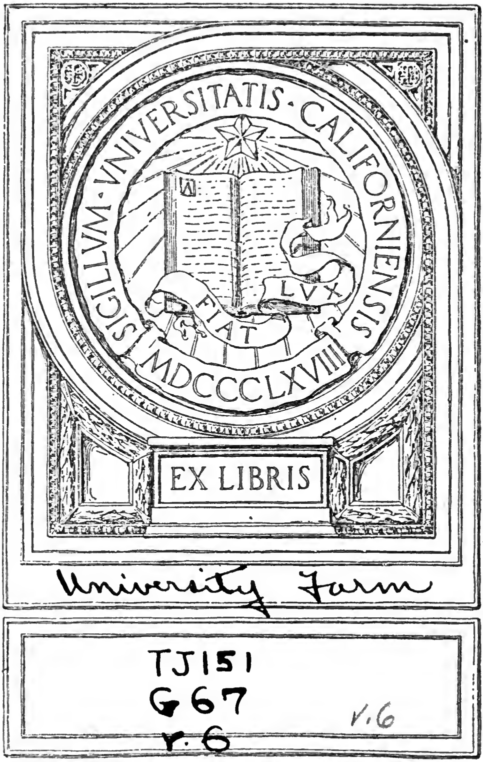
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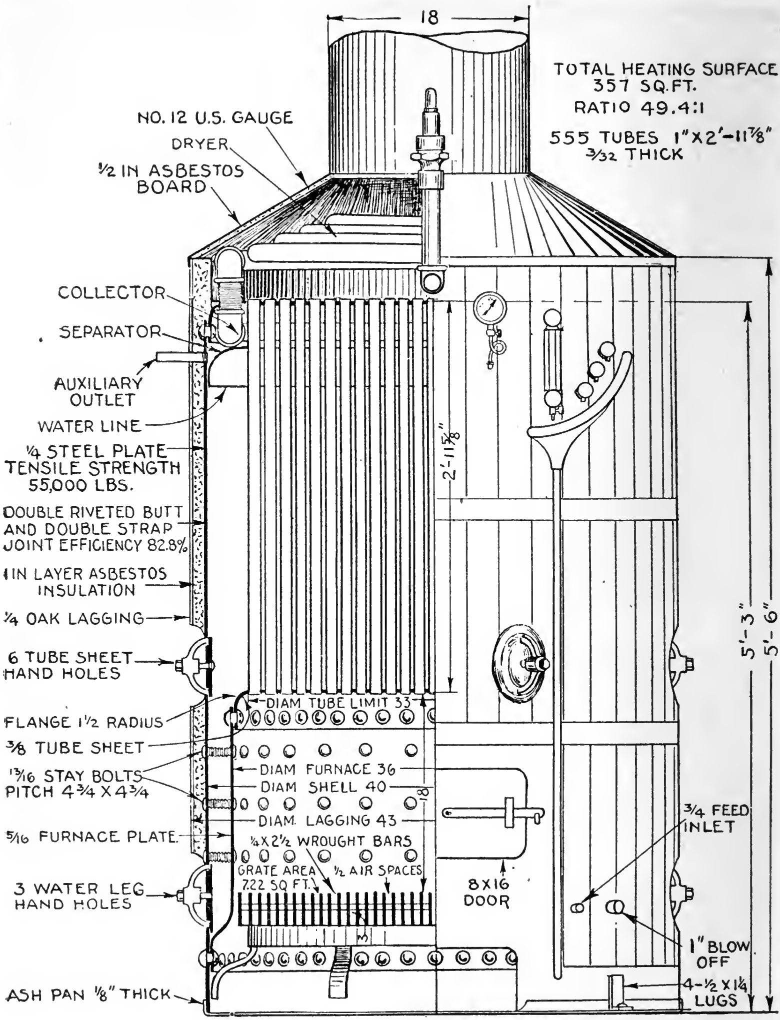

Plate 6.—Graham through tube vertical marine boiler.

The aim of the author in designing this boiler was to avoid the faults of the ordinary vertical boiler, such as inadequate heating surface, large space required and excessive weight for power developed. Capacity about 2½ times that of the ordinary boiler. Designed strictly in accordance with the requirements of the ***A.S.M.E. Boiler Code.***

AUDELS ENGINEERS AND MECHANICS GUIDE 6

A PROGRESSIVE ILLUSTRATED SERIES
WITH QUESTIONS-ANSWERS
CALCULATIONS

COVERING

MODERN ENGINEERING PRACTICE

SPECIALLY PREPARED FOR ALL ENGINEERS ALL MECHANICS AND ALL ELECTRICIANS. A PRACTICAL COURSE OF STUDY AND REFERENCE FOR ALL STUDENTS AND WORKERS IN EVERY BRANCH OF THE ENGINEERING PROFESSION

BY

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NOTE

In planning this helpful series of Educators, it has been the aim of the author and publishers to present step by step a *logical plan of study in* ***General Engineering Practice,*** taking the middle ground in making the information readily available and showing by text, illustration, question and answer, and calculation, the theories, fundamentals and modern applications, including construction *in an* **interesting** *and* **easily understandable** *form.*

Where the question and answer form is used, the plan has been to give *short, simple* and *direct answers*, limited to one paragraph, thus simplifying the more complex matter.

In order to have adequate space for the presentation of the important matter and not to divert the attention of the reader, descriptions of machines have been excluded from the main text, being printed in smaller type under the illustrations.

Leonardo Da Vinci once said:

> "Those who give themselves to ready and rapid practice before they have learned the theory, resemble sailors who go to sea in a vessel without a rudder"

—in other words, "*a little knowledge is a dangerous thing.*" Accordingly the author has endeavored to give ***as much*** *information* ***as possible*** in the space allotted to each subject.

The author is indebted to the various manufacturers for their co-operation in furnishing cuts and information relating to their products.

These books will speak for themselves and will find their place in the great field of Engineering.

Contents of Guide No. 6

CHAPTER 69

HOW TO OPERATE A BOILER

A boiler is a dangerous device in the hands of an inexperienced operator, hence a thorough knowledge of its behaviour under varying conditions is necessary for safety. This knowledge should be obtained both by study and by operating under the guidance of a competent engineer. The term operation, broadly speaking, embraces:

1. Installation.
2. Running.
3. Care.
4. Repair.

1. INSTALLATION

The subject of boiler settings has been treated at such great length in Chapter 76, that nothing more need be said here. Installation, however, involves not only the setting of the boiler, but its proper location and connections as well.

Ques. Where should a boiler be located?

Ans. As near the engine as possible.

Ques. Why?

Ans. To reduce the loss of heat in the pipe line, and thus deliver steam to the engine with minimum moisture, or minimum loss of superheat, according as the boiler furnishes saturated or superheated steam.

The short pipe line, moreover, costs less, gives less trouble and because of its less frictional resistance, delivers steam to the engine with less **drop.**

Ques. Where should the main steam outlet on the boiler be located?

Ans. At the end which will give the shorter pipe line between engine and boiler.

This outlet should be connected to a so called dry pipe inside the boiler, running the entire length of the shell. A full length dry pipe should be

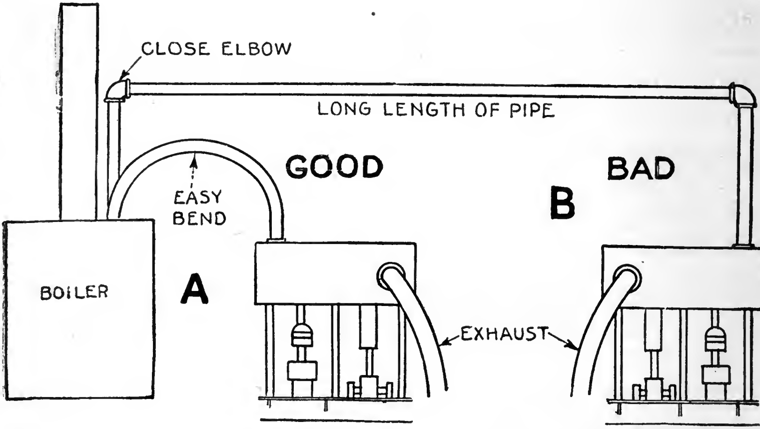


FIG. 4,033.—Right and wrong methods of piping boiler and engine of steam vessel. **A,** shows short steam pipe with long sweep fittings, or made in one piece bent to easy curve. This arrangement gives the minimum resistance to steam flow and minimum radiation loss. **B,** shows a very objectionable method, and represents the actual piping which the author once saw in a U. S. Navy launch. Note the extra length of pipe due to placing the *h.p. cyl.* aft, also the close elbows. This arrangement will give considerably more pressure drop between boiler and engine and radiation loss than the arrangement at **A.** The author cannot think of any reason that would justify turning the engine around backward, as in arrangement **B,** and considers the whole arrangement very objectionable.

insisted upon, regardless of ordinary practice or suggestions of boiler makers to the contrary. Of course in marine practice the dry pipe should not be so long that its ends might become submerged by disturbance of the water due to rolling of the vessel.

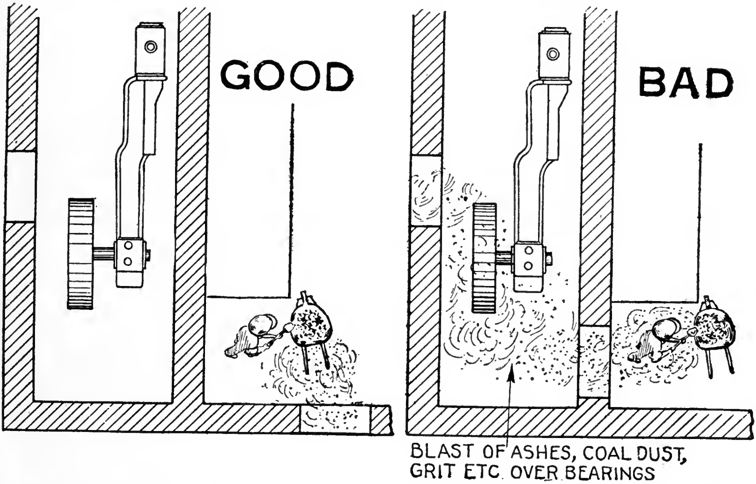
Ques. What important provision should be made in erecting the piping between boiler and engine?

Ans. These should be so inclined that the condensate will drain toward the engine—**not** toward the boiler.*†

This point is illustrated in fig. 5,012 and 5,013, page 2,816.

Ques. What should be interposed between boilers and engines?

Ans. Where possible the space should be divided by a brick



FIGS. 4,034 and 4,035.—Good and bad practice in power house construction. The only way to protect engine bearings from a constant bath of grinding matter from the boiler room is to build a solid wall as in fig. 4,034. The result of providing a door between boiler and engine room is seen in fig. 4,035. This door is always kept open, especially when the fireman is removing the ashes and the only way to keep such doors closed is to make them of solid brick, as in fig. 4,034.

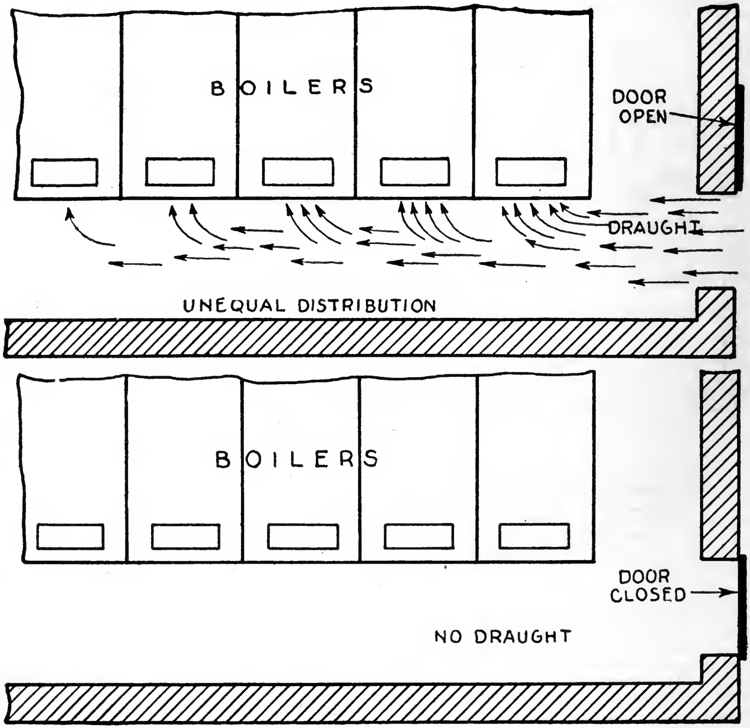
* NOTE.—The fallacy of expecting the condensate to drain back into the boiler is well expressed by Crane: "Sometimes a man, connecting a steam pipe to an engine, will incline the pipe toward the boiler as it seems that the proper place for the water is in the boiler and the drain for the pipe should go there. He will learn that the drain will not flow back against a current of steam. He will also learn that when the load is light and the current of steam slow and apparently largely along the top of the pipe the water will loaf along the pipe, fill up all pockets, etc., and when a heavy pull comes on the engine it will all come over in body and that it is better to slope toward the engine so as to drain all the time and avoid any accumulation."

† NOTE.—If proper attention were given to correct methods of collecting the steam within the boiler by providing well designed dry pipes, separator, etc., and also to properly insulating the pipe line, the draining of the steam main would not be so important a matter. In the author's boiler (page 2,406), *three* devices are provided for securing dry or saturated steam: a separator, collector or so called dry pipe, and an external dryer.

wall or partition so that coal dust, ashes, etc., will not be blown into the engine bearings, as in fig. 4,034.

If the wall be perforated with doors, it is rendered useless, as the doors are invariably left open, if not removed from their hinges, hence, a wall to be an effective protection for the engine should have no openings.

Ques. What mistake is usually made in the design of boiler houses?



FIGS. 4,036 and 4,037.—Poor provision for draught in boiler room. Where the air must come in through a door located at the end of the room, evidently the boiler nearest the door will get most of the air and the others less and less, leaving hardly any air for the most remote boiler. When the door is closed as in cold weather, fig. 4,037, the draught in all the boilers will be very poor, the only air available being that which leaks in through cracks.

Ans. Usually, there is no provision for equalized draught in the case of a battery of boilers.

Where air comes in from a door at one end, the boiler nearest the door gets the greatest proportion of air, thus the draught in the other boilers is not so satisfactory. In cold weather the door and all other openings are closed tight and the fireman wonders why there is no draught.

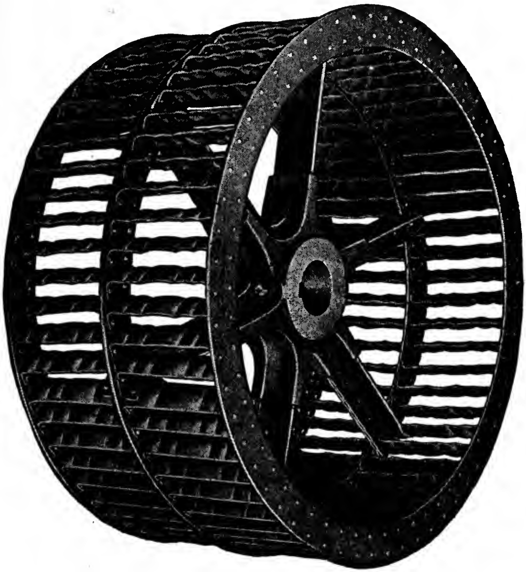


FIG. 4,038.—Sturtevant wheel of high speed multivane fan. Each blade has hot pressed cup shaped depressions which "grip" the air and tend to prevent it slipping along the blade to the side of the wheel opposite the inlet.

2. RUNNING

The term running is broadly used here to comprise the various duties to be performed in operating a boiler, such as:

1. Inspection before getting up steam.

2. Getting up steam.
3. Firing methods.
4. Water tending.
5. Meeting fluctuating loads.
6. Banking fires.
7. Blowing off.

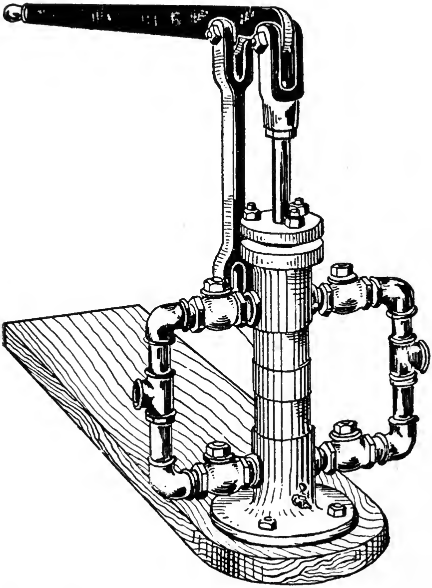


FIG. 4,039.—Marine Iron Works test pump. Suction 1 inch; discharge ¾ inch. One man can work it against 500 pounds hydrostatic pressure. The long standing base is convenient for inspectors and yard use. For shipboard a square base for fastening down is used. ***In construction*** the cylinder is of semi-steel; piston rod brass; piston (packed) brass; forged connections; weight including base plate, 60 pounds.

Inspection Before Getting up Steam.—This embraces 1, the annual inspection made by the Government official to determine whether the boiler be in safe condition to withstand the working pressure, and 2, the ordinary inspection that should be, but usually is not, made by the man in charge.

An engineer on first taking charge of a plant, should trace out all the pipe lines and note condition of same; he should carefully examine the safety valve and blow off valve and see that both are in proper working order, likewise the gauge cocks and water column and inserting a rod to ascertain that the piping is clear of obstructions.

The check valve on the feed line should be examined and reground if necessary, so that it will seat properly.

The injector and feed pump should also receive proper attention; in fact, every precaution should be taken that the feed system is in proper working order before getting up steam, especially if the boiler be of the water tube type. Of course a steam test is necessary to know absolutely that the feeding apparatus is in working order, but a thorough examination before

***U.S. Marine Rules.**—Drilling to determine thickness.*

6. The shell of any boiler which has reached the age of 10 years shall, at the first annual inspection thereafter, and at such subsequent periods as the local supervising inspectors may deem necessary, be drilled near the water line and at such other points in the shell as may be necessary to determine as nearly as possible the thickness of material, which ascertained thickness, together with the general condition of the boiler, shall govern the steam pressure allowed. (Secs. 4418, 4430, R. S.)

7. The hydrostatic pressure applied shall be in the proportion of 150 pounds to the square inch to 100 pounds to the square inch of the steam pressure allowed, and the inspector, after applying the hydrostatic test, shall thoroughly examine every part of the boiler. (Sec. 4418, R. S.)

9. The diameter of rivets, rivet holes, distance between centers of rivets, and distance from centers of rivets to edge of lap for different thicknesses of plates for single and double riveting shall be determined by the following rules.

3. Whenever any inspector shall find it necessary, in conducting his investigations or in the performance of any of his duties, to obtain testimony from the inspectors of other districts, he shall request the same through the supervising inspector. (Sec. 4405, R. S.)

4. Local inspectors, at their annual inspections of steam boilers, may cause to be removed from the surface of such boilers as are covered so much of said covering as may be necessary to enable them to examine parts of the boilers which can not be properly examined from the inside, and shall examine in a thorough and careful manner, when practicable, either externally or internally, all parts of the shell of every boiler; and the masters engineers, and owners of every steam vessel shall afford every facility necessary to carry out in the most effective and efficient manner the provisions of this section, and in no case shall an intermediate inspection be deemed any part of the regular annual inspection. (Secs. 4405, 4418, R. S.)

6. It shall be the duty of the inspector who inspects the boilers of any steamer to actually enter the boiler or boilers where it is possible to do so, and to thoroughly examine the interior of all such boilers to see that the braces are in place and of proper size, and to determine whether the boilers are in good condition, before granting a certificate of inspection, such examinations to be made after the hydrostatic pressure has been applied. A record shall be made in the boiler inspector's report of inspection showing whether or not the inspector did actually enter the boiler, and if he did not enter the boiler, he shall give his reasons for not entering it. (Secs. 4405, 4418, R. S.)

9. It shall be the duty of both the hull and boiler inspectors to be present when the boiler is being tested by hydrostatic pressure, and the hull inspector, as well as the boiler inspector, shall observe and note the indication upon the gauge.

***A.S.M.E. Boiler Code.**—Test gauge connection.*

298 Each boiler shall be provided with a ¼-inch pipe size valved connection for attaching a test gauge when the boiler is in service, so that the accuracy of the boiler steam gauge can be ascertained.

getting up steam may avoid unnecessary delay, and perhaps also the unpleasant task of repacking a hot stuffing box, cleaning an injector tube, etc.

Chills down the back or nervous prostration may be avoided by giving proper attention to the blow off valve before raising steam as previously mentioned, as a blow off valve that objects to being closed will cause an uncomfortable half hour—this applies also to the so called ball or weighted gauge cocks which require packing.

Ques. What else should be done before getting up steam?

Ans. The boiler should be filled with water to the proper level.

FIG. 4,040.—Experience of the author with ball or weighted valve gauge cocks when the packing blew—the author does not recommend these cocks where the boiler is placed in a small room as it is a nice job to stop the flow of steam under such circumstances.

Getting Up Steam.—The ordinary way of starting the fire is to throw in all the wood the furnace will hold, saturate the mass with kerosene and apply a match. This way of doing it indicates either ignorance, or a desire to help the repair man. The author confesses that this was his favorite method of starting a fire, *but,* he was operating a small water tube boiler, so constructed that sudden heating and expansion of some of the parts would not cause any undue stresses, such as would result for instance in a vertical tubular boiler where the same kind of treatment

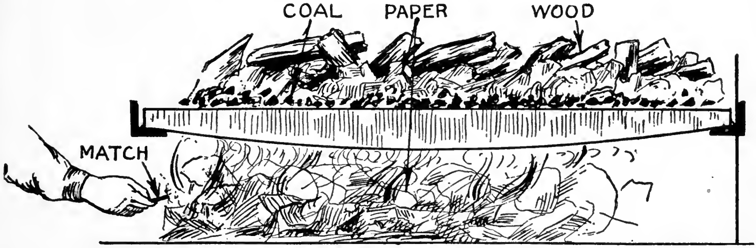


FIG. 4,041.—Method of starting the fire: The thin layer of coal protects the grate bars. The mass of wood is best ignited by lighting paper in the ash pan. In this way ignition of the wood is secured in several places at once instead of only at a single point.

would almost persuade the furnace walls to force the tubes out of both tube sheets.

The fireman should understand the characteristics of the boiler he is operating—what it will and will not stand.

Ques. How should the fire be started?

Ans. Spread a thin layer of coal over the grate, then some paper and a moderate amount of wood. It is best ignited by burning some paper in the ash pan, or in the case of a large boiler, some oily waste may be placed in the interstices of the wood.

Ques. What precaution should be taken upon lighting the fire?

Ans. The draught should not be too strong, as unequal expansion of the metal will cause leakage in the tubes, seams or rivets.

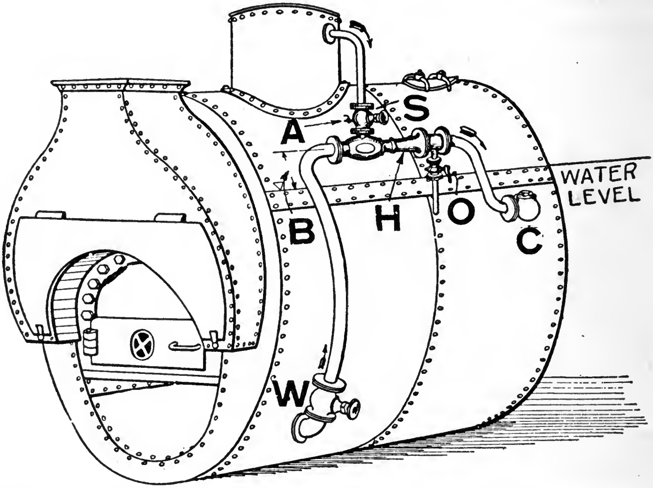


FIG. 4,042.—Koerting *external* hydrokineter attached to a Scotch boiler. This type of boiler especially, often suffers on account of unequal distribution of heat, resulting in unequal expansion of the boiler, and leaky joints. ***In operation*** the hydrokineter draws the cold water from the lower points and forces it to the highest water level, that is, to the hottest water, so that a vigorous circulation of water is accomplished. ***Manipulation:*** open valve W, and the air cock A, until water appears, then shut cock A, open starting cock O, and then the steam valve S, then slowly close starting cock O.

There is special danger in fire tube boilers, where the great body of water in the lower part of the water chamber remains quite cold, and is liable to set up severe racking strains, if the upper part be heated quickly by forcing the fire.

Ques. What should be done as soon as the wood is well ignited?

Ans. Coal should be added, a little at a time.

This will hold the fire in check and prevent sudden heating of the metal.

Ques. What other methods are employed to prevent uneven heating of the water in large fire tube boilers, especially Scotch boilers?

Ans. One method is by heating with steam, taken from a donkey boiler, the steam is blown directly into the cold water

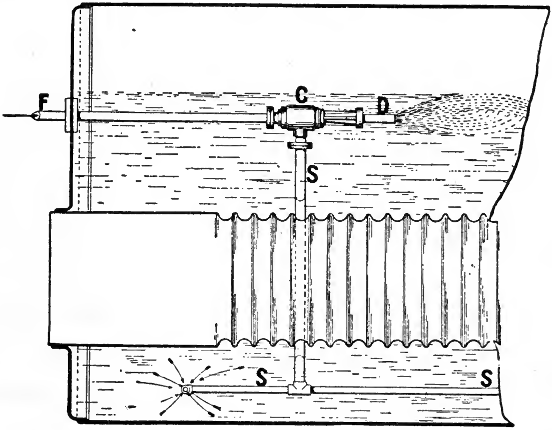
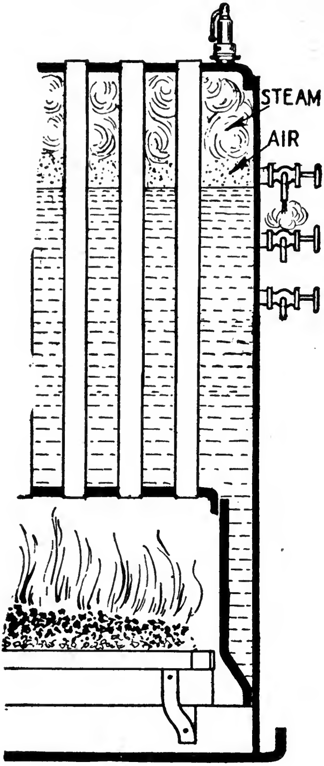


FIG. 4,043.—Koerting *internal* hydrokineter for increasing the circulation in boilers. In this type the force of the feed water is used to draw the cold water from the bottom of the boiler and to force it into the upper water levels. The apparatus is connected and works on the *eductor* principle. ***In operation,*** feed water enters at F, and in passing through the hydrokineter C, draws up cold water from the bottom of the boiler through pipe S, discharging at D, thus causing a circulation.

through a hydrokineter, or nozzle system similar to an injector, thus both heating and aiding the circulation. Another method is by pumping cold water from the bottom to the top of the boiler.

Frequently the cold water is blown out by the bottom blow valve, and the boiler is filled up again with the pump, by which process the warmer water at the top gradually sinks to the lower parts of the boiler. With such additional, artificial circulation, steam may be raised much more rapidly than when accomplished without such help, and it does not strain the boiler excessively.



Ques. What should be done before steam begins to form?

Ans. The gauge cocks or safety valve should be opened so that when steam forms it may drive out the air.

Ques. Why?

Ans. The air, if not removed, would work through to the condenser and retard the vacuum, moreover its presence would furnish oxygen which would be active in corroding the boiler.

Ques. Why open gauge cock instead of the safety valve?

Ans. Air, being *heavier* than steam, will be next

FIG. 4,044.—Method of expelling air from boiler in getting up steam. Air being heavier than steam, will lie in a layer next to the water line, while steam will rise to the top, hence to get out all the air open the water gauge cock (nearest above water line) and *not* the safety valve.

the water, while the steam will rise, hence the air should be expelled at a point as near the water line as possible.

Ques. When steam forms what should be done?

Ans. The safety valve and gauge cocks should be closed, and the steam gauge should at once be observed.

If the hand remain on the pin for any length of time, the gauge is not in proper working order. It is in a condition termed "*slow*" that is, the pressure on the boiler will be greater than that indicated by the gauge, and it should be repaired at the earliest opportunity.

Ques. What attention should be given to the water gauge?

Ans. The water level should be observed. If it appear stationary or "dead," see that the valves are open.

If the gauge be working properly, the water level will fluctuate up and down, this being quite marked in some water tube boilers.

To test the gauge, open the blow cock and let the steam blow all the water out of the glass. Close the cock and if all the connections be clear, the water will at once rise to its former level.

A final test is by the gauge cocks. When the water line appears dead it should always be regarded with suspicion.

Ques. What should be done when steam is up to the desired pressure?

Ans. If no steam is being used, the fire should be checked by closing the damper, a little coal being thrown on, being careful to spread it well.

Both closing the damper and throwing on the coal tends to prevent a further rise of pressure.

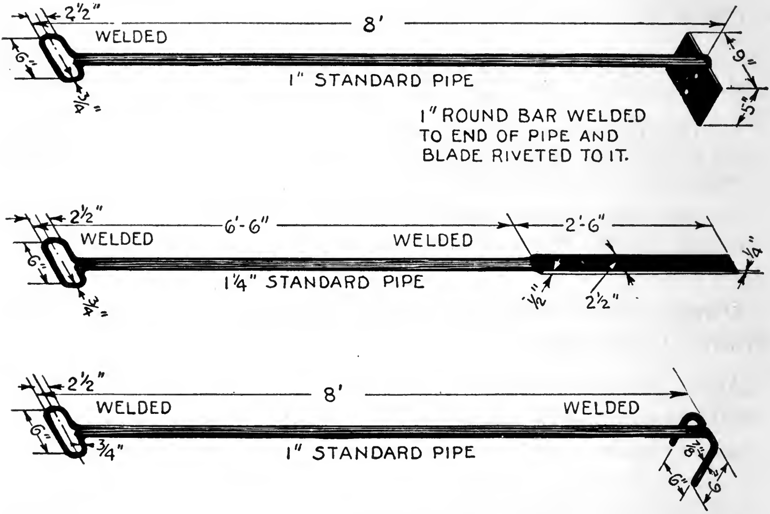
Ques. What should not be done when steam is up to the desired pressure?

Ans. The hinges of the fire door should not be dislocated by throwing it open, as is customary.

A damper is placed in the stack for the purpose of checking the fire. When the door is opened, the sudden inrush of cold air striking the highly heated surfaces, cause rapid cooling of the metal with unequal contraction, thus subjecting the boiler to severe strains which will eventually call for repairs.

Ques. Why should the ash pit doors be left open at all times?

Ans. To prevent the grate bars becoming overheated, thus prolonging their life.



FIGS. 4,045 to 4,047.—Fire tools as recommended by the Bureau of Mines showing construction and dimensions.

Ques. How is the fire tended after raising steam?

Ans. The firing must be done in such manner that the prescribed steam pressure is held as steady as possible.

The ideal method of firing, as approximated with a gas or oil fire, is to produce from the furnace a steady flow of fire gases, of such temperature and such volume as will evaporate from the heating surface the exact volume of steam required for opreating the engine and its auxiliaries.

Ques. How far is this condition realized in the ordinary manner of firing coal?

Ans. It results in a rather unsteady steam pressure, particularly in the case of water tube boilers.

The firing must be done so that the fluctuations are, at least, held within the smallest range, by keeping the steam production at times a little above the normal, thus making up for the inevitable falling below this average at other times.

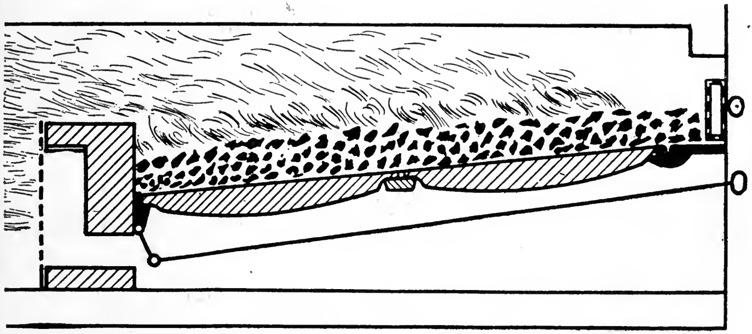


FIG. 4,048.—Even spread mode of firing, the result of which will be a uniform generation of gas throughout the charge.

Firing Methods.—Boilers may be fired by hand or by mechanical stokers. Firing by hand is a laborious and as usually done, an inefficient process.

There are four methods of hand firing, each of which has its advantages and faults. These methods are:

1. Spreading methods:

   a. Even spread.
   b. Alternate side spread.
   c. Alternate front and back spread.

2. Coking method.

Even Spread Firing.—In this system, the fireman spreads the coal evenly, beginning at the back of the grate and working toward the door. The intervals between firing and the amount of coal fired at each time vary with the experience of the engineer in charge and with the kind of coal and amount of draught in use. Some coals burn better with a thick fire, with the coal fired in large quantities at long intervals; others give better results with a moderately thick fire, using a shorter interval and a smaller charge of coal. The most economical methods of burning various coals under varying draughts can be determined only by experiment, and the economical working of the plant depends entirely on the attention given to these points by the engineer in charge.

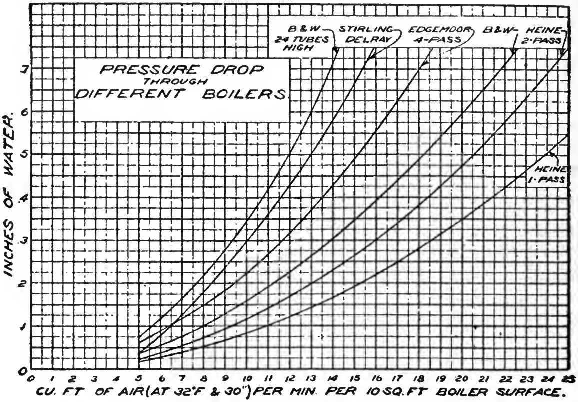


FIG. 4,049.—Pressure drop curves for some well known boilers. Since the resistance of the fuel bed is ordinarily the only changeable resistance in a boiler draft problem, it may be said that the weight of gases varies inversely as the resistance of the fuel bed, the total pressure drop remaining constant. Less heat is delivered to the boiler when the resistance through the fuel bed increases, the initial temperature of the gas and the total pressure remaining constant.

As regards efficiency, there is not much difference between a thick and a thin fire, unless it be too thick or too thin.

If the fire be too thick, say over 10 inches to 12 inches, with different coals, the air supply will be choked, and incomplete combustion with the formation of carbonic oxide will result; and the carbonic oxide will escape unburned with a great loss in economy. If the fire be too thin, say under 5 inches to 6 inches, with different coals, holes are more liable to be burned in it, giving an excess of air, with a consequent loss of economy and, perhaps, damage to the boiler. The best thickness depends upon the quality and the size of the coal, the draught and the rate of firing.

Objections to the even spread system are:

1. When the coal is spread evenly over the whole grate, the fine coal chokes the air passages through the bed of coke on the grate and reduces

the air supply at the time when it is most needed to burn the water gas and hydrocarbon gases distilled from the fresh coal.

2. When the coal is first fired, if spread evenly over the furnace, the moisture in the coal is distilled from it, a cooling process which is taking place all over the grate.

3. The formation of water gas when the steam in (2) is brought in contact with the highly heated carbon on the grate is a cooling process and also takes place all over the grate.

4. The formation of smoke due to the incomplete combustion spoken of in (1).

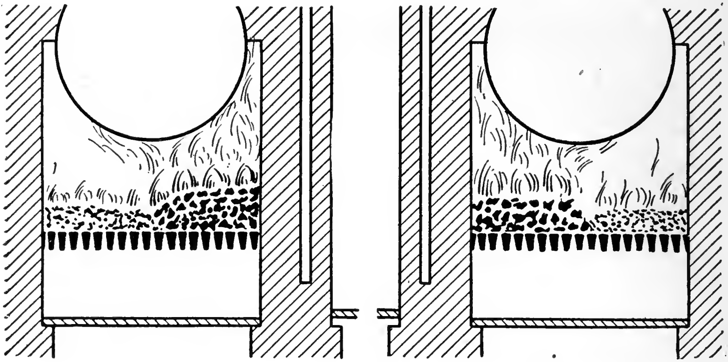
Alternate Side Spread Firing System.—This system seems to have all of the advantages of the coking system without its disadvantages. It consists of spreading fresh coal on one side of the grate over its whole length, then over the other side, alternately, at equal intervals of time. Instead of covering the whole grate with fresh coal at long intervals, only half of the grate is covered at each firing and the firing interval is shortened to one-half the time.

After each firing the volatile gases from the fresh coal rise from it, and become mixed with the hot gases and hot air from the other half of the grate, resulting in more complete combustion and less smoke. With this system of firing, economical and smokeless combustion depend in a large measure upon the skill of the fireman, but more especially upon the size of the combustion chamber space and the opportunity it affords for the thorough admixture of two currents of gas. Alternate firing is of no use unless there is ample combustion chamber space in which the two currents of gas are mixed and the smoke is burned before the gases come in contact with the comparatively cool heating surfaces.

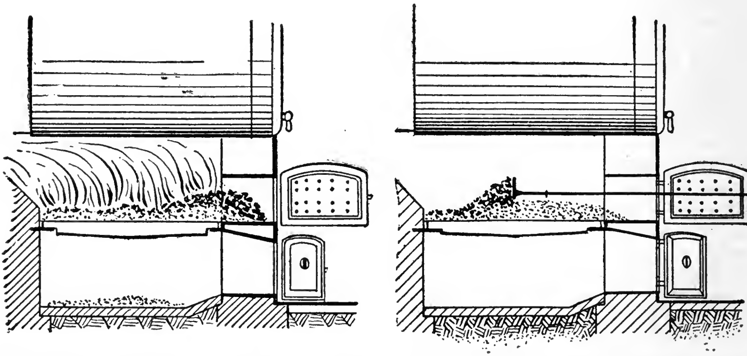
Alternate Front and Back Spread Firing.—This system is the same as that above except that the fresh coal is alternately fired on the front and back halves of the grate, instead of the right and left halves. The action of the gases is the same and the results are practically the same.

Improper firing is probably the most common of all the many causes of poor economy of steam boilers. Often the fact that an improper method of firing is being used can be ascertained by careful observation, but at times it can only be discovered by a series of systematic tests.

In some tests on a furnace equipped with three firing doors, the *Bureau of Mines* used the following spreading method: The rear half of the section of grate fired through doors 1 and 3 and the front half of the section fired through door 2, were fired at the same time. At the next firing, the front half of the section of grate fired through doors 1 and 3 and the rear half of that fired through door 2 were fired.



FIGS. 4,050 and 4,051.—Alternate side spread firing. Fig. 4,050, fresh coal put on right side; fig. 4,051, fresh coal put on left side. The coal should be fired in small amounts and will spread. In some cases a boiler that requires a fire on both sides, say every 10 minutes, will require a fire on the right side every 10 minutes, and on the left every 10 minutes, making 5-minute intervals between firings. The gas given off by the fresh coal on one side rises into a hotter furnace or combustion chamber (than it would if both sides were fired simultaneously) on account of the hot, clear fire on the opposite side, and the result is that most of this gas is burned if the proper amount of air be admitted through the door. When the last side fired burns clear, the opposite side is fired, thus the clear fire on one side serves to ignite the gases baked out of the fresh coal on the other side.



FIGS. 4,052 and 4,053.—Coking method of firing. Fresh coal is placed just inside the furnace door on the dead plate, covering a few inches of the grate as in fig. 4,052. The draught plate in the fire door is left partly open so as to admit air to the fresh coal. The heat of the fire gradually bakes the volatile matter out of the coal and if this be mixed with the proper quantity of air entering through the door a considerable proportion of the mixture can be burned. When the fire needs more fuel the pile just under the door is spread over the incandescent coals with a hoe, as in fig. 4,053. The pile of coal is thus reduced to coke which burns without smoke, after spreading a new charge of coal in place on the front of the grate and dead plate

The Coking Method.—In this system the fresh coal is piled on the front of the grate, while the rear half is covered with partially burned coke. The gases distilled from the fresh coal then pass over the rear half of the grate, through which an excess of air is entering, the air being highly heated as it passes through the bed of coke. The two gases, one containing the distilled gases, the other the heated air, intermingle in the combustion chamber, or in the combustion space of a water tube boiler, and are completely burned to carbon dioxide and steam.

In the coking method, fresh coal is fired at considerable depths at the front of the grates, and when nearly or wholly coked, is pushed to the back of the furnace. The object is to maintain a bed of incandescent carbon at the rear of the grate, in passing over which the volatile gases from the green coal at the front will be burned. This method is particularly adapted to furnaces wherein gases pass horizontally over the fire.

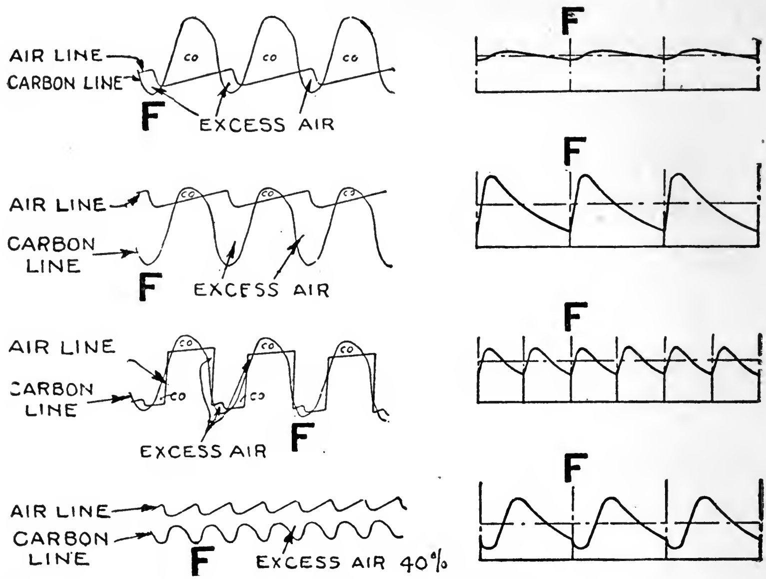
Before each firing the coked fuel is pushed back, leaving about one-third of the grate bare and all of the green fuel is fired on the bare grate. The fire door is cracked slightly to admit air for the volatile gases.

Hays says that the coking method is impossible with a fluctuating load. Holes that cannot be seen develop in the rear of the fuel bed. The coking method is a good smoke preventer, but experience is required before it can be used without loss of efficiency.

NOTE.—***No Particular System Adopted in the Navy.***—Up to the present time no one of the four systems of firing described above has been adopted in preference to the others. The method of firing water tube boilers having more than one door to each furnace approaches very nearly the alternate side firing system. That part of the furnace that can be fired through one door is covered evenly all over with coal at one signal to fire, and that through another door at the next signal, thereby keeping one part of the furnace covered with green coal while other parts are covered with coke. Economical firing has taken rapid strides in the past few years. The even spread system is the only one in practical use in the navy in fire tube boilers having only one door to a furnace, though there is reason to believe that more economy may result from the alternate back and front or alternate side firing; for it is probable that with these systems there will be better combustion of the volatile gases and smaller losses on account of lowering the temperature below the ignition point when the fresh coal is thrown on.

NOTE.—The ***spreading*** or ***alternate*** method of firing gives higher efficiency, higher CO_2, lower temperature of exit gases and generates steam more uniformly than does the coking method, due to more uniformity in furnace temperature. The *Bureau of Mines* states that about the same amount of slicing and raking is required in either coking or spreading methods (of course excluding in this the leveling required in the coking method).

