety valves are constructed so that a less pressure is needed to hold them open than that required to open them, but they will not close until a lower pressure is reached. There results a larger discharge opening, a quicker discharge, and the valve operated a much less number of times, thus greatly reducing the wear. If the steam pulsations at a safety valve nozzle are considerable, say three pounds, then the pop relief must be set higher, say five pounds, to prevent the valve from chattering on its seat.

Water reliefs are generally plain spring-loaded valves that open very slightly when they start to blow. The valves shown in Figs. 182 and 183 are specially suited for large discharges of water, and that shown in Fig. 184 for smaller quantities.

Class V5 — Sundry Pressure or Speed Regulator Connections. A satisfactory method of piping pump governors is shown in Fig. 89. To insure smooth running, a sufficient volume of steam is required between governor and machine. (See Fig. 93.) An engine driving a centrifugal pump or running at different constant speeds should have a slide weight governor similar to that shown in Fig. 96. Governors that control pumps delivering against a uniform head are so unchangeable in the position of the valve that very satisfactory results can be secured by hand control. A by-pass should be placed around the governor on such a pump, then repairs can be made to the governor while the pump is under hand control.

It is advisable to furnish feed pump governors with a by-pass. Then if the governor is controlling the pumps, the feed valves may be opened or closed to regulate the feed to the boilers. If a pump is hand controlled, regulation requires that the steam throttle to the pump be changed. This increases or decreases the delivery of the pump. Probably the best control is obtained with a weight so hung on the pump governor lever that it may be adjusted by a screw and hand wheel. Then for regulation, instead of altering the feed valves, the output of the pump can be altered.

A fire pump should be provided with a by-pass around the governor if there is any possibility of the governor being disarranged while in operation. In case of fire it would be far better to have a man stand at the throttle, working it by hand, than to risk a poor governor interfering with the water supply. The successful continuous operation of a fire pump should not be dependent upon any device that cannot be hand operated if necessary.

For every given speed of an engine driving an electric generator the governor opens the valves a given amount, making it impossible to secure the same speed with different amounts of valve opening. If a condenser is thrown on, it immediately relieves the engine of a large part of its load, and to reduce the steam fed to the engine it is necessary for the engine to increase its speed until the port openings of valves correspond with the smaller amount of steam required. Engine governors also fail to "anticipate the on-coming variations."

The inertia governor has been in use for a considerable time on high-speed shaft governor engines. It is the most approved type and with it it is possible to secure higher speeds with a heavy load than with a light load. This is because the valve opening is controlled partly by the retardation of shaft rotation. Such retardation is wholly a result of load, not speed. There are a few types of Corliss inertia governors, but as they are operated by belts most of the small amount of acceleration or retardation is lost. High-speed engines have their inertia governors directly attached to the moving parts; the balance wheel is relatively light and subject to retardation and acceleration. Heavy Corliss engines are slow in this inertia movement and the force is liable to be lost in the governor belt. These corrections for variable loads, and for vacuum, should be refinements that could be thrown on and off at will and not make the regulation of the engine dependent upon them.

Class V6 — Sundry Lubricator Connections. The old-style glass sight-tube gravity lubricator should not be ordered with new equipment because a mechanically driven force feed pump can be secured for a price that will enable it, in a short time, to effect sufficient saving in oil to pay for itself. The larger engine builders furnish good types of force feed pumps and all necessary connections. An oil pump invariably delivers far more oil than is required, and if two feeds are used they should both lead to the steam line. It would otherwise be quite difficult to cut down the stroke or oil discharge sufficiently if two were working. The same principle should be observed for small stoker and fan engines which get too much oil. Rather than use a two-plunger pump it will be better to use in conjunction with a small single-plunger pump a plain gravity cup available for emergency cases. If a pump is compound then a larger oil pump can be used with it, having a dividing partition so that two kinds of oil may be fed. In practice, however, it has been found that little or no additional oil is required for low-pressure cylinder other than that which is carried through from the high-pressure end. By using a two-compartment pump, each compartment having one plunger, both feeds may serve the high-pressure cylinder, or if one pump will serve the other may be held in reserve or be used with low-pressure oil for low-pressure cylinder.