NOTE.—The coking method of firing produces less clinker, since the leveling of the fire at the firing period shakes more ash through the grate, and lower CO_2, due to longer firing period results, with a tendency to admit excess air, through the thin spots. The analysis of ash shows no difference in the amount of combustible for the two methods of firing.



FIGS. 4,054 to 4,061.—Combustion results obtained by different firing methods. Diagrams by Edge and Geusch. In each diagram, F represents the point of firing. In the first four figures the air line represents the relative amounts of air passing through the fuel bed; when the coal is fired, the air supply through the fuel bed is immediately cut down and a crust quickly forms by fusion and further cuts down the air. Then, as combustion of the solid part of the fuel proceeds, the fuel bed becomes more porous or holes may burn through, gradually increasing the relative amount of air through the fuel bed until the next firing. The carbon line represents the relative amount of carbon which is in the process of burning. After firing an appreciable time is taken for all of the coal to ignite. After the peaks of the carbon line are reached the amount of incandescent carbon decreases by combustion. When the air line is above the carbon line, excess air is entering the furnace; when the carbon line is above, there is insufficient air and the combustion is incomplete. The last three represent the relative amounts of air required for coals at different times between firing periods. The last figure represents the rate of heat liberation with firing at long intervals. Fig. 4,054, *heavy firing at long intervals, with the dampers choked down.* The air supply is proper for much less than half the time. This is a common occurrence; fig. 4,055, *heavy firing at long intervals, damper wide open.* This results in a little CO immediately after firing and large amounts of excess air for most of the time. This is also a common condition; fig. 4,056, *heavy firing damper regulated to suit.* This is a better method than either the first or second; heavy firing at longer intervals. The damper is opened wide soon after the firing periods and is closed down after part of the fuel has burned away; fig. 4,057, ***correct method*** of firing: *light and frequent with damper regulated.* The damper is set so that the load may be carried with the highest CO_2 and no CO. Figs. 4,054 to 4,057 apply where secondary air is supplied through holes in the fire. If the secondary air be supplied through dampers in the fire doors, this supply increases after firing, due to higher draught; fig. 4,058, *air required for burning anthracite*, firing at fairly long intervals; fig. 4,059, *air required for burning high volatile coals*, firing at fairly long intervals; fig. 4,060, *air required burning high volatile coals, frequent firing*; fig. 4,061, heat liberated with firing methods of figs. 4,054 to 4,059.

Ques. How should coal be fired in the spreading method?

Ans. It should be fired in small quantities at short intervals, so that thin places do not burn through and admit large excess of air.

Ques. Upon what does the quantity depend?

Ans. Upon the size of grate and draught.

With a draught of 1 in. in the uptake, 2 to 2½ lbs. per square foot of grate is a good average. Thus, on a grate 6 by 8 ft., 100 to 125 lbs. of coal, or about 6 to 9 shovelfuls, would be the quantity for one firing. The intervals should be about 5 minutes. For a higher draught, the periods could be 3 minutes with a weaker draught they could be lengthened to 8 minutes, but under ordinary circumstances should never be more than 10 minutes. This method makes the coal supply more nearly proportional to the air supply, which in most hand fired plants is nearly constant.

Ques. What are the reasons for light and frequent firing?

Ans. When fresh coal is fired, the volatile matter is immediately distilled. The process is nearly completed in 2 to 5 minutes, therefore immediately after firing, large quantities of air should be admitted over the fire. After 2 to 5 minutes it should be cut down. Such regulation is practically impossible, hence large quantities of fuel should not be fired at one time.

As the air supply is practically constant, immediately after firing, it becomes insufficient and incomplete combustion results. After most of the volatile matter has been driven off, the air is in excess. The two losses are much less when small amounts are fired at frequent intervals. Automatic air control devices can be purchased, but even with these, frequent and light firing is best. Frequent firing alleviates the tendency to form a crust on top of the fuel bed.

The diagrams figs. 4,054 to 4,061, show effect of different firing methods.

Ques. Where are thin spots especially likely to occur?

Ans. In the corners at the front of the furnace, and between the firing doors.

Ques. How does the skillful fireman treat thin spots?

Ans. He gauges the right amount and selects the proper mixture of fine and coarse coal.

If the coal be burned way down, he selects coarse coal, to avoid its sifting through the grate. This also permits of the building up of the level on the spot more quickly.

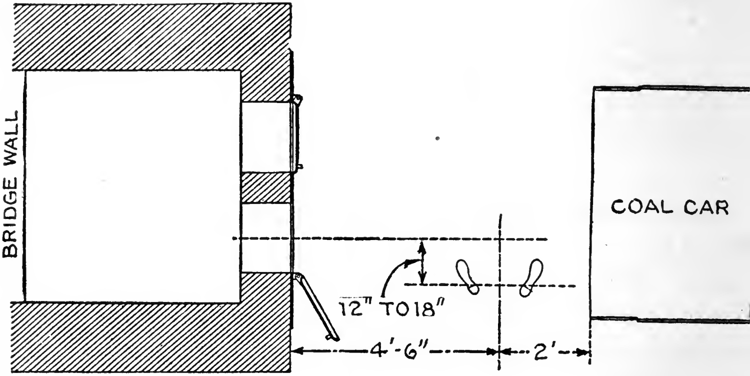


FIG. 4,062.—*Proper position for firing.* According to the *Bureau of Mines*, the fireman should stand in such position that he can see the thin spots and can throw the coal onto them with the least effort. He should stand 4½ to 5 feet in front of the furnace, and 12 to 18 inches to the left of the center line of the door. He should then be about 2 feet from the coal, which is 6 or 7 feet from the furnace front and should preferably be on a car.

Thin and thick spots will occur, even with most careful firing. In places where the air flows freely, the coal burns faster, forming a thin spot.

The cause of the variation in air flow may be the difference in the size of the coal, the accumulation of clinker or the fusing of coal into a hard crust. Before firing fresh coal, the fireman should note the thin places. They have bright, hot flames, while high spots have smoky flames or none at all. *Uehling* says to cover the holes, if burned through, with incandescent coal before firing. Place the coal on the thin spots in thin layers.

If deep hollows be filled at once, fresh coal may fuse and choke off the air, forming a new high spot. If high spots be missed for one or two firings they will burn down to normal. If the high spot be due to clinker, the clinker must be removed.

Firing Newly Set Boilers.—When boilers are newly set they should be heated up very slowly indeed, and the fires should not be lighted under the boilers for at least two weeks after setting, if it is possible to wait this length of time. This two weeks enables all parts of the mason work more likely to set gradually and harden naturally; the walls will be much more likely to remain perfect than when fires are lighted while the mortar is yet green.

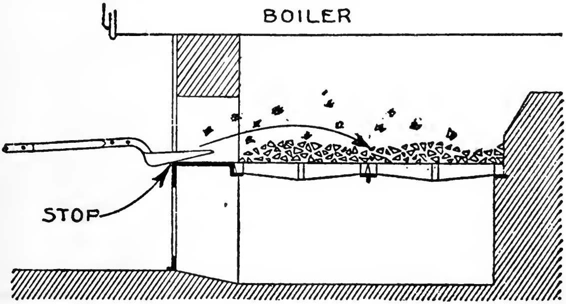


FIG. 4,063.—***End of the throw.*** The scoop should travel in a nearly straight line. At the end of the throw, the scoop should suddenly be stopped by laying it on the bottom edge of the door frame. The coal then flies off and is scattered over the proper spot. By thus stopping the scoop, the fireman saves effort, and locates the coal better. If he push the scoop way into the furnace, he has to jerk it back to get the coal off.

When fire is started under a new boiler the first time, it should be a very small one, and no attempt should be made to do more than moderately warm all parts of the brick work.

A slow fire should be kept up for twenty-four hours, and on the second day it may be slightly increased. Three full days should elapse before the boiler is allowed to make any steam at all.

When the pressure rises, it should not be allowed to go above four or five pounds, and the safety valve weight should be taken off to prevent any possibility of an increase. Steam should be allowed to go through all the pipes attached for steam, and blow through the engine before any attempt is made to get pressure on them. The object of all these precautions and this care is to prevent injury by sudden expansion, which may cause great damage.

Firing with Bituminous Coal.—Difficulty is experienced i burning bituminous slack coal, because it fuses into a hard, tigh crust. This admits little air, and therefore the combustion rat is low. The heavier the firing, the worse is this condition. Som firemen fire heavy charges of 300 to 500 pounds. They brea the crust by lifting with the slice bar, and then level the fir This is satisfactory with coals whose ash does not fuse readily.

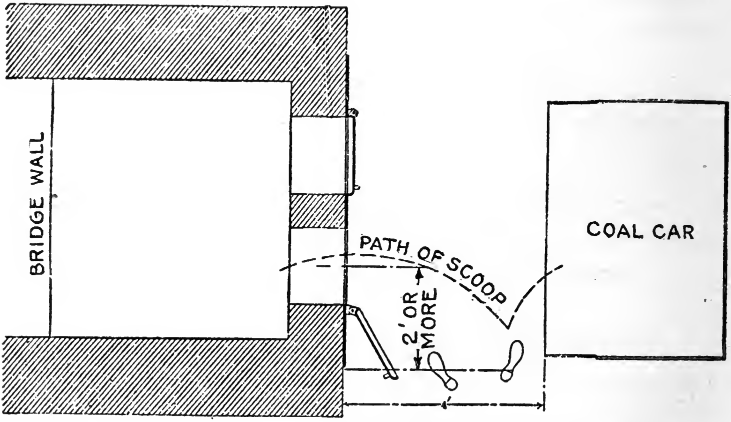


FIG. 4,064.—*Improper position in firing*. If the coal be closer than 6 or 7 feet, the firemar crowded and will stand away to one side of the door to avoid the intense heat. He cannot the fire, and throws the coal in by guess. His scoop travels in the arc of a circle, scatter coal on the floor, and dumping it in a heap directly inside of the door. This results in uneven fire, low efficiency, and requires raking of the coal onto the back part of the f Provide a smooth firing floor, or a smooth bottom to the coal car, so that the shovel d not hit bumps and rivets. Such items delay the firing operation, keeping the door o longer than necessary and admitting excess air.

For coals with a fusible ash, the better method is to keep the fire abc 5 in. thick, and fire small charges. The prongs of the rake can be used break the crust if it do not burn through.

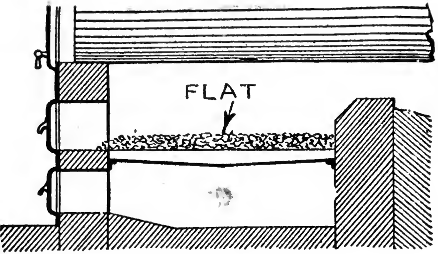
The fire should be worked as little as possible, as the working of a fire liable to cause clinker, furthermore, while the doors are open, excess ai admitted and the fireman has more work.

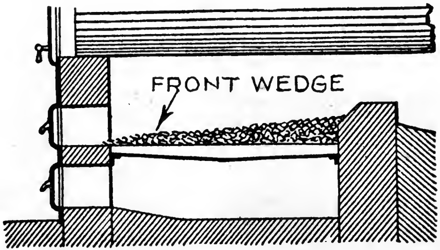
The too frequent opening of the door may be avoided by cutting in t door a small hole just large enought to admit a pointed slice bar, which inserted through this hole when it is necessary to break up the crust. A pivoted shutter will prevent inflow of air when slice bar is removed. Such arrangement is shown in fig, 4,065, as used by the author, on a 6×9 vertical marine boiler.

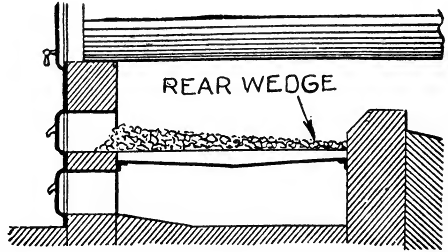
Firing with Anthracite Coal.—Fire evenly, in small quantities, at frequent intervals, otherwise dead spots will appear in the fire. If the fire become too irregular, burning in patches,

FIG. 4,065.—Firing soft coal in vertical marine boiler of author's steamer ***"Atlantic City,"*** showing small hole in door, through which slice bar is inserted to break up the fuel. The shutter, loosely pivoted above the hole, falls into place, closing the hole after the bar is removed. This arrangement will be found of great help in firing soft coals.

NOTE.—*Hays* says: "Turn the hose on any fine coal pile. It is impossible to burn some fine coals without wetting them. Fine coal tends to pack in the furnace, especially if dry, or if it contain much ash. If it be wet, the steam generated will tend to loosen it. As a result, more coal will be burned and that more uniformly, with less combustible in the ash, and less combustible carried over by the draught into the combustion chamber. There will be fewer cracks in the fuel bed, and the coal will burn with a great deal less excess of air."







FIGS. 4,066 to 4,068.—Firing with hard (anthracite) coal. Fig. 4,606, flat method; fig. 4,067, wedge method with thick fuel at the front; fig. 4,068, wedge method with thin fuel at the front. These methods give good results when the fires are properly handled.

nothing can be done, but to clean the entire fire. After firing, the fire should be left alone, and the fire tools used as little as possible.

Owing to difficulty in igniting, care must be taken in cleaning the fire. Intervals of cleaning depend on the coal and the rate of combustion. With small sizes and moderately high rates of combustion fires will have to be cleaned twice each eight-hour shift. As the fires become dirty, the depth of fuel may

Firing with Coal Dust.—This fuel, instead of being introduced into the fire box in the ordinary manner, is first reduced to a powder by pulverization, and in place of the ordinary boiler fire box, a combustion chamber is used in the form of a closed furnace lined with fire brick. This furnace is provided with an air injector having a nozzle which throws a constant stream of powdered fuel into the chamber, spraying it throughout the whole space of the fire box. This powder is first ignited by raising the lining of the fire box to a high temperature by an open fire. The combustion of the powdered fuel then continues in an interval and regular manner under the action of the air current which carries it into the combustion chamber.

U. S. Navy Pointers on Firing.—The following suggestions by the Navy Bureau will be found of value:

The above pointers, used intelligently in connection with a fair knowledge of what chemical reactions take place in the furnace, should give economical firing.

1. Keep a good bright fire. The color of the flame should be a light yellow. When dark shadows are thrown into the ash pan, it is an indication that there is clinker formed on the grate, directly above; this clinker prevents the air getting through, and results in incomplete combustion. Use the slice bar on such clinkers, removing them at once, and do not make a dirty fire wait on the clock.

2. Avoid excess of air. The greatest loss in furnace practice is due to excess of air. The waste chargeable to this cause will probably, in ordinary cases, be ten times that due to incomplete combustion. Excess air may enter in the following ways:

a. Through open furnace door. Place coal in the best position for throwing it in the furnace and work rapidly when the door is open. The CO_2 charts show material reduction of CO_2 when the doors are open. Any means of reducing the period of open door will pay. There is a great difference in furnace temperatures between the conditions of open and closed furnace doors; the resulting contractions and expansions are bad for the boiler.

b. Through badly fitting furnace doors and furnace fronts. The fit of the doors and fronts should be made good and kept in that condition.

c. Through the grate. Keep all the grate covered and all the fire clear of holes, bare spots, hills and hollows. A bare spot on the grate is the worst enemy of the coal pile.

3. There is no absolute rule as to the height of fire to carry. Fires for natural draught should be carried roughly from 8 inches to 10 inches, and for forced draught a little thicker. A thin bed of fuel will admit more air to the furnace chamber than a thick one. It is a matter of pressure (draught), and resistance (thickness of fuel); there is a relationship between the two which must be studied with each fuel and each furnace to operate furnaces with the greatest economy. This relationship can best be studied by analyzing the gases of combustion.

4. Find the draught and thickness of fire which will give best average percentage of CO_2. Too high a percentage of CO_2 entails a likelihood of too much CO; in addition to the CO, there is probably some unburned hydrocarbon gases which are lost.

5. When fires require slicing, slice them, and at no other times; the same applies to raking and cleaning.

6. Use a time firing device to fix the stoking interval, as it leads to uniformity. The device should not be used to regulate anything but the stoking interval, as the times for slicing, raking and otherwise working the fires must be dictated by human judgment. When the bottom of the fire is in bad condition, it requires slicing or cleaning; when the top is in bad condition, it requires raking; trouble on one side of a fire cannot be cured by treating the other.

Under natural draught conditions, Burnot found that when burning about 11 pounds of coal per square foot of grate surface per hour, the efficiency increased as the firing interval and weight of charge were decreased. He found evaporative efficiencies as follows (ordinary coal):

With charge equal to 1 shovelful	9.64
With charge equal to 2 shovelfuls	9.38
With charge equal to 3 shovelfuls	9.18
With charge equal to 4 shovelfuls	8.91

In this connection it has been found that if the boiler dampers be partly closed when the furnace door is open, the efficiency is increased.

7. Boiler dampers are the throttle valves of the draught, and should receive as much attention as the steam throttles, or any other controlling device in the plant. When the damper is closed, the vacuum in the furnace and passes of the boilers is decreased. The lever for regulating the dampers should be long, and the more holes in the arc for regulating the position of the dampers the better. For controlling the steam supply, use the dampers and ash pit doors—never open the furnace doors for this purpose, as it causes too much expansion and contraction. Never throw on green coal for checking the supply of steam; it does check the steam supply, but it is coal wasted.

8. Leaks of air into the uptakes cause great waste of heat units. One of the most marked improvements in recent years in boiler economy has come from having tight boiler casings. The excess of air coming through these leaks is simply so much air to be heated, and the process cools the heating

surfaces. Analysis of combustion gases near the furnaces and further on near the uptake will show whether there be uptake leaks. A lighted candle carried around the joints will also show where there are leaks. The leaks can be stopped by some effective kind of cement or plaster. Some one man aboard ship should be charged with the regular duty of seeing that the casings are kept tight.

No air should be allowed to flow through the passages of any boiler except at the furnace.

U. S. Navy Remarks on Good Firing.—The best method of firing is the one that will insure that the smoke pipe gases contain no carbonic oxide (CO) and no hydrogen or hydrocarbon gases, and at the same time contain not more than 6 per cent. of free oxygen.

The presence of combustible gases, even in very small quantities, in the smoke pipe gases is a sign of imperfect combustion and the consequent loss of economy. The presence of from 4 to 6 per cent. of free oxygen in the smoke pipe is usually a necessary accompaniment of complete combustion. A greater quantity means an unnecessarily large supply of air, and consequently unnecessary loss due to heating the excess of air. The percentage of carbon dioxide in the smoke pipe gas is not as good a criterion of the furnace conditions as would be obtained from a quantitative analysis of smoke pipe gases showing the percentage of CO_2, CO and O.

A wrong idea prevails that when the percentage of CO_2 is as high as possible the boiler economy is a maximum. This is true only when the analysis of the gases shows *no* CO, and only a reasonable amount of free oxygen, not over 6 per cent. The presence of *any* CO indicates a heat loss, which rises quickly with the rise in CO percentage.

In some boilers, notably those on shore with large combustion chambers, the percentage of CO_2 will run high, say up to 13 per cent., and yet no CO will be present in the gases. In other boilers, where the combustion chambers are small, as soon as the CO_2 percentage runs above a certain limit CO begins to show up in the flue-gas analysis, bringing with it the large heat loss. This limit with the marine type of boiler is about 10 per cent. of CO_2.

In order, therefore, to get the best results from a boiler some form of gas-analysis instrument must be at hand by which the percentage of CO_2, CO and O can be determined. Then a good rule for economical firing would be:

Keep the percentage of CO_2 as high as possible, consistent with the absence of CO and with the presence of O in small amounts—never over 6 per cent.

These conditions can be fulfilled only from experiments made by the engineer in charge of each individual plant.

Where the thickness of the fire and the force of the draught are under the control of the fireman or water tender, as they are on board naval vessels, good results may be obtained with either thin, medium thick or heavy fires, if the force of the draught be regulated in proportion to the thickness of the fires. The proper thickness of the fire and the proper force of the draught to be used with the coal on hand have to be determined by experiment, or by observation by the engineer in charge, to determine that force of draught and that thickness of the fire used that will give the best results.

The best regulation of the force of the draught and the thickness of the fire is that which makes the hottest fire. If an integrating pyrometer, giving the average temperature of the fire over the whole of the grate, could be made, it would be the ideal indicator of the furnace conditions. Deficient air supply, causing imperfect combustion, and excessive air supply, causing too great a dilution of the gases of combustion, both tend to cool the furnace. The hottest fire that can be made is one in which the air is enough in excess to insure perfect combustion and no more. The hottest fire is also obtained when the smoke pipe gases show by analysis from 4 per cent. to 6 per cent. of free oxygen. The analysis of the smoke pipe gases, therefore, gives an excellent indication of the furnace conditions.

U. S. Navy Remarks on Bad Firing.—Much can be learned by observing the mistakes of others and avoiding them. Some of the mistakes made by ignorant or negligent firemen are:

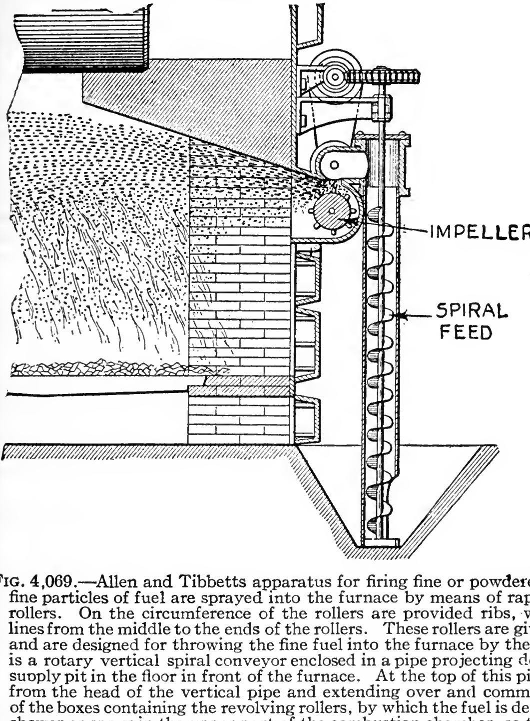
1. Putting too large a quantity of coal on the fire at a time, covering the fire so thick that the air supply is choked, resulting necessarily in incomplete combustion.

2. Firing at regular intervals, sometimes having the fire too thick, and again allowing it to burn so low that holes are burned in it, or so low that a large excess of air is passed through it, diluting the gases of combustion, and thereby sending too much heat up the smoke pipe and reducing the furnace temperature.

3. Neglecting to cover the whole of the grate surface properly, allowing holes to burn in the fire at places and having the fire too thick in others. This can result in having an excess of carbonic oxide and an excess of oxygen in the smoke pipe gases at the same time, if the excess of air passed through the thin fire at one place and the excess of carbonic oxide formed where the fire is too thick, be cooled below the temperature of ignition before they are mixed.

4. Not keeping the fires properly cleaned, thereby choking the air supply and causing imperfect combustion.

5. Errors in firing, requiring a series of boiler tests or an analysis of the smoke pipe gases for their detection, are often committed by the most careful and intelligent firemen without any suspicion that they are in the wrong. These are: *a*. Carrying the bed of fire too thick or too thin on the grate for the size of the coal and the force of the draught; *b*. unskilful regulation of the draught.



Intelligent Supervision of Firing.—Competition has become so keen, both in the navy and on the outside, that it is imperative that those in charge of an engineering plant get the maximum efficiency from the fuel.

FIG. 4,069.—Allen and Tibbetts apparatus for firing fine or powdered fuel. ***In operation*** the fine particles of fuel are sprayed into the furnace by means of rapidly revolving distributing rollers. On the circumference of the rollers are provided ribs, which are fixed in diagonal lines from the middle to the ends of the rollers. These rollers are given rapid revolving motion, and are designed for throwing the fine fuel into the furnace by their centrifugal force. There is a rotary vertical spiral conveyor enclosed in a pipe projecting down to the bottom of a coal supply pit in the floor in front of the furnace. At the top of this pipe are branch pipes leading from the head of the vertical pipe and extending over and communicating with the interior of the boxes containing the revolving rollers, by which the fuel is delivered into the furnace in a shower or spray in the upper part of the combustion chamber, so that the particles will catch fire in transit and be consumed or partly consumed before falling upon the fire floor, the draught being through the grated door, thus avoiding the opening of the doors for feeding purposes. In instances when the fire dirt is used, no grate bars need be employed in the flow but as a general rule, when the coarser grades of fuel are used, grate bars should be used for providing a draught upward into the fire.

NOTE.—***Coal Dust Fuel.*** It is used extensively in the U. S. in rotary kilns for burning Portland cement and to some extent in Germany; it has not until recently been applied to steam generation. The absence of smoke cinders and sparks is a feature of its use. Low grade coals in powder form can be used. With respect to the degree of pulverization, not less than 95 per cent should pass 100 mesh and not less than from 80 to 85 per cent. 200 mesh.

Firing with Coke.—In order to be completely consumed, coke needs a greater volume of air per pound of fuel than coal, and therefore, requires a stronger draught, which is increased by the fact that it can only burn economically in a thick bed. It is also necessary to take into account the size of the pieces. The ratio between the heating and grate surface should be less with coke than with coal; that is to say, the grate should be larger.

The difference amounts to about 33 per cent. In fact, about 9¾ lbs. of coke should be burned per hour on each square foot of grate area, while at least 14½ lbs. of coal can be burned upon the same space.

The high initial temperature which is developed by the combustion of coke requires conducting walls. Therefore the furance should not be entirely surrounded by masonry; and the plates of the boiler should form at least the crown of the fire box. In externally fired boilers, the furnace should be located beneath and not in front of the boiler.

Internal fire boxes may be used, but the greatest care should be exercised to avoid any incrustation of the plates, and in order that this may be done, only the simplest forms of boilers should be used.

With coke it is not essential that long passages should be provided for the passage of the products of combustion, since the greater part of the heat developed is transmitted to the sheets in the neighborhood of the furnace.

Since coke contains very little hydrogen, the quick flaming combustion which characterizes coal is not produced, but the fire is more even and regular. Finally, the combustion of coal is distinguished by the fact that in the earlier phases there is usually an insufficiency of air, while in the last there is no excess.

The advantage of coke over raw soft coal as a fuel is that otherwise useless slack can be made available by admixture in its manufacture, and especially that it can be perfectly and smokelessly burned without the need of skilled labor.

Firing with Lignite.—This is more difficult than firing with soft coal, and a large combustion space is desirable. The best results are obtained with a reverberatory furnace giving long travel to the gases. The fuel bed can be 4 to 6 inches thick.

Fire lignite in small quantities by the alternate method. Above certain rates, clinker forms rapidly. Considerable draught should be available, but should be carefully regulated by a damper. Smokeless combustion with hand firing is practically impossible. There is a strong tendency to foul the heating surfaces, which should be cleaned frequently. Shaking grates assist in cleaning the fire, but considerable fuel may pass through.

Firing doors are opened too frequently when coal is not being fired in order to see the condition of the fire and excess air admitted. A 1½-inch mica-covered peep hole in the door avoids this. The CO_2 percentage was increased by 1½ per cent. in one plant by this method.

Firing with Coal Tar.—The problem of firing retort benches with tar instead of coke has engaged the attention of gas managers for many years, and various modes have been adopted for its management. The chief difficulty has been in getting a constant flow of tar into the furnace, uninterrupted by stoppages caused by the regulating cock or other appliance not answering its purpose and by the carbonizing of the tar in the delivery pipe, thus choking it up and rendering it uncertain in action.

To obviate these difficulties various plans have been resorted to, but the best means for overcoming them are thus described: Fix the tar supply tank as near the furnace to be supplied as convenient, and one foot higher than the tar injector inlet. A cock is screwed into the side of the tank, to which is attached a piece of composition pipe ⅜-inch in diameter, 10 inches long. To this a ½-inch iron service pipe is connected, the other end of which is joined to the injector. By these means it is found that at the ordinary temperature of the tar well (cold weather excepted), four gallons of tar per hour are delivered in a constant steam into the furnace. If more tar be required, the piece of ⅜-inch tube must be shortened, or a larger tube substituted; if less tar be required it must be lengthened.

The risk of stoppage in the nozzle of the injector is overcome by the steam jet, which scatters the tar into spray and thus keeps everything clear.

Trouble being occasioned by the retorts becoming too hot, in which case, on shutting off the flow of tar for a while, the tar in the pipe carbonized and caused a stoppage, a removable plug injector is fitted and ground in like the plug of a cock, having inlets on either side for tar and steam. This plug injector can be removed, the tar stopped in two seconds and refixed in a similar time. The shell of the injector is firmly bolted to the top part of the door frame. The door is swung horizontally, having a rack in the form of a quadrant, by which it is regulated to any required height, and to admit any quantity of air.

Firing with Straw.—The operation of burning straw under a boiler consists in the fuel being fed into the furnace only as fast as needed. When the straw is handled right, it makes a beautiful and very hot flame and no smoke is seen coming from the stack. The whole secret of getting the best results from this fuel is to feed it into the furnace in a gradual stream as fast as consumed. When this is done complete combustion is the result.

A little hole may be drilled in the smoke box door, so that the color of the fire can be seen and fire is handled accordingly. When the smoke comes from the stack the color of the flame is that of a good gas jet. By feeding

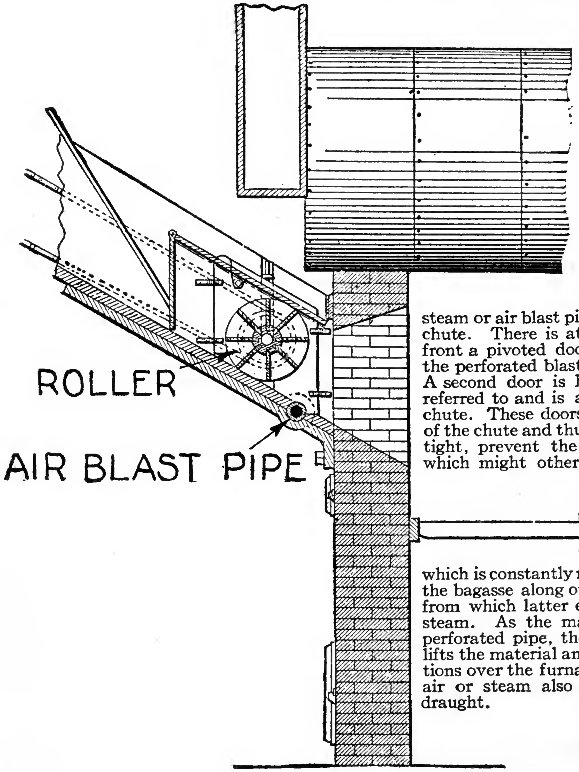
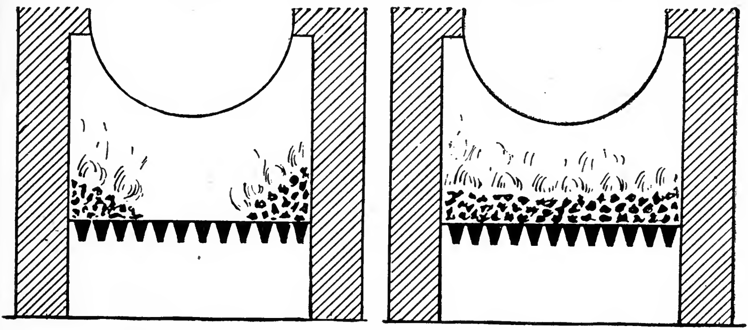


FIG. 4,070.—Fischer apparatus for firing bagasse. *It consists of* an inclined chute down which the bagasse is fed. At the lower end and near the furnace front is a roller having radial blades, which roller is driven by any suitable mechanism. Between this roller and the furnace front is a perforated steam or air blast pipe extending across the chute. There is attached to the furnace front a pivoted door extending over both the perforated blast pipe and bladed roller. A second door is hinged to the one just referred to and is adapted for closing the chute. These doors fit in between the sides of the chute and thus, being practically air-tight, prevent the escape of any sparks which might otherwise fly out from the mouth of the furnace. The bagasse, after being discharged upon the chute, slides down to the bladed roller, which is constantly rotating and which feeds the bagasse along over the perforated pipe, from which latter escapes a blast of air or steam. As the material passes over this perforated pipe, the blast of air or steam lifts the material and scatters it in all directions over the furnace grate. The blast of air or steam also serves to increase the draught.

faster still, the flame is extinguished, clouds of black smoke come from the stack and the pressure is falling rapidly.

Firing with Oil.—There are various devices used for this purpose, most of them depending upon a steam jet to atomize the oil, or a system of retorts to first heat the oil and convert it into gas before being burned.

The subject of oil burning has been presented at such length in Chapter 75, it is not necessary to add anything here, beyond perhaps to state that among the advantages claimed for the use of oil over coal are 1, uniform heat; 2, constant pressure of steam; 3, no ashes, clinkers, soot or smoke,



Figs. 4,071 and 4,972.—Firing shavings by hand. ***For hand firing*** it is necessary to burn the shavings from the top as otherwise the fire and heat are only produced when all the shavings are charred. To do this, provide a half-inch gas pipe, to be used as a light poker; light the shaving fire, and when nearly burned take the half inch pipe and divide the burning shavings through the middle, banking them against the side walls, as shown in fig. 4,071. Now feed a pile of new shavings into the center on the clean grate bars, as shown in fig. 4,072, and close the furnace doors. The shavings will begin to burn from above, lighted from the two side fires, the air will pass through the bars into the shavings, where it will be heated and unite with the gas, making the combustion perfect, generating heat, and no smoke, and the fire will last much longer and require not half the labor in stoking.

and consequently clean flues; 4, uniform distribution of heat and therefore less strain upon the plates.

Firing with Saw Dust and Shavings.—Air is forced into the furnace with the planer shavings at a velocity of about 12 feet per second, and at an average temperature of about 60 degrees Fahr.

The shavings are forced through a pipe 12 inches in diameter, above grate, into the combustion chamber. The pipe is provided with a blast gate to regulate the air in order to maintain a pressure in the furnace, which a little more than balanced the ascending gases in the funnel or chimney.

The shavings are forced into the combustion chamber in a spray-like manner, and quickly ignite. The oxygen of the air so forced into the furnace along with the shavings gives full support to the combustion.

It is important to keep the blower going continuously to pre-

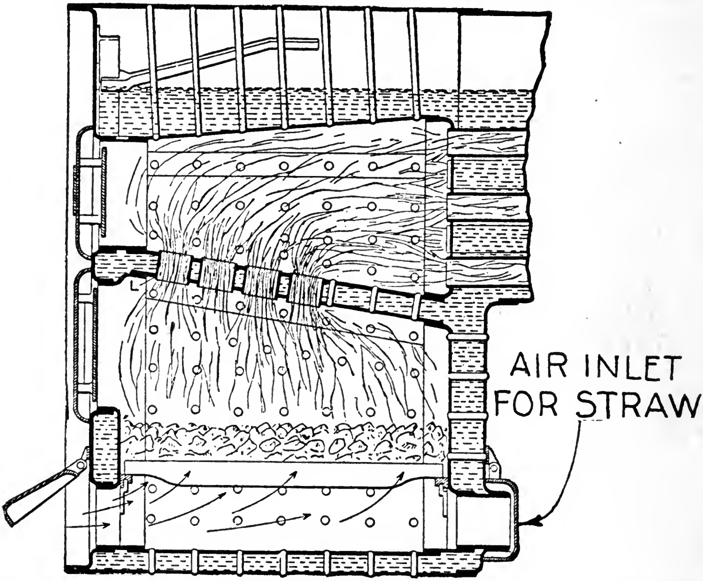


FIG. 4,073.—Heggem's boiler for burning either straw or solid fuel, the fire box being provided with a draught apparatus that may be made applicable in each case for the particular fuel burned. Connected to the fire door is a funnel provided with a hinged shutter as shown, the free end resting continually against the straw as it is forced into the fire box. ***In operation,*** the damper under the panel of the boiler being raised, a current of air flows into the fire box as indicated by the arrows, causing the straw to burn at the ends as it is forced through the funnel. ***When coal is used*** the forward damper is closed and the rear damper (under the fire door) opened.

vent the flames going up the shutes, thence through the small dust tubes leading from the bin to the various machines. Figs. 4,071 and 4,072 show how to fire shavings by hand.

Firing with Tan Bark.—By mixing with bituminous screenings, tan bark can be burned upon ordinary grates and in the ordinary furnace.

One shovelful of screenings to four or five of bark will produce a more economical result than the tan bark separate, as the coal gives body to the fire and forms a hot clinker bed upon which the bark may rest without falling through the spaces in the grate bars, and with the coal, more air can be introduced to the furnace.

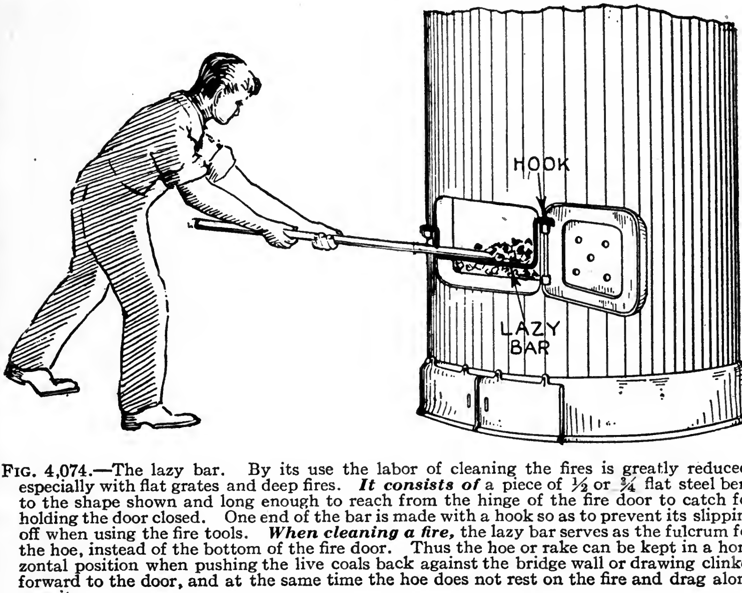
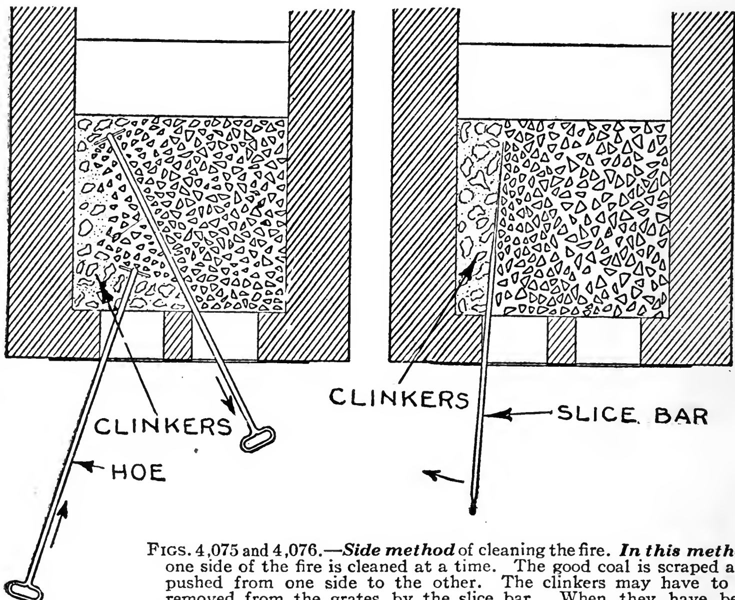


FIG. 4,074.—The lazy bar. By its use the labor of cleaning the fires is greatly reduced, especially with flat grates and deep fires. ***It consists of*** a piece of ½ or ¾ flat steel bent to the shape shown and long enough to reach from the hinge of the fire door to catch for holding the door closed. One end of the bar is made with a hook so as to prevent its slipping off when using the fire tools. ***When cleaning a fire,*** the lazy bar serves as the fulcrum for the hoe, instead of the bottom of the fire door. Thus the hoe or rake can be kept in a horizontal position when pushing the live coals back against the bridge wall or drawing clinker forward to the door, and at the same time the hoe does not rest on the fire and drag along over it.

The above relates to common furnaces, but special fire boxes may be obtained, fed by power appliances, which work admirably. The point principally to be noted as to the efficiency of tan bark as a fuel, is that like peat, the drier it is, the more valuable it is as a fuel.

Cleaning the Fire.—This is frequently necessary because the clinker and coarse ash will not pass through the grate. The hoe and slice bar are used for cleaning the fire, and the rake for leveling the fuel bed.

The intervals between cleaning depend upon the proportion of ash in the coal, the character of ash, and the type of the grate. If the coal contain much ash, or ash that is fusible, the fires have to be cleaned often; if light fires be carried, less clinker forms, and under such conditions the fire can often be run through a day shift without cleaning.



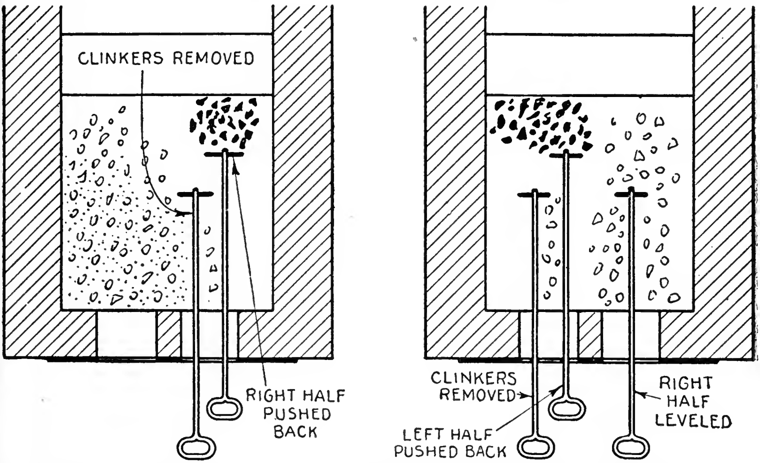
FIGS. 4,075 and 4,076.—*Side method* of cleaning the fire. ***In this method*** one side of the fire is cleaned at a time. The good coal is scraped and pushed from one side to the other. The clinkers may have to be removed from the grates by the slice bar. When they have been loosened and broken up, they are scraped out of the furnace with the hoe. The fireman should gather the clinker on the front part of the grate before pulling it out into the wheelbarrow, as this saves him from exposure to the heat. After the one side is cleaned, the burning coal from the other is moved and scraped to the clean side. It is spread evenly over the clean part of the grate, and a few shovelfuls of fresh coal are added, in order to have enough burning coal to cover the entire grate when the cleaning is done. This adding of coal is important, especially when the cleaning must be done with the load on the boiler. The clinkers are then removed from the second half of the grate. When cleaning is started, there should be so much burning coal in the furnace that enough will be left to start a hot fire quickly, when the cleaning is completed. If a light fire be carried, it may be necessary when starting to clean to put some fresh coal on the side to be cleaned last. During cleaning, the damper should be partly closed. A fireman after becoming familiar with the side method should be able to clean a 200 *h.p.* boiler furnace in 10 to 12 minutes.

The cleaning of the fires should be done thoroughly. All the clinker and ash should be removed so that they cannot fuse to the side wall. They should be removed in such a way as to waste very little combustible.

Ques. Name two methods of cleaning the fire.

Ans. The side method as shown in figs. 4,075 and 4,076, and the front to rear method, as in figs. 4,077 and 4,078.

Thickness of Fire.—This will depend upon the available



FIGS. 4,077 and 4,078.—***Front to rear method*** of cleaning the fire. In this method the burning coal is pushed with the hoe against the bridge wall. It is usually preferable to clean one-half of the grate at a time. The clinker is loosened and pulled out of the furnace and the burning coal is spread evenly over the bare grates. If the front to rear method must be used while the load is on the boiler, the side method should be employed after the day's run is over, so as to prevent the large accumulation of thick and hard clinker at the bridge wall. Some firemen have the habit of pulling the clinkers out of the furnace without scraping and pushing the burning coal against the bridge wall or to one side. This really is not a method of cleaning the fire. They run a slice bar under the clinker to lift it to the surface of the fuel. Then they take a hoe and pull the large pieces out. The small pieces are not easily detected and are left in the fire. These fuse in a few minutes, due to the high temperature near the surface of the fuel bed, and then run into the grates. Thus more masses of clinkers are formed, which are usually worse than those previously removed. This habit should be discouraged.

NOTE.—In cleaning the fire in a plant running morning to noon, and noon to, 5:30 P. M. break the clinker at 10:30 A. M., clean the fire at noon, again break the clinker at 4 P. M., and clean again after the day's shift is over. The cleaning of a banked fire should be done about two hours before steam is needed. It is advisable to bank the fire at the front of the grate near one of the doors. This exposes the clinkers, which can be pulled out.

draught. If difficulty be experienced in maintaining steam pressure with a thick fuel bed, try carrying a thinner bed.

Ques. What is the objection to a thin fuel bed?

Ans. Too much air flows through without uniting with the carbon, because of holes.

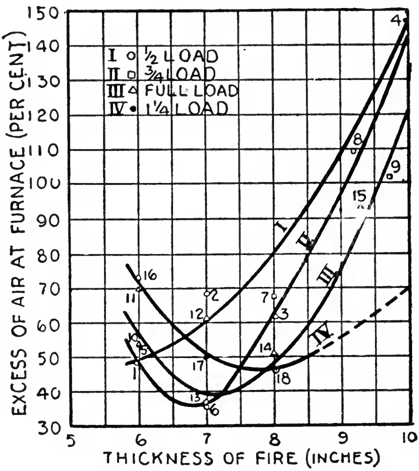


FIG. 4,079.—Relation between thickness of fire and excess air in the furnace, according to A. P. Kratz in University of Illinois tests in a B. & W. boiler fitted with a chain grate in a Dutch oven. The combustion chamber was unusually long, being formed by a tile roof on the lower row of boiler tubes. The first gas pass was at the back of the boiler, instead of at the front. The samples of flue gas were taken from the combustion chamber just at the rear of the tile roof at the point where the gases turn to go up to the first pass. This point was so close to the furnace that no air leaks chargeable to the boiler setting could occur, and yet so far away that the combustion was complete. These results were obtained with a chain grate and probably indicate what can be expected from that type of furnace by varying the thickness of the fuel bed. The adjoining curves show the relation between the thickness of the fire and the percentage of excess air, taking into account the load on the boiler. A 7-inch fire gives about the smallest percentage of excess air. It must be understood that the curves are only approximate, as a number of other factors beside thickness of fire affect the amount of excess air, such as draught conditions. At different loads the excess air decreases to a minimum and then rises to a maximum as the thickness of the fire increases. With a thin fire, there is a tendency to the formation of air holes. As the depth of the fuel bed is increased a greater draught is required, and there is a greater infiltration of air. The combined result of increasing the depth of the fuel above 7½ inches is an increase in the excess air. Inspection of the curve shows that for a thin fire of constant depth, the excess air increases when the load or rate of combustion is increased, while for a thick fire of constant depth the reverse is true. When the load is made greater, a larger amount of air must be drawn through the fuel bed. In the case of a thin fire, holes burn through quickly with a heavy load. With a thick fire light loads would entail a very slow travel of the grate, with probability of burning through the admission of excess air at the back.

Experiments show that from a fuel bed 3 to 4 inches thick, the gase rising from the surface average less than 2 per cent. oxygen, and about 2 per cent. combustible gas, hence considerable air must be admitted throug the fire doors and other openings to burn the combustible gases.

Ques. What is the effect of a thick fuel bed?

Ans. Thickening the fuel bed increases the resistance to th passage of air through it, thus requiring stronger draught.

The draught, however, does not increase as rapidly as the resistanc As the fuel bed is thickened, less air passes through it, and less combustib

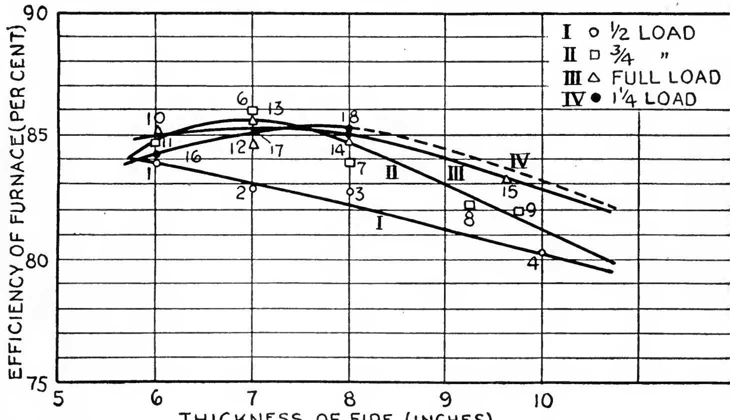


FIG. 4,080.—Relation between thickness of fire and efficiency of furnace according to Krat The curves show that for each load there was a well defined thickness of fire that gave the be efficiency. As the load decreased this thickness became less. For 1¼ load the best fire was to 8½ inches thick. For full load, the best fire was 7 to 7½ inches thick. For a ¾ load was 6½ inches thick.

gas rises from its surface. The higher draught, however, brings in more a over the fuel bed, resulting in a greater amount of free oxygen in the flu gases. Clinker has the same effect.

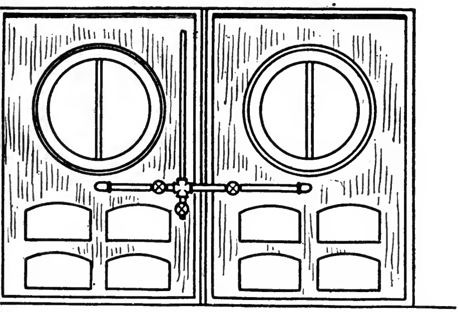
NOTE.—From experiments of the *Bureau of Mines*, the relation of draught and thickne of fuel bed may be summed up as follows: The rate of flow through a bed of constant thickne is approximately proportional to the square root of the pressure drop. As the thickness of th bed increases, the weight of air admitted decreases rapidly at first, then more and more slowl To put air at the same rate through double the thickness of bed requires twice the differen of pressure and twice the work on the fan. If the height of a cross flow water tube boiler b doubled, or if the length of the tubes of a parallel flow boiler be doubled, and the thickness the fuel bed be doubled, double the fan work will be required if the same weight of gas is t be carried through the boilers. If two or three times the weight of gases be forced through given fuel bed and boiler resistance to produce two or three times the capacity, the wor expended by the fans will be 8 or 27 times as great.

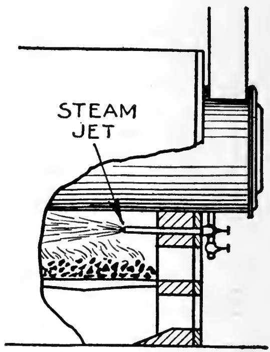
Ques. With a given draught, how can the rate of combustion be increased?

Ans. By reducing the thickness of the fuel bed.

This reduces the resistance to the air passing through the fuel, hence a larger quantity passes through.

Points Relating to Hand Firing.—The duties of the fireman in the routine of the day may be thus briefly stated:





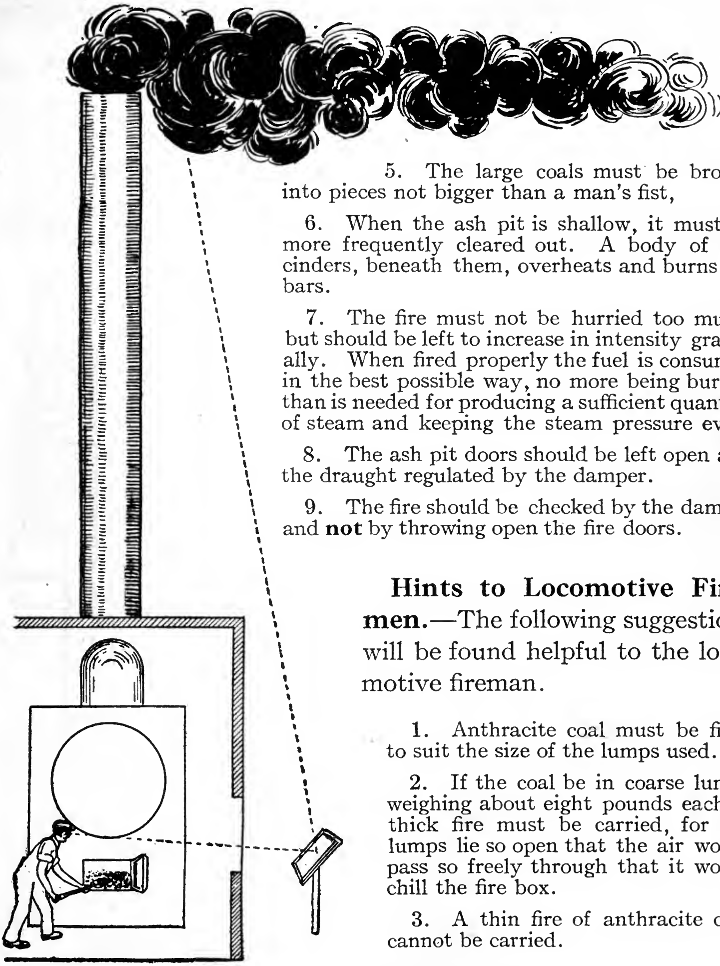
FIGS. 4,081 and 4,082.—One method of smoke prevention by means of a steam jet. The jet is located just above the fire door as shown. After each firing the jet is opened a few minutes, which prevents black smoke, reducing its density to a haze.

1. Begin to charge the furnace at the bridge end and keep firing to within a few inches of the dead plate.

2. Never allow the fire to be so low before a fresh charge is thrown in, that there shall not be at least three to five inches deep of clean, incandescent fuel on the bars, and equally spread over the whole.

3. Keep the bars constantly and equally covered, *particularly at the sides and the bridge end*, where the fuel burns away most rapidly.

4. If the fuel burn unequally or into holes, it must be leveled, and the vacant spaces must be filled.



5. The large coals must be brok into pieces not bigger than a man's fist,

6. When the ash pit is shallow, it must more frequently cleared out. A body of h cinders, beneath them, overheats and burns t bars.

7. The fire must not be hurried too muc but should be left to increase in intensity grad ally. When fired properly the fuel is consum in the best possible way, no more being burn than is needed for producing a sufficient quanti of steam and keeping the steam pressure eve

8. The ash pit doors should be left open a the draught regulated by the damper.

9. The fire should be checked by the damp and **not** by throwing open the fire doors.

Hints to Locomotive Fire men.—The following suggestio will be found helpful to the loc motive fireman.

1. Anthracite coal must be fir to suit the size of the lumps used.

2. If the coal be in coarse lum weighing about eight pounds each, thick fire must be carried, for t lumps lie so open that the air wou pass so freely through that it wou chill the fire box.

3. A thin fire of anthracite co cannot be carried.

FIG. 4,083.—Method of observing the top of the stack from boiler room. By means of mirror fixed at a suitable angle, the fireman can, while firing, note the smoke indication The device will be found helpful in securing more efficient combustion.

4. In firing lump coal of large size, even with a thick fire, constant care is necessary to prevent loss of heat from excessive amount of air passing through holes.

5. There is a constant tendency for air passages to form close to the sheets, hence the fire should be heavier here than at other parts.

6. Too much air admitted through the fire tends to reduce parts of the fire box below the igniting temperature.

7. Firing with large lumps is wasteful with either hard or soft coal.

8. For small sizes of anthracite a very large grate area is necessary, because the fire must be thin, which precludes a strong exhaust unless the blast be divided over a wide area.

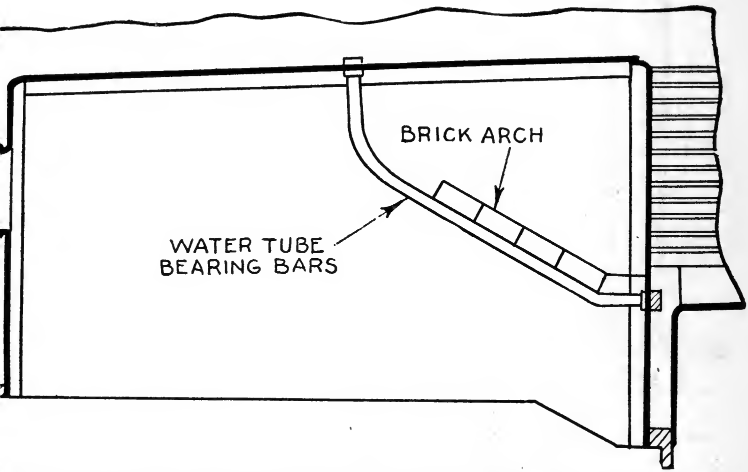


FIG. 4,034.—Locomotive brick arch furnace with water tube bearing bars secured to the tube sheet at one end and to the crown sheet at the other end. The water circulation through these pipes prevents burning out. Fire tiles are placed on top of the bearings bars.

9. In using soft coal do not carry over ten or twelve inches of fire in the center of the fire box; keep the sides and corners a little higher; aim to fire in the corners and sides more than in the center.

10. If the boiler will not steam well with a light fire, more air is probably needed at the front of the box. Leave the fire door open a little way for a few seconds after putting in coal; it helps to consume the smoke.

11. Two shovelfuls of coal is enough at one time if put on the bright spots. No boiler will steam well with the fire box and flues full of smoke.

12. If necessary to use the hook be careful not to mix the green coal with that partly consumed.

13. Do not use a slash bar if it can be avoided.

14. Be careful not to get green coal on the grates.

15. If the fire box have an arch, keep a good space open between the arch and the fire.

16. If the train be heavy, it will need a heavier fire than with a light train and a fast run; always make calculations to fire according to train and speed.

17. Hook out all clinkers from the fire as soon as you find them.

18. Do not fire much while pumps or injectors are on full.

19. If the engine have ash pan dampers use them when necessary.

20. If there be more steam than is needed, the dampers should be closed; a certain amount of air is necessary to make a fire burn as it should; if too much air be admitted, the gases will be chilled; if too little, they will not ignite: no rule can be made for the exact amount of air required, because different kinds of coal require varying quantities of air; only keep a bright fire low in the center of the box where the most air is needed and watch when the greatest flame appears in the fire box with the least smoke going out of the stack; attend to the fire often.

Mechanical Stoker Firing.—The construction and operation of mechanical stokers has been presented in considerable detail in Chapter 71.

Stokers under ordinary operating conditions will give more nearly smokeless combustion than will hand fired furnaces and for this reason must often be installed regardless of other considerations. While a constant air supply for a given power is theoretically secured by the use of a stoker, and in many instances the draught is automatically governed, the air supply should, nevertheless, be as carefully watched and checked by flue gas analysis as in the case of hand fired furnaces.

There is a tendency in all stokers to cause the loss of some good fuel or siftings in the ash pit, but suitable arrangements may be made to reclaim this.

In respect to efficiency of combustion, other conditions being equal, there will be no appreciable difference with the different types of stokers, provided that the proper type be used for the grade of fuel to be burned and the conditions of operation to be fulfilled.

No stoker will satisfactorily handle all classes of fuel, and in making a selection, care should be taken that the type is suited to the fuel and the operating conditions.

A cheap stoker is a poor investment. Only the best stoker suited to the conditions which are to be met should be adopted, for if there is to be a saving, it will more than cover the cost of the best over the cheaper stoker.

Wetting Coal.—The object of wetting coal is to cause it to burn slower, thereby giving the gases a better chance to mix with

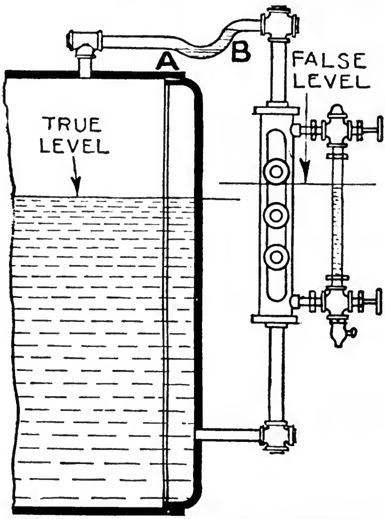
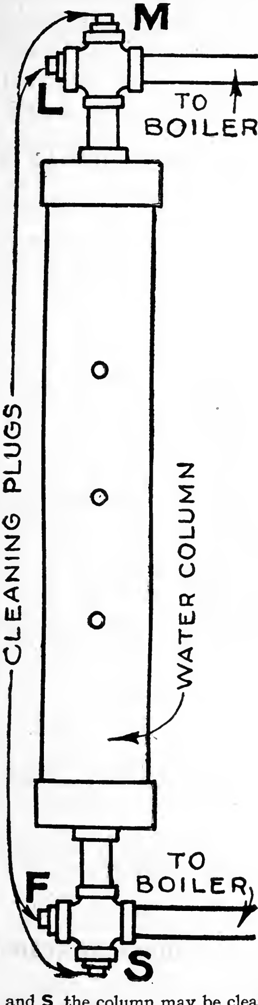


FIG. 4,085.—False water level due to pocket in connection filled with condensation. Where a pocket exists in the top connection similar to AB, it causes a false level in the glass because when the condensation fills the pocket, steam is shut off between the glass and boiler, and as it condenses, the pressure drops and the water rises in the glass, giving a water level above the true water level in the boiler. The change of level continues until the water in the bend is forced over into the water column, when the water in the glass suddenly drops to its correct reading.

the air. When coal is first thrown on the fire it gives off gas faster than it can be brought into contact with the necessary amount of air for complete combustion.

Wetting also prevents the loss of fine coal dust, however no more water should be used than is necessary because *the water must be evaporated and this* **wastes heat.**



Water Tending.—In taking an examination for engineer's license, probably the first question the examiner will ask is:

What is the first thing you would do on entering the boiler room? and your answer should be, in case you expect to pass the examination: *I would find out if there be the proper amount of water in the boiler.*

Ques. What is the proper amount of water that should be in the boiler?

Ans. The water level should be high enough to submerge all heating surfaces exposed to intense heat, the exact level depending on the type of boiler thus:

1. In vertical through tube boilers, as high as is practical to operate without unduly increasing the moisture over the steam.

2. In horizontal tubular marine boilers, sufficiently high to avoid exposing any of the heating surface due to rolling of the vessel.

3. In locomotive boilers sufficiently high to avoid exposing the crown sheet due to inclination of the locomotive in descending a hill.

4. The safe range of water level is detained by the designer in locating the water gauge, and ***in general, the water level is normally carried between the second and top cocks.***

If the examiner take a delight in trying to "trip" the candidate the question may be somewhat as follows:

Ques. Does the water gauge show the true level of the water in the boiler?

Ans. No.

Ques. Why not?

FIG. 4,086.—Proper method of connecting water column to boiler. By the use of two crosses and plugs the entire system is made accessible for internal cleaning which is important. Thus by removing plugs **M** and **S**, the column may be cleaned, and by removing **L** and **F**, the connections to boiler. Preferably a cock should be used instead of plug **S**, which would permit frequent blowing off of the column and facilitate draining when laid up in cold weather.

Ans. Because the density of the water in the glass at relatively low temperature is greater than the density of the water in the boiler at relatively high temperature, hence the level indicated by the glass is lower than the true level as shown in fig. 4,087.

Ques.—What is the indication that the water gauge is not working?

Ans. A stationary water level.

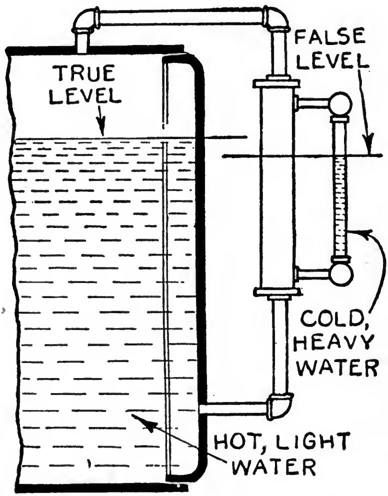


FIG. 4,087.—False water level due to difference in density of the cold water in the gauge glass and the hot water in the boiler. The difference between the two levels is considerably exaggerated for clearness, in reality this difference is very small and may be disregarded.

When all the connections are clear, the level will fluctuate up and down more or less depending on the type of boiler, being especially marked or "lively" in a water tube boiler.

Ques. If the gauge appear stationary, how is it tested to determine if it be in working order?

Ans. Open drain cock wide till all water disappears from glass, then close and if gauge be in proper working order, water will rise at once to former level.

Ques. How should steam be raised in a vertical tubular boiler with through tubes?

Ans. To prevent burning the tubes the boiler should be entirely filled with water, leaving a vent by raising the safety valve or blocking open whistle valve to allow for expansion of the water as it is heated.

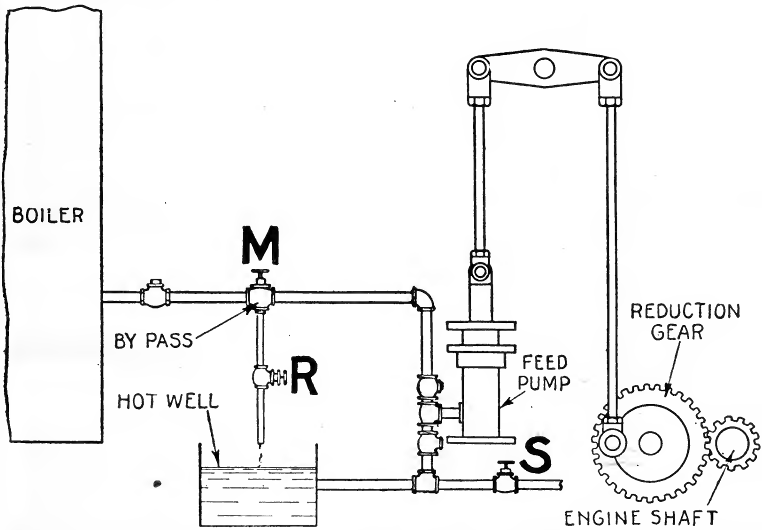
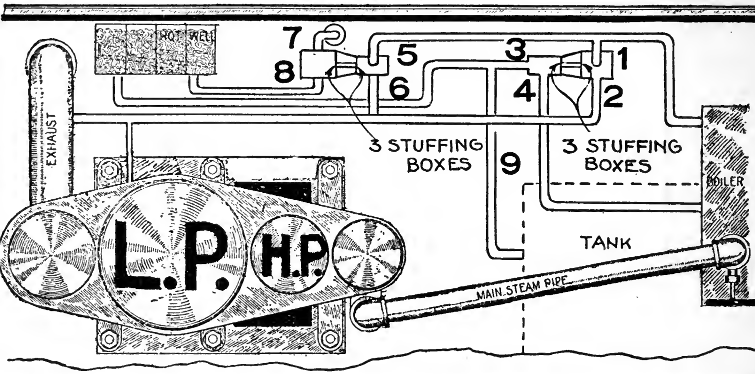


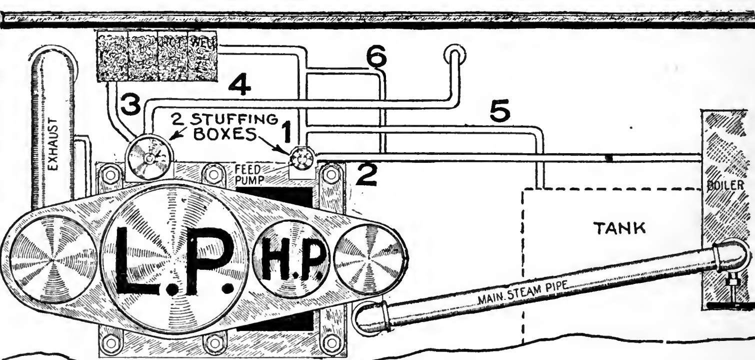
FIG. 4,088.—Diagrammatic sketch illustrating ideal method of boiler feeding. The feed pump is driven by the main engine through suitable reduction gear (in cases where engine runs too fast for direct connection). The pump thus operates continuously at main engine efficiency. ***In condensing plants,*** the condensate delivered from condenser to hot well is pumped into boiler by the feed pump. Since the latter of necessity has excess capacity, a by pass valve **M**, is provided so that the excess may be returned to the hot well, otherwise the hot well would soon empty and the pump would force both water and *air* into the boiler. By close adjustment of valve **M**, the water is pumped into the boiler at the same rate it is delivered to hot well by the air pump, thus the suction pipe remains covered with water preventing any air being carried over into the boiler. In time the water level in the boiler gradually falls, due to loss of water through stuffing boxes, whistle and safety valve, and this may be made up by closing **M**, and opening make up valve **S**. When the water rises to the normal level **S**, is closed and **M**, again adjusted. By providing a small valve **R**, in the by pass pipe this valve may be used to shut off the by pass so that when the correct adjustment of **M**, has been found, it need not be again disturbed.

Ques. How high should the water be carried in a vertical boiler, and why?

Ans. As high as can be without causing wet steam, because it increases the efficiency of the heating surface, and prolongs the life of the tubes.

In the author's boiler (page 2,368), he has provided a separator, collector and dryer to permit carrying abnormally high water level.





FIGS. 4,089 and 4,090.—Independent and engine-driven pumps in marine practice. Which do you prefer? Nine pipe lines and six stuffing boxes, or six pipe lines and two stuffing boxes. Watt has said: *"The supreme excellency in machinery is simplicity."* Engine driven pumps are not only simple, but highly efficient, and the author has always preferred them to independent pumps.

Ques. How should water be fed to a boiler?

Ans. In general the feed should be continuous, though in some special cases intermittent feed is more desirable.

Where the load is constant, or nearly so, as in marine service, a pump operated by the main engine, pumping water into the boiler (from the hot well), at the same rate it is being evaporated is the ideal method.

Again, a locomotive, especially in hilly sections, demands an intermittent feed. Thus, while descending a long grade with throttle closed, the boiler

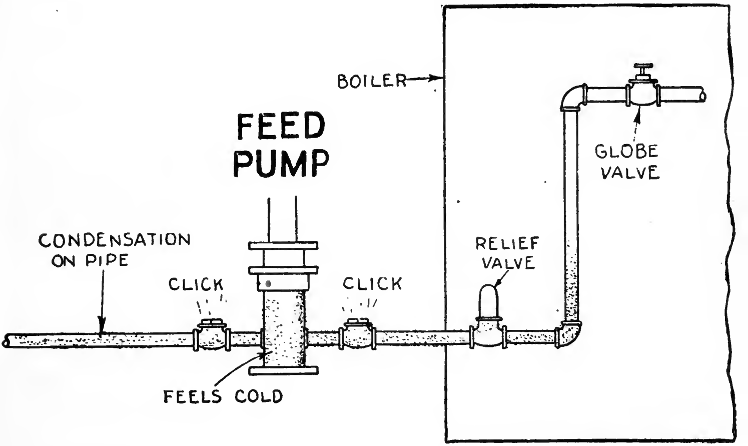


FIG. 4,091.—Feed pump piping and indications of proper operation. ***There should be*** a globe valve next the boiler so that in case the pump fail to operate the check valves may be examined with boiler under steam by closing the globe valve. When the pump is working properly, it will feel cool, but if anything become lodged under the checks, the pump will feel warm, indicating back flow of water through the pump from the boiler. ***Proper operation*** with cool feed water is further indicated by condensation on the surface of the feed line, especially in hot engine rooms.

may be filled to the top gauge and then shut off. This prevents the safety valve blowing off, and during the ascent of the next grade when every pound of steam is needed, the evaporation is not reduced by absorption of heat in the feed water.

Ques. What means is used to prevent loss of feed water by the safety valve blowing off on a vessel when landing?

Ans. A "bleeder" or connection between boiler and condenser is provided. The bleeder valve is opened, allowing steam to blow through into the condenser, the condensate being pumped back into the boiler by the air pump.

With this arrangement independent feed and air pumps must be used or the engine must be turned over slowly so as to pump the condensate into the hot well with the air pump and thence into the boiler with the feed pump.

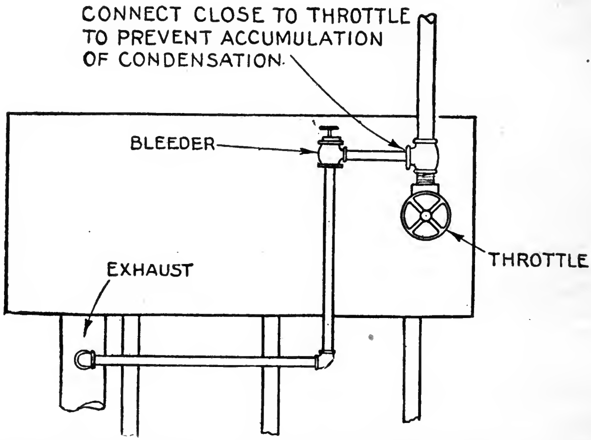


FIG. 4,092.—Combination "bleeder," and main steam pipe drain. When thus connected the steam pipe may be drained and warmed up before opening the throttle, thus reducing the amount of water to be worked through the engine in the warming up process preliminary to starting, and facilitating same, especially with multi-stage expansion engines. ***Example:*** Calculate size of bleeder pipe for a 30 horse power boiler to take care of 50 per cent of boiler capacity at 10,000 feet flow, steam pressure 125 pounds. Fifty per cent. of 30 *h.p.* =15 *h.p.* (15×30) ÷60 =7.5 pounds of steam discharged per minute. Volume of 1 pound of steam at 125 pounds pressure (from table page 43, vol. 1) =3.219 cubic feet. Volume of steam discharged at 125 pounds pressure =3.219×7.5 =24.14 cubic feet.

$$\text{area bleeder pipe} = \frac{24.14}{10,000} \times 144 = .348 \text{ square inches}$$

Size of bleeder pipe having nearest (larger) transverse area (from table, page 2,908), is ¾ inch. Transverse area =5.33 square inches, hence this pipe will take care of 15 $h.p. \times \frac{.533}{.348} = 23\ h.p.$ at 10,000 feet flow, or (23 ÷30) ×100 =77 per cent boiler capacity.

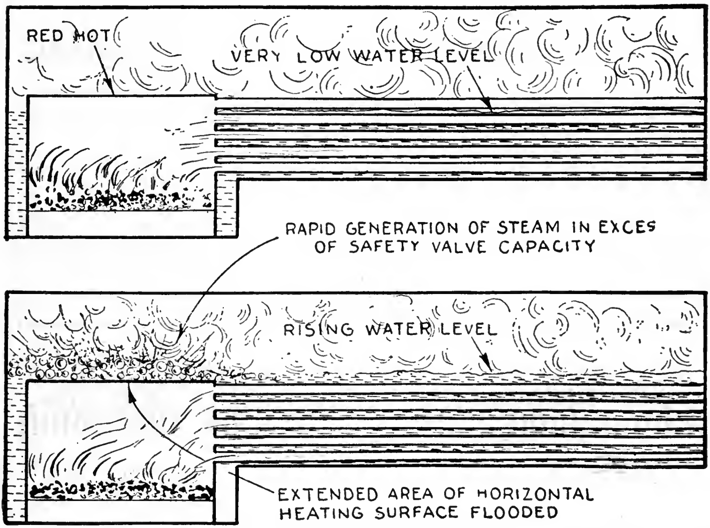
Ques. What are the indications that the feed pump is working?

Ans. The "click" or noise made by the check valve each time it seats, also the low temperature of the pump and feed line.

If the feed pump do not work, take off bonnets of both checks and examine valve and seats for dirt or other foreign matter.

A globe valve should be provided between check and boiler to permit such examination while under steam.

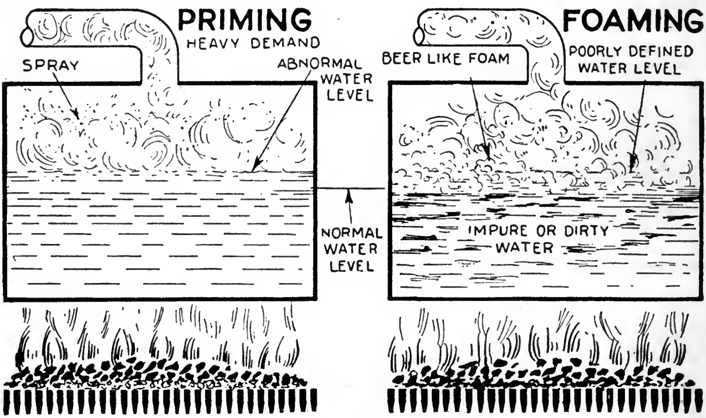
A relief valve should also be provided in case the pump be started before opening globe valve, otherwise the apparatus may burst from over pressure, especially on an engine driven pump.



FIGS. 4,093 and 4,094.—Sectional view of locomotive boiler with dangerously low water level, illustrating *why the feed pump should* **not** *be turned on*. With the feed pump in operation the water level gradually rises and when it reaches the elevation of the crown sheet this extended area of heating surface (now red hot), becomes suddenly flooded with water with the result that steam is generated quicker than can be discharged by the safety valve, hence the pressure rises, bringing more strain on the crown sheet already weakened by the excess heat, and therefore increasing the chances of an explosion.

Ques. If on entering the boiler room you would find the water out of glass, safety valve blowing off strong, and a good, hot fire under boiler, what should be done?

Ans. First, the fire should be smothered as quickly as possible with wet ashes, earth or coal, closing ash pit doors and leaving furnace doors and damper open. If now it be found that the water has not fallen below the level of either the crown of any other extended area of heating surface, the feed pump may be started with perfect safety, but if this certainty cannot be assured,



FIGS. 4,095 and 4,096.—Elementary boilers illustrating the difference between *priming* and *foaming*, and the conditions which produce these effects.

the boiler must be cooled down completely, carefully inspected, and repaired if necessary. If no part of the exposed metal be heated to redness, there is no danger except from a rise in the water level sufficient to flood the overheated metal. Hence, care should be taken that the safety valve be not raised so as to produce a priming that might throw the water over the overheated metal, and *that no change be made in the working of either engine and boiler that shall produce priming or an increased pressure.*

If any portion of the boiler plate be red hot, an additional danger is due to the steam pressure, which should be reduced by continuing the engine in steady operation while extinguishing the fire. If the safety valve be touched at such a time it should be handled very cautiously, allowing the steam to issue steadily and in such quantity that the steam gauge does not show any sudden fluctuations while falling. The damping of the fire with wet ashes will reduce the steam pressure very promptly and safely.

Ques. What is priming, and what causes it?

Ans. A boiler primes when it lifts the water level and delivers steam containing spray or water as in fig. 4,095. It is usually caused by forcing a boiler too hard or by a too high water level, or a combination of both these causes.

When a boiler primes violently it may be necessary to close all outlets to find the true water level.

Ques. What is foaming, and what causes it?

Ans. Foaming is severe priming or agitating of the water level due to dirty or impure water, as showh in fig. 4,096.

Ques. In case of fire in the building, what should be done?

Ans. Haul fire from under boiler, start fire tank pump and abandon boiler room.

Ques. If fire had gained such headway that there was no time to haul fire from under boiler, what should be done?

Ans. Open furnace doors, start feed and tank pump full speed and abandon boiler room.

In case building had its own electric plant, the engine should be left running.

The term care as here used relates chiefly to the method employed in keeping the various parts of the boiler clean and in proper condition. For satisfactory and economical operation evidently the extreme surfaces should be kept free of soot, and the interior surfaces of scale and other impurities. When a boiler is laid up for any length of time it should receive proper attention to protect it from rapid deterioration.

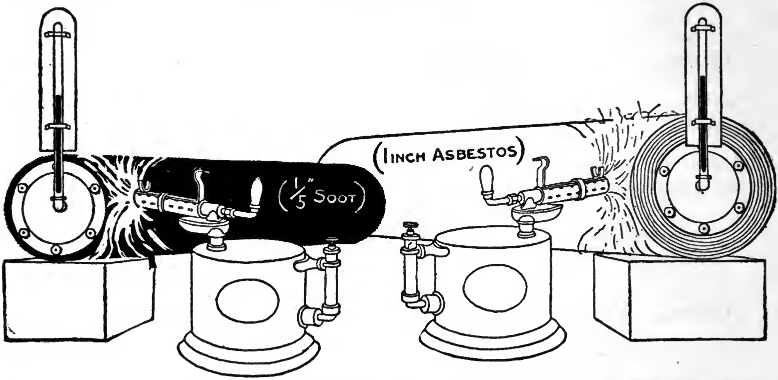


FIG. 4,097.—Soot as an insulator. Soot is about five times as effective as fine asbestos as a heat insulator. If two containers insulated in the manner shown be filled with water and an equal amount of heat applied to each, the water in the container insulated with asbestos will show the greater increase in temperature.

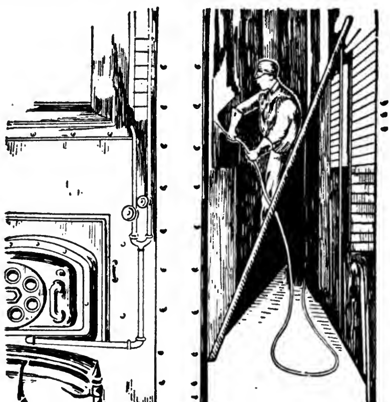


FIG. 4,098.—How a boiler is cleaned by hand. A man must stand on a ladder, and at a great height for modern settings, and handle a hot, flexible steam hose which is liable to burst and burn him. The width of the alley limits the length of a steam lance which can be used and the distance reached inside the setting.

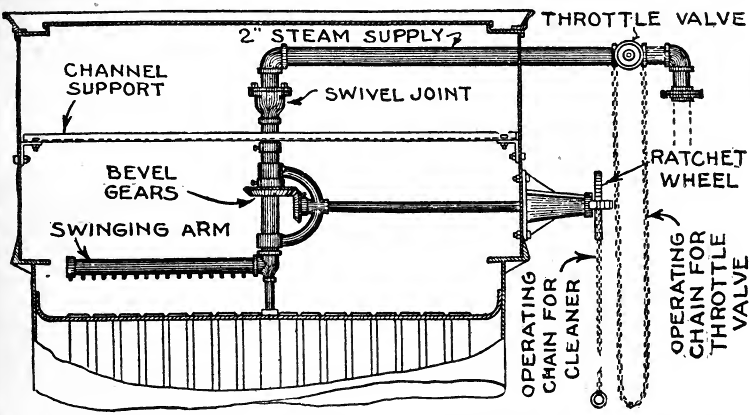


FIG. 4,099.—General arrangement of Vulcan soot cleaner as applied to Manning boilers, showing gear inside of smoke box.

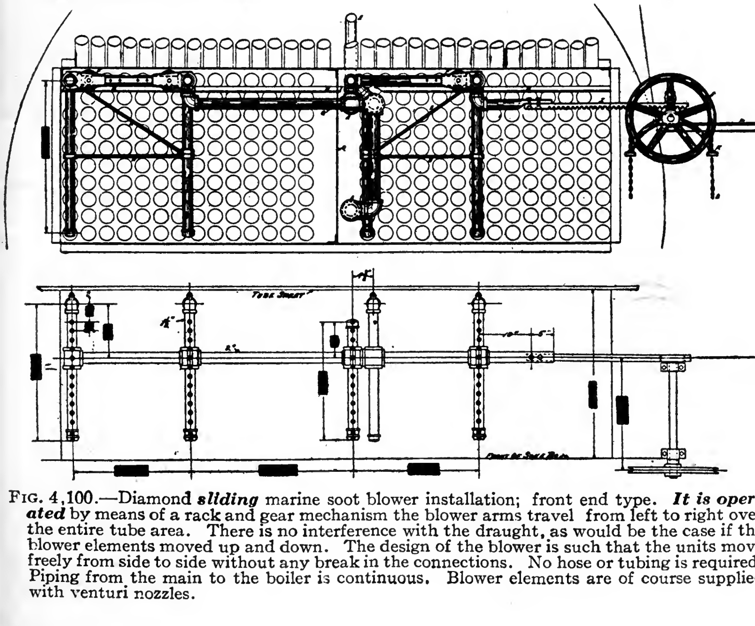
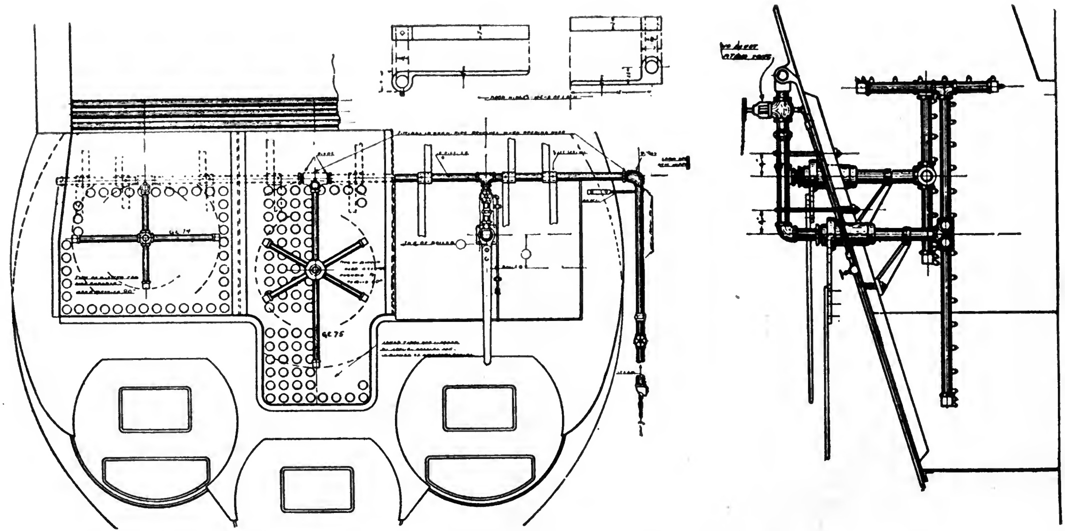


FIG. 4,100.—Diamond ***sliding*** marine soot blower installation; front end type. ***It is operated*** by means of a rack and gear mechanism the blower arms travel from left to right over the entire tube area. There is no interference with the draught, as would be the case if the blower elements moved up and down. The design of the blower is such that the units move freely from side to side without any break in the connections. No hose or tubing is required. Piping from the main to the boiler is continuous. Blower elements are of course supplied with venturi nozzles.



FIGS. 4,101 and 4,102.—Diamond oscillating soot blower for three-furnace Scotch boiler. Four or more blower arms are provided for each furnace. Each arm is supplied with nozzles from which jets of steam are shot into the boiler tubes at high velocity. The arrangement is such that uptake tubes are cleaned at the same time. The blower arms are oscillating in movement, swinging about a central pivot when the operating handle is moved. Every tube in the boiler is covered by the apparatus.

Soot.—The principal constituent of pure soot or lamp black, is carbon. Mixed and associated with this carbon are various tar products and acids.

So called soot as found in steam boilers varies considerably in appearance and composition, depending upon the grade of coal burned and conditions of combustion.

Analysis of same samples taken from a boiler show beside pure soot, the presence of silica, aluminum, iron oxide, various alkalis, and sulphur dioxide.

In all but the coolest portions of the boiler soot is usually gritty in texture. The grains may be as large as medium sand, or fine as cigar ash.