Class V7 — Sundry Trap Connections. Steam traps are commonly looked upon as a nuisance, but there are situations which will permit of no other method of doing their work. If a plant is carefully laid out it is quite probable that traps will not be required for any of the steam lines. Steam machines will take through them considerable condensation and oftentimes a trap need not be used; but in this connection it must be remembered that for every pound of condensation sent through a steam machine there is a loss of one pound of steam in addition to the loss of condensation by using steam in this condition. If there is no other way of freeing a steam line of this entrainment, then a trap should be used, even if it is necessary to blow the drips to waste.

The intermediate receiver has virtually no other way of discharging its drips except through a trap, and to unify the responsibility for a satisfactory engine installation it will be found advisable in ordering an engine to specify that the builder furnish the trap. A trap for receiver service should be of large capacity. The use of two valves seated simultaneously is questioned, because this is a form of construction that it is next to impossible to keep tight. The trap shown in Fig. 330 is suitable for receiver service. Either of the two valves can be seated separately. To permit repairs it is necessary to have a by-pass with a valve and also valves in the trap inlet and outlet. In ordering a by-pass it is generally understood that these three valves are required whether the by-pass be for a trap, governor, reducing valve or any other flow-regulating device.

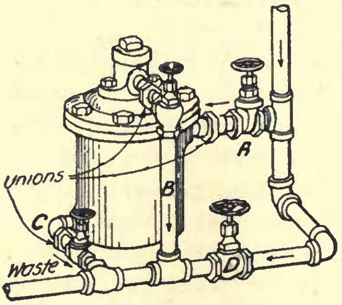

Fig. 389 (V7–1).

In addition to the by-pass all traps should have a blow-off connected to the trap discharge line. Fig. 389 (V7–1) shows a trap with a drip inlet, *A*, a drip discharge, *B*, a trap blow-off, *C*, and a by-pass valve, *D*. It will be noted that the three unions are located between the valves and the trap, permitting the trap to be removed at any time, even though there is pressure on the drip line. It will also be noted that all the connections drain into the waste and thus are safe against freezing if out of service.

Class V8 — Sundry Plugged Openings and Air Vents. The bottoms of water pump cylinders are invariably supplied with plugs, but these are generally made of cast iron. Brass should be used instead of iron because iron plugs are liable to rust in so they cannot be removed. If a plant is to be shut down and there is a possibility of water freezing it is absolutely necessary to drain the water out of all pipes and machines to prevent them from being damaged. All exhaust and. steam branches not having permanent drains should be provided with plugged openings at each low point. A plugged opening should be provided in the feed main next to a pump and another at the extreme end of the feed line so that a gage may be used if desired. Tapped openings should also be provided in a compressed air line, one close to the compressor and another at the extreme end of the line. The vacuum lines should also have plugged openings at the condenser and at the engine. These different plugged openings should be provided before the pipe lines are blown out, as considerable risk is run in drilling and tapping into lines that are liable to carry chips into cylinders or valves.

The gage openings should be 0.25 in. and closed with brass plugs. Openings for thermometers may be plugged also if there is no certainty of their immediate use. The openings in smoke flues, furnaces, etc., to obtain temperatures and draft readings should all be determined early in the work and their locations stated so that contractors may not overlook them. A pipe sleeve should be built in such walls. The outside of the walls will generally be found cool enough so that a wooden plug will stand the heat; if not, a washer with a small hole in it can be placed over a $\frac{5}{16}$-in. spring cotter, the ends of the cotter being allowed to spring open and hold washer up against the end of the pipe sleeve.

To avoid rumbling in closed heaters and economizers it is necessary to discharge the air. A small blow-off should be provided for this purpose. This blow-off may be open to the atmosphere if desired, because it will be closed as soon as it has served its purpose in discharging the air. A valve $\frac{1}{4}$ in. or $\frac{3}{8}$ in. in size would be of ample size as an air blow-off for almost any heater or economizer. It is the usual practice to use the blow-off at the extreme top of a heater for a scum blower as well as to discharge air. At the top of an economizer there would be placed only the relief valve, but an air vent also should be placed at the top of the upper economizer manifold. A careful operator desires neither water hammering nor snapping in pipe lines and station apparatus. If he is in doubt as to the amount of pressure at the end of a line there should be means for his determining it.

There is too strong an inclination on the part of the employer, and to a large extent on the part of the designing engineer also, to limit power station facilities to those readily apparent as absolute essentials. Rather than reduce these facilities to the least possible amount it would be better to slightly overdo and afford the operator every means for doing his duty well, even though a few of these means provided are never used.

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