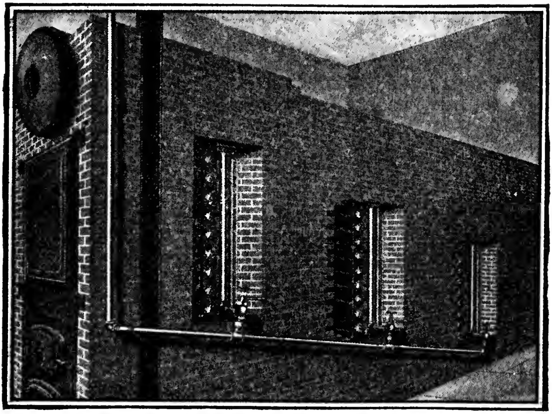
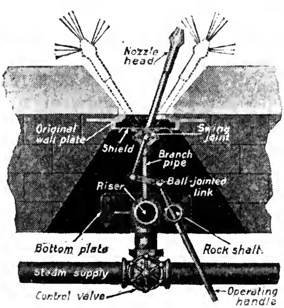
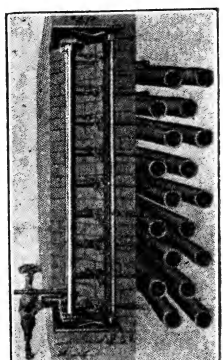


FIG. 4,103.—Bayer type B steam soot blower installed on a vertically baffled boiler. This type is one of four distinct soot blowing systems manufactured by the Bayer Company, and is especially adapted to cleaning tubes of vertically baffled, horizontal water tube boilers. As will be noted above, and in the details of figs. 4,104 and 4,105, ***it consists of*** an air tight shield set against the original wall plate of the cleaning pocket, through which a series of nozzles extend into the boiler furnace. The back and forth movement of the operating handle which is connected through ball jointed links to the nozzle stems, imparts an oscillating motion to the nozzles, through which steam jets are directed over the entire tube surfaces. All soot and fine ash deposits are dislodged, resulting in a saving (as claimed) of from 4 to 9% in fuel alone.





FIGS. 4,104 and 4,105.—Bayer cleaning pocket and blower unit indicating method of imparting oscillation to the soot blower nozzles, and (fig. 4,105) section through cleaning pocket. ***It will be noted*** that the Bayer type B unit is connected to the steam supply line by a control valve, through which steam passes to a riser connected with the nozzles forming the unit. Operation is simple—merely open the control valve, oscillate the nozzles several times, then close the control valve. The time required is less than 5 minutes. Note how the ledge built up at the bottom of the cleaning pocket protects the nozzle heads from direct contact with the furnace gases.

These particles are in a plastic state when they leave the furnace and enter the tubes, and in this condition they will adhere readily to any surface with which they come in contact.

If the soot deposit be not removed *frequently*, it quickly increases in amount and changes in character. The carbon burns out in part and the mass tends to cement together. The increasing accumulation of soot in the tubes interferes with the draught and ***reduces considerably** the amount of heat transmitted to the water, as is indicated by the increase in the temperature of the chimney gases.*

Soot is almost the best insulator known. Its insulating properties are more than five times as effective as fine asbestos. In this connection it should be noted that more heat would be transmitted to the water in the boiler through a full 1-inch layer of asbestos in the tubes than through

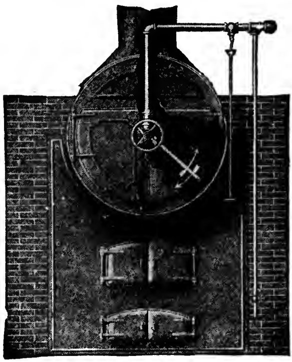


FIG. 4,106.—Bayer type F front end steam soot blower for the *h.r.t.* boilers. This type is particularly effective in cleaning the soot clogged flues of fire tube boilers. ***In operation,*** steam is projected through a series of nozzles so located in an arm swinging in front of the flue sheet in the smoke box, that at some part of every full or semi-revolution of the arm, one steam jet blows directly into each flue. Steam is projected into the flues against the direction of the draught, but since only a few of the flues are blown at one time, the action is to reverse the draught, completely free the tube surfaces of soot and fine ash which is blown into the combustion chamber and returned through the tubes not then being blown and up through the stack. The steam supply line is connected to the dome or other point where relatively dry steam is available, and brought through the breeching for a length of 8 ft., in the direct path of the gases. The effect is to supply superheated steam for the cleaning operation. With the Bayer system no soot is blown out into the boiler room because the blast of the steam jets is not against the smoke box doors. The operation of all Bayer blowers is simple; in type F, merely open a drip valve, turn on the steam, rotate the blowing arm, and turn off the steam.

1/5 inch of soot. The loss of heat conductivity of boiler plate, due to soot deposit, may be seen from the following table:

Thickness of soot	Per cent. of loss	Thickness of soot	Per cent. of loss
clean tube	0	clean tube	0
1/32 inch	9.5	1/8 inch	45.3
1/16 inch	26.2	3/32 inch	69

This shows ***extreme necessity** of **frequent** and **thorough cleaning** of the heating surface*. Morever, another bad feature of soot deposits is that if they be allowed to remain, the boiler is exposed to the corrosive action of the various constituents of the soot.

Tubes may be cleaned by hand blowing or by special apparatus permanently fixed to the boiler.

The objection to hand blowing is that it is not efficient. Going after the tube surface of a boiler with a steam lance is such a hot, grimy and disagreeable job that it has been relegated to the "under-dog" in the boiler room, with the result that even the limited possibilities of hand cleaning are seldom if ever realized.

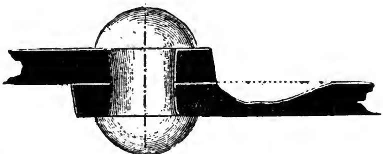


FIG. 4,107.—Section of boiler plate at a riveted joint, showing the effects of corrosion of the metal. The normal surface of the plate is indicated by the dotted line across the opening of the corroded gap.

The installation of a soot cleaning system will not of itself remedy poor boiler operation, for unless the cleaner be correctly installed and operated, the boiler having been *thoroughly cleaned just prior* to the installation, good results cannot be obtained.

The necessity of cleaning the boiler before the system is installed is so important that it cannot be overlooked, for in many cases it is found that a heavy deposit is packed almost solid among the tubes of boilers which had been "cleaned" by a hand lance. No cleaner will remove such a deposit, but when it has been removed by hand, the cleaner, if correctly operated, will prevent it forming in the future.

Corrosion and Incrustation.—Boilers corrode *on the outside as well as within*, and to a great extent unless carefully cleaned and painted; but it is the damage caused by "hard" and acidulated water within the boiler that is to be principally guarded against.

Ques. What is corrosion?

Ans. *Corrosion is simply rusting* or the wasting away of the surfaces of metals, for instance, as shown in fig. 4,109.

Corrosion is a trouble from which few if any boilers escape. The principal causes of external corrosion arise from undue exposure to the weather, improper setting, or possibly damp brick work, leakage consequent upon faulty construction, or negligence on the part of those having them in charge.

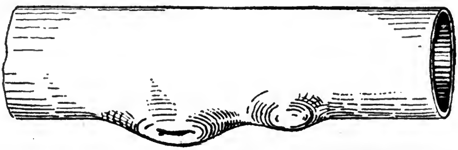


FIG. 4,108.—Tube from the lower row of a tubular boiler in a sugar refinery. On account of sugar in the boiler, the tube became overheated and gave away in the furnace. No elongation was observed at the place of the fracture.

Damp ashes contain a considerable amount of alkaline salts of enough strength to vigorously attack the iron. The soot in the tubes also becomes charged with acids, especially where wood has been used for fuel. Where coal is used the soot becomes charged with sulphur acids, and the combination of these acids causes corrosion. Keeping the tubes free from soot by frequent cleaning prevents the acids doing any damage, and by keeping the boiler clean and dry, external corrosion is practically eliminated.

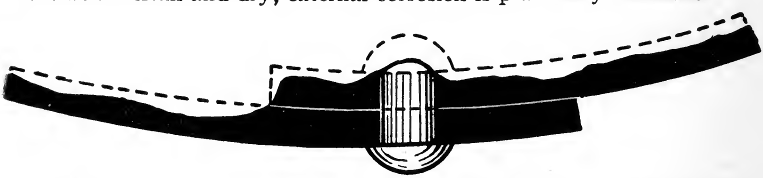


FIG. 4.109.—Corrosion of boiler shell along seam. This eating away of the plates is due to the chemical action of impure water. Gases absorbed by water, such as sulphuretted hydrogen and carbon dioxide are very active in the corrosion of boiler plates. Grease and organic matter also promotes corrosion.

Ques. What is the cause of internal corrosion?

Ans. It is due to the presence in the water of some oxidizing agent, such as air, carbonic acid, free acids and dissolved salts which have a corrosive action on iron and steel.

Ques. What part of the boiler is especially susceptible to corrosion and why?

Ans. Corrosion occurs especially along the water line because the air in the water on being given up during evaporation, being heavier than the steam, collects in a layer between the water and the steam and attacks the metal at this point.

Ques. What is pitting?

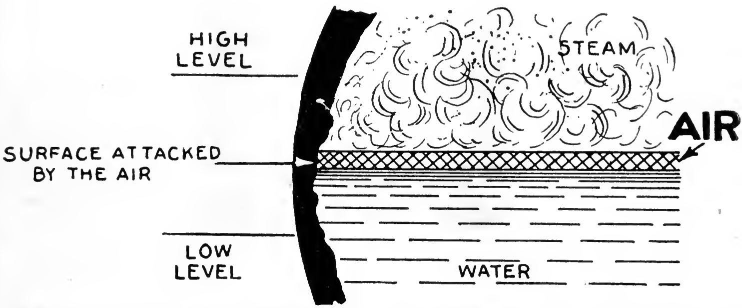


FIG. 4,110.—Corrosion along the water line due to air. Even the most nearly pure water, when containing air, will cause corrosion. Air, since it is heavier than steam, forms a layer between the water and steam and rapidly corrodes the plate along the water line. Accordingly, care should be taken to prevent the feed pumps drawing in air.

Ans. It consists of a series of holes often running into each other in lines and patches, eaten into the surface of the iron to a depth sometimes of one-quarter of an inch.

Pitting is the more dangerous form of corrosion, and the dangers are increased when its existence is hidden beneath a coating of scale.

The best waters, such as rain and snow, generally contain dissolved gases, and when used in a clean boiler will sometimes cause pitting and corrosion, due to the fact that the free acids and gases have not spent their strength on the elements of the earth, and they enter the boiler with their full power.

When a boiler is merely warm, pitting and corrosion occur to a much greater extent than when under pressure. The reason for this is that the acids and gases are liberated when under pressure and pass out with the steam, whereas, in a boiler that is merely kept warm there is not enough heat to drive out the acids, leaving them in the water to continue their corrosive action until they have entirely spent their strength.

When a boiler is kept out of service for any great length of time, care should be taken to see that the water in it, if it have corrosive tendencies, is neutralized by the addition of a proper chemical, such as soda ash.

Ques. What is frequently used in boilers to prevent the corrosive action of water on the metal?

Ans. Zinc.

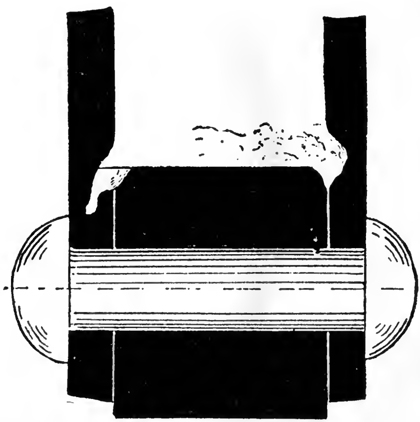


FIG. 4,111.—Water leg of vertical boiler showing corners of the shell and furnace plate at the level of the foundation ring.

Slabs of zinc are suspended in the water by means of wires which are soldered to the upper part of the shell so as to make an electrical connection.

Ques. Explain the action of the zinc.

Ans. The zinc forms one element of a galvanic battery and the iron the other, with the result that the zinc is eaten away and the iron is protected.

On account of this action it is generally believed that zinc will prevent corrosion and that it cannot be harmful to the boiler. In numerous cases, however, zinc has not only been of no use, but has even been harmful. In one case a tubular boiler contained scale consisting chiefly of organic matter and lime, and zinc was tried as a preventive. The beneficial action of the zinc seemed apparent for some time until the water supply was changed. The new water was supposed to be free from lime, and after three months' use, the tubes and shell were found to be coated with an

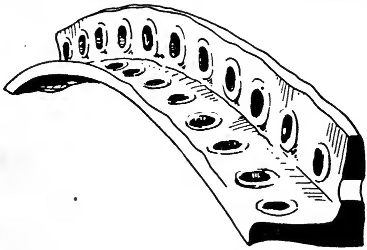
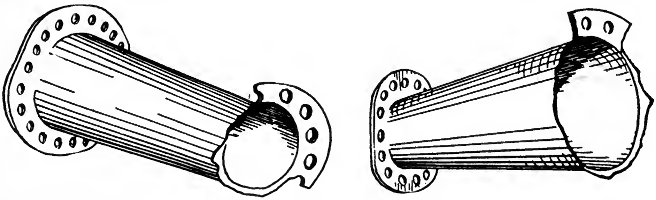


FIG. 4,112.—Angle iron from an internal furnace boiler, being a piece of the angle iron attaching one of the furnaces to the front end, and illustrating a crack enlarged by corrosion which runs all along the iron. The latter is further deeply corroded. The corrosion is in the form of pitting which is practically continuous.

obstinate adhesive scale, composed of zinc oxide, organic matter and the sediment of the water. The deposit became so heavy in places as to cause overheating and bulging of the plates over the fire.

Test for Corrosiveness.—Fill a tumbler nearly full of water, then add a few drops of methyl orange. If the water be acid and corrosive, it will



FIGS. 4,113 and 4,114.—Fractured Galloway tubes. In fig. 4,113 the upper flange is fractured all round the circumference and the lower, two-thirds around. At the prolongation of the fractures, cracks both superficial and otherwise were noticed. The appearance of the fractures seems to indicate that the metal was very brittle. In the tube, fig. 4,114, the upper flange is fractured at the beginning of the curvature for nearly the whole of the circumference.

become pink, but if it be alkaline, and harmless, it will turn yellow. In case the water in boiler be tested and found to be corrosive, and if corrosion has set in, the water in the gauge glass will appear red, or it may be black.

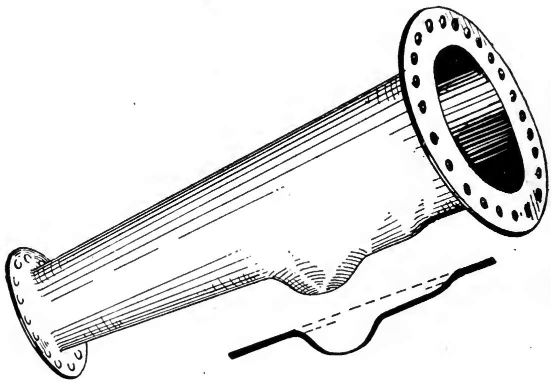
As soon as the color has passed a straw color, lime or soda should be introduced to neutralize the acid in the feed water.

Ques. What is incrustation?

Ans. The term incrustation means simply a *coating over*, the coating being commonly known as *scale*.

Ques. Describe the formation of scale.

Ans. Water, on becoming steam, is separated from the impurities which it may have contained, and these form sediment and incrustation.



FIGS. 4,115 and 4,116.—View and section of Galloway tube, showing a bulge, the thickness of the lowest part of the tube being considerably reduced.

In condensing plants where the condensate is returned to the boiler, more or less oil is carried into the boiler, the minute globules of oil, if in great quantity, coalesce to form an oily scum on the surface of the water, or if present in smaller quantities, remain as separate drops; but show no tendency to sink, as they are lighter than water.

Slowly, however, they come in contact with small particles of other solids separating from the water and sticking to them, they gradually coat the particles with a covering of oil, which in time enables the particles to cling together or to the surfaces which they come in contact with. These solid particles of calcic carbonate, calcic sulphate, etc., are heavier than the water, and, as the oil becomes more and more loaded with them, a point is reached at which they have the same specific gravity as the water, and then the particles rise and fall with the convection currents which are going on in the water, and stick to any surface with which they come in contact, in this way depositing themselves, not as in common boiler incrustation, where they are chiefly on the upper surfaces, but quite as much on the under sides of the tubes as on top.

The deposit so formed is a most efficient heat insulator, and also from its oily surface tends to prevent intimate contact between itself and the water. On the crown of the furnaces this soon leads to overheating of the plates, and the deposit begins to decompose by heat, the lower layer in contact with the hot plates giving off various gases which blow the greasy layer, ordinarily only 1/64 inch in thickness, up to a spongy leathery mass often 1/3 inch thick, which, because of its porosity is an even better insulator than before, and the plate becomes heated to redness.

When water attains a temperature, as it does under increasing pressure, ranging from 175° to about 420° Fahr., all carbonates, sulphates and chlorides are deposited in the following order:

First. Carbonate of lime at 176° and 248° Fahr.

Second. Sulphate of lime at 248° and 420° Fahr.

Third. Magnesia, or chlorides of magnesium, at 324° and 364° Fahr.

The following shows the content of the average boiler scale:

Analysis of Average Boiler Scale

	Parts per 100 parts of deposit	
Silica	.042	parts
Oxides of iron and aluminum	.044	"
Carbonate of lime	30.78	"
Carbonate of magnesia	51.733	"
Sulphate of soda	trace	
Chloride of sodium	trace	
Carbonate of soda	9.341	"
Organic matter	8.06	"
Total solids	100.	parts

Ques. What is the proper method of eliminating scale?

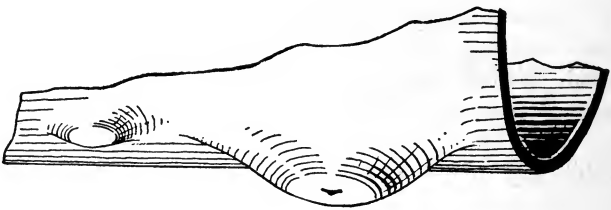
Ans. Some reagent should be used which will precipitate the scale-forming ingredients and soluble salts, and convert them into insoluble salts without increasing the total amount of solids.

Ques. What two methods are employed?

Ans. By treating the feed water before it enters the boiler, or by putting the chemicals into the boiler direct.

The best way to eliminate trouble from scale is to remove the scale forming matter from the feed water before it enters the boiler. Where there is only a small amount of such matter in the water, the expense of a water treating system may not be justified, and it will be cheaper to remove the scale from the boiler. The boiler should be opened at regular intervals in order to note the rapidity with which scale forms or the rapidity with which it comes off if a compound be used.

A very efficient method of removing scale forming substance from the feed water consists of heating the water to boiler temperature before it enters the boiler.



Figs. 4,117 and 4,118.—Piece of furnace plate of a semi-tubular boiler, with drums fed with very hard water, and section of same. The tubes were arranged too near one another, making serious cleaning impossible. The scale detached for the tubes formed patches on the furnace plates and, under these, bulges developed, several being formed each year. The piece shown is fractured at the lowest part at the front of minimum thickness.

The preheating is accomplished by means of a live steam heater and purifier, and in some cases provision is made for the automatic introduction of a suitable reagent for the chemical treatment of the water, for the proper sedimentation, filtering and testing of the water, and for automatically supplying the pumps with hot softened water, should the filter become overburdened through clogging or under peak load conditions.

In view of the increasing importance laid upon a knowledge of the chamical formation of feed water, a few chemical terms are here given to indicate the direction in which the advanced engineer must push his inquiries.

Chemical Terms

Element.—In general, the word element is applied to any substance which has as yet never been decomposed into constituents or transmuted to any other substance, and which differs in some essential property from every other known body. The term simple or *undecomposed substance* is often used synonymously with element.

There are about 70 *simple elements*, three-quarters of which are to be met with only in minute quantities and are called rare elements. Copper, silver, gold, iron, and sulphur are simple elements—*the metal irridium, for example, is a rare element*—it is the metal which tips the ends of gold pens—it is heavier than gold and much more valuable. Probably there are not two tons of it in existence.

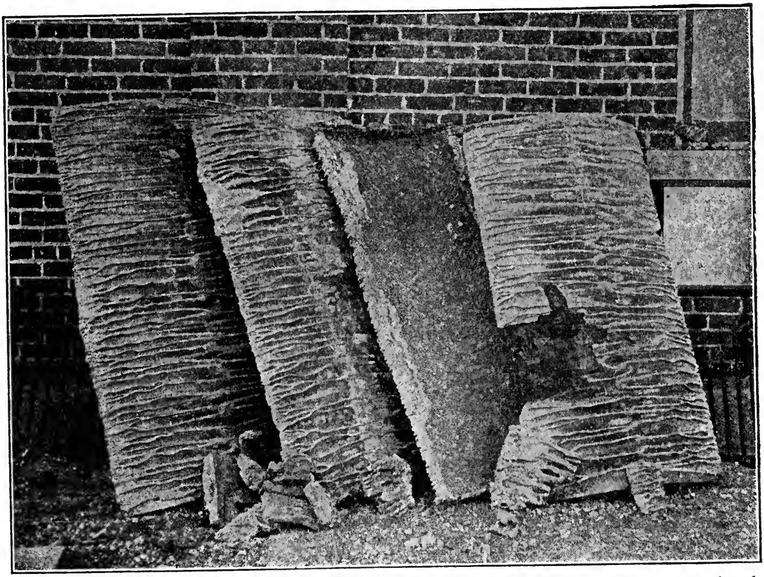


FIG. 4,119.—Pans for Hoppes exhaust steam feed water heater showing large amount of scale precipitated by heating the feed water and how the scale adheres to the underneath surface of the pans. The second pan from the right shows the deposit of scale on the inside or trough of the pan.

A Re-Agent is a chemical used to investigate the qualities of some other chemical—example, hydrochloric acid is a re-agent in finding carbonic acid in limestone, or carbonate of lime, which when treated by it will give up its free carbonic acid gas, which is the same as the gas in soda water.

An Oxide is any element, such as iron, aluminum, lime, magnesia, etc., combined with oxygen. To be an oxide *it must pass through the state of oxidation*. Iron after it is rusted is the oxide of iron, etc.

A Carbonate is an element, such as iron, sodium, etc., which forms a union with carbonic acid—the latter is a mixture of carbon and oxygen in the proportion of 1 part of carbon to 2 of oxygen. Carbonic acid, as is well known, does not support combustion and is one of the gases which come from perfect combustion. This acid, or what may better be termed a gas, is plentifully distributed by nature and is found principally combined with lime and magnesia, and in this state (*i. e.*, carbonate of lime and carbonate of magnesia) is one of the worst enemies to a boiler.

An Acid is a liquid which contains both hydrogen and oxygen combined with some simple element such as chlorine, sulphur, etc. It will always turn blue litmus red, and has that peculiar taste known as acidity; acids

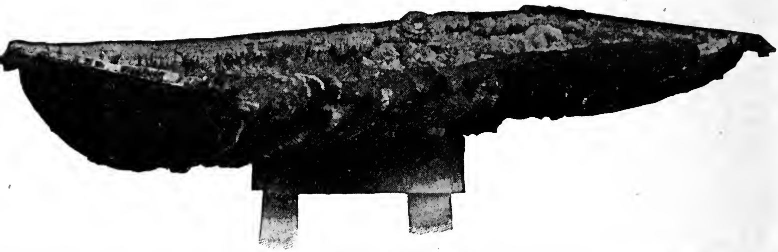


Fig. 4,120.—Another pan for Hoppes exhaust steam feed water heater showing large amount of scale precipitated both inside and outside of the pan.

range in their power from the corrosive oil of vitriol to the pleasant picric acid which gives its flavor to fruits.

Alkalies are the opposite to an acid; they are principally potash, soda and ammonia—these combined with carbonic acid form carbonates. Sal-soda is carbonate of soda.

A Chloride is an element combined with hydrochloric acid—common salt is a good example of a chloride—being sodium united with the element chlorine, which is the basis of hydrochloric acid. Chlorides are not abundant in nature but all waters contain traces of them more or less and they are not particularly dangerous to a boiler.

Lime, whose chemical name is *calcium*, is a white alkaline earthy powder obtained from the native carbonates of lime, such as the different calcerous stones and sea shells, by driving off the carbonic acid in the process of calcination or burning.

Sulphates are formed by the action of sulphuric acid (commercially known as the oil of vitriol) upon an element, such as sodium, magnesia, etc.

The union of sodium and sulphuric acid is the well-known glauber salts—this is nothing more than sulphate of soda; *sulphate of lime is nothing more than gypsum.* Sulphates are dangerous to boilers, if in large quantities *should they give up their free acid*—the action of the latter being to corrode the metal.

The peculiarity about the sulphate of lime is that *the colder the water, the more of it will be held in solution.* Water of ordinary temperture may hold as high as 7 per cent. of lime sulphate in solution, but when the temperature of the water is raised to the boiling point, a portion of it is precipitated, leaving about .5 of one per cent. still in solution. Then, as the temperature of the water is raised, still more of the substance is precipitated and this continues until a guage pressure of 41 pounds has been reached which gives a temperature of about 200 degrees; at this point all the sulphate of lime has been precipitated.

Many other scale forming substances act in a similar manner. This shows quite plainly that any temperature that can be produced by the use of exhaust steam would not be sufficient to cause the precipitation of all the substances which might be contained in the water.

Silica is the gritty part of sand—it is also the basis of all fibrous vegetable matter—a familiar example of this is *the ash* which shows in packing, which has been burnt by the heat in steam; by a peculiar chemical treatment silica has been made into soluble glass—a liquid—65 per cent. of the earth's crust is composed of silica—it is the principal part of rock—pure white sand is silica itself—it is composed of an element called *silicum* combined with the oxygen of the air. Owing to its abundance in nature and its peculiar solubility it is found largely in all waters that come from the earth and is present in all boiler scale.

In water analysis the term *insoluble matter*, is silica. This is one of the least dangerous of all the impurities that are in feed water.

Magnesia is a fine, light, white powder, having neither taste nor smell, almost insoluble in boiling, but less so in cold water. Magnesia as found in feed water exists in two states, oxide and a carbonate, when in the latter form and free from the traces of iron, tends to give the yellow coloring matter to scale—in R. R. work, yellow scale is called magnesia scale.

Carbonate of Magnesia is somewhat more soluble in cold than in hot water, but still requires to dissolve it 9,000 parts of the latter and 2,493 of former.

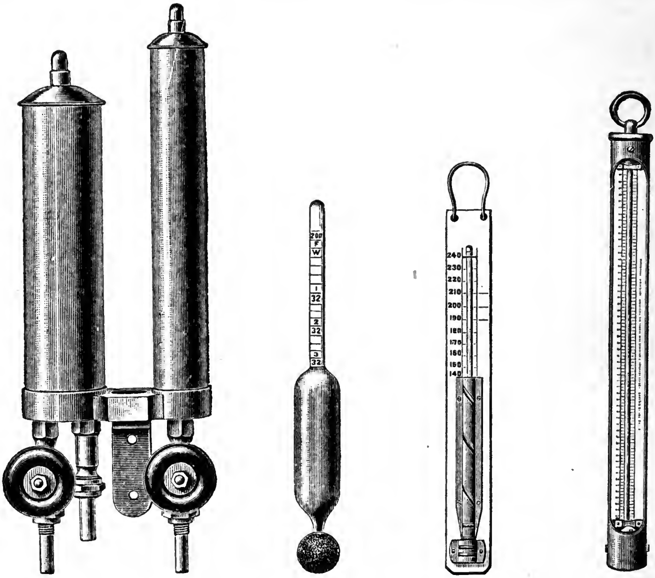
Magnesia, in combination with silica, enters largely into the composition of many rocks and minerals, such as soapstone, asbestos, etc.

Soda is a grayish white solid, fusing at a red heat, volatile with difficulty, and having an intense affinity for water, with which it combines with great evolution of heat.

The only re-agent which is available for distinguishing its salts from those of the other alkalies is a solution of antimoniate of potash, which gives a white precipitate even in diluted solutions.

Sodium *is the metallic base of soda.* It is silver white with a high luster; crystallizes in cubes; of the consistence of wax at ordinary temperatures, and completely liquid at 194°, and volatilizes at a bright red heat. It is very generally diffused throughout nature though apparently somewhat less abundantly than potassium in the solid crust of the globe.

Salt, the chloride of sodium, a natural compound of one atom of chloride and one of sodium. It occurs as a rock inter-stratified with marl,



FIGS. 4,121 to 4,124.—Long's salinometer pot hydrometer and thermometers. There is a short and long pot; the latter contains a small inside tube, which is sealed at the upper end with a number of small holes on the side to prevent sputtering over or boiling of the water when drawn off from the boiler under pressure, and the consequent inconvenience and danger of scalding. The water from the boiler, which is regulated by the valve at the bottom, passes up the small inner tube through the perforated holes at the top, thence down through the annular space into passage leading into the testing pot, which contains a hydrometer and thermometer, the latter being hung by a spring hook on the upper edge of the pot. The middle connection, as shown in cut, is to allow the overflow to pass out, and the valve at the bottom of the testing pot is only used for emptying it when required, and has no connection with anything else. The hydrometer used with the salinometer pot is a graduated glass tube, and floats in the water at a height proportional to its density or saltness. It is marked o for fresh water, 1-32 for sea-water that contains 1 lb. of salt to 32 lbs. of water, 2-32 when it contains 2 lbs. of salt to 32 lbs. of water, and so on. Each division is subdivided into four parts, showing halves and quarters. It is graduated for a temperature of 200° F. A uniform standard of temperature is necessary, since water must be taken from the pressure in the boiler in order that it may assume its regular temperature under the pressure of the atmosphere, because steam of different pressures has different temperatures, and a difference in temperature will alter the indications of the hydrometer. ***How to use a salinometer:*** Draw off some water from the boiler and when the ebullition has ceased, try its temperature with a thermometer. If the temperature exceed that marked on the salinometer hydrometer, let it cool down till it reaches that degree; and if the temperature be less than that marked on the hydrometer, it must be raised till it reaches that degree. Then immerse the hydrometer in the water and let it float; if the level of the water be at 2-32 or less, there is no occasion for blowing off; but if it exceed 2-32, the water must be changed. **Before using the hydrometer, it should be wet all over with water.**

sand stones, and gypsum, and as a base of salt springs, sea water, and salt water lakes.

The proportions of its elements are 60.4 per cent. of chlorine and 3.96 per cent. of sodium.

In salt made of sea water the salts of magnesia with a little sulphate of lime are the principal impurities.

The above mentioned chemical substances can be classified into two distinct classes: 1, incrusting, and 2, non-incrusting.

Of the incrusting salts, carbonate of magnesia is the most objectionable, and any feed water that contains a dozen grains per gallon of magnesia can be expected to have a most injurious effect on the boiler, causing corrosion and pitting.

Carbonate of lime, while not as bad as the magnesia carbonate, yet has a very destructive action on a boiler and 20 grains per gallon of this is considered bad water.

All silicates, oxides of iron, and aluminum, and sulphate of lime are also incrusting. The non-incrusting substances are three, viz., chloride of sodium (common salt), and sulphate and carbonate of soda.

Engineer's Tests for Impurities in Feed Water.—Much expense can be saved in fuel and boiler repairs by a little preliminary expenditure of money in securing a supply of good water for the steam boilers of a new establishment. There are reliable concerns who make a specialty of analyzing feed water and advising the proper treatment of same, and it is advisable to have them make the analysis unless the engineer in charge be competent to do so and have the apparatus for making the tests. There are, however, a few simple tests that anyone can make which will indicate the quality of the feed water.

Take a large (or tall) clear glass vessel and fill it with the water to be tested; add a few drops of ammonia to the water until the water is distinctly alkaline; next add a little phosphate of soda; the action of this is to change the lime, magnesia, etc., into phosphates, in which form they are deposited in the bottom of the glass. The amount of the matter thus collected gives a crude idea of the relative quality of sediment and scale-making material in the water.

Test for Acid.—Water turning *blue litmus paper red*, before boiling, contains an acid, and if the blue color *can be restored by heating*, the water contains carbonic acid. Litmus paper is sold by druggists.

Test for Sulphurous Water.—If the water have a foul odor, giving a black precipitate with acetate of lead, it is sulphurous.

Test for Determining Amount of Impurities.—Dissolve common white or other pure soap in a glass of water, and then stir into the glasses of water to be tested a few teaspoonfuls of the solution; the matter which will be deposited will show the comparative amount of the scale making material contained in the feed water.

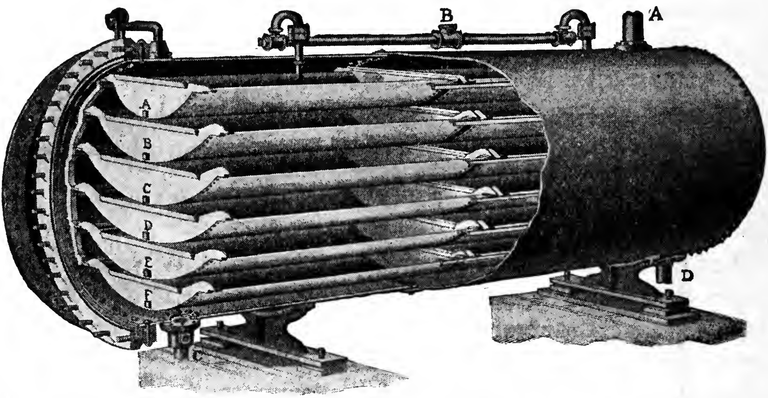
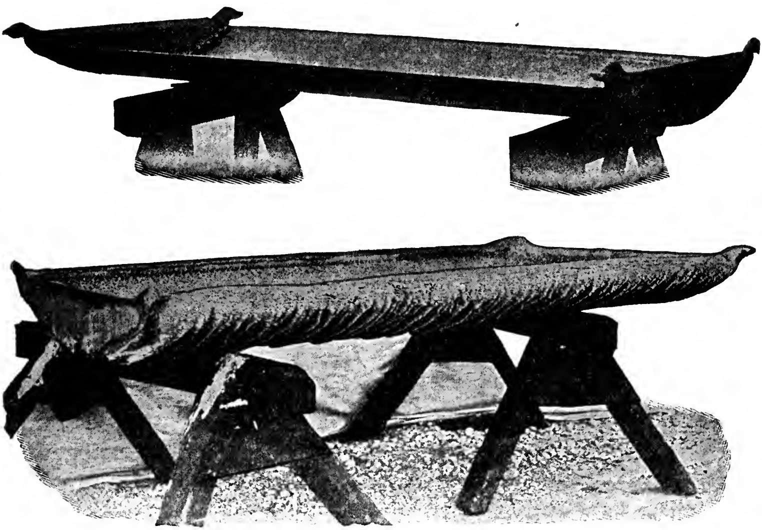


FIG. 4,125.—Hoppes live steam feed water purifier. ***It consists of*** a cylindrical shell of flange steel, having a pressed flange steel head riveted in the back end and a removable head of the same material secured by studs and nuts to a heavy ring riveted to the end of the shell. Within the shell are a number of trough-shaped pans, or trays, located one above another and supported on angle ways running longitudinally and fastened by brackets to the sides of the shell. The ends of the pans are higher than the sides and have projectors at each extremity to rest upon the ways on which the pans are adapted to slide. A water gauge and column is provided and the gauge should never show more than half full of water.

Test to Determine Proportion of Soda Required.—1. Add $\frac{1}{16}$ part of an ounce of the soda to a gallon of the feed water *and boil it*. 2. When the sediment thrown down by the boiling has settled to the bottom of the kettle, pour the clear water off, and 3, add $\frac{1}{2}$ drachm of soda. Now, if the water remain clear, the soda, which was first put in, has removed the lime, but if it become muddy, the second addition of soda is necessary.

In this way a sufficiently accurate estimate of the quantity of soda required to eliminate the impurities of the feed water can be made and the due proportion added to the feed water.

Test for Carbonate of Lime.—In half a tumbler of the feed water put a small amount of ammonia and ammonium oxalate. Heat to the boiling point. If carbonate of lime be present a precipitate will be formed.



FIGS. 4,126 and 4,127.—Pans for Hoppes live feed water purifier. Fig. 4,126, clean pan; fig. 4,127, same pan covered with scale after three weeks' use.

Test for Sulphate of Lime.—Add a few drops of hydrochloric acid and a small quantity of a solution of barium chloride to three-quarters of a tumbler of the feed water and heat the mixture slowly. If a white precipitate form that will not dissolve on adding a little nitric acid, sulphate of lime is present.

Test for Organic Matter.—Put a few drops of sulphuric acid into a tumbler of water, add a sufficient quantity of pink colored solution of potassium permanganate to make the entire mixture a faint rose color. If after standing three to five hours, no change in color occur, no organic matter is present.

Test for Matter in Mechanical Suspension.—By allowing a glass of feed water to stand eight to ten hours, any mechanically suspended matter (if any), will settle to the bottom and the amount of sediment may be noted.

Ques. What may be said with respect to patented boiler compounds?

Ans. The *base* of most of them is *tannen* (whence tannic acid) and some form of alkali, and if the compounds were to be deprived of these two elements they would be absolutely worthless.

Where they contain sal-ammoniac, muriatic, hydrochloric and sulphuric acids, they cannot but act as boiler destroying agents.

Use of Kerosene in Boilers.—Among the substances which act mechanically, crude petroleum and kerosene oils are extensively used. The latter may be recommended as the better of the two, as the crude oil will sometimes aid in scale formation. They apparently act best when some sulphates are present, as in slightly brackish waters.

Ques. How does kerosene act?

Ans. It prevents the particles of scale sticking closely together or adhering to the heating surface, so that much of the matter will collect as a sludge in the bottom of the boiler, and that on the heating surfaces will be more easily removed.

Ques. What precaution should be taken when there is reason to expect an accumulation in the bottom of the boiler of deposits thrown down in a loose or powdery form?

NOTE.—A sufficiently accurate chemical set can be bought, including full instructions for operating it, all contained in a neat wall cabinet for a nominal sum.

NOTE.—***To Make caustic soda at little expense,*** take a tank that will hold 1,000 pounds of water. Put into the tank 1,000 pounds of hot water. Then put in 100 pounds of soda ash, then 70 pounds of lime; stir thoroughly and let it settle, which will give a clear 10 per cent. solution of caustic soda. Siphon the solution into another tank, keep the air away from it, and use the sediment in the mixing tank to fertilize your kitchen garden or put it on the grass in your front yard, and watch things grow.

Ans. The bottom blow should be frequently used to prevent undue accumulation, or opportunity for its hardening into scale.

Scumming Apparatus.—In addition to the bottom blow out apparatus, every boiler should be provided with means for blowing out water from the surface in order to remove the fine particles of foreign matter floating there, which afterward settle and consolidate as scale on the heating surfaces.

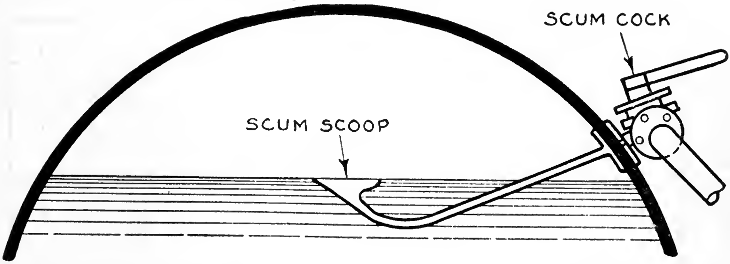


FIG. 4,128.—Scum scoop or surface blow for blowing out fine particles of foreign matter floating on the surface of the water. There are several efficient ways of arranging a surface blow-off. The principal part of the blow-off is a pan or perforated pipe placed horizontally at the water level having a pipe leading outside the boiler to any convenient place where the scum may be blown. When a perforated pipe is used the action is to force the scum from the top of the water during the time the valve is open, and blow it through the pipe. In using an apparatus of this kind it should be blown often, but only for a moment at a time, as all the scum near the pipe is removed immediately, and to keep the valve open longer than necessary to remove the scum near the pipe would allow the escape of clean water or steam which would be wasteful. If a pan be used and be fastened so that the top is secured at the ordinary water level, as here shown, the blow-off pipe leading from near the bottom of the pan, it will be more efficient than the perforated pipe arangement as it will not require to be used so often, and the waste of water and steam will not be so great. The pan, by producing an eddy in the water, causes all the scum to gather over the top, and as the water is quiet there, it will gradually settle into the pan, where it will remain as mud. When the blow off valve is opened, the greater part of the mud which is gathered is blown out, and but very little water is carried with it.

It consists, in its simplest form, of a pan, or a conical scoop, near the surface of the water, but below it, connected with a pipe passing through the boiler shell, on which is a cock, or valve, for regulating the escape of the water laden with the impurities deposited in the pan.

A surface blow used occasionally will remove a considerable portion of the scum and keep the boiler reasonably free from scale and mud.

In condensing plants when the condensate is used as feed water, oil coming in with the feed water is caught by the circulating currents and distributed more or less throughout the boiler, though by reason of its lesser weight it will tend gradually to rise and accumulate as a scum at the surface of the water. The surface blow is very effective in receiving this scum.

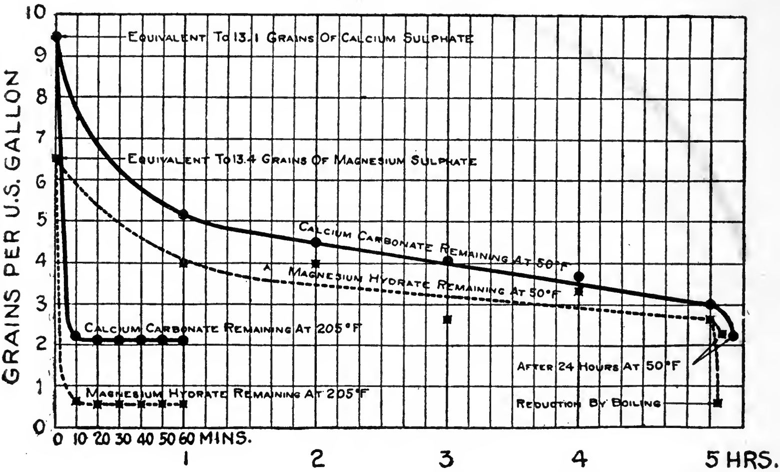


FIG. 4,129.—Value of heat in water softening. The same quantities of the same treating solution were added to equal amounts of the water at 205° F. and 50° F. Solid curves show calcium carbonate remaining in solution after treating calcium sulphate with sodium carbonate (soda ash). Dotted curves show magnesium hydrate remaining in solution after treating magnesium sulphate with calcium hydrate (lime). ***In all tests*** the theoretical quantity of softening chemicals was used to combine with the scale forming solids. In 10 min. the hot sample had a little less calcium carbonate than the cold sample had after 24 hr. In 10 min. in the hot sample all the possible precipitation of magnesium hydrate had taken place. After 24 hr. the cold sample had three times as much magnesium hydrate left in solution as the hot sample after 10 min. The same minimum was reached by boiling the cold sample.

The danger of a combination of scale and oil deposited on the heating surfaces is not in its close adherence to the surfaces, but in the effect of the oil in considerably increasing its efficiency as a heat insulator. *Even a thin coating of cylinder oil may cause slow damage, and necessitate expensive repairs.*

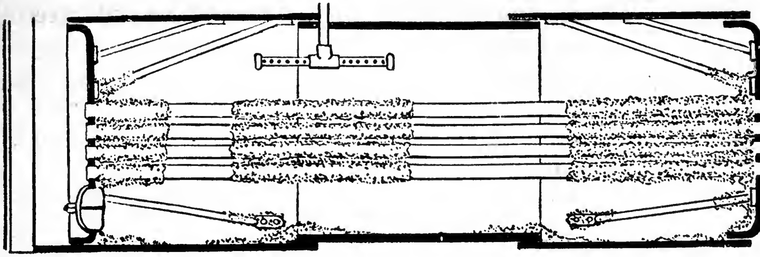
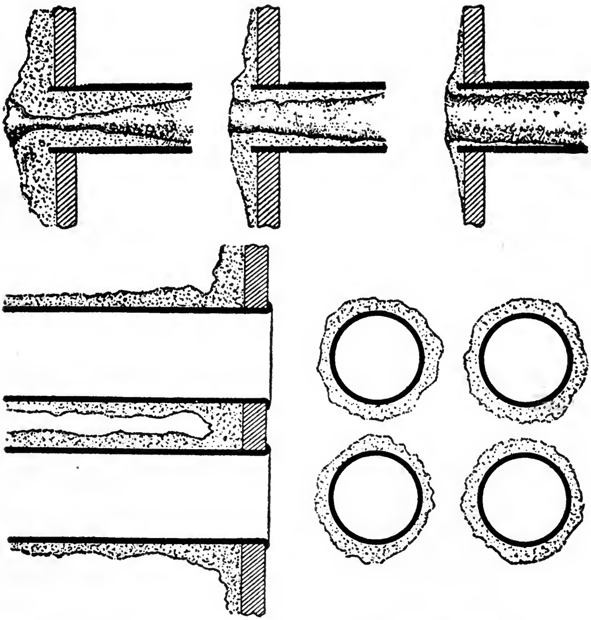


FIG. 4,130.—Horizontal tubular boiler showing where scale accumulates most rapidly.



FIGS. 4,131 to 4,135.—Accumulation of scale between the ends of tubes and at the entrance to column pipes. One patch of thick scale in proper place can retard the flow of water as thoroughly as a much larger area of very thin scale. It acts as a dam or baffle between the tubes of a fire tube boiler and in the tubes of a water tube boiler.

Ques. How is the presence of oil in the boiler indicated?

Ans. It shows in the glass water gauge when in large amounts, but a boiler may contain a dangerous amount of oil without this indication.

Ques. How may the oil be reduced?

Ans. By boiling out the boiler with kerosene and soda ash, or by scraping and scrubbing, or a combination of these two methods.

The hand hole plates should be removed and the shell and all other accessible surfaces thoroughly scraped, and then scrubbed with a stiff brush wet with kerosene. The boiler should also be entered from above, and the oil scum that has collected upon the side sheets above the water line scraped and scrubbed off in like manner, followed by thorough washing and ventilation of the boiler.

Ques. What precautions should be taken when treating a boiler with kerosene?

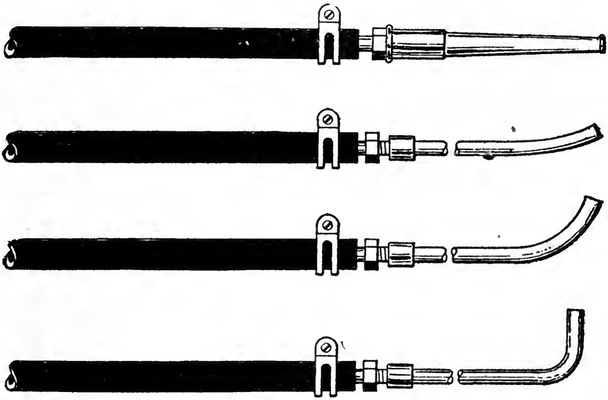
Ans. Keep all lighted candles, lamps or other fire away from the boiler openings, both when applying the kerosene and upon opening the boiler again.

If a light be necessary, either use an incandescent electric light or reflected light.

NOTE.—***Modern methods of softening water.*** Hydrate of lime, in the form of lime water or milk of lime, still remains the most economical and practicable means for neutralizing acids, absorbing carbon dioxide and converting bicarbonates to carbonates or hydrates. Likewise, soda ash is the preferred means for transforming sulphates, chlorides and nitrates to carbonates. Where the respective amounts of carbonates and sulphates are in the right proportion, a single chemical, sodium hydrate, can be employed both for absorbing carbon dioxide and for transforming sulphates and chlorides. Other methods for producing non-scale forming water are distillation, the expense of which is ordinarily prohibitive, and the use of socalled zeolites. Zeolites are suitable only for correcting permanent hardness. When used in connection with water containing temporary hardness, they introduce into the treated water sodium carbonate in quantities proportional to the amount of lime and magnesium carbonates removed. For this reason they are not suitable for softening water for boiler feed purposes. While the chemical reagents used for softening water are limited chiefly by the availability and cheapness of certain substances, the engineering methods and appliances by means of which the softening process is carried out have undergone a radical evolution, so that their efficiency has been increased several fold.

NOTE.—***The effects of heat upon chemical reactions.*** The statement has been made that the rate of reaction doubles for each 10 degs. C. added to the temperature. Another estimate is that chemical reactions are speeded up approximately as the twentieth power of the absolute temperature. These two formulæ are not in agreement, but the fact remains that there is a tremendous increase in speed of reactions with rise in temperature. In the softening

Use of the Blow Off.—To remove sediment the blow off should be opened in the morning while the fires are still banked, because a considerable amount of sediment will have settled down during the night, during the inactive interval of no steam demands. If the boiler be used night and day, the blowing should



FIGS. 4,136 to 4,139.—Forms of nozzle for washing out boilers. The hose should not be less than 1½ inches in diameter. An armoured or wire-wound hose is best as it will stand the most rough usage. The water pressure should be at least 75 lbs. With a hose of this size and with this pressure, loose or soft scale will be knocked off. In washing a horizontal tubular boiler two or more nozzles are needed. A straight nozzle and one bent to about 75 degrees, or an adjustable nozzle may be used. The bent nozzle is used to wash the front head and the tubes close to it. This is a point at which scale cannot be easily gotten at and where it will do considerable damage. The bent nozzle on a long pipe enables the rear head to be reached. When the boiler is first opened there will usually be found a pile of loose scale on the plate over the fire. After removing the loose scale the hose is put in at the top of the boiler, pushing the nozzle down between the tubes. Then through the lower manhole at the front or rear the lower part of the tubes and shell can be washed, using the bent or straight nozzle to reach the different parts. It will not suffice to allow the water to flow over the tubes and through the shell, every part must be reached with the full force of the nozzle stream. An incandescent lamp or other light on the end of a pole enables one to see whether the work has been thoroughly done. This examination should be made by the engineer no matter who does the washing-out.

NOTE.—*Continued.*

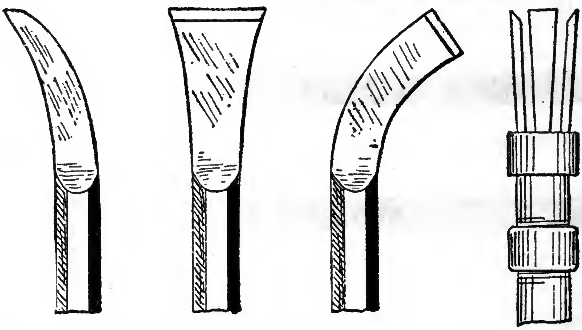
of water by means of lime and soda ash, the reactions involved are greatly accelerated by heat, so that better results can be obtained at a temperature of 200° to 210° F. in a few minutes than in cold water in several hours. Experimental results, which are supported by experience with hot process softeners in practical service, demonstrate that ten minutes at the boiling temperature will soften water to a lower degree of hardness than can be secured by the same number of *hours* at 50° F., the same softening reagents being used in each case. Analyses of the treated water also show that the incrusting substances in the water which has been softened at 200° to 210° F. are much less in amount than those remaining in solution in water softened at 50° F. Not only is the chemical reaction completed much sooner in hot water than in cold water, but the resulting precipitates are of such a nature that they can be more quickly removed by sedimentation.

be done at the end of the noon hour, when the sediment has had a chance to settle.

Ques. How should the blow off valve be handled?

Ans. It should be opened and closed gradually to avoid sudden shocks, but should be fully opened, so as to cause a swift outgoing current which will catch up and expel the sediment.

Ques. How much and how often should a boiler be blown down?



FIGS. 4,140 to 4,143.—Forms of chisel used in boiler cleaning.

Ans. At least "one gauge" a day, depending upon the amount of sediment forming.

Ques. What precaution should be taken in closing the blow off valve?

Ans. Observe the end of the blow off pipe and see that the valve is tightly closed.

Cleaning a Boiler.—In order to clean a boiler it should not be blown down the night before cleaning, but the water should be allowed to remain in the boiler until the time of opening.

Then the safety valve should be raised, the blow off valve opened and the water allowed to run out by gravity. In many cases this cannot be done, owing to the peculiar way in which the blow off may be connected, or the fact that there may be but one boiler in the plant; under such conditions, the best thing possible must be done.

Some engineers blow down the boilers on Saturday night and on Sunday open the boiler for cleaning. This is poor policy as the brick work around the boiler is hot and after the water is all blown out, the heat from the brick work rapidly dries the metal and nearly all the scale and sediment will be found to adhere tenaciously to the shell and tubes, thereby causing extra labor to remove the scale.

If the water be allowed to remain in the boiler over night, a great portion of the scale will be deposited on the crown sheet, thus facilitating its removal.

It might be argued that if this plan be followed, the boiler will be too hot for cleaning, but this can be prevented to a large extent by leaving the doors and damper open during the night and by cleaning out as late as possible the next afternoon.

It is not necessary to take out all the man hole and hand hole plates at every cleaning. Good results will be obtained by taking out the front hand hole or man hole plate and removing the scale from the back with a long hoe, washing the entire boiler out with a hose. This method could be followed with good results, provided it is done about twice each month.

A great deal depends upon the kind of water being used and the method of feeding the boiler. If the water be impregnated with lime, magnesia, etc., the boiler may have to be cleaned out oftener than twice each month.

Ques. Describe a good method of washing a boiler.

Ans. When the boiler is shut down, close all draughts and allow the boiler to cool in unison with the surrounding brick work. This will take from two to four days, depending in a great measure upon the amount of water that the boiler contains and also upon the size of the boiler. By doing this, the water will disintegrate the scale and a large amount of it will be deposited on the bottom. After the water is run out of the boiler, the man hole and hand hole plates should be taken off and a strong stream of water should be played between the tubes and around the shell and heads. *Don't attempt to place a lighted candle or lamp in the boiler until after the boiler is partly washed out.*

If any boiler compound or kerosene oil be used as a scale preventer, an explosion may occur if the light be first placed in the boiler. This same precaution should be taken when washing out a feed water heater.

Ques. What should be done after the boiler is washed out?

Ans. It should be entered for inspection and all braces and stays should be carefully tested.

Ques. In looking for scale in horizontal boilers where should the lamp be placed, and why?

Ans. Beneath the tubes so that any scale which may be lodged between the tubes can be easily seen.

Ques. What should be done after closing the boiler?

Ans. Pour into the boiler several gallons of kerosene and allow water to flow into the boiler very slowly, the slower the boiler is filled, the more opportunity will the kerosene have to attack the scale.

How to Lay Up a Boiler.—After the boiler is cleaned and inspected, all loose parts, such as grates and grate bearers, are stored in a dry place, and the furnaces, combustion chambers and tubes are given by some engineers a thin coat of linseed oil, after being first thoroughly dried.

Ques. How is the interior of the boiler prepared for laying up?

Ans. After being cleaned it is thoroughly dried and must be kept dry to prevent corrosion.

Ques. How may the interior be kept dry?

Ans. Some engineers make use only of the natural circulation through upper and lower man and hand holes. Others place flat vessels, filled with quicklime, for the absorption of all moisture into the boiler, and then close it up tight.

Ques. How are the fittings prepared for laying up?

Ans. They are taken apart, cleaned, and, after being greased with a slight coat of clean tallow, are put together again without packing.

To make sure that no rusting or sticking takes place, the valves and cocks are moved occasionally. The sea valves and bottom blow valves, or cocks, must be put into serviceable condition, with complete packing at the time of docking, as it is desirable to keep the water and moisture out of the ship as completely as possible.

4. REPAIR

If it be necessary to repair a boiler and it be insured in a responsible boiler insurance company, the nearest agent of the company should be notified, and he will arrange to have the inspector at the plant as soon as possible. The inspector will recommend how the repairs should be made, so that they will be satisfactory to both the owners and the insurance company. In any event the work should not be entrusted to the local handy man or jack of all trades.

Ques. What breakdowns are most likely to occur in a boiler?

Ans. Cracks in the plates, bulges in the heating surfaces split or leaky tubes, stay bolts or braces, and defective fittings.

Cracks may be due to original defects of the material, to faulty methods in the manufacture or to excessive local strain. They may show around rivet holes, at flanged corners or between tube openings, although these accidents are seldom found in modern boilers.

Ques. What should be done if the leakage for cracks be large?

Ans. The boiler must be placed out of service, blown down and cooled until it is possible to enter and make repairs.

Ques. What is grooving?

Ans. The surface cracking of boiler plates. It is caused by its expansion and contraction, under the influence of differing temperatures and is attritubable generally to the too great rigidity of the parts of the boiler affected.

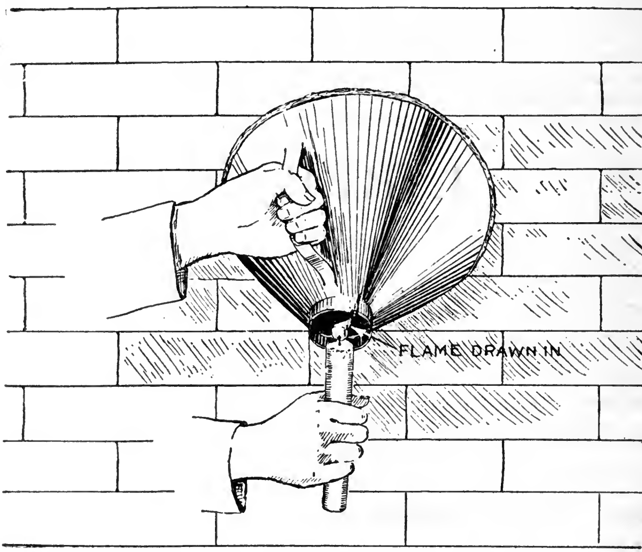


FIG. 4,144.—Air leak detector cone, and method of using it. The cone is easily made from sheet metal. The large end should be flanged and the flange faced with a soft felt gasket to prevent air leaking in past the flange when pressed against the back setting. The seam should be soldered, thus making it air tight. Now, when the boiler is in operation, by pressing the cone up against the setting and holding a candle in front of the small hole, any air leak in the brick wall will be indicated by the inrushing air drawing the flame into the cone. Evidently with the small hole at the end of the cone, the effect is magnified by the increased velocity of the air at that point. The hole should not be more than, say, 1 inch in diameter. With such arrangement very minute leaks may be detected.

NOTE.—Large cracks in boiler settings may be mounted up with lime mortar. A quantity of cement may also be used. Cement is sometimes painted over the cracks with a brush, and fire clay is used in the same manner. These fillers often crack when thoroughly dry and are of little value in preventing air leakage. A little fine waste or asbestos wicking may be added which tends to prevent cracking and holds it in place.

Ques. How should cracks be repaired?

Ans. If possible the cracks should be drilled off at the ends by small holes, which will prevent further extension, and patches put over them, either on the inside or on the outside.

If riveting and caulking of the patches be not practicable, bolting must be resorted to, for holding them down. The so called boiler patch bolt, which screws through the plate against a conical head, proves much more efficient for a tight joint than a common bolt. The patches are put on with a good fit and the interstices completely filled with red lead, putty or iron rust cement.

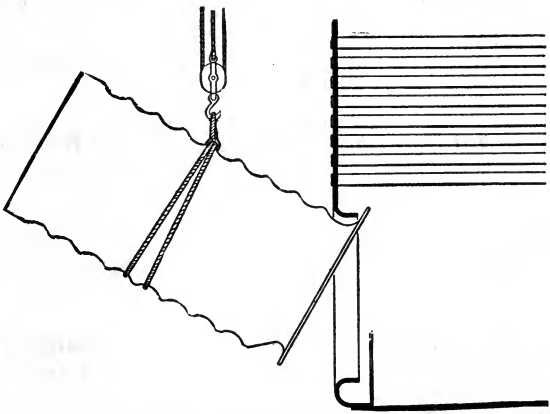


FIG. 4,145.—Method of removing a cylindrical furnace from its position in the boiler.

Ques. How should bulges in the heating surface be treated?

Ans. If they be not large, and the surrounding stays or braces prove all sound and well fitted, no special remedy may be required, apart from careful and frequent inspection and measure ing with templates. Where the bulges are large and the stay bolts, or braces, are torn out of the plate, or ruptured, staying must be resorted to.

Such staying generally proves preferable to any attempts to force the surface back into its original form. The number of stay bolts is preferably increased with closer spacing in new positions.

A bulge may occasionally occur, in consequence of a rupture of one of the old large braces. In such a case it proves advantageous to employ a heavy girder plate that takes the repaired brace in the center, and a number of screw stay bolts around its circumference. The stay bolts are conveniently tapped and riveted into the material, while a plug closes the old brace hole. The connection to the old shortened brace may be effected by a cross key behind the girder plate. This repair leaves the plate effectively exposed to the cooling circulation of the water.

Ques. How may a bulge be forced back into place?

Ans. If the plate be not burned, and not drawn thin, heat it red hot by rigging up a gas furnace under the bulge and drive it up into its original position.

Ques. What should be done if the plate were burned?

Ans. The burned part must be cut out and a patch put on.

A slightly bulged plate may be prevented getting worse by putting a stay through the center of bulge and attaching the other end of stay to some part of boiler diametrically opposite. If a bulge, bag or blister be very large, or if the metal be wasted thin, a new fire sheet should be put in.

Ques. What may be resorted to if the bulged plate be not in convenient reach from rigid parts of the boiler for stay bolt connection?

Ans. Girders.

The girders should extend well over the nearest rigid points of attachment, and support the plate by numerous carrying bolts. Good clearance under the girder will insure active circulation and avoid further over heating.

Ques. How should bulged circular furnaces be treated?

Ans. If not altogether collapsed, they may be put in such condition that they will safely carry a reduced steam pressure, by closely spaced circular rings of angle or bar iron, fitted in halves.

In marine practice, on small vessels having only one boiler, it may be of prime importance to make temporary repairs so boiler can be operated under reduced pressure till vessel reaches port.

Ques. How are split tubes repaired?

Ans. By plugging.

In fire tube boilers a temporary repair of this sort is made by means of a soft wooden plug, which is driven into the tube until it covers the split. The water leaking through swells the plug and by pressing tightly against the surface of the tube, prevents further escape of water.

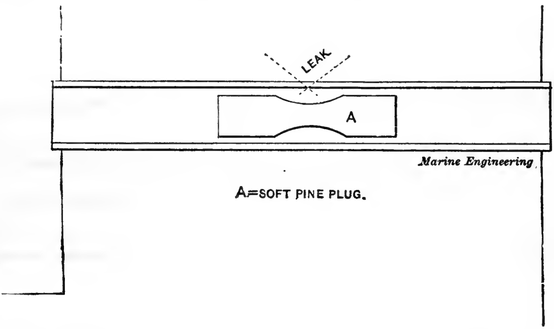


FIG. 4,146.—Easy method of repairing a leaky boiler tube. A plug, shaped as at A, is pushed into the flue until it reaches the point of leakage, where the escaping steam and water cause it to swell, thus stopping the leak.

A better form, employed where there is serious leakage, is the tube stopper, containing two conical cast iron plugs, fitted with metal packing in the tube ends, and drawn up tight by the nuts of a through bolt.

Ques. How is a tube stopper applied?

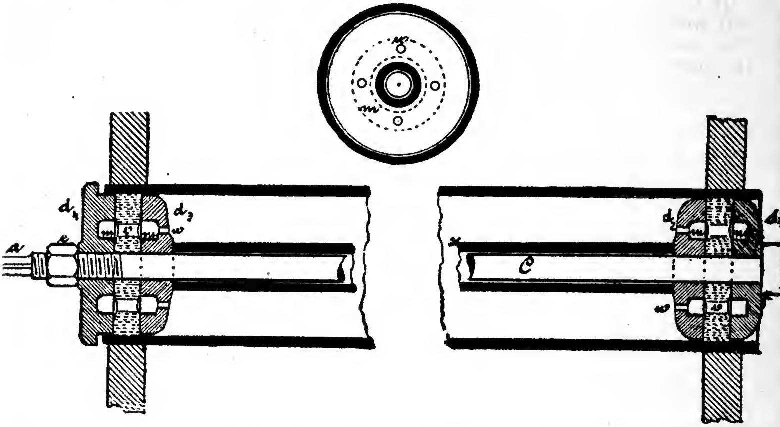
Ans. The fires must be drawn so that a man can enter the combustion chamber to insert the plug.

Another form of tube stopper which can be inserted entirely through the uptake doors, figs. 4,147 to 4,149, consists of two heavy rubber washers between two pairs of plate discs.

The two inside discs are spaced and held apart by a piece of gas pipe, while the outside ones can be drawn together by the nuts on a central bolt, thereby compressing and spreading the washers, until they bear tightly against the side of the tube and stop the leakage.

In water tube boilers the repair is more difficult, as the fire must be drawn and water blown down, there being difficulty in locating the split tube.

Ques. What causes leakage around the tube end of vertical boilers with through tubes?



FIGS. 4,147 to 4,149.—Rubber tube stopper. As shown, *a* is the threaded end of the iron rod *C*; *e*, the nut; d_1, d_2, d_3, d_4, washers; *d* and *d*, rubber discs; *x*, iron gas pipe; *m*, *m*, holes in washers, open at *ww*.

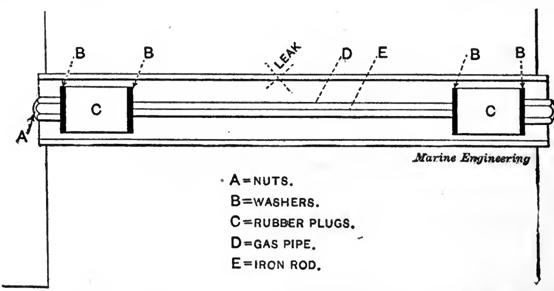


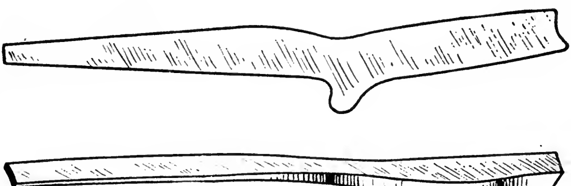
FIG. 4,150.—Emergency device for stopping a leaky boiler flue. An iron rod, E, having a thread at both ends, is fitted with a nut A. A washer, B, is then put on; then a rubber plug, C, another washer, C, and a length of gas pipe against the second washer. The opposite end of the rod, E, is similarly fitted, after which the act of screwing up the nuts causes the rubber plugs to bulge, filling the tube.

Ans. Forcing, carrying the water level too low, getting up steam without entirely filling the boiler.

MANAGEMENT

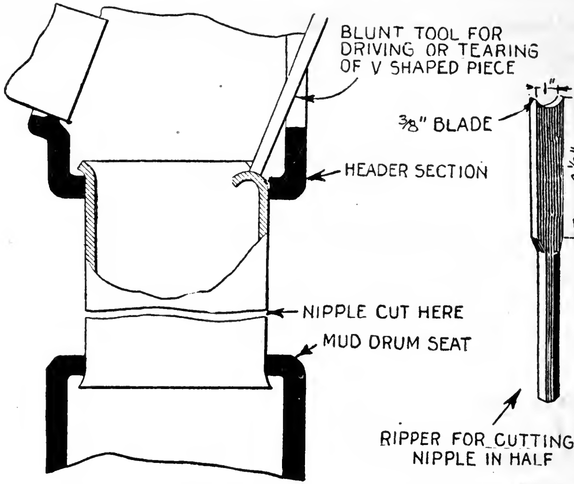
Grooving and Cracking of Tubes.—This usually occurs in the lower tubes at the rear end, and results from pumping comparatively cold water into the boiler in such a way that it comes in contact with the hot tubes.

FIG. 4,151.—Ripper or plough chisel. *It consists of* a flat chisel about 1½ inches wide and 5/16 inch thick. It is made convex, or crescent shape, on the end and is ground perfectly square, or blunt similar to a calking tool.



FIGS. 4,152 and 4,153.—Beading tool and long wedge used to fold tubes.

The very common practice of pumping cold, or slightly warmed, water into the blow off might easily produce this result, by chilling the tubes at their hottest part causing them to contract, thus inducing severe strains. The girth seams of old iron boilers frequently cracked between the rivet holds at the bottom, because they were constantly fed through the mud drums, thus cooling the shell plate by the comparatively cold feed valve.



FIGS. 4,154 and 4,155.—Method of replacing nipples in water tube boilers (B. & W. type). It is useless to try to batter or crush the nipple, but if the following method be employed, one man can easily remove a nipple in less than an hour. First, take off the two lower caps and remove the mud drum plates, then with a long narrow ripper such as is shown in fig. 4,155, cut the nipple in half, working the ripper (which has a curved end) around the girth of the nipple in the space between the header and mud drum. Next, with an ordinary chisel bar, through the lower header hole, cut a vertical slot entirely through the part of the nipple that extends above and below the header seat, and partly through the portion directly over the seat, being careful not to cut entirely through, as seat is easily ruined. Then cut another slot, starting about an inch from the first and cutting at an angle so that the two will intersect below the seat, cutting a small V-shaped piece out of the nipple except for the small portion over the seat which is not cut entirely through; bend the top of the V-shaped piece inward, using a hook ended bar, and drive it downward with a blunt tool. This will tear off the small sections over the seat, and a few blows will crumple the remainder so as to permit its removal. The process is repeated on the lower half, in the mud drum. It is important that the new nipples be the proper length; that is, they should extend ¾ inch below the lower edge of the mud drum seat and ½ to ⅝ inch above the top of the header seat. To cut the nipple to length, never use the ordinary pipe cutters; the work should be done in a lathe. If that be not possible, use a hacksaw that does not leave a burr. Before proceeding, all scale or dirt should be cleaned from the header to prevent its being rolled into the joint. Put the nipple into place, blocking it substantially in position from the inside of the mud drum. If the nipple is found to be loose in the seats, shims should be fitted, but if no regular shim stock be at hand, ordinary stove pipe iron is a good substitute. Shims should be fitted carefully, especially the joints, so as not to cause a hump or uneven spot; the ends should be lapped ⅛ inch and filed to the same thickness as the remainder of the shim. If a small amount of powdered graphite be placed around the top of the seat, it will work into the joint and help materially in filling any unevenness in the face of the seat or nipple, thus promoting a tight joint. To expand the nipple, the expander should be fitted with the straight rollers, which should be centered over the seat, and using the single jointed mandrel, the expander is turned until the nipple is rolled tight. Then the straight rollers are removed and the tapered ones substituted, placing the large ends upward and fitting the expander so as to allow the top of the rollers to extend a short distance, say 3/16 to ¼ inch above the top of the nipple, when the rolling operation is repeated, resulting in flaring, or belling, the nipple. The bell should be at least ⅛ inch; that is, the top diameter of the nipple is increased ¼ inch. The belling is very important, as it is depended upon to support the end stress, which is proportional to

Splitting of Lap Welded Tubes.—Sometimes, notwithstanding the care taken in manufacture and inspection, lap welded tube will split at the seam. To guard against this and also reduce the trouble due to laps, extra heavy tubes are sometimes used for the lower rows for pressures over 125 pounds. The better way is to use seamless tubes. Since these tubes are drawn from solid billets, they have no seams to split. Moreover, the drawing process makes them tougher and denser, therefore stronger and more durable.

Retubing.—When boiler tubes have to be renewed the old tubes must be cut out. This is done by cutting a long slot in

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NOTE.—***In ordering new tubes,*** the length should be accurately measured on a strip of wood or a piece of pipe passed through the old ones, allowing from 1/8 to 3/16 inch on each end for beading over. If more than one boiler is to be retubed, measure each one, as it will probably be found that there is a difference although they are all supposed to be the same. The ends of the new tubes are supposed to have been annealed before delivery, but it is doubtful if this has been done, so it is a good plan to heat them to a dull red and bury them in lime, allowing them to cool very slowly. This will make them much easier to expand and bead, and will reduce the liability of their cracking during these operations.

NOTE.—***Rolling tubes too much*** thins the metal and hardens it, resulting in cracking in rerolling.

NOTE.—***In water tube boilers,*** the process of removing tubes is about the same as in tubular boilers, but the tubes are taken out with less difficulty. Since the ends are not so easily reached a ripper is almost a necessity for splitting the tubes. The ends can then be folded in by the means of the long slender wedge shown in fig. 4,153. A good plan is to cut two deep notches in the end of the tube, about an inch apart, and then with a bar force the part of the projecting end of the tube between these notches, away from the tube sheet or header, using the edge of the handhole as a fulcrum for the bar. This produces a slight space between the tube and the tube sheet, into which the wedge may be started, and when it is driven home there is plenty of space left, so there is no danger of scoring the tube sheet with a ripper. If the defective tube be in the lower row, as is usually the case, its removal may be facilitated by cutting the tube into two or three sections with a three wheel pipe cutter, and removing the ends from the tube sheets from inside the furnace. From this point the operation is the same as that described for the horizontal tubular boiler, except that they are flared by one of the methods described in previous paragraphs.

FIGS. 4,154 and 4,155.—*Text continued.*

the area of the nipple multiplied by the boiler pressure. After the upper end is rolled, the blocking may be removed from the mud drum and the lower end of the nipple expanded and belled as in the header, except that the double jointed mandrel is used and the large ends of the tapered rollers are placed downward and extended 1/4 inch past the lower end of the nipple in order that it may be given a flare also. It sometimes happens that the expander is too short to enable the rollers to extend to their proper position and an attempt to bell will result in the lower end of the nipple being crimped inward. A better job would result if one of the rollers were replaced with a headed one and the expander located so as to bead the nipple just below the seat. After putting in a new nipple, the boiler should always be subjected to a hydrostatic test and the expanding operation repeated if a leak be found.

tube from front end; this slot should be cut with a ripping chisel and should extend back about 3 inches; the tube may now be contracted and by cutting the back end loose, can easily be pulled out. A new tube is now inserted and secured into both heads with an expander and the ends of tube riveted over.

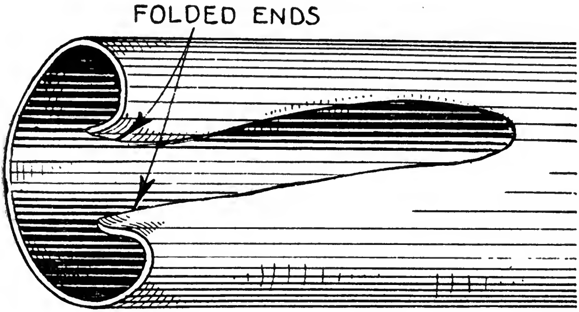
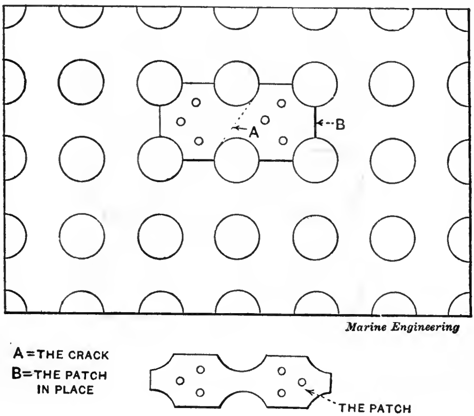


FIG. 4,156.—Method of cutting and folding in tube end for removal and tools used. Removing the old tube is the most difficult part of tube renewal, especially in a horizontal tubular boiler, as the tube is usually covered with scale, which adds to the difficulty of removing it. When the defective tube is so located that it can be removed through the manhole, it is a simple matter to cut it off at each end just inside the tube sheet with a sharp cold chisel and remove it through the manhole, afterwards cutting out the ends remaining in the tube sheets. The tubes, however, usually have to be removed through the holes in the sheets. To do this, first cut off the beading with a sharp cold chisel, then with a "ripper" or plough chisel (fig. 4,151), cut out a strip 4 or 5 inches long and the width of the tool. If no ripper be at hand and only a few tubes are to be cut out, a diamond point chisel does very well for cutting out this strip, but great care must be used to avoid cutting the tube sheet. After this strip has been removed, fold in the edges of the tube, as shown above, so as to loosen it in the tube sheet. After thus loosening the tube at each end, push or drive the tube out through the front tube sheet as far as possible, which will usually be very little. Now the hard work begins, as the scale adhering to the tube makes it difficult to withdraw it. Take a hitch around the projecting end, and with a block and tackle, or a chain block fastened to something rigid, pull on the tube, at the same time hammering on it and working it around with a pipe wrench or chain tongs. This will cut and hammer the scale off sufficiently to allow the tube to be drawn out through the hole in the sheet. While this is being done a helper should hold up the rear end by means of a rod passed through the back tube sheet, or by a rope sling from the inside of the boiler. Sometimes the scale is so thick and hard that it is simply impossible to remove the tube in this way. In this case it becomes necessary to cut out several good tubes, removing them through the manhole, in order that the defective one may be removed in the same way. Having removed the old tubes, remove all burrs and sharp edges from the tube holes and insert the tubes. As the holes are necessarily slightly larger than the tubes this is an easy matter, but care must be taken not to allow either end of the tube to drop, as this would dent or crush it where it passes through the tube sheet. Now carefully equalize the projection at each end and secure the tube in this position. This can be done either by driving in little wedges made by flattening nails or by turning over a couple of little lips on each end of the tube with a peen of a hammer. If the hole be more than 1/16 inch larger than the tube, cut strips of copper or soft sheet iron about 3/4 inch wide and just long enough to pass around the tube neatly, and use these to shim up the space. Now expand each tube just enough to hold in position. Then with the peen of a hammer bell out the ends, striking light blows and turning the metal back all around the circumference carefully so as not to crack it. This bead is then finished and set up tight against the tube sheet with the beading tool (fig. 4,152). The tubes are next given a final rolling to make them steam tight, being careful not to roll them too much.

Patching.—There are two kind of patches—*soft* and *hard*. A soft patch is a covering over a leak or defect which is fastened *with* ***bolts,*** as distinguished from a hard patch, which *is* ***riveted.**** Repairs which necessitate the putting on of a soft patch can sometimes be handled by the engineer with good results.

A soft patch is of no use when it must be located where the fire will reach it or intense heat will play against it, and where there is no opportunity for water to get at the other side of the patch. When it is required to close a hole or a crack located where the fire cannot burn the metal, then good results will be obtained from the use of a patch bolted on.



FIGS. 4,157 and 4,158.—A convenient method of repairing a cracked tube sheet. A patch, such as is shown at base of the cut, is shaped to fit neatly over the crack and between the tube ends. After smearing both surfaces with red lead, it is secured in place by tap bolts.

Ques. How is a soft patch put on so that no caulking is necessary?

Ans. It may be fitted as closely as possible by heating and forging. The holes may then be drilled and those in the shell

* NOTE.—The ***difference*** between a ***soft*** and a ***hard patch*** is a favorite question with examiners, hence the applicant for license should understand this thoroughly.

beneath the patch tapped, or drilled large, and through bolts used.

Tap bolts are preferable, for jamb nuts may be put on the bolts inside the shell and leakage through bolt holes prevented.

After the patch has been bedded and fitted, coat the inside of the patch and the outside of shell, where the patch is to come, with Portland cement mixed with sufficient water to make it into a paste which will spread, but which will not run when the sheet is turned upside down. Wet the metal before applying the cement paste, and make sure that the surfaces are clean and free from grease especially. When the patch is in place and the cement is between the surfaces, the bolts may be inserted and screwed down to within ⅛ inch or so of where they will be when fully screwed home. Then

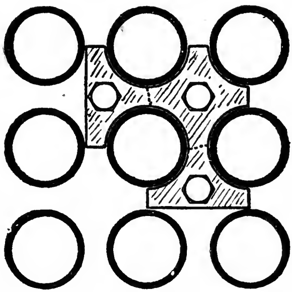
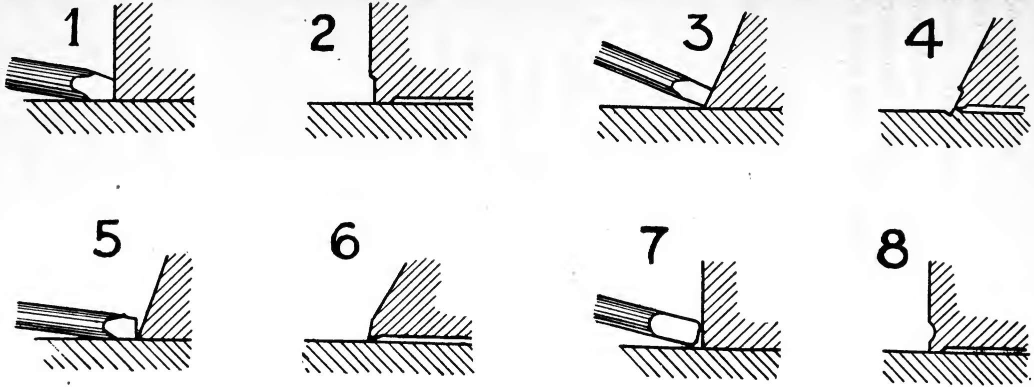


FIG. 4,159.—Extended "spectacle piece," or patch covering tube sheet cracks between three adjacent tubes. Such cracks are usually caused by allowing scale to collect on the sheet inside the boiler, or by frequent opening of the fire doors, when boiler has a heavy fire.

let the joint stand about one hour, depending on the cement used. It should stand until the cement just begins to set and not after. This may be determined by testing the protruding fringe of cement around the patch. Just as the cement begins to refuse to flow readily, screw the bolts tight, putting an even strain on each, and let the job stand ten hours—twenty-four hours if possible—but ten hours will do. The boiler may then be fired without any sign of leakage. The cement hardens as much in a few hours under steam heat and pressure as in twenty-eight days in the open air.

Ques. What is a spectacle piece?

Ans. A boiler patch, so called, used to repair a crack situated between the tube ends of a boiler.



FIGS. 4,160 and 4.161.—***Caulking.*** Opinions differ as to the proper shape of the caulking tool and proper shape of the plate edges to obtain the best results in caulking seams. **1,** shows the shape of the caulking tool and proper way to hold the tool when the edge of the plate is square; **2,** result of caulking a seam in this manner, giving fair results; **3,** shows same tool improperly held when the edge of the plate is bevelled; **4,** shows the bad result of caulking a seam in this manner; **5,** shows the proper way to hold this tool against the bevelled edge of the plate; **6,** result obtained after caulking—although the tool is held properly the result is not good; **7,** shows a better method, or proper way to hold a round nose caulking tool against a square edged plate; **8,** result after caulking. In caulking with this shape of tool, care must be taken that it is not too small, as it will then act as a wedge and separate the plates. Care must also be used in grinding the flat nosed tool; if the tool have too much bevel, the lower edge will bite into the lower plate.

The patch piece is machined out to encircle the tubes adjacent to the crack, or in other words, to be a duplicate of a portion of the tube plate cracked. These plates after being carefully fitted, are then screwed or riveted to the tube sheet so as to cover the crack, a layer of red lead and iron filings being spread under the patch.

Caulking.—Every engineer should have two or three caulking tools in his kit. To make a caulking tool in a hurry, select a very heavy cold chisel (one made from $\frac{7}{8}$-inch to 1-inch octagon steel is the best), and forge or grind the end off until it is about ¼-inch thick. Then round the end of the tool until it is a perfect half-circle ¼-inch in diametr and at least 1 inch wide. Place this tool against the slope of a rivet about 1/16-inch from the shell plate, and strike the tool with a hammer, keeping the tool inclined more or less parallel with the shell of the boiler.

CHAPTER 70

HOW TO SELECT A BOILER

The selection of a boiler is a matter requiring careful consideration of the many conditions of operation, such as:

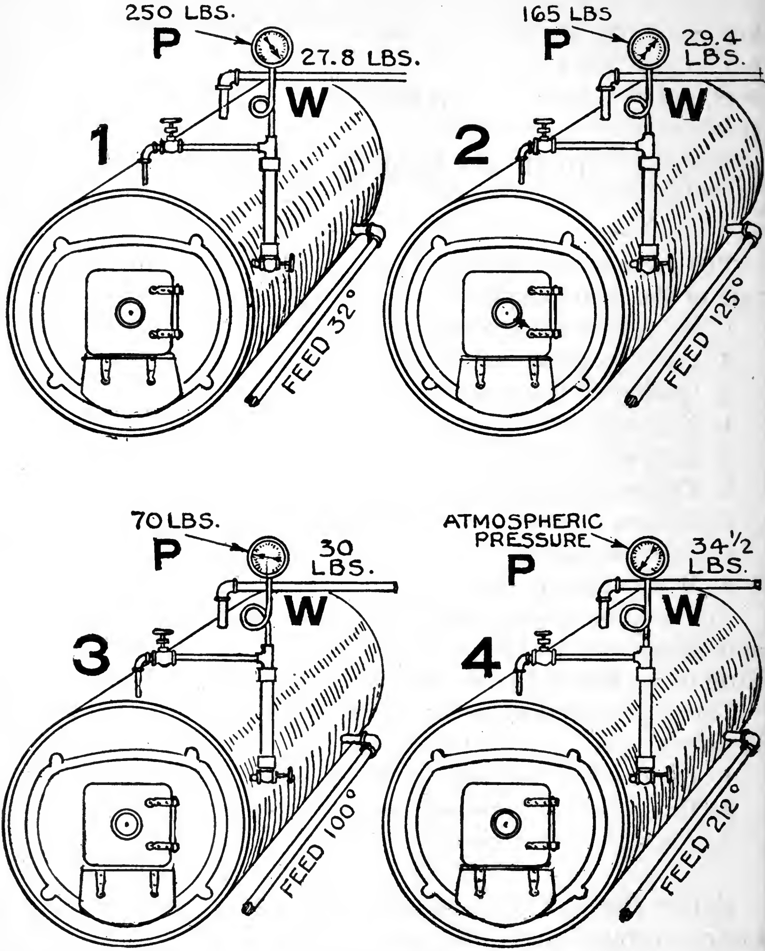
1. Total feed water consumption of the engine and auxiliaries.
2. Quality of the feed water.
3. Quality of the steam.
4. Nature of the fuel.
5. Rate of combustion.
6. Efficiency desired.
7. Nature of load, present and future.
8. Space available.
9. Workmanship, etc.

The solution of the problem, as must be evident, is complex, and should not be left, as is usually the case, to those having little or no knowledge of the requirements.

The experienced engineer, by a careful study of the several items just given, is able to determine:

1. Evaporative capacity or "horse power" of boiler.
2. Proportion of grate and heating surface.
3. Type of boiler best suited for the work.

Boiler Horse Power.—First of all it is necessary to have a clear understanding of the term "boiler horse power." There has been entirely too much criticism of this term. For instance, the following appears in the catalogue of a prominent builder of marine machinery:

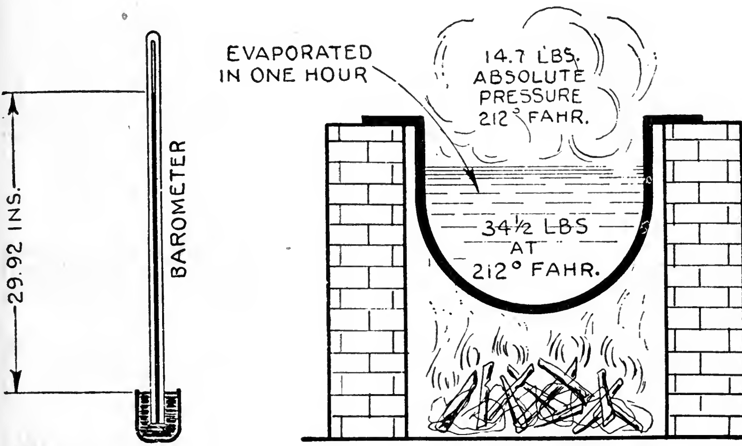


FIGS. 4,162 to 4,165.—All these boilers are developing ***one boiler horse power,*** that is to say: boiler 1 is delivering 27.8 lbs. (weight) of steam at 250 lbs. (pressure) evaporated from feed water at a temperature of 32° Fahr.; which is equivalent to boiler 2 evaporation of 29.4 lbs., from 125° at 165 lbs., equivalent to boiler 3 evaporation of 30 lbs., from 100° at 70 lbs., equivalent to boiler 4, evaporation of 34½ lbs. from and at 212°. In each case distinguish between lbs. pressure **P**, and lbs. weight **W**.

"We do not place a horse power rating on our boilers. The term as applied to marine boilers in particular, leaves room for serious misunderstanding, for it is the design, size and details of the engine that determines the power."

There is nothing the matter with the term as it is just as definite a unit as the pound, or gallon—it is the ignorance of the user that causes the confusion.

The design, size and details of the engine have nothing to do with the meaning of the term "boiler horse power," but the number of heat units



FIGS. 4,166 and 4,167.—***One boiler horse power.*** If sufficient heat be applied to the pot to evaporate 34½ pounds of water per hour having a temperature of 212° F. into steam of the same temperature, one *boiler horse power* is developed. The water and steam will have a temperature of 212° F. when the barometer reads 29.92 inches, corresponding to a pressure of 14.7 pounds absolute.

used by the engine *less* the number returned to the boiler in the feed water per hour determine how many boiler horse power is required. Builders, however, cannot be blamed because, as before stated, the selection of boilers is usually left to those having little or no knowledge of the requirements.

By definition one boiler horse power is the *evaporation of* 30 *pounds of water from an initial temperature of* 100° *Fahr. to steam* *at* 70 *pounds gauge pressure*, which (as accepted by the A. S. M. E. Power Plant Code Committee), is equivalent to 34.5 *pounds of water evaporated per hour from a feed water temperature of* 212° *into dry steam at the same temperature.**

Example.—A 250 horse power triple expansion marine engine requires 15 pounds of steam per hour per horse power at 165 pounds pressure. If the feed water be delivered to the boiler at 122° Fahr., how much boiler horse power is required, allowing 10 per cent. of the total steam for auxiliaries?

Steam required by engine	=250×15	=3,750 lbs.
Steam required by auxiliaries	=10 per cent. of 3,750 =	375 "
Total steam required per hour		=4,125 "

From the table of "factors of evaporation" (page 1,808), factor for evaporation at 165 pounds pressure for feed water at 122° by interpolation =1.145.

Equivalent evaporation from and at 212°=4,125×1.145=4,723, or

4,723÷34.5=137 boiler horse power

Example.—A 250 horse power tug engine requires 50 pounds of steam per horse power hour, at 70 pounds pressure. If the feed water be delivered at 100° Fahr., what boiler horse power is required, allowing 10 per cent. of the total steam for auxiliaries?

Steam required by engine	=250×50	=12,500 lbs.
Steam required by auxiliaries	=10 per cent. of 12,500 =	1,250 "
Total steam required per hour		=13,750 "

Since one boiler horse power=30 pounds evaporation from feed at 100° into steam of 70 pounds pressure,

Boiler capacity=13,750÷30=458 horse power

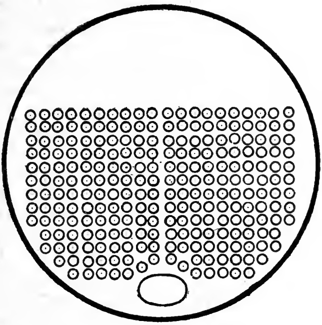
The two examples just given show that engines of the same horse power may require boilers of widely different capacities, hence, *engine horse power is no index of boiler horse power*.

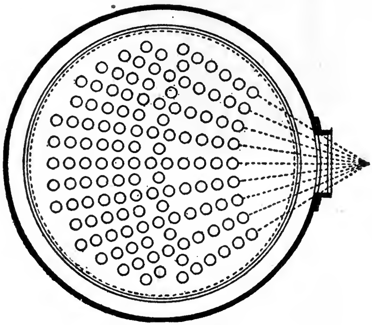
* NOTE.—Using the figures for total heat of steam given in Marks and Davis steam tables 34½ pounds from and at 212° is equivalent to 33,419 *B.t.u.* per hour, or to an evaporation of 30.018 pounds for 100° feed water temperature into steam at 70 pounds pressure.

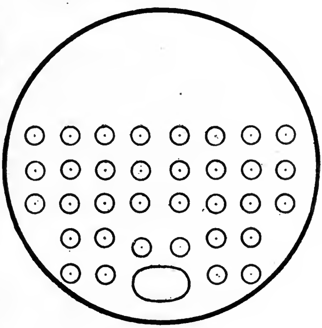
† NOTE.—The expression "from a feed water temperature of 212° into dry steam at the same temperature" is generally abbreviated to ***"from and at 212°."***

The items upon which the boiler horse power depends are:

1. Total steam required (in pounds per hour).
2. Pressure and temperature* of the steam.
3. Temperature of the feed water.

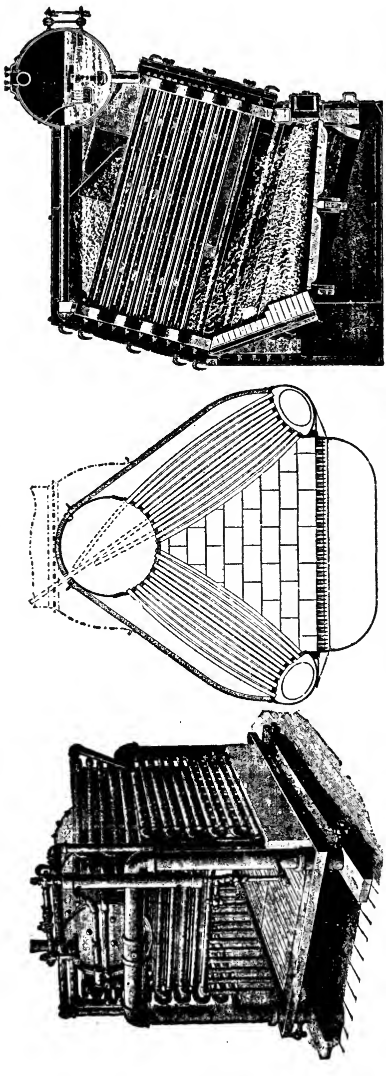






FIGS. 4,168 to 4,170.—Types of boilers in which the surfaces subject to scale and sediment deposit are ***inaccessible, semi-accessible,*** and ***accessible*** for cleaning. Fig. 4,168, ***inaccessible*** tube spacing of vertical boiler; fig. 4,169, ***semi-accessible,*** radial tube spacing of Reynolds vertical boiler; fig. 4,170, horizontal tubular boiler with lower manhole rendering bottom of shell ***accessible.***

* NOTE.—The two examples just given are for ***saturated steam,*** but it should be noted that where ***superheated steam*** is used, allowance must be made for the additional heat furnished per pound of steam.



FIGS. 4,171 to 4,173.—Various water tube boilers illustrating *inaccessible*, *semi-accessible* and *accessible* arrangement of tubes. Evidently the pipes in fig. 4,171 cannot be reached internally for cleaning; the tubes in fig. 4,172 are reached with some difficulty, especially in the small sizes, while those in fig. 4,173 are fully accessible.

Quality of the Feed Water.—As stated by Shealy:

"The waters of our lakes rivers, springs, and underground streams contain more or less mineral substances that have been dissolved by the water in its passage through the earth and also more or less dirt mud, and vegetable matter which have been taken up and carried along by the water. When water is evaporated in a boiler, all of these impurities are left behind and are usually deposited in solid form. In some cases these substances merely settle as a soft mud and can be blown off, but more often they form a hard scale on the heating surface, which is difficult to remove."

Since this scale is a very poor conductor of heat, its presence 1, reduces the efficiency of the boiler, and 2, by separating the plate from the water causes overheating of the metal which may be followed by serious consequences."

Accordingly, it must be evident that the quality of the feed water must be considered in determining what type of boiler to use.

For instance, where the feed water is bad, a vertical fire tube boiler with closely spaced tubes, as in fig. 4,168, rendering tube sheet *inaccessible* for cleaning would not be the proper type.

Provision has been made in the Reynolds vertical boiler so that the tube sheet is *semi-accessible* by the radial spacing of tubes as in fig. 4,169.

In the horizontal return tubular boiler the surfaces that are liable to be overheated because of scale and sediment are more easily reached in the return tubular boiler by providing man holes in the heads at the expense of a few tubes as shown in fig. 4,170; this renders all the surface *accessible*.

It is claimed by makers of water tube boilers having sections made up of pipes and return bends, or so called "coils," that although the interior of the section is inaccessible for cleaning, the rapid circulation prevents the formation of scale. Although the circulation may reduce the amount of scale that would otherwise be formed, such boilers are not to be recommended for scale forming, or muddy feed waters.

The parallel arrangement of tubes expanded into drums or headers, so that they are accessible for internal cleaning, is the kind to use for such feed waters where a water tube boiler is preferable to the fire tube type.

Figs. 4,171 to 4,172 show these types of water tube boiler, with inaccessible, semi-accessible, and accessible tube interiors.

Quality of the Steam.—According to the view of a good many engineers, "steam is steam;" however, there are several kinds of steam, and it is generally classified:

1. According to pressure, as:

   a. Low pressure (5 pounds to 50 pounds).
   b. Medium pressure (50 pounds to 150 pounds).
   c. High pressure (150 pounds to 300 pounds).
   d. Extra high pressure (300 pounds and above).

2. According to its state, as:

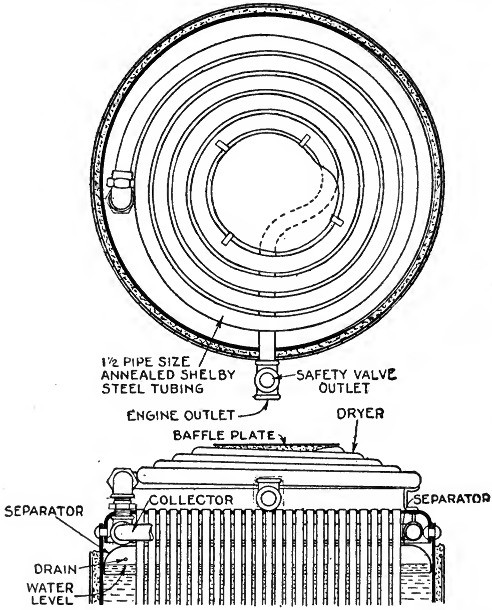
   a. Wet.
   b. Saturated.
   c. Superheated.

Accordingly, before deciding on the type and construction of the boiler, it is necessary to know what kind of steam is wanted.

On page 1,639 (vol. 4), the author shows the adaptation of the three kinds of steam.

For contractors' rough work, where a temporary installation is provided and fuel is cheap, it is not necessary to dry and superheat the steam, but where economy is aimed at, saturated or superheated steam should be used according to the degree of economy sought.

For saturated steam a boiler should be selected that has adequate liberating surface and should be provided with a dry pipe running the entire length of the liberating surface, as shown in figs. 4,174 and 4,175. A sepa-



FIGS. 4,174 and 4,175.—The author's method of securing dry or saturated steam from a vertical shell boiler. Fig. 4,174 shows plan of upper portion of boiler and fig. 4,175, elevation of same. ***Two troubles*** frequently encountered with vertical boilers are: 1, burnt tubes and 2, poor efficiency of the tubular heating surface not in contact with the water. The first objection is in fact due to faulty operation. Vertical boilers with through tubes should be filled to the top in getting up steam, then blown down to a *proper* water level. As a rule water is carried too low in this type of boiler, which together with the practice of raising steam without filling the boiler to top as mentioned is the cause of trouble with the tubes. The ***collector*** or so called dry pipe takes steam through small holes distributed along its length, which encircle the tubes thus avoiding any disturbance of the water level. The steam then passes out through the external dryer where any moisture entering with the steam into the collector is re-evaporated.

should also be provided at the engine to catch any condensate in the steam when it reaches the engine.

Of course, superheated steam requires a boiler with a superheater.

Nature of the Fuel.—Upon the kind and quality of the fuel to be used will depend the type of furnace most suitable for proper combustion. Thus a furnace suitable for burning high grade coal will be quite different than one suitable for burning shavings, dry and wet saw dust, bagasse and other refuse fuels.

Furnaces for burning these refuse fuels are of the "Dutch oven" pattern, equipped with special grates and air ducts for the admission and distribution of the proper amount of air for thorough and complete combustion.

The saw dust from mill saws is very fine, and when coming from certain kinds of timber, such as hemlock and elm, is very difficult to burn; the mills using tubular boilers, set in the ordinary way, have to air dry slabs from the logs and then use in large quantities to help burn the saw dust, even then experiencing the greatest difficulty. With the Dutch oven setting the saw dust is burned completely, without difficulty, without the use of slabs.

Upon the heating value of the fuel and efficiency of the boiler will depend the amount necessary to burn in a given time to generate the required amount of steam.

Example.—If the heating value of a certain coal and efficiency of boiler be such as to give an evaporation of 8 to 1, from and at 212° Fahr., how many pounds of coal are required per hour for an evaporation of 500 pounds of steam at 80 pounds per hour with feed water at 100° Fahr.

Factor of evaporation for 80 pounds pressure and 110° feed water is (from table), 1.1412.

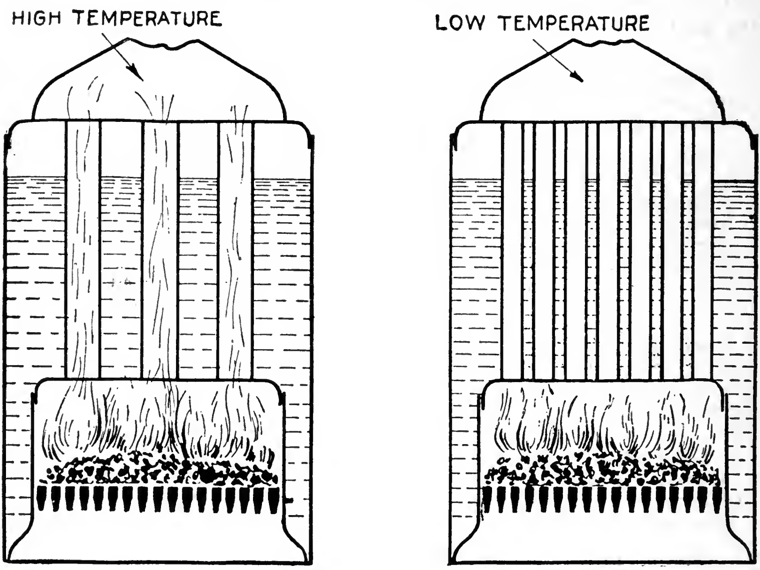
Equivalent evaporation at 80 pounds and 110° = 8 ÷ 11-14 = 6.99.

Coal required = 500 ÷ 6.99 = 71.4 pounds per hour

Rate of Combustion.—Having determined the quantity of a given coal necessary to burn per hour to generate the required amount of steam as in the example just given, the size of grate will depend on the rate of combustion, which is governed by the intensity of the draught. Thus, for locomotives from 80 to 125 pounds of coal are ordinarily burned per square foot of grate per hour, whereas in some stationary boilers the combustion rate is only from 11 to 15 pounds per square foot per hour.

Example.—What size grate is required for the boiler of the preceding example if the rate of combustion be 15 pounds of coal per square foot of grate per hour?

Size of grate = 71.3 ÷ 15 = 4.75 sq. ft.



FIGS. 4,176 and 4,177.—Wasteful and efficient vertical shell boilers. A few short tubes of large size as in fig. 4,176 results in high stack temperature and poor economy. This represents the usual cheap construction which has given this boiler a bad reputation among users, not only in regard to economy, but with respect to burnt tubes also. Fig. 4,177 shows the remedy for these defects, the heating surface being composed of a large number of small tubes instead of a few large tubes. ***With this arrangement*** the hot gases are sufficiently cooled on reaching the water level to give high efficiency and avoid burning the tubes. This principle has been employed commercially in the Manning boiler and other boilers imitating the Manning design.

Example.—A locomotive when developing 1,000 horse power, requires 30 pounds of steam per horse power hour at 175 pounds pressure, feed water 70° Fahr. What size grate is required if the evaporation be 7 to 1, and rate of combustion be 125 pounds of coal per square foot per hour?

Total feed water $=1,000 \times 30 = 30,000$ lbs. per hour.

Factor of evaporation (from table), for 175 lbs. and $70° = 1.1936$.

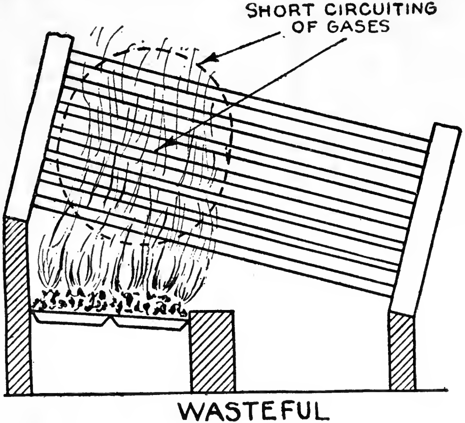
Equivalent evaporation from and at 212° is

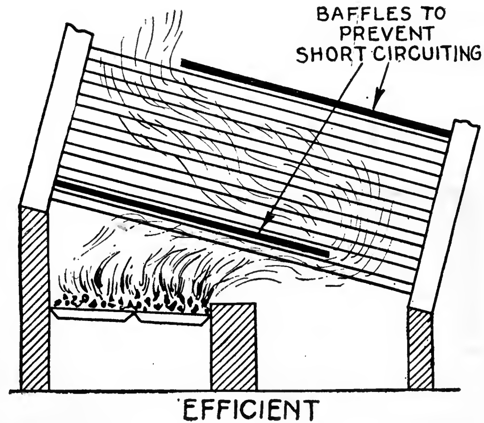
$$30,000 \times 1.1936 = 35,808 \text{ lbs.}$$

Coal per hour $= 35,808 \div 7 = 5,115$ lbs.

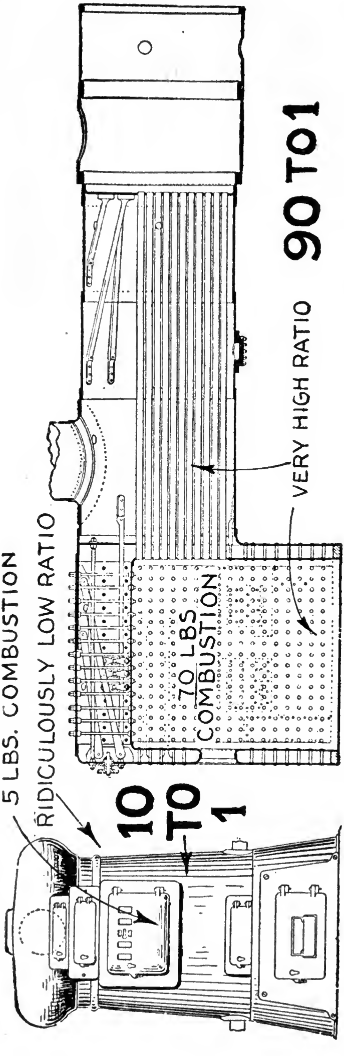
Size of grate $= 5,115 \div 125 = 40.9$ sq. ft.

Efficiency.—This will depend principally upon the relation between ratio of grate area and heating surface, and rate of





FIGS. 4,178 and 4,179.—Wasteful and efficient water tube boilers. In fig. 4,178, there being no provision for guiding the hot gases, they naturally take the shortest path, then a large portion of the heating surface is rendered inefficient. By providing guides or ***baffles*** as in fig. 4,179, the gases must traverse practically all the heating surface resulting in high efficiency. Each run is called a ***pass***, fig. 4,179 being what is called a two pass boiler. ***In practice*** frequently three and four passes are provided, especially in water tube boilers.



FIGS. 4,180 and 4,181.—Two extremes in heating surface ratios due to widely different rates of combustion. House heating boilers (fig. 4,180) as usually constructed have the ridiculously low ratio of only 10 or 12 square feet of heating surface to 1 square foot of grate. Even with the very low rate of combustion of 5 pounds of coal per hour per square foot of grate, more heating surface should be provided. Fig. 4,181 shows the large amount of heating surface necessary for economy with the high combustion rate employed in locomotive boilers.

combustion; also in a lesser degree upon numerous other items, such as arrangement of the heating surface, baffles, etc.

It must be evident that the higher the rate of combustion, the greater the amount of heating surface that must be provided per sq. ft. of grate to absorb the heat, otherwise more heat will be lost through the stack at the expense of the efficiency.

The efficiency of a boiler, as stated by Kent, is *the percentage of the total heat generated by the combustion of the fuel which is utilized in heating water and in raising steam.*

With anthracite coal the heating value of the combustible portion is very nearly 14,800 *B.t.u.* per pound, equal to an evaporation from and at 212°, of $14,800 \div 970.4 = 15.26$ pounds of water.

A boiler which when tested with anthracite coal shows an evaporation of 12 pounds of water per pound of combustible, has an efficiency of

$$12 \div 15.26 = 78.6 \text{ per cent.}$$

a figure which is approximated, but scarcely ever reached in practice.

The difference between the efficiency obtained by test and 100 per cent. is the sum of the numerous wastes of heat, *the* **chief** *of which is the necessary loss due to the temperature of the chimney gases.*

Conditions for high economy are:

1, High temperature approaching 3,000° Fahr. in the furnace, and,
2, Low temperature below 600° in the stack.

For satisfactory results the heating surface to grate ratio should not be less than 30 to 1 when the combustion rate is 12 pounds per square foot of grate per hour; for high combustion rates the ratio should be 50 to 1 and over.

Where economy may be secondary to capacity, as where fuel is very cheap, it is customary to proportion the heating surface much less liberally.

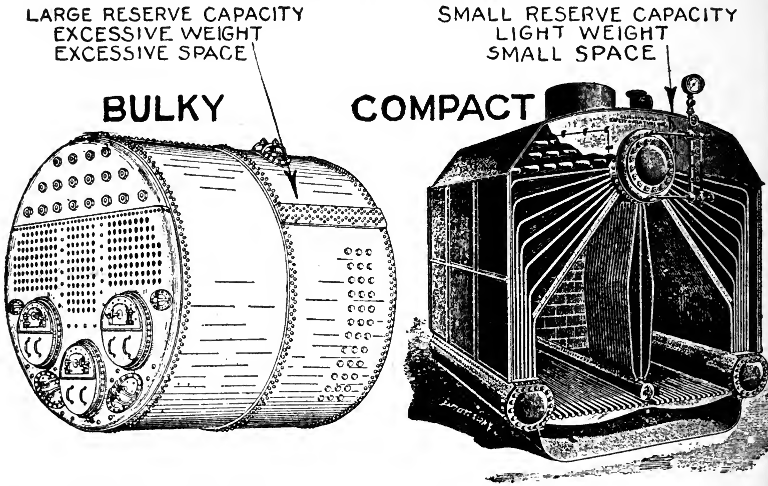
According to Kent the relative results that may be expected with different rates of evaporation, with anthracite coal are as follows:

Pounds of water evaporated from and at 212° per square foot of heating surface per hour:										
2	2.5	3	3.5	4	5	6	7	8	9	10
Square feet of heating surface required per horse power:										
17.3	13.8	11.5	9.8	8.6	6.8	5.8	4.9	4.3	3.8	3.5
Heating surface to grate ratio if ⅓ square foot of grate surface be required per horse power:										
52	41.4	34.5	29.4	25.8	20.4	17.4	13.7	12.9	11.4	10.5
Probable relative economy:										
100	100	100	95	90	85	80	75	70	65	60
Probable temperature (degrees Fahr.), of chimney gases:										
450	450	450	518	585	652	720	787	855	922	990

Nature of the Load.—In determining the boiler capacity to be provided, a careful study of the nature of the load, present and future, is necessary. The load may be:

1. Continuous.
2. Intermittent.
3. Uniform.
4. Variable.
5. Gradually increasing.

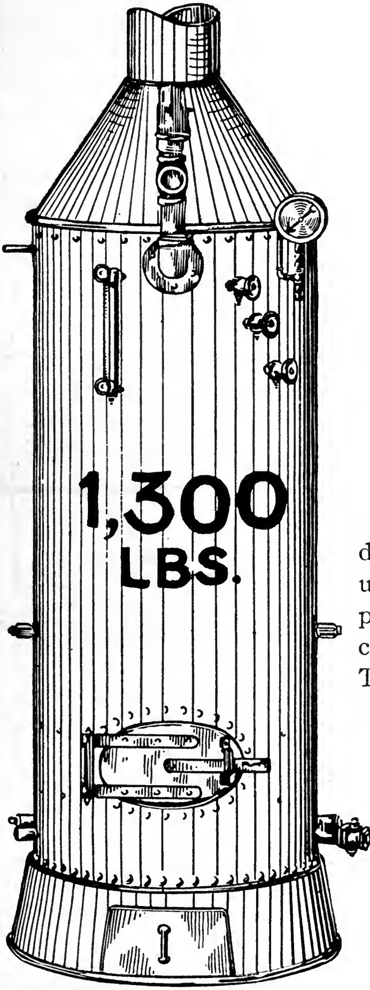
Where a plant must operate continuously, a spare boiler is necessary to permit cleaning and repairs. Although for intermittent operation, a spare boiler is not necessary, however it is sometimes provided as a



FIGS. 4,182 and 4,183.—Two widely different types of boiler, the choice between the two depending upon the nature of the load. Thus for a ferry boat or lighter where the demand for steam is intermittent, and sometimes without notice, a Scotch boiler (fig. 4,182) with its large reserve power would be suitable, but for a vessel making regular and extended trips, especially at high speed, a water tube boiler should be used because this type gives the greatest power per pound weight. As an example of wrong selection of these two types of boiler, a high speed passenger boat making regular trips on a 20-mile run was originally fitted with Scotch boilers. The boat could not make the required schedule time because of their bulkiness. Sufficient boiler capacity could not be placed in the space available, and their excessive weight so increased the draught that additional power was necessary to overcome the added resistance. These boilers were replaced by water tube boilers of considerably greater capacity, and although of a heavy type, the draught was reduced 9 inches and the speed increased to the desired rate.

safeguard against shut down. Where the load is uniform the problem of boiler capacity is simple, but for variable load it is often quite complex.

For variable load it is necessary to determine what is called the **load factor,** or ratio of the average load to the maximum load during a certain period



of time as a day, month or year. Station economizers depend on load factors and high load factors are uncommon except in metallurgical plants. Railway plants give very valuable load factors.

A station with a high load factor should have few and large boilers, and for low load factor a larger number of small boilers should be provided.

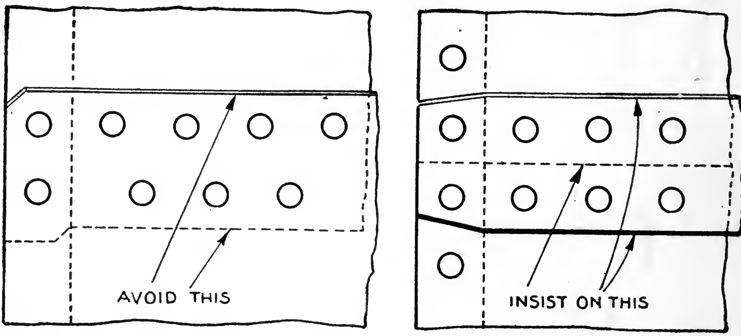
Nearly all plants begin with a small load, which gradually increases from year to year as the plant grows, accordingly in designing the boiler house this should be taken into account, and room should be provided either in the house or for an extension, so that additional boilers may be installed when necessary to meet the increase in load.

Space Available.—This often dictates the style of boiler to be used, and frequently it is a problem to get the required boiler capacity within the given space. The locomotive boiler is an

Figs. 4,184 and 4,185.—Two boilers of the same power with widely different space requirements. Fig. 4,184, ordinary vertical shell boiler; fig. 4,185, Stanley automobile shell boiler, as described in the accompanying text. Scale of the illustration: 1 inch = 1 foot.

example of a large power unit within a restricted space. Such boilers have well defined limits as to width and height, resulting in a long boiler worked at very high rate of combustion, the latter condition, making it necessary to employ a high heating surface-grate ratio to secure proper efficiency.

Some types of water tube boiler are built with very low center of gravity to adapt them to the limited head room in office buildings.



FIGS. 4,186 and 4,187.—***What to look at, 1:*** For moderate and high pressures avoid lap longitudinal joints (fig. 4,186), and insist upon butt and double strap longitudinal joints (fig. 4,187), made in accordance with the ***A. S. M. E. Boiler Code*** requirements.

The most extreme examples of power concentrated within a small space are the shell and flash boiler used in steam automobiles.

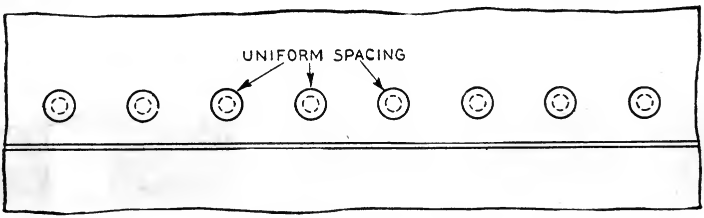
For instance, in the Stanley 14-inch shell boiler there are 309 tubes 13 inches long and 33/64 outside diameter, giving 45 square feet of heating surface, weight 112 pounds. To appreciate the compactness of this boiler it should be compared with the ordinary stationary boiler of same capacity, where proportions are: diameter, 24 inches; height, 4 feet; 28 tubes 2 inches by 24 inches; square feet of heating surface, 44; weight, 1,300 pounds.

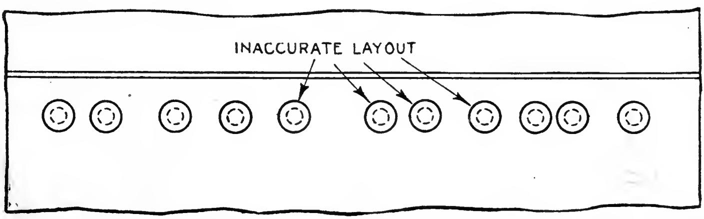
Workmanship.—Many buyers when about to purchase a boiler, visit the boiler shop of the maker and examine the boiler.

Or if they purchase from a dealer, they visit the dealer's warehouse and look the boiler over.

The boiler offered generally presents a pleasing appearance to the eye, being nicely painted with a thick coating of black paint.

The cylindrical surface and the heads look smooth. The rivets *neatly* spaced. The boiler maker or dealer, irrespective of the class of work he is building or offering, is familiar from long





FIGS. 4,188 and 4,189.—***What to look at, 2:*** The spacing of the rivets. Irregular spacing as in fig. 4,189, indicates poor workmanship.

experience with the usual verdict, which is, "the boiler looks fine, the workmanship is good." The author concedes the boiler will look "fine." The paint is largely responsible for that, but is the workmanship good? Can the average buyer express an accurate opinion as to the workmanship used in the construction of a boiler merely by external inspection? This is difficult but not impossible, provided the buyer knows just what to look at.

WHAT TO LOOK AT

1. Any boiler, 48 inches diameter and larger, which must withstand a working steam pressure up to and including 125 pounds, should have triple riveted butt joints with double covers on all longitudinal seams. For 150 pounds pressure, the butt joints should be quadruple riveted. ***Avoid lap joints on longitudinal seams.***

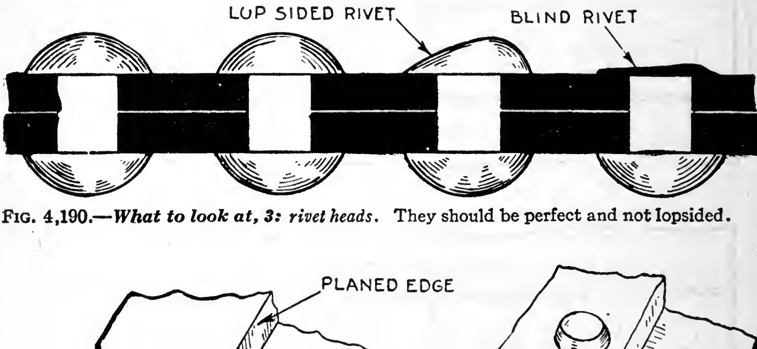
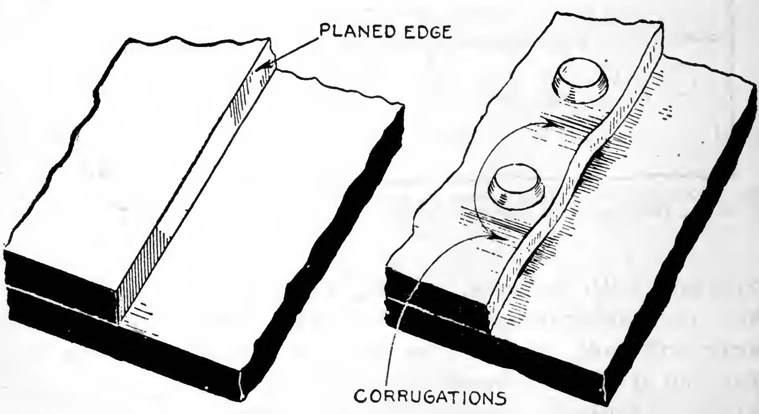


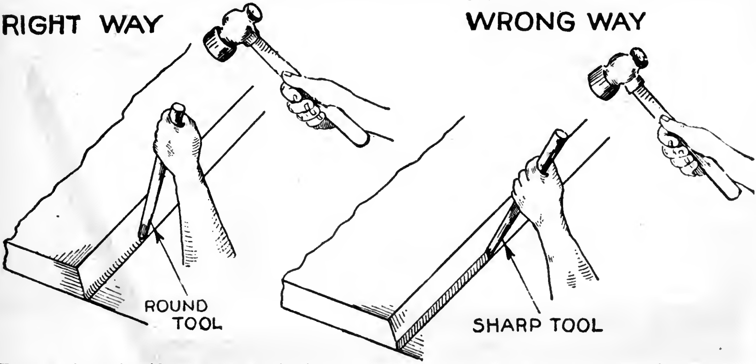
FIG. 4,190.—***What to look at, 3: rivet heads.*** They should be perfect and not lopsided.



FIGS. 4,191 and 4,192.—***What to look at, 4:*** *plate edges and condition between rivets.* The edges should be planed, and not show any bulges or corrugations between rivets.

2. Measure and compare the distance between centers of the rivets, in both longitudinal and circular seams, in a number of different places. This will be an indication of the accuracy used in spacing the rivet holes and driving rivets.

3. Examine the rivet heads. They should be button type, uniform, full, true, with heads accurately centered. If irregular or lop sided, it is logical to deduce they were hurriedly and carelessly driven. Also look particularly for blind rivets put in to plug holes carelessly punched out of line.



FIGS. 4,193 and 4,194.—***What to lool at, 5:*** *Caulking with wrong kind of tool.* No caulking should be done with a sharp tool, as in fig. 4,194.

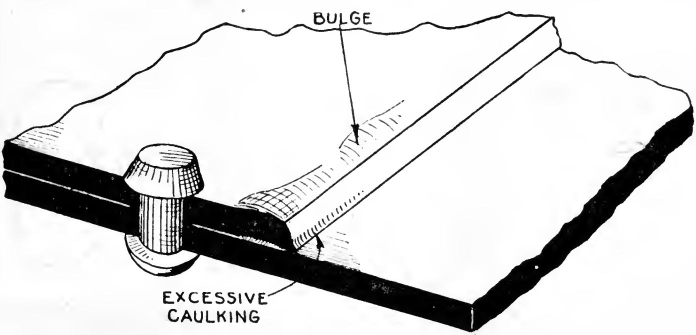


FIG. 4,195.—***What to look at, 6:*** *Excessive caulking.* Too much pressure brought on the plate edge will cause it to bulge between the edge and rivet leaving no contact except at the edge to form a tight joint.

4. Examine the edge of each sheet to determine if each has been planed. Also for corrugations, caused by squeezing and distorting the plate, on account of using excess pressure in riveting.

5. Examine the caulking of each seam to determine if done with a round nose tool. No *caulking done with a sharp tool should be accepted.*

6. Examine the plate between rivet holes for bulges, indicating excessive caulking, which shows that the plate was not up in place during the operation of caulking.

7. Hammer marks on the edge of the plates indicate careless workmanship.

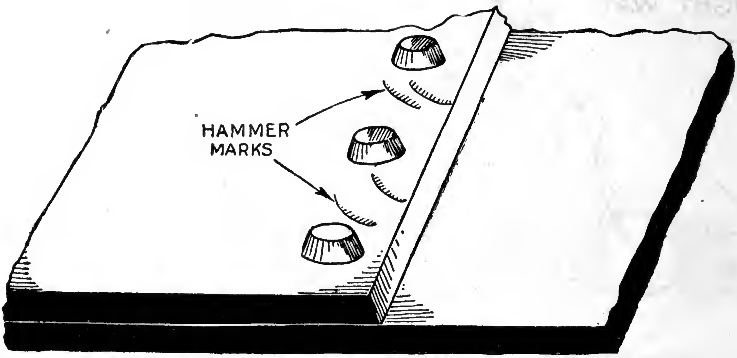


FIG. 4,196.—***What to look at, 7: hammer marks;*** indication of poor workmanship.

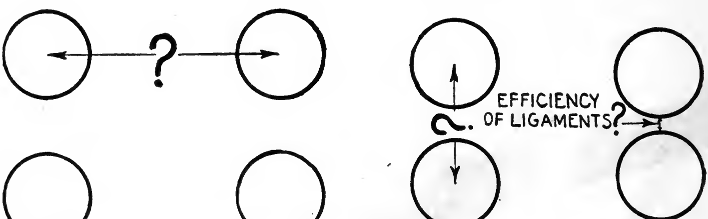


FIG. 4,197.—***What to look at, 8:*** *tube spacing.* Note thickness of tube plate and calculate efficiency of ligaments. See ***A. S. M. E. Boiler Code,*** page 46, par. 192.

8. Examine the spacing of the tubes and compare with the spacing requirements of the ***A.S.M.E. Boiler Code.*** Measure the distance from center to center of a number of the tubes. Here is an indication of the character of the design and the accuracy of the laying out.

9. The beading at all of the tube ends should be carefully examined. *The beading should be* **"full"** *and* **smooth.**

10. The beading of all of the tube ends should also be carefully examined for **cracks,** which indicate the metal is too brittle.

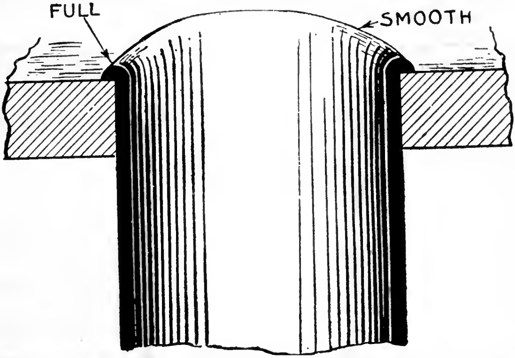


FIG. 4,198.—***What to look at, 9:*** *the beading.* It should be full and smooth.

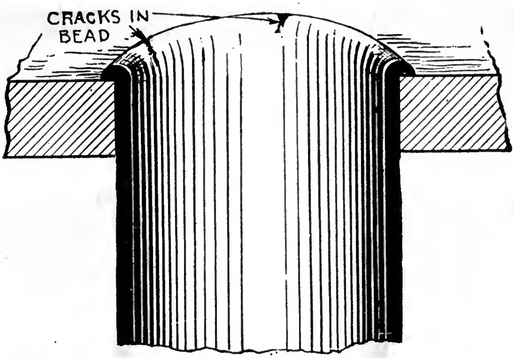
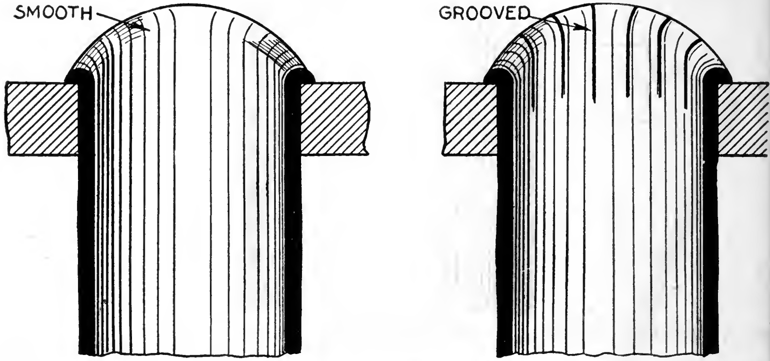


FIG. 4,199.—***What to look at, 10:*** *the beading.* There should be no cracks in the beading, for if the tubes be of good quality and the beading has been correctly done, the tube ends will not be injured.

11. The buyer should ascertain if the **insides of the tubes** be perfectly smooth and **without grooves** at the inside of each tube sheet, which indicates that **a roller expander** has been used for expanding the tubes *and* **not** *a Prosser expander.*

12. The plate immediately surrounding the tube ends should be carefully examined. Excessive rolling will be indicated by enlargement of the tube holes.

13. Lay a straight edge on the tube sheets, which will indicate if the heads have been thoroughly straightened and annealed after flanging, or not drawn out of line by tubes or braces.



FIGS. 4,200 and 4,201.—***What to look at, 11:*** *the tube ends*, to determine by their appearance whether a roller or Prosser expander was used. Fig. 4,200, expanded by roller expander, fig. 4,201 by Prosser expander.

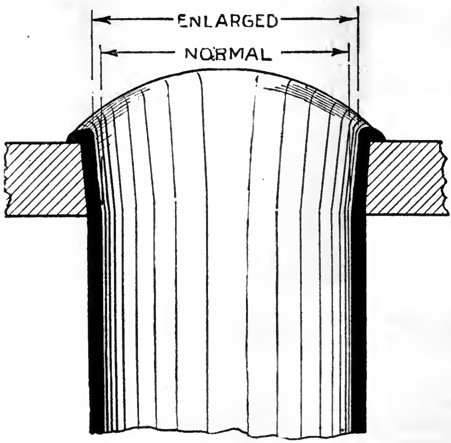


FIG. 4,202.—***What to look at, 12:*** *the tube ends*. They should be practically straight and not flared, as the latter indicates excessive expanding.

14. Examine the spacing of the rivets which connect the braces to the heads and compare with the spacing recommended by the *A.S.M.E. Boiler Code*.

15. Examine if lugs which support boiler be made of cast iron. They should be of pressed steel.

16. Ascertain if all flanges and nozzles be made of wrought material,

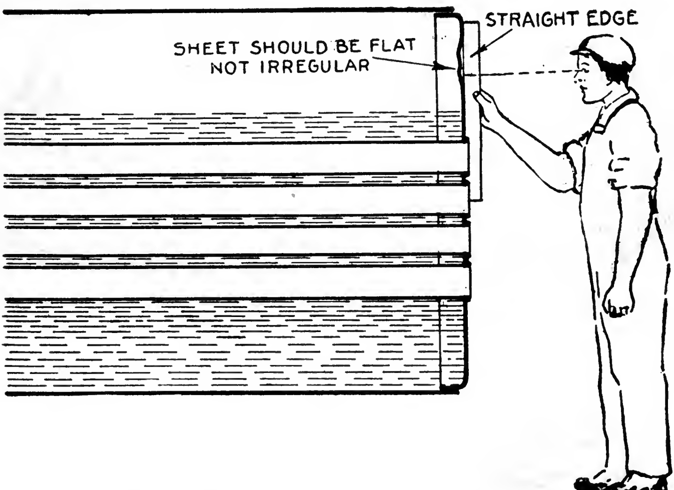


FIG. 4,203.—***What to look at, 13:*** *the tube sheets.* They should be flat and not show any irregular surfaces.

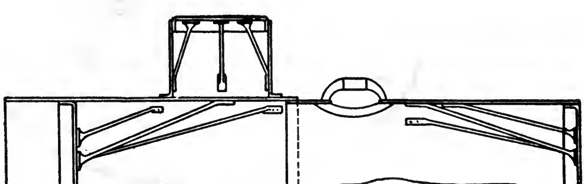
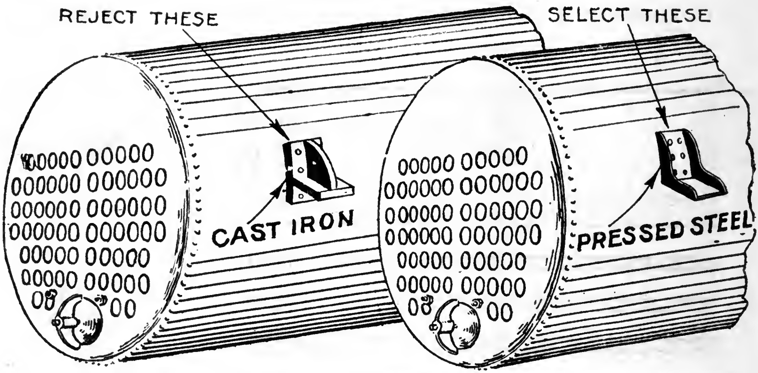


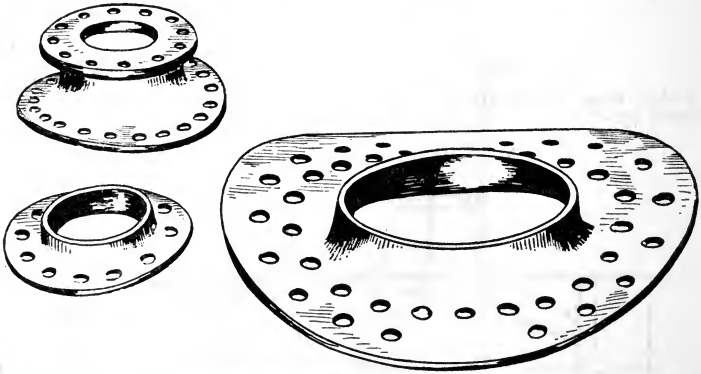
FIG. 4,204.—***What to look at, 14:*** *the braces.* These should be in accordance with the requirements of the *A.S.M.E. Boiler Code.*

instead of cast iron. Examine the caulking. *The plate is often carelessly cut while caulking flanges and nozzles*. Look for the mill stamps on the plates.

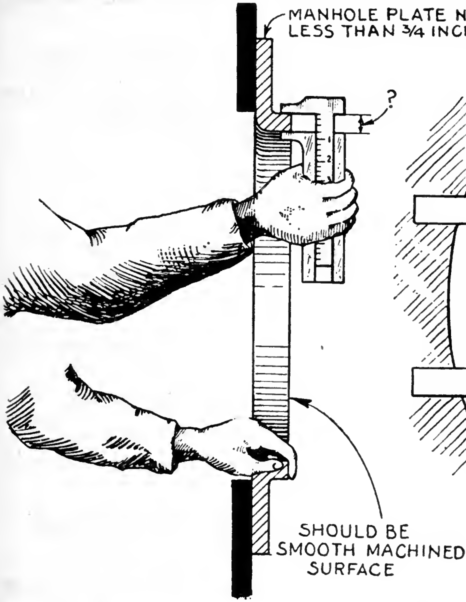
17. **Insist** *on having a man hole cover removed*, then examine the seat of



Figs. 4,205 and 4,206.—***What to look at, 15: the lugs.*** Pressed steel for these parts represents the most up to date practice. Cast iron lugs indicate that the shop is not fully equipped with modern tools.



Figs. 4,207 to 4,209.—***What to look at, 16:*** *nozzles and flanges.* These, as in the case of the lugs, should be of pressed steel.



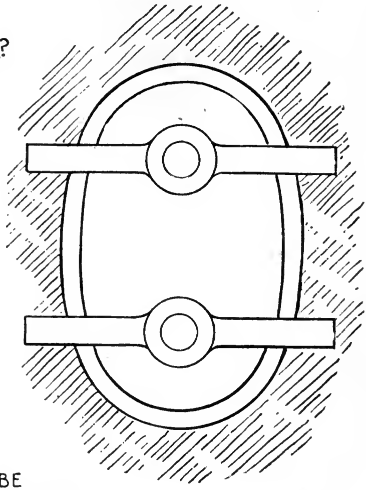


FIG. 4,210.—***What to look at, 17:*** *the man hole.* Note thickness of cover seat and condition ot surface.

FIG. 4,211.—***What to look at, 18:*** *man hole cover and crabs;* should be of pressed steel.

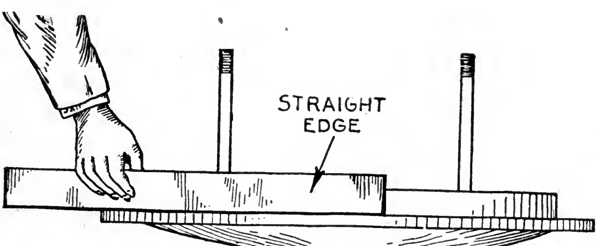


FIG. 4,212.—***What to look at, 19:*** ***man hole cover joint surface.*** Test with straight edge, as evidently if the surface be not true there will be difficulty in obtaining a tight joint.

the gasket of the man hole cover, which should be properly machine faced and not less than ¾ of an inch wide.

18. Man hole cover and crabs should be flange steel, pressed in shape.

19. The surface of the man hole cover which comes in contact with the gasket should be perfectly true when tested with a straight edge.

CHAPTER 71

HOW TO DESIGN A BOILER

This chapter may be regarded as virtually a continuation of Chapter 52, in vol. 4, on "How to Design an Engine," for having designed the engine, the next problem is to design a boiler suitable for supplying it with steam. Boiler design involves:

1. Selection of type.
2. Porportion or parts.

The requirements for the boiler under consideration are stated in the example which follows:

Example.—Design a boiler for the engine of Chapter 52, vol. 4, to operate under the following conditions: Working pressure, 100 pounds saturated steam; feed water temperature 100° Fahr.; engine, 30 horse power, requiring 20 pounds of feed water per horse power per hour; evaporation, 8 to 1; combustion rate, 12 pounds coal per hour per square foot of grate; grate-heating surface ratio proportioned for quick raising of steam and high overload capacity without material economic loss.

Type of Boiler.—A special design of vertical shell boiler will be found well adapted to the requirements, as it takes up little room fore and aft, its center of gravity is within limits, and the weight will not exceed that desirable for a boat of the character for which the engine is intended.

Steam Required.—The factor of evaporation for steam at 100 pounds pressure from feed water at 100° Fahr., is (from table), 1.1555, hence

Total steam per hour = 30×20 = 600 lbs. per hour,

Equivalent evaporation = 600×1.1555 = 693 lbs. "from and at 212° Fahr."

Coal required.—The rate of evaporation is given as 8 pounds of steam per lb. of coal, accordingly

Total coal per hour = 693 ÷ 8 = 86.6 lbs.

Size of Grate.—This depends on the rate of combustion and amount of coal to be burned per hour. For normal operation, the combustion rate is 12 lbs. of coal per sq. ft. of grate per hour, from which

Area of grate = 86.6 ÷ 12 = 7.22 sq. ft. = 7.22×144 = 1,040 sq. ins.

$$\text{Diameter of grate} = \sqrt{\frac{\text{area}}{.7854}} = \sqrt{\frac{1{,}040}{.7854}} = 36.4 \text{ ins., say } 36 \text{ ins.}$$

Diameter of Shell.—For a vertical boiler the shell must be of such diameter as to enclose the furnace with proper margin for the surrounding water leg. Now, diameter of furnace equals diameter of grate, hence,

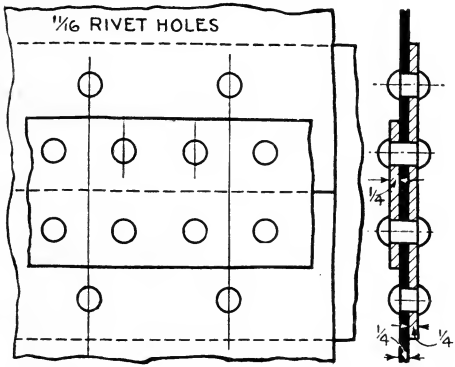
inside diam. of shell = diam. grate + 2 (width water leg + thickness sheet) . . . . (1)

For a small boiler, 2 inches will be ample for width of water leg plus thickness of furnace sheet, then substituting in (1).

Inside diameter of shell = 36 + 2×2 = 40 inches.

Thickness of Shell.—In determining the thickness of shell, both the efficiency of the riveted joint, and the efficiency of the ligament, between the tube holes must be considered substituting in the formula for thickness of shell, whichever be the weaker (joint or ligament), because a boiler, like a chain, is no stronger than its weakest member.

Evidently, for good design, the ligament should at least be as strong as the joint, and in designing, the tube sheets will be designed so that this condition will obtain. Since the strength of the riveted joint is always *less* than the strength of the shell plate, the type of joint to be used must first be decided upon.



Now, according to the ***A.S.M.E. Boiler Code:***

187. *Longitudinal Joints.* The longitudinal joints of a shell or drum which exceeds 36 inches in diameter shall be of butt and double strap construction.

FIGS. 4,213 and 4,214.—Butt and double strap double riveted longitudinal joint with given and selected items for calculating the thickness of shell.

This partly decides the matter, a choice being left of several forms of butt and double strap joints. Of these, the *double riveted butt and double strap joint*, as shown in figs. 4,213 and 4,214, is the simplest, and answers the requirements.

To obtain the exact value for the efficiency of the joint, the thickness of shell must be known, hence a preliminary calculation must be made with assumed values for thickness of shell and efficiency of joint, also the tensile strength of the boiler plate.

NOTE.—***In designing a boiler*** for a given set of conditions, the grate surface should be made as liberal as possible, say sufficient for a rate of combustion of 10 lbs. per square foot of grate for anthracite, and 15 lbs. per square foot for bituminous coal, and in practice a portion of the grate surface may be bricked over if it be found that the draught, fuel, or other conditions render it advisable. In earlier times, when plain cylinder and two flue boilers were in common use, it was customary to have a ratio of say 1 to 20, or 1 to 25, of grate heating surface. With very slow rates of combustion these proportions gave a fair degree of economy, but as boilers were driven faster, the economy fell off, and the loss of heat in the chimney gases became excessive. This was corrected by the introduction of horizontal tubular boilers, in which the grate surface remaining the same, the extent of heating surface was increased until the ratio of grate to heating surface became 1 to 30. When water tube boilers came largely into use it was found that the highest economy could be obtained with a ratio of 1 to 40 or 1 to 50. In recent years it has become quite common to pile up heating surface on a given area of grate, so that ratios of 1 to 60 are not infrequent

The experienced designer knows approximately the required values before making the calculation, and accordingly trial values of ¼ inch for thickness of shell and .8 for efficiency of joint will be taken.

Now, according to the ***A.S.M.E. Boiler Code:***

17. *Thickness of Plates.* The minimum thickness of any boiler plate under pressure shall be ¼ inch.

The trial value is therefore not beyond the limit of approved practice.

Again, according to the ***A.S.M.E. Boiler Code:***

14. *Tensile Strength of Steel Plate.*—The tensile strength used in the computations for steel plates shall be that stamped on the plates as herein provided, which is the minimum of the stipulated range, or 55,000 pounds per square inch for all steel plates, except for special grades having a lower tensile strength.

Using plate of 55,000 pounds tensile strength, and assuming the ligament to be as strong as the joint,

$$\text{maximum pressure} = \frac{\text{tensile strength} \times \text{thickness of plate} \times \text{eff. of joint}}{\text{inside radius of shell} \times \text{factor of safety.}} \quad (2)$$

Substituting the above values, and adopting a factor of safety of 5 as prescribed in the ***A.S.M.E. Boiler Code*** (section 180):

$$\text{Maximum pressure} = \frac{55{,}000 \times \frac{1}{4} \times .8}{20 \times 5} = 110 \text{ lbs. per sq. in.}$$

The next step is to find the exact value for efficiency of joint, using the following data from the ***A.S.M.E. Boiler Code:***

19. Minimum thickness of butt straps for ¼-inch shell plate in ¼-inch.

16. *Strength of Rivets in Shear.*—In computing the ultimate strength of rivets in shear, the following values in pounds per square inch of the cross sectioned area of the rivet shank (after driving) shall be used: steel rivets in single shear, 44,000; in double shear, 88,000.

15. *Crushing Strength of Steel Plate.*—The resistance to crushing of steel plate shall be taken at 95,000 pounds per square inch of cross section.

The joint is calculated according to section 413 of the ***A.S.M.E. Boiler Code,*** which is fully explained in Chapter 68.

Data

From Code

TS = 55,000 pounds per square inch

t = ¼ inch = .25 inch

b = ¼ inch = .25 inch

P = 4 inches

s = 44,000 pounds per square inch

S = 88,000 pounds per square inch

c = 95,000 pounds per square inch

n = 1

N = 2

Selected

P = 4 inches

d = 11⁄16 inch = .6875 inch

a = .37122 inch

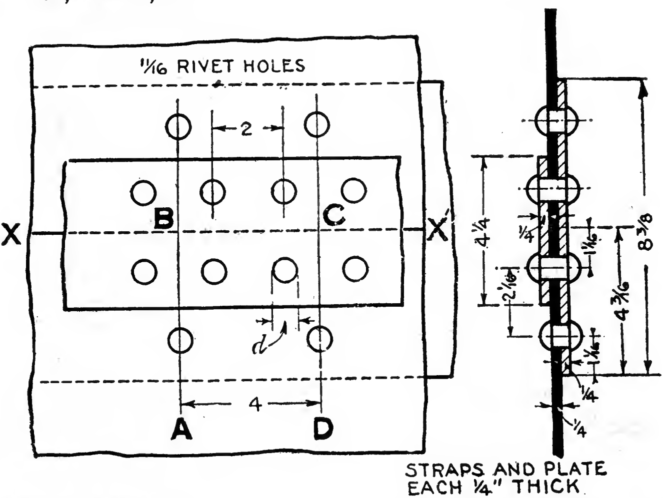
$A = P \times t \times TS = 4 \times .25 \times 55{,}000 = 55{,}000.$

$B = (P - d)t \times TS(4 - .6875).25 \times 55{,}000 = 45{,}547.$

$C = N \times S \times a + n \times s \times a = 2 \times 88{,}000 \times .37122 + 1 \times 44{,}000 \times .37122 = 81{,}668.$

$D = (P - 2d)t \times TS + n \times s \times a = (4 - 2 \times .6875).25 \times 55{,}000 + 1 \times 44{,}000 \times .37122 = 52{,}257.$

$E = (P - 2d)t \times TS + d \times b \times c = (4 - 2 \times .6875).25 \times 55{,}000 + .6875 \times .25 \times 95{,}000 = 52{,}353.$



IGS. 4,215 and 4,216.—Butt and double strap double riveted longitudinal joint showing dimensions as obtained from the ***A. S. M. E. Boiler Code*** and those selected.

$F = N \times d \times t \times c + n \times d \times b \times c = 2 \times .6875 \times .25 \times 95{,}000 + 1 \times .6875 \times .25 \times 95{,}000 = 48{,}985.$

$G = N \times d \times t \times c + n \times s \times a = 2 \times .6875 \times .25 \times 95{,}000 + 1 \times 44{,}000 \times .37122 = 48{,}990.$

H = Divide B, C, D, E, F, or G (which ever be the least), by A, and the quotient will be the efficiency of the joint, thus:

$$\frac{45{,}547(B)}{55{,}000(A)} = 82.8 \text{ per cent.}$$

with which value, assuming at least equal efficiency of ligament, and again substituting in (2)

$$\text{Maximum pressure} = \frac{55,000 \times 1/4 \times .828}{20 \times 5} = 114 \text{ lbs. per sq. in.}$$

being 14 lbs. above the required 100-lb. pressure.

For the circumferential joints a single riveted lap joint will suffice, its strength, as will be shown later, being far in excess of that required.

Furnace.—This consists of a circular shell, riveted to the boiler shell at its lower end, and to the lower tube sheet at the

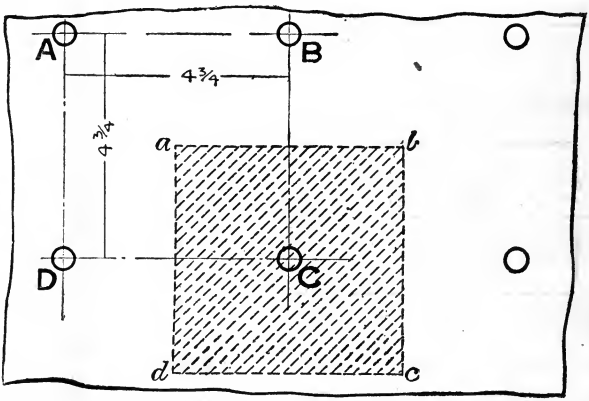


FIG. 4,217.—Portion of cylindrical internal furnace showing spacing of screwed stay bolts.

upper end, being reinforced by stay bolts tapped radially to furnace and boiler shell. According to the ***A.S.M.E. Boiler Code:***

212. An internal cylindrical furnace which requires staying shall be stayed as a flat surface as indicated in Table 3.

For a plate thickness of 5/16 and 120 pounds steam pressure, the table gives a maximum allowable pitch of 4¾ inches for screwed stay bolts with ends riveted over.

In fig. 4,217, *abcd* is the area to be supported by each stay bolt; this is equal to ABCD, that is, area per stay bolt $= abcd =$ ABCD $= 4\frac{3}{4} \times 4\frac{3}{4} = 22.56$ sq. ins.

and for 114 pounds (maximum steam pressure allowed on boiler),

load on each stay bolt $= 22.56 \times 114 = 2{,}572$ lbs.

According to the ***A.S.M.E. Boiler Code*** 418, Table II, the allowable load on stay bolts with V thread, 12 threads per inch, is for a $\frac{13}{16}$ bolt 2,632 pounds (based on 7,500 lbs. stress per sq. in.) being $2{,}632 - 2{,}572 = 160$ lbs. in excess of required amount. ***Use*** $\frac{13}{16}$ in. stay bolts. These stay bolts should be located with respect to the longitudinal joint in furnace sheet as in fig. 4,218.

For the fire door opening through furnace sheet, the latter may be flanged outward and riveted to the outer shell, as in fig. 4,229, or door

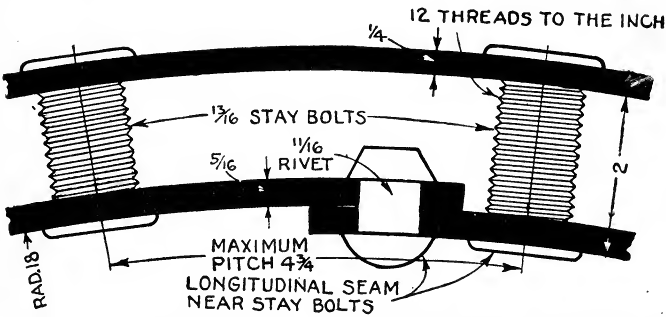


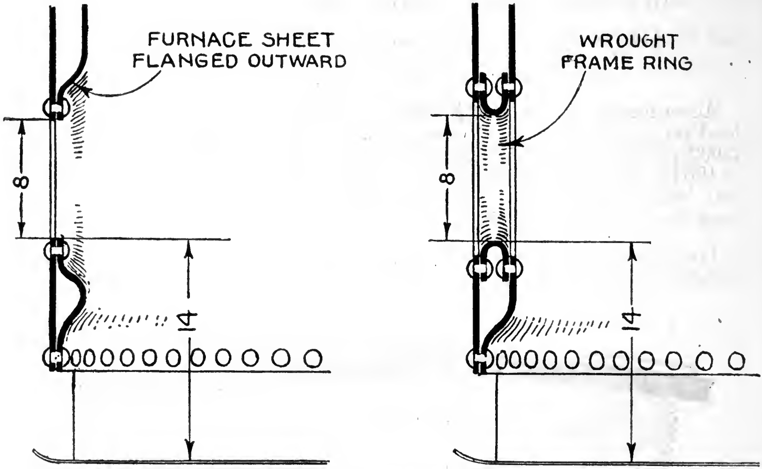
FIG. 4,218.—Section of shell and internal cylindrical furnace showing proper location of stay bolts adjacent to longitudinal joint in furnace sheet.

frame ring connecting the two may be used, as in fig. 4,220, the ring to be of wrought iron or steel.

Lower Tube Sheet.—Upon the lower tube sheet depends the tube capacity, for its effective diameter for tubes is considerably less than the shell diameter, because of the space taken up by the water leg and flange.

Thus, in fig. 4,221, the width of water space + thickness of furnace sheet = 2 ins., and allowing $1\frac{1}{2}$ in. tube sheet flange radius gives a radial distance of $2 + 1\frac{1}{2} = 3\frac{1}{2}$ inches on each side not available for tubes, or $3\frac{1}{2} \times 2 = 7$ ins. total. Hence, diameter of tube sheet available for tubes, or

tube limit diameter $= 40 - 7 = 33$ ins.



FIGS. 4,219 and 4,220.—Fire door opening constructed between shell and furnace sheet. Fig. 4,219, outwardly flanged furnace sheet riveted to shell; fig. 4,220, wrought frame ring construction.

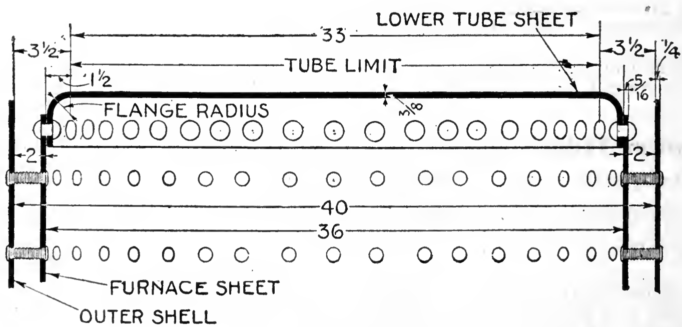


FIG. 4,221.—Detail of lower tube sheet showing diameter of surface available for tube layout. As shown, the shell diameter of 40 inches is reduced 2 inches each side by water leg and furnace sheet and an additional 1½ in. must be allowed on each side for flanging leaving 40—(2×2 +2×1½)=33 ins. available in tube sheet section for tubes.

The tube layout for drilling the tube sheets will now depend on

1. Heating surface.
2. Diameter of tubes.
3. Length of tubes.

In the catalogue of a well known builder of vertical marine boilers, the following proportions are given:

Proportions of Vertical Marine Tubular Boiler

Size	No. of 2-inch tubes	Sq. ft. of grate	Sq .ft. of heating surface	***Ratio heating surface ÷ grate***	Weight lbs.	
					Total	***Per sq. ft. of heating surface***
30×54	64	3.68	71	**19.3**	1,450	**20.4**
36×60	91	5.58	105	**18.8**	2,000	**19**
42×64	120	7.87	143	**18.2**	2,900	**20.3**

An inspection of the table, especially the columns giving *heating surface-grate* ratios and *weights* will reveal at once ***why*** *this type of boiler is in bad repute among users*, ***especially*** *those who have had experience with water tube boilers.*

Evidently in designing the line of boilers listed in the table, a *heating surface-grate* ratio of only 20 was aimed at. For economy, even with the low rate of combustion ordinarily employed, such ratio is ridiculous and has nothing to commend it except cheapness of construction, which no doubt, from the manufacturer's standpoint, is necessary to meet competition. *Since the author does not have to meet this kind of competition, it will be instructive to follow the present design from this point on to see what can be done in reducing size, weight and increasing efficiency of the vertical boiler.*

In the example one of the requirements is that the grate-heating surface ratio shall be proportioned for quick raising of steam and high overload capacity without material loss of economy. This means a high heating surface-grate ratio. In marine practice ratios of 25 to 50 are common.

To adapt the boiler to the very high overload capacity of the engine due to its variable cut off valve gear, and render it sensitive as required, a ratio of 50 : 1 will be used, assuming that the shell will accommodate the required tubular area without undue length, for ***in marine practice,*** *the height is limited because of the necessity of a low center of gravity.*

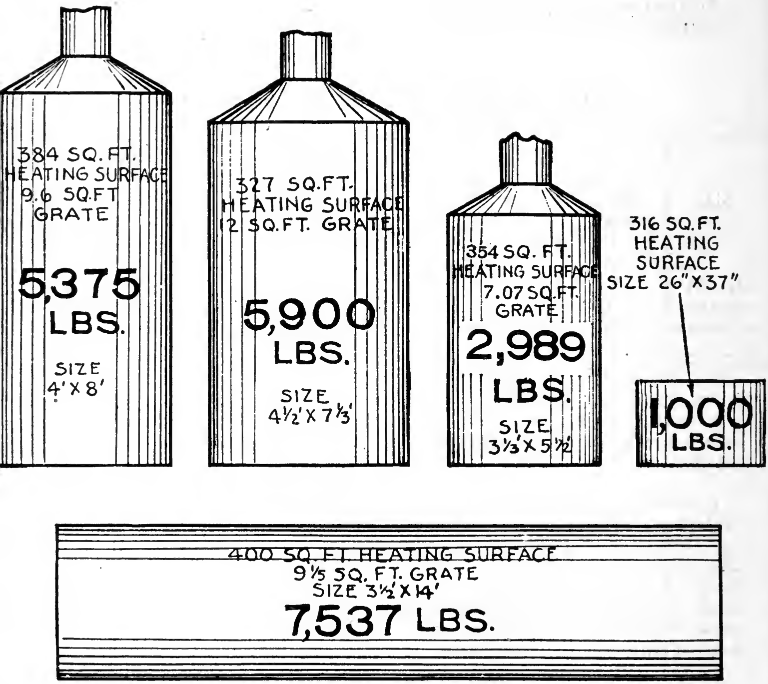
For the 50 to 1 ratio,

$$\text{heating surface} = \text{grate area} \times 50 = 7.07 \times 50 = 354 \text{ sq. ft.}$$

of which, approximate heating surface of furnace sheet and lower tube sheet

$$= 3.1416 \times 3 \times 1\tfrac{1}{2} = 14 \text{ sq. ft.*}$$

hence tubular heating surface $= 354 - 14 = 340$ sq. ft.



FIGS. 4,222 to 4,226.—Comparisons of various boilers. Fig. 4,222, ordinary stationary vertical boiler; fig. 4,223, submerged tube marine boiler; fig. 4,224, the author's boiler; fig. 4,225, approximate proportion of auto type shell boiler with ½-inch tubes.

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*NOTE.—Factor 3 feet is diameter of furnace, factor 1½ feet, is height of furnace. In the approximation, by not deducting the surface cut out of furnace sheet by door opening, the error of not including area of tube sheet (not cut away by holes for tubes), is about offset. Of course, the net area of tube sheet cannot be calculated until the number and size of tubes are known.

The number of tubes necessary will depend on their diameter and length and to arrive at the best proportions several "trial layouts" should be made, with different size tubes—say 2, 1½ and 1 inch tubes. The boiler being for marine service, the center of gravity, as previously mentioned, must be kept as low as possible, accordingly the tube length will be limited to say 3 feet.

Now, for 2,* and 1½ inch tubes, their "properties" are from table (of National Tube Co.):

Properties of Boiler Tubes

Size outside diameter	Thickness	Weight per ft. lbs.	Length of tube per sq. ft. of internal surface
2	.095	1.932	2.11 feet
1½	.095	1.425	2.915 feet

For the high concentration of power required, the experienced designer knows at once from a sense of proportion, that 2 inch tubes are impossible, but they will serve to illustrate the method of design.

First, the trial layouts are made to determine the approximate number of tubes for each size, only a quadrant or quarter of the tube sheet being considered, great accuracy not being necessary. For 2 inch tubes, with ½ inch ligaments, the tube sheet will accommodate 143 tubes, as obtained in fig. 4,227.

Since (from table above) 2.11 feet of 2 inch tube are required

* NOTE.—The tube should be of such length that the length as manufactured is a multiple of the tube length as cut for the boiler to avoid waste of material in cutting, remembering that boiler tubes are expensive.

NOTE.—Tubes 2 inches in diameter are the standard for small tubes and is the size generally used in vertical boilers up to 72 inch. It is a satisfactory size for the ordinary commercial proposition where size and weight of boiler are of no consequence.

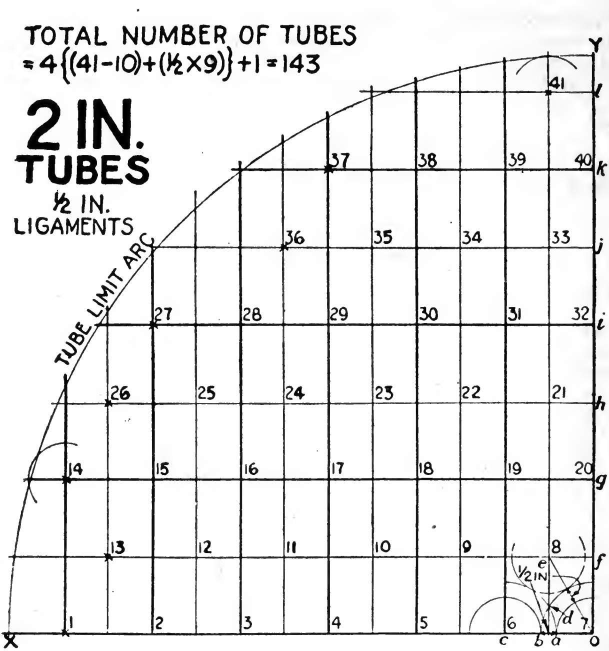


FIG. 4,227.—Trial tube sheet layout for ***2 inch tubes,*** *½ inch ligaments*. Draw the axes OX, and OY, and describe the tube limit arc with radius = 16½ inches. With O, as center and radius oa=½ inch, describe arc representing a 2 inch tube, and lay off the ligament ab= ½ inch, and radius bc of next tube = ½ inch. Then oc is the tube pitch on X axis. This should be done accurately. With dividers set to pitch oc, step off tube centers, on OX, obtaining OX tubes. Now with o and c, as centers and radius = ob, describe arcs intersecting at d, and draw through d, a line parallel to OY. Describe with tube radius a circle whose center is on this line and tangent to the arcs just described. Oe, then will be the diagonal pitch, and Of, its projection on OY. Now with dividers set to Of, step off on OY, the points g, h, i, j, k, l. Draw with soft pencil (2H) parallels to OX through points g, i, and k, also go over OX and OY with soft pencil, and with hard pencil (6H), draw parallels through f, h, j and l. Number the tube centers previously found on OX, 1, 2, 3, 4, 5, and 6, and draw with soft pencil, line through these centers parallel to OY. Take a strip of paper and mark off on the edge these tube centers, and transfer these distances to the parallel through f, obtaining tube centers, which number 8, 9, 10, 11, 12 and 13, and through these centers draw with hard pencil, lines parallel to OY. By construction then any tube center will be at the intersection of any two light lines or any two heavy lines. Now mark on each line parallel to OX, indicating with a cross the center of last tube that will come within the tube limit arc, drawing a tube arc, as at 14, where it cannot be judged by eye. Next number all the light line intersections, and all the heavy line intersections, obtaining centers up to 41. Now since only half of each tube on OX and OY (except center tube No. 7), comes within the quadrant, each tube on OX and OY (except center tube), will count as ½ in the estimate, and as there are four quadrants in the tube sheet, the total number of tubes $=4\left\{(41-10)+(\frac{1}{2}\times 9)\right\}+1=$ **143.**

per sq. ft. of internal heating surface, and total tubular heating surface is 340 sq. ft.

total length of **2 inch** tubes = 340×2.11 = 717 ft.

length of each tube = 717÷143 = 5.01 ft.

being 5.01—3 = 2.01 feet longer than the 3 ft. limit.

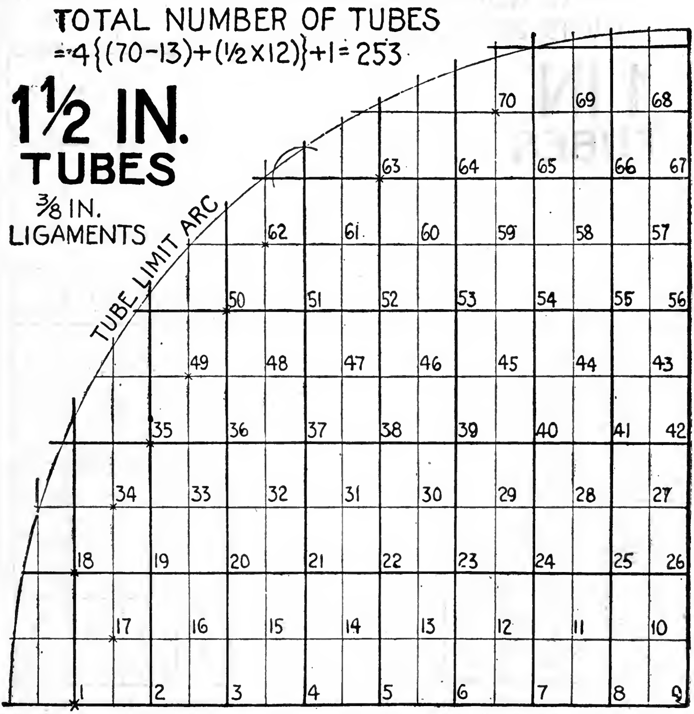


FIG. 4,228.—Trial tube sheet layout for 1½ *inch tubes*, ⅜ *inch ligament*. This combination requires 253 tubes cut to 3.92 ft. lengths, being .92 ft. in excess of the 3 foot limit.

Next try 1½ inch tubes with ⅜ inch ligaments. The tube sheet will accommodate about 253 tubes as obtained in fig. 4,228.

Since (from table above), 2.915 feet of 1½ inch tube are required per sq. ft. of heating surface,

total length of **1½ inch** tubes $=340\times2.915=991$ ft.
length of each tube $=991\div253=3.92$ ft.

being $3.92-3=.92$ ft. longer than the 3 ft. limit.

It is thus seen, from the two trials, that the amount of heating surface

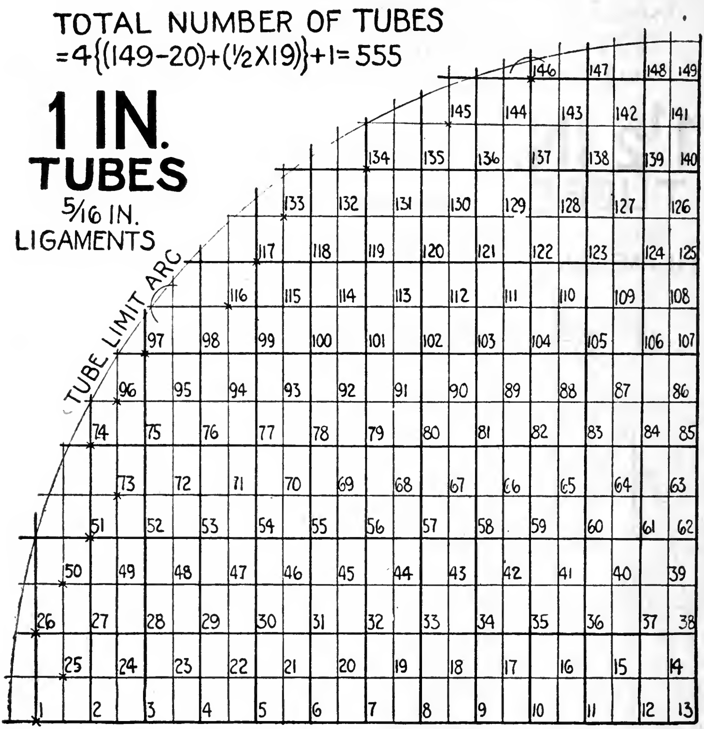
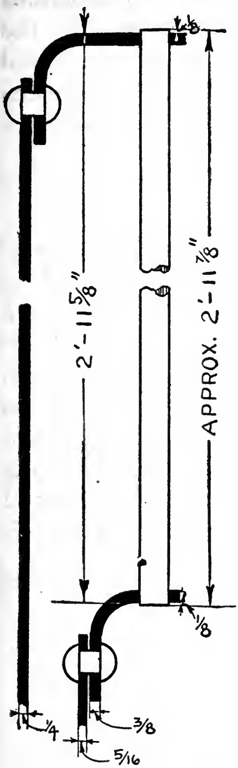


FIG. 4,229.—Trial tube sheet layout for ***1 inch tubes, 5/16 inch ligaments***. This gives 555 tubes, each 2.9 ft. long or approximately 2 ft. 11 in. which is practically the 3 foot limit. The actual length of the tubes as cut from tubes of 12 foot length will be 3 feet less the thickness of the metal removed by cutting as shown in fig. 4,230.

that can be crowded into a given space is increased as the size of tube and ligaments are reduced.

Now for the 1 inch tubes with 5/16 inch ligaments, the author has



no table at hand giving properties, so these will have to be calculated, taking thickness at 3/32-inch.*

inside diam. $=1-2\times\frac{3}{32}=1-2\times.09375=.8125$ ins.

inside circum. $=\pi\times$ diam. $=3.1416\times.81=2.55$ ins.

$$\left.\begin{array}{l}\text{length of tube per}\\ \text{sq. ft. internal area}\end{array}\right\}=\frac{144}{2.55\times12}=4.7\ldots\ldots\ldots(1)$$

With 1 inch tubes and 5/16-inch ligaments, the tube sheet will accommodate 555 tubes, as shown in fig. 4,229, and from (1)

total length of **1-inch** tubes $=340\times4.7=1,598$ ft.
length of each tube $=1,598\div555=2.9$ or approximately 2 ft. 11 ins.

This is practically the three foot limit, and in construction assuming the material can be obtained in 12 foot lengths, each length would be cut into four pieces, giving 3 foot tubes less the amount of metal cut away—say 1/8 inch per cut, and allowing 1/8 overlap at the ends for beading. The actual distance between outer surface of tube sheets would be, say 3—(2/8 overlap + 1/8 cut away) = 2′ − 11 5/8″ as shown in fig. 4,230. Figs. 4,231 and 4,232 show dimensions of lower tube sheet.*

Upper Tube Sheet.—This is identical with the lower tube sheet, except that its diameter is extended to 40 inches in order that the flange may be riveted to the shell, and has a 1½ in. tap for main outlet.

FIG. 4,230.—Detail of tube and sheets showing allowance for cutting and tube margin outside of sheets for heading.

*NOTE.—Since making the calculation, the author has inserted on page 2,238 a table giving the "properties" of standard boiler tubes. The 3/32 (.094) thickness selected above is virtually the same as given in the table (.095), but in practice the standard tube No. 13 gauge (.095 in.) would be used because of cost and durability, unless extreme lightness be desired.

NOTE.—To avoid reducing decimal feet to fractional inches, set dividers to 2.9 inches on engineer's scale and placing dividers on architect's scale of 1″ = 1′, the equivalent is read off direct, here taken approximately as 2 ft. 10 15/16 ins. This avoids the time and trouble of figuring, and also the chance of making an error in figuring

Tube Sheet Circumferential Seams.—Since a considerable portion of the load coming on the tube sheets is carried by the tubes, and the area reduced by the tube holes, the circumferential seam need not be so strong as the longitudinal seam. The circumferential seams should be designed to meet the following requirements:

A.S.M.E. Boiler Code.

184 *a*. *Circumferential Joints*. The strength of the circumferential joint of boilers, the heads of which are not stayed by tubes or through braces shall be at least 50 per cent. that of the longitudinal joints of the same structure.

b. When 50 per cent. or more of the load which would act on an unstayed solid head of the same diameter as the shell, is relieved by the effect of tubes or through stays, in consequence of the reduction of the area acted on by the pressure and the holding power of the tubes and stays, the strength of the circumferential joints in the shell shall be at least 35 per cent. that of the longitudinal joints.

U.S. Marine Rules.—*Maximum pitch*

9. For single riveted lap joints

$$\text{Maximum pitch} = (1.31 \times T) + \tfrac{5}{8}$$

in which T = thickness of plate in inches.

Since as just explained, only part of the load is carried by the circumferential seam, single lap riveting is found amply strong.

Lower Tube Sheet Circumferential Seam.—From the detail of lower tube sheet figs. 4,231 and 4,232,

Gross area 36-inch circle = $.7854 \times 36^2$	= 1,018 sq. ins.
Area 555, $1\frac{1}{32}$-inch holes = $555 \times .7854 \times (1\frac{1}{32})^2$ =	463 " "
Net area of tube sheet	= 555 " "

Here practically 50 per cent. of the load is removed by the reduction of tube sheet area alone, the holding power of the tubes being so great that a calculation is unnecessary and the circumferential seam need be only 35 per cent of that of the longitudinal seam to meet requirement 184, *b*, of the *A.S.M.E. Boiler Code* just quoted; that is, efficiency of longitudinal seam being 82.8 per cent., then

$$\text{efficiency of circumferential seam} = 35\% \text{ of } 82.8\% = 29\%$$

Now, according to the *U. S. Marine Rules*, for single riveted lap joint.

$$\text{maximum pitch} = 1.31 \times T + 1\tfrac{5}{8}$$

and substituting thickness of plate ($\frac{1}{4}$ inch),

$$\text{maximum pitch} = 1.31 \times \tfrac{1}{4} + 1\tfrac{5}{8} = 1.95 \text{ inches}$$

Upper Circumferential Seam.—From the detail of upper tube sheet, figs. 4,223 and 4,224.

Gross area 40-inch circle (from table) =	1,256.6 sq. ins.
Area 555, $1\frac{1}{32}$ tube holes (as calculated) =	463 " "
Net area of tube sheet =	793.6 " "

Thus $(463 \div 1{,}256.6) \times 100 = 36.8\%$, leaving $50 - 36.8 = 13.2\%$ of the load to be carried by the tubes to meet the requirements of 184, *b*, ***A. S. M. E. Boiler Code,*** just quoted.

Now, from experiments by Yarrow & Co. on steel tubes 2 to $2\frac{1}{4}$ inches diameter, the holding power was found to range from 7,900 to 41,715 pounds, the majority ranging from 20,000 to 30,000. In the absence of data on 1-inch tubes, consider that the holding power varies with the circumference and thickness, then from table of tube dimensions: ***circumference:*** 1-inch tube = 3.142; 2-inch tube = 6.283, and ***thickness:*** 1-inch tube = $\frac{3}{32}$ = .0934; 2-inch tube = .095. Taking 8,000 pounds as the holding power of a 2-inch tube, then

$$\text{holding power of 1-inch tube} = 8{,}000 \times \frac{3.142}{6.283} \times \frac{.0934}{.095} = 3{,}910 \text{ lbs.}$$

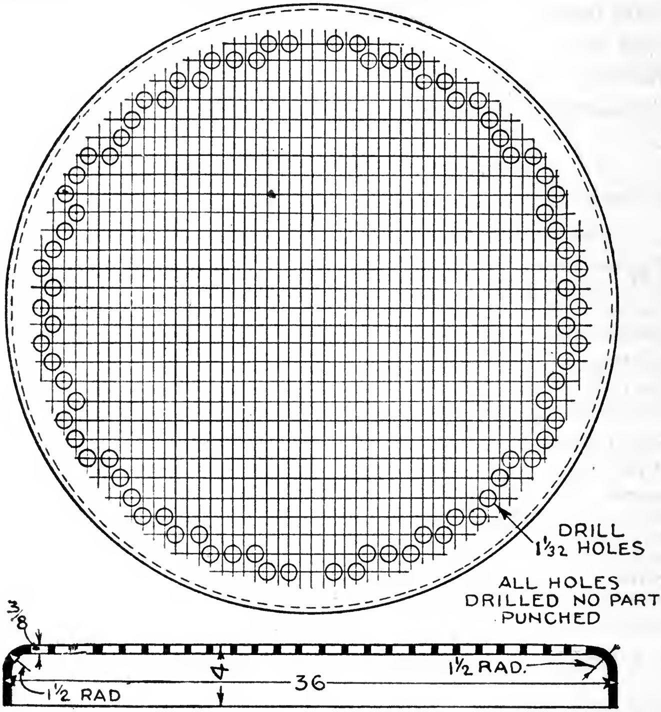
(by slide rule), which is a very conservative estimate from which holding power 555, 1-inch tubes = $555 \times 3{,}910 = 2{,}170{,}050$ pounds. Total load on 40-inch solid tube sheet

$$= 12{,}566.6 \text{ sq. ins.} \times 114 \text{ steam pressure} = 1{,}432{,}592 \text{ lbs.}$$

thus, the holding power of the tubes is considerably in excess of the total load that would come on the tube sheet even if the latter were solid, and accordingly a single riveted lap joint having an efficiency of 35 per cent. of that of the longitudinal seam (in accordance with ***A. S. M. E.*** requirements) is amply strong.

Main Steam Outlet.—Since the boiler is designed for high overload capacity, the main outlet should be of adequate size for the excess steam flow.

Assume a maximum combustion rate of 50 pounds per square foot of grate per hour, and 7 : 1 combustion, then



FIGS. 4,231 and 4,232.—Lower tube sheet. The holes are drilled 1/32 inch larger than the tubes, or 1 1/32 to allow easy insertion and removal.

$$\text{steam capacity per minute} = \frac{7.07 \times 50}{60} \times 7 = 41.24 \text{ lbs.}$$

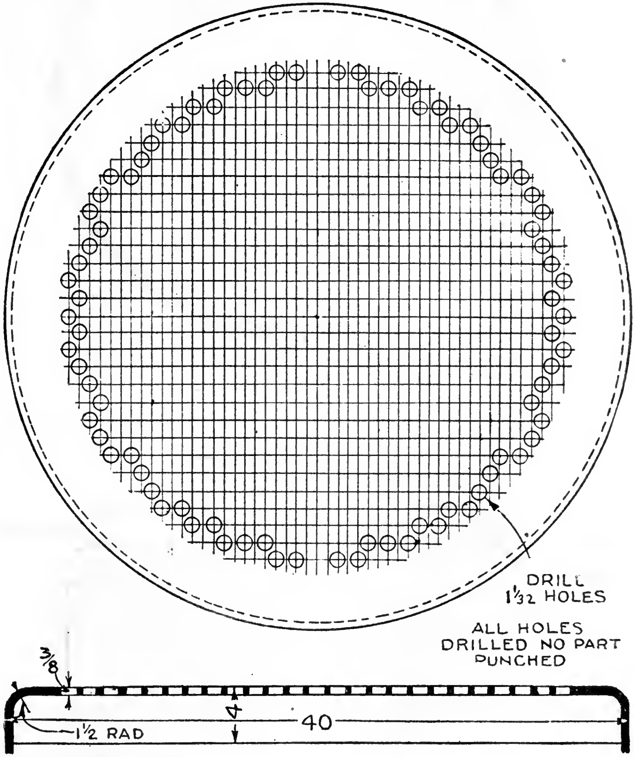
and since (from table), volume of 1-pound of steam at 100 pounds pressure =3.82 cubic feet,

$$\text{volume of steam per minute} = 41.24 \times 3.82 = 157.5 \text{ cu. ft.}$$

For 10,000 feet per minute steam flow

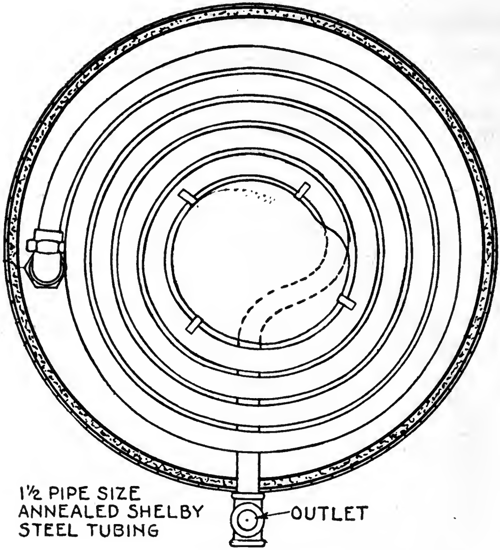
$$\text{sectional area of outlet} = \frac{157.5 \times 144}{10,000} = 2.27 \text{ sq. ins.}$$

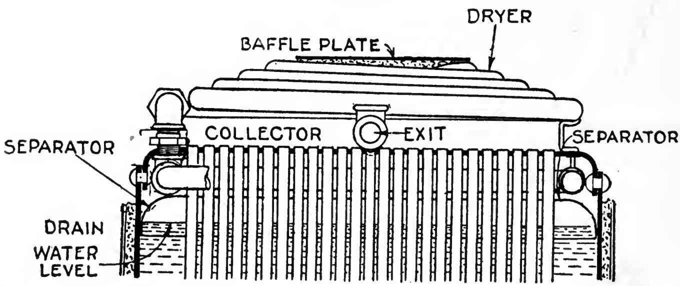
From table of wrought pipe, 1½-inch pipe = 2.036 sq. ins., and 2-inch pipe = 3.356 sq. ins. internal area; make outlet 1½-inch pipe size.



Figs. 4,233 and 4,234.—Upper tube sheet, showing tube layout.. The ligaments are 5/16 in. The centers are located by the method shown in fig. 4,222. The drawing does not show tappings for dryer connection or for smoke ring bolts.

Auxiliary Steam Outlet.—For the 50 pound combustion rate, feed water per hour is $41.24 \times 60 \div 8\frac{1}{3} = 297$ gallons. Now,





FIGS. 4,235 and 4,236.—Detail showing upper tube sheet, separator, collector and dryer. The ***separator*** is made of thin sheet metal about No. 12 gauge and being shaped as shown extending over to the tubes. This forces the steam arising from the liberating surface near the shell to pass over some of the tubes, and suddenly change its direction as indicated by the arrow before entering the collector. The holes in the collector being on the upper side near the top, the steam makes a second change of direction before entering the collector, thus giving two-fold separation. The ***collector*** is made of light tubing and encircles the boiler tubes, the ends being tightly joined to a special T. 3/16 holes spaced about 1 inch apart should be drilled all around the outer side of the collector at 45° to the vertical. The ***dryer*** is connected with the collector by a short nipple elbow and union. It consists of a spiral coil as shown. This coil should have a liberal number of convolutions, the diameter, of the innermost turn being as small as advisable for the size pipe used. The T near the outlet is for branch to safety valve. This T should be special so as to bring top of collector within ½ in. of tube sheet.

from some injector catalogues, as the Pemberthy, for instance, under table of capacities, sizes B and BB have capacity of 250 and 340 gallons per hour respectively, each having ¾-inch steam connection, hence make auxiliary outlet for ¾-inch pipe.

Collector.—In vertical tubular boilers, the surface of the tubes not covered by water is very inefficient in transmitting heat, hence for economy, the water level should be carried as high as possible. In order to do this, the steam is collected in a pipe bent into a ring which encircles the tubes, and being perforated with small holes along the top, takes steam all around the top instead of in one place, thus there is no marked tendency to raise the water with the steam.

Separator Cone.—To prevent any undue excess of water entering the collector, a cone shaped plate is provided extending from the shell to the tubes all around and just under the collector as shown in fig. 4,236. Thus the steam in passing from the liberating surface to the collector must pass over the tubes and change its direction, undergoing the process of separating and drying.

Dryer.—Connected to the main outlet is a coil of pipe placed directly over the tube sheet as shown in figs. 4,235 and 4236, so that any water that may enter the collector may be evaporated in traversing the dryer.

It should be noted that the function of the dryer is to *dry* and not *superheat* the steam, the object being to deliver steam to the engine in the saturated state. The temperature at the point where the dryer is located is about right for the purpose intended, though for efficient operation it should be frequently cleaned of soot.

Stack and Smoke Cone.—The power of a stack varies directly as its effective area, and as the square root of its height. A formula for stack area often used is:

$$E = .3 \text{ horse power} \div \sqrt{H} \quad \ldots\ldots (1)$$

in which E = area is square feet, and H, height in feet.

Now for 30 horse power capacity and 2-foot height, substituting in (1)

$$E = .3 \times 30 \div \sqrt{4} = 4.5 \text{ sq. ft.}$$

Approximate diameter corresponding is 28¾ ins. As calculated, the formula gives a ridiculous value which shows that it is not suited to marine conditions. Since the effect of the breeze produced by the motion of the boat is to give a semi-forced draught, a smaller stack may be used and in this case its diameter may be fixed at a little less than half the boiler diameter, say 18 ins., this proportion having been found by experience with similar boilers ample to meet the conditions of operation.*

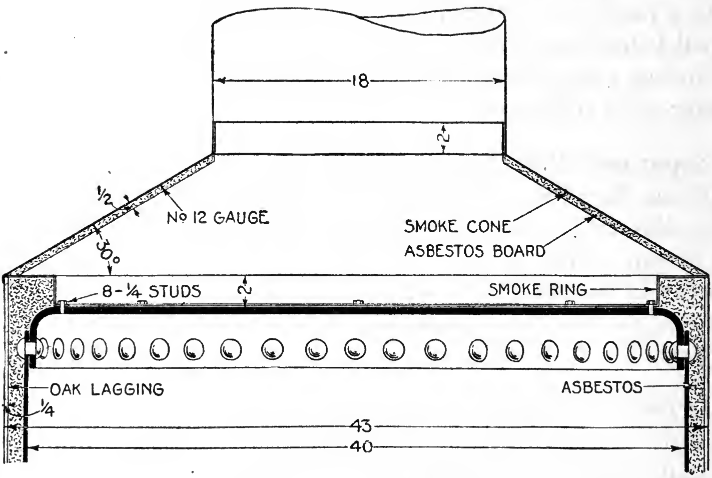
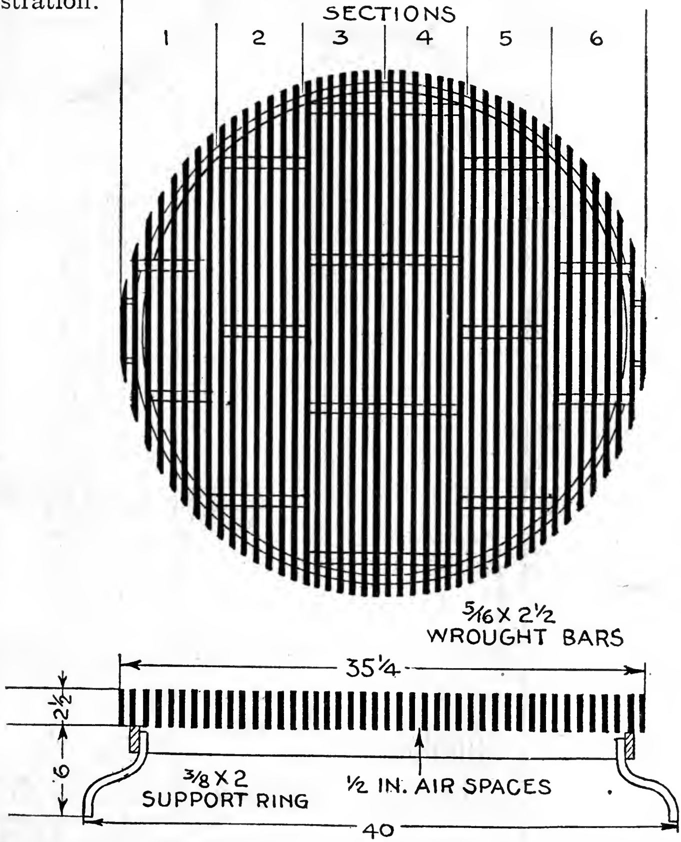


FIG. 4,237.—Detail of smoke ring, smoke cone, and stack. The liberal amount of insulation provided prevents rapid cooling of the hot gases, thus improving the draught, and protecting the oak lagging from the heat. The smoke cone has a slope angle of 30° and rests on a sheet metal rim, so as to clear the dryer, as shown in fig. 4,231. The inside of the smoke cone is covered with asbestos board. The ring is flanged inward at the bottom, which serves to fasten it to the boiler. At the top is an external flange, which covers the asbestos insulation and oak lagging, and to which is fastened the smoke cone.

Grate Bars.—These may be either cast or of the wrought built up construction. Figs. 4,238 and 4,239 show the latter type. For lightness as much air space is allowed as possible, which for

*NOTE.—the value obtained by use of formula (1) above shows that the designer should know from experience approximately what the size should be, otherwise serious errors might result.

pea coal may be the maximum spacing between bars is ½-inch. By reducing the thickness of bars to $\frac{5}{16}$-inch a large percentage of the grate is occupied by the air spaces thus reducing the weight to a minimum. The construction of the grate is shown in the illustration.



FIGS. 4,238 and 4,239.—Wrought built up grate. The bars are $\frac{5}{16}$×2½ held together by bolts and spacers or thimbles as shown. ½-inch bolts are used and the thimbles may be cut from a piece of 1-inch double extra strong wrought pipe. The grate is supported by a ring having lugs attached which are bolted to the shell.

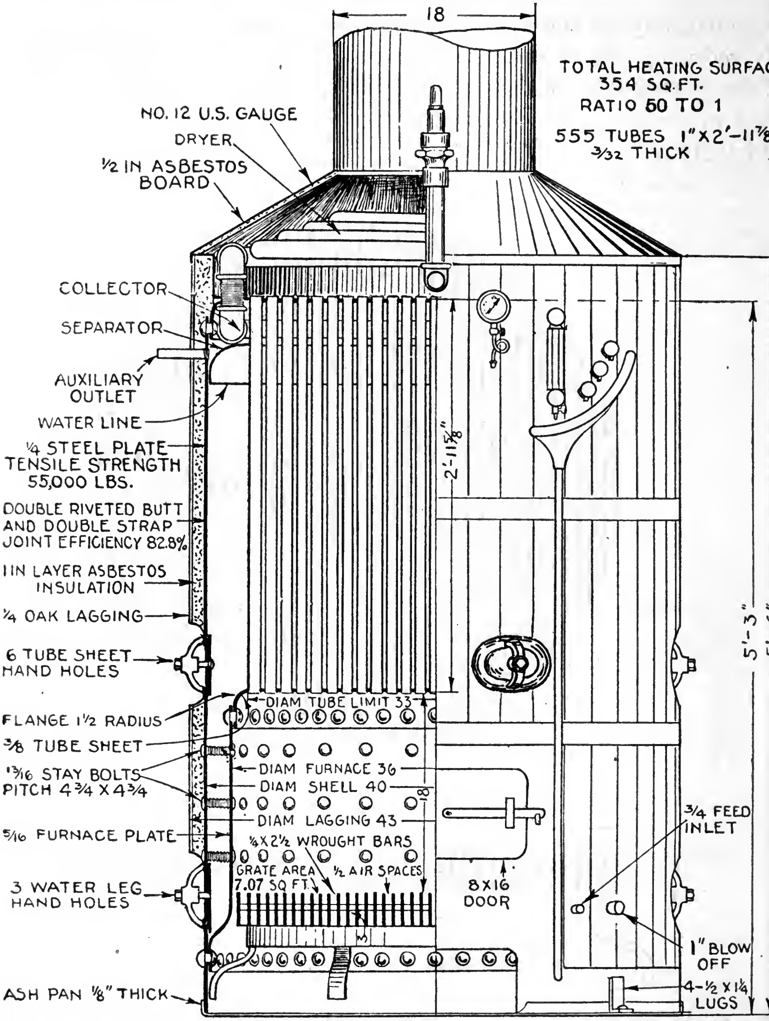
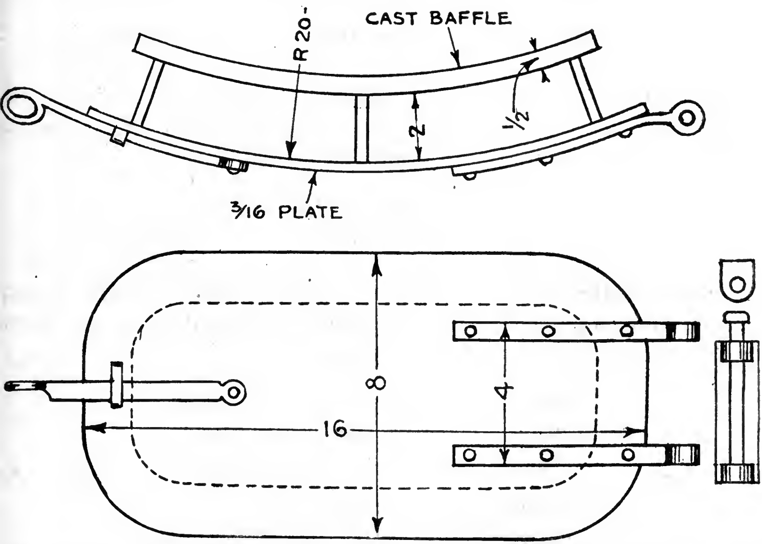


FIG. 4,240.—Sectional view of boiler as designed by the author showing principal dimensions separator, collector and dryer, light weight built up grates, covering, etc. The oak lagging secured by metal bands makes a neat covering, though Russia iron could be used instead

Weight of Boiler.—For the service intended this is an important item, as in marine practice all unnecessary weight represents a dead load, that could otherwise be utilized in increased carrying capacity, or its absence contributing to increasing the speed. The general method of approximating the weight is as follows:

In the calculation of weight of the various parts the following units are used:



FIGS. 4,241 to 4,244.—Door construction. The construction should be as light as is consistent, with adequate strength. It is made up of 3/16 plate with cast iron baffle bolted with 2 inch air space between. The door may be either *right* or *left* as desired.

Weight Unit for Sheet Steel

Weight of sheet steel 490 lbs. per cu. ft.; .2836 lbs. per cu. in.
Weight of sheet steel 1/8 in. thick 5.1 lbs. per sq. ft.
Weight of sheet steel 1/4 in. thick 10.2 lbs. per sq. ft.
Weight of sheet steel 5/16 in. thick 12.75 lbs. per sq. ft.
Weight of sheet steel 3/8 in. thick 15.03 lbs. per sq. ft.
Weight of sheet steel No. 12 U. S. gauge 4.462 lbs. per sq. ft.
Weight of 13/16 round steel for stay bolts .147 lbs. per in.
Weight of 1 in. boiler tube No. 13 gauge, .918 lbs. per ft.

In the calculations these units are given in **heavy figures,** to avoid explanation in each case.

Shell.—The general dimensions of shell and other parts are given in fig. 4,240, and from which

Square feet of shell $=3\ 1416 \times \frac{40}{12} \times 5.25 = 54.9$

Weight of shell $= 54.9 \times \mathbf{10.2} = \ldots\ldots\ldots\ldots$ 560 lbs.

Furnace.—In calculating weight of furnace walls by disregarding metal cut away for door opening, this will approximately allow for weight of door and baffle.

Sq. ft. of furnace walls $= (3.1416 \times 3) \times 2 = 18.86$

Weight of furnace walls $= 18.86 \times \mathbf{12.75} = \ldots\ldots\ldots$ 2.41 lbs.

Lower Tube Sheet.—There are 555—1⅓₂-inch tube holes, the combined area of which must be subtracted from the sheet area to obtain net area of sheet, thus:

Gross area of sheet $= .7854 \times 3^2 = \ldots\ldots\ldots\ldots$	7.07 sq. ft.		
Approximate area of flange $= 3.1416 \times 3 \times 1/6 =$	1.57 " "		
Total $=$	8.64 " "	8.64	(A)
Diameter tube holes $= 1\frac{1}{32} = \frac{33}{32} = 1.031$ inches			
Area 555 tube holes $= (.7854 \times 1.031^2) \times 555 = 463$ sq. ins. or $463 \div 144 = \ldots\ldots\ldots\ldots$	3.22 sq. ft.	3.22	(B)
Net area lower tube sheet $=$ (A)—B $= \ldots\ldots\ldots\ldots$		5.42 sq. ft.	
Weight lower tube sheet $= 5.42 \times \mathbf{15.03} = \ldots\ldots\ldots\ldots$	82 lbs.		

Upper Tube Sheet.—The net area of the upper tube sheet is the same as that of the lower tube sheet plus area of annular ring where outer diameter is 40 inches, and inner diameter 36 inches, thus:

Net area of lower tube sheet = ...5.42 sq. ft...(**A**)

Area 40-inch circle (from table) = 1,256.6 sq. ins.

Area 36-inch circle (from table) = 1,017.9 " "

Area annular ring = ... 238.7 " "
or 238.7 ÷ 144 = ...1.66 " " ..(**B**)

Net area of upper crown sheet = (**A**) + (**B**) = ...7.08 " "

Weight of upper crown sheet = 7.08 × **15.03** = ..106 lbs.

Tubes.—For $\frac{3}{32}$ thickness of metal, inside diameter of tubes = $1-2\times\frac{3}{32}=\frac{13}{16}$. Now, from "memory," area 1 inch circle = .7854 sq. in., and from table, area of $\frac{13}{16}$-in. circle = .5185 sq. ins., hence, cross sectional area of metal of tube = .7854 — .5185 = .2669 sq. in.

Weight of tubes per foot = .2669 × 12 × **.2836** = .91.

Weight of 555 one inch tubes 3 feet long = (3 × **.91**) × 555 = 1,515 lbs.

Grate Bars.—From the working drawing of grate, find the average length of bar in one quadrant. This is from measurements:

$$\text{Average length}=\left\{\begin{array}{l}2+5\tfrac{1}{4}+7\tfrac{1}{16}+8\tfrac{1}{2}+9\tfrac{11}{16}+10\tfrac{11}{16}\\ +11\tfrac{9}{16}+12\tfrac{1}{4}+12\tfrac{11}{16}+13\tfrac{9}{16}+\\ 14\tfrac{1}{8}+14\tfrac{5}{8}+15+15\tfrac{3}{8}+15\tfrac{9}{16}+\\ 16+16\tfrac{3}{16}+16\tfrac{7}{16}+16\tfrac{9}{16}+16\tfrac{3}{4}+\\ 16\tfrac{13}{16}+16\tfrac{7}{8}+16\tfrac{15}{16}\ \ldots\ldots\ldots\end{array}\right\}\div 23=13.05\text{ inches}$$

Instead of taking these measurements the average length of grate bars may be calculated thus: Consider half of the grate and describe semi-circle ABC, whose diameter AC, = diameter of grate..

$$\text{Since area of a circle}=\pi R^2,$$
$$\text{area of ABC,}\quad=\frac{\pi R^2}{2}$$

Now the area of a rectangle AMSC, whose ordinate x = length of average grate bar, will be equal to the area of semi-circle ABC. That is, area rectangle AMSC = area semi-circle ABC

$$\text{or } 2Rx = \frac{\pi R^2}{2}$$

Solving for x:

$$x = \frac{\pi R^2}{4R} = \frac{3.1416R}{4} = .7854R = 14 \text{ ins.}$$

which agrees with the measured result as nearly as could be expected. The reason that the two results are not the same is because of the width of the bars which materially reduces the length of each, especially the shorter ones. Now, estimating from measurements,

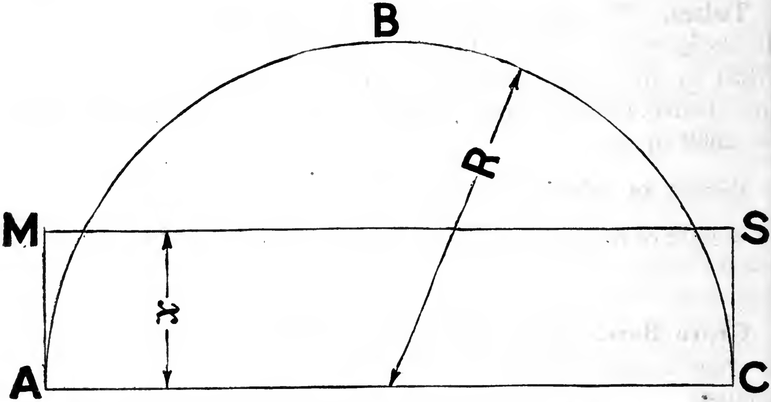


FIG. 4,245.—Limiting semi-circle for half of grate bars, illustrating method of calculating average length of grate bars.

$$\left.\begin{array}{r}\text{Volume of bars per}\\ \text{quadrant of grate}\end{array}\right\} = 23 \times \left\{ 13.05 \times \tfrac{1}{4} \times 2\tfrac{1}{2} \right\} = 188 \text{ cubic ins.}$$

Weight of grate bars 4×188×**.2836** = ... 213 lbs.

Ash Pan.—This is ⅛-inch thick and is flanged upward 1 inch. Inside diameter of flange = 40½ inches.

Area of 40½ circle (from table) = ... 1,288.2 sq. ins. .... **(A)**

Area of flange = 3.1416×40½×1 = ... 127 " " .... **(B)**

+

Total area of pan = (**A**+**B** = ... 1,415.2 " "

or 1415 ÷ 144 = ... 9.83 sq. ft.

Weight of ash pan = 9.83×**5.1** = ... 50 lbs.

Stay Bolts.—As calculated, the area of furnace is 14 sq. ft., and with stay bolt pitch of $4\frac{3}{4}$ ins.

$$\text{Area per stay bolt} = 4\tfrac{3}{4} \times 4\tfrac{3}{4} = 22.6 \text{ sq. ins.}$$

$$\text{Number of stay bolts } (14 \times 144) \div 22.6 = 89 \ldots\ldots\ldots\ldots (1)$$

In equation (1), 14 = sq. ft. of furnace walls. Length of stay bolts less thickness of shell and furnace walls is approximately 2 ins.

$$\text{Weight of projecting stay bolt iron} = 89 \times 2 \times \mathbf{.147} = 26 \text{ lbs.}$$

Rivets.—The weight of the metal of the rivets which project on each side of the seams may be taken as $\frac{2}{3}$ of the weight of $\frac{11}{16} \times 1$ rivets which weigh 22.4 lbs. per hundred, thus

$$\text{Weight of projecting metal} = \tfrac{2}{3} \text{ of } 22.4 = 15 \text{ lbs. per hundred}$$

There are approximately 277 rivets in the boiler, and weight of projecting metal = $(277 \div 100) \times \mathbf{15} = 42$ lbs.

Longitudinal Seam Straps.—There are two straps: one $4\frac{1}{4}$ ins. wide, and the other $8\frac{3}{8}$ ins. wide.

Total width of straps $= 4\frac{1}{4} + 8\frac{3}{8} = 12\frac{5}{8}$.

$$\text{Surface of straps} = \frac{12\frac{5}{8} \times 63}{144} = 5\tfrac{1}{2} \text{ sq. ft.} \ldots\ldots\ldots\ldots (2)$$

NOTE.—In equation (2), 63 is the length of the longitudinal seam in ins.

$$\text{Weight of straps} = 5\tfrac{1}{2} \times \mathbf{10.2} = 56 \text{ lbs.}$$

Separator.—Consider the separator approximately equivalent to the surface of a cone whose lower base is 40 ins. in diameter, upper base 36 ins., and slant height = 6 ins.

Rule for slant surface: Multiply half the sum of the circumference of the two bases by the slant height.

Circumferences (from table), 36-inch circle = 113 ins; 40-inch circle = 126 ins.

Slant surface = $\frac{1}{2}$ of $(113 + 126) \times 6 = 717$ sq. ins.
or $717 \div 144 = \ldots\ldots\ldots\ldots\ldots\ldots$ 4.98 sq. ft.

Weight of separator $= 4.98 \times \mathbf{5.1} = \ldots\ldots\ldots\ldots\ldots\ldots$ 25 lbs.

Collector.—Diameter of circle to which tube is bent is 34 inches, say 3 feet.

Length of collector (=circumference 3-foot circle) = 9.43 ft.

Weight of collector = 9.43 × **1.425*** = ... 13 lbs.

*NOTE.—Weight of 1¼ in. standard wrought pipe = **1.425** lb. per ft.

Dryer.—To approximate the spiral of four convolutions as shown in fig. 4,240, consider length equal to sum of circumferences of circles 36, 24, 16 and 8-inch diameter plus 2 feet. Now, from table:

Circumference of: 36 in. circle = 9.43 ft.; of 24 in. circle = 6.28 ft.; of 16 and 8 in. circles = 50.3 + 25 ins. = 6.27 ft. Length of straight run = 2 ft.

Length of convolutions + straight run, or

length of dryer = 9.43 + 6.28 + 6.27 + 2 = 24 ft.

Weight of dryer = 24 × **1.425** = ... 34 lbs.

Smoke Cone.—By measurement diameter of upper base = 1½ feet; of lower base = 3.58 feet; slant height = 1.25 feet.

Slant surface = ½ of 1.25 × (1.5 + 3.58) = ...3.18 sq. ft... (A)

Area lower ring	(3.1416 × 40) × 3 =	377 sq. ins.
" upper "	(3.1416 × 18) × 1 =	56 " "
" upper and lower rings =		433 " "

or 433 ÷ 144 = ...3 " " ..(B)

Total surface of smoke cone = (A) + (B) = ... 6.18 " "

Weight of smoke cone = 6.18 × **4.462** = ... 28 lbs.

Summary of Weights

Shell	560 lbs.
Furnace	241 "
Lower tube sheet	82 "
Upper tube sheet	106 "
Tubes	1,515 "
Grate bars	213 "
Ash pan	50 "
Stay bolts (projecting metal)	26 "
Rivets (projecting metal)	42 "
Longitudinal steam straps	56 "
Separator	25 "
Collector	13 "
Dryer	34 "
Smoke cone	26 "
Weight of boiler =	**2,989 lbs.**

CHAPTER 72

HOW A BOILER IS BUILT

The author is indebted to the **Wickes Boiler Co.** *for the instructive series of illustrations in this chapter showing the various operations in boiler making as performed at their shops at Saginaw, Mich.*

Very few purchasers of boilers have any idea of how it is built, and consequently they do not know what to look at to determine the quality of the workmanship.

It is a fact that usually very little consideration is given by the purchaser not only to *workmanship*, but even to the *design* of a boiler. The importance of correct design and good workmanship is indicated in the following quotation from the report of the inspectors of the Hartford Boiler Insurance Co.:

> "Careful investigation into the causes of these terrible accidents divests them of the mysterious atmosphere which in the minds of the majority of people, surrounds them. Investigation shows that in almost every case the cause is traceable to poor material, faulty construction, poor workmanship and incompetent management. . . . It is a lamentable fact that there are boiler makers who will use a cheap and low grade of material, and whose workmanship is very inferior. They 'scamp' and 'shim' and to cover the defects put on a thick coat of coal tar, and the boiler is ready for market."

Usually when bids are taken on horizontal tubular boilers, comparison is made by the purchaser of the overall dimensions, thickness of shell and heads, number and diameter of tubes and allowable working pressure. These factors are compared with extreme scrutiny. Noting that all specifications say "the workmanship will be of the very best," the contract is generally placed with the lowest bidder, without any regard to the number of operations through which the boiler is to be put in the shop and how these operations are to be performed. The workmanship which, from the number of defects found in boilers, would seem to warrant the closest scrutiny and mention is passed over with these words, "the workmanship will be the very best"—and what is the best?

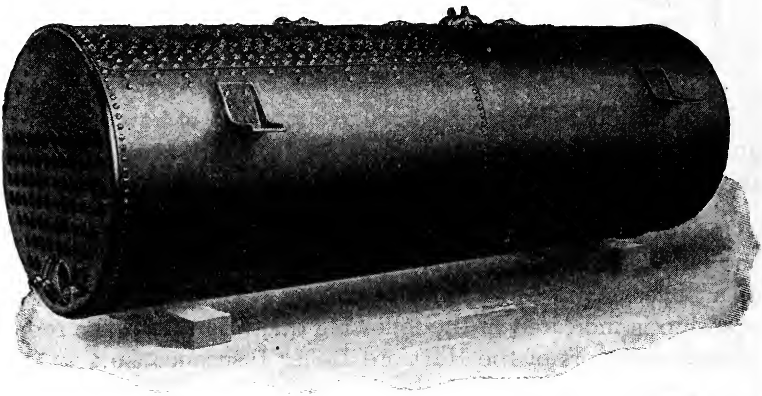


FIG. 4,246.—Wickes horizontal tubular boiler designed to pass inspection of the Department of Public Safety, Philadelphia, Pa., the workmanship being in accordance with the methods described in this chapter.

Ques. How should the laying out of the riveted joints be done?

Ans. This should be done *only* by an experienced "layer out" for templates, so as to secure absolute correctness in spacing.

Ques. What difficulty is encountered in flanging a head?

Ans. Owing to the heating and cooling of the dies and varying thicknesses of heads, it is impossible by any process to turn a flange on a head which is of a fixed diameter or circumference, because there is a variation using the best dies obtainable.

Ques. What then is necessary to secure uniform spacing of circumferential seams?

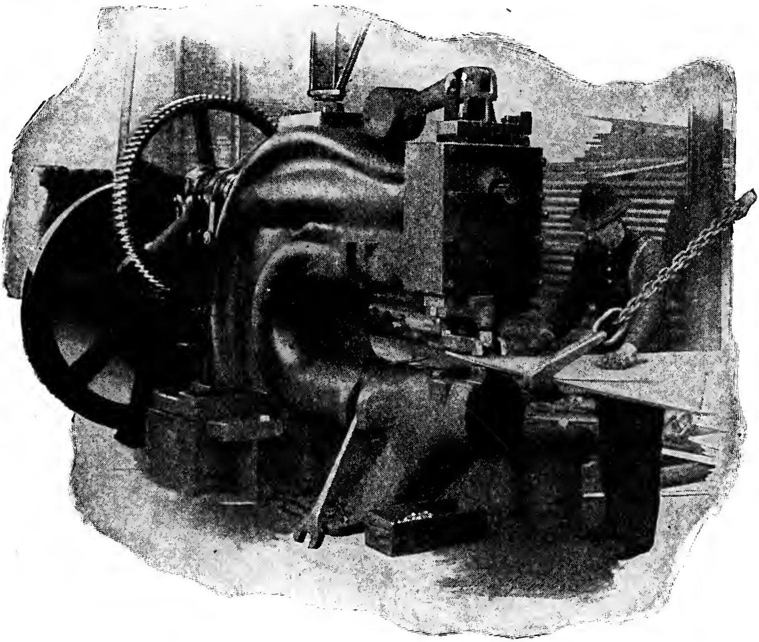


FIG. 4,247.—Punch at work centering rivet holes. These holes are centered by $1\frac{7}{16}$-inch punched holes, and afterward drilled to finished size with a twist drill.

Ans. The holes for the rivets in circumferential seams should be spaced only by dividers, after the head flange has been measured, so as to divide equally the rivet spacing, and thus correct, after the head has been flanged and annealed, any slight irregularity in diameter or circumference.

After the plates and heads have been laid out, 7/16-inch centering holes for the drills should be punched on one set of plates, the other set being left blank. This practice, which should be adopted with all rivet holes drilled from solid plate, gives one 7/16-inch centering hole for the drill and thus insures accuracy in spacing.

The centering holes having been punched, the shell and cover plates must be planed on all four sides not less than 1/4 inch in from the shearing edge in order to cut away any material affected by shearing.

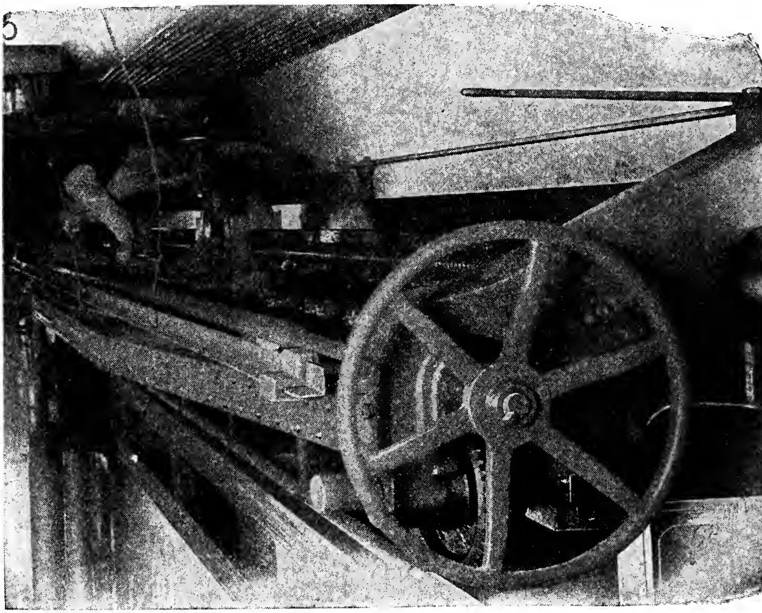


FIG. 4,248.—Plate planer at work.

On two sides, the plates must be planed to a beveled edge for the caulking tool; and on the meeting edges, to a square edge, so that the plates may be brought up close together under the butt straps.

By closely adhering to this practice, the edges of the plate, where the head flange is turned in, do not have to be upset or split or have a wedge inserted, in order to close the opening between the edges, which must be done where the rough sheared edge has been left and planing has been done only on two sides.

Ques. After planing, what is the next operation?

Ans. The shell plates and butt straps are passed through bending rolls in a manner that will insure their being brought up as nearly as possible to a true circumference without the use of sledges.

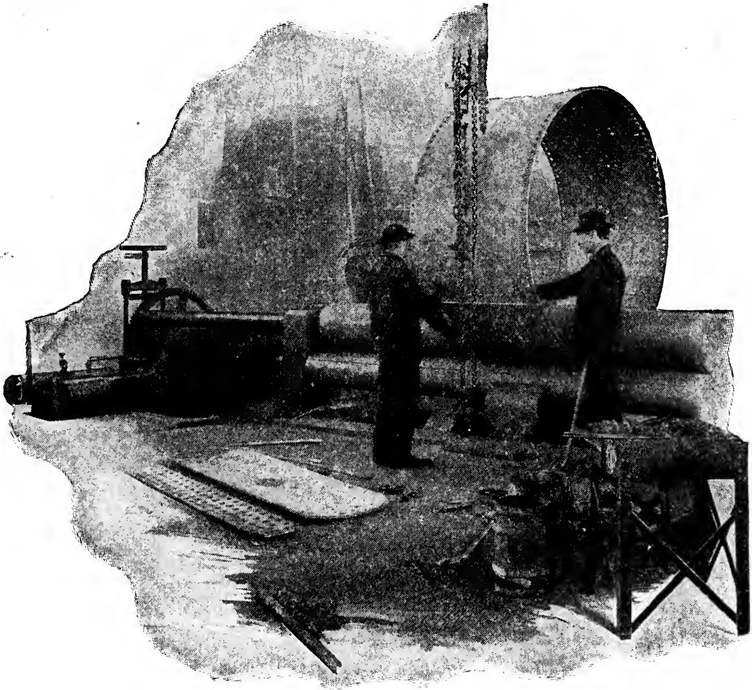


FIG. 4,249.—Plate bending machine rolling boiler shell.

This operation is considerably more important than is generally supposed, as emphasized in the following for the Hartford Boiler Insurance Co.:

"In rolling plates into the cylindrical form, preparatory to riveting them into shells, it is customary to bend one end of the plate to what is judged to be the proper radius by use of the sledge hammer. The plate is then

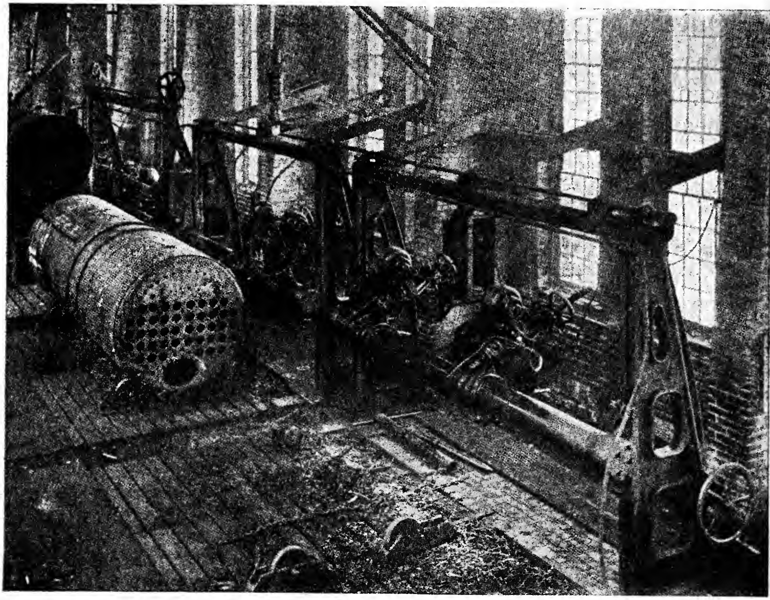


FIG. 4,250.—View in shop of Pennsylvania Boiler Works, showing battery of rivet hole drilling machines designed for drilling rivet holes out of the solid with all members in place. This is superior to methods which employ punches, and for marine boilers the requirement is that no part of a rivet hole shall be punched.

NOTE.—***Rivet shapes.*** With machine riveting, the end of the rivet is formed either into a button point, or into a turncated cone. With hand riveting, the conical point is generally formed. Where the riveting must be done by hand, the holes must be coned. For either hand or hydraulic riveting, all holes are drilled $^1/_{16}$ in. larger than the rivet.

NOTE.—***Ordinary tubes.*** As generally used, these are for No. 9 to No. 13 *B.w.g.* .148 to .095 in. thick), the front ends being swelled to a slightly larger external diameter (from $^1/_{16}$ to $\frac{1}{8}$ in.) to facilitate their entry and removal. The holes in the tube sheets are drilled slightly larger than the tubes, so that the latter can be pushed into place by very slight pressure, and the tube holes are rounded at edges to prevent cutting the tubes when being expanded.

NOTE.—***Boiler covering or lapping.*** To reduce the loss by radiation, all boilers should be covered with some insulating material. The covering is usually put on after the boiler has been installed and tested. The insulating material is lagged or covered for protection by canvas, wood, or sheet iron. In covering a boiler the covering, inoluding the insulating material, should be arranged in sections so as to be easily removable.

NOTE.—***Manholes.*** Some manufacturers place a manhole in the front head underneath the tubes; others leave this manhole out and crowd in some extra tubes. The practical engineer can readily see that a boiler without a manhole underneath the tubes cannot be cleaned. It is also quite essential to have an unbroken body of water in the bottom of a return tubular boiler, as it materially aids the circulation of the water in the boiler.

run through the rolls and rolled into shape, the end that was previously bent being introduced first. When the plate has been rolled all but the last five or six inches, the last end slips off of the first roll, and the rolls can no longer 'grip' the sheet. The result is, that the last end of the sheet is not bent to the proper radius, but remains straight or nearly so. . . . In order to bring the outer lap to the proper curvature, it is customary for one man to hold a sledge against the projecting edge of the lap, while another workman strikes the shell on the inside. In this way the lap is bent down into place, and after the shell has been brought to conform with the 'sweep' or template, in every part, it is ready for riveting. . . . If the sledging were done while the sheet is hot, it would not be so objectionable, but the great majority of boiler makers will not attempt to heat the plate before sledging the lap down, because when the sheets are hot they are apt to buckle out of shape, and give great trouble. If the sheets are to be sledged cold, the proper way to do it is to bend each end to the proper radius before beginning the operation of rolling. A convenient way to do this is to lay the ends of the sheet over the upper roll and bring it down to the proper radius very gradually.

Ques. What operation in boiler making results in cracking a large number of plates?

Ans. Plates are frequently cracked in bending by hammer.

Since numerous explosions have resulted from this cause, the greatest caution should be exercised in the operation.

Ques. How should boiler heads be flanged?

Ans. They should be flanged at a cherry red heat by hydraulic pressure or spun into shape, and great care should be exercised that they are not thinned or cracked in the heel of the flange during the flanging process.

Cracks are often discovered along flanges that have been turned to too short a radius. Careless flanging is apt to start small cracks through the skin of the iron, and these frequently extend inward and eventually become dangerous. The incipient cracks on the inside of a boiler sometimes develop into deep grooves, the slight yielding of the shell, under varying pressures, opening up the interior of the metal to the corrosive action of the water.

Ques. What precaution is necessary when the flanging is done in one operation with dies?

Ans. The greatest skill must be exercised to see that the heel of the flange is burned to an easy radius and has not been drawn out and thinned by clinching and drawing in the dies.

Ques. What is the proper temperature at which the flange should be turned?

Ans. Dull red or orange yellow.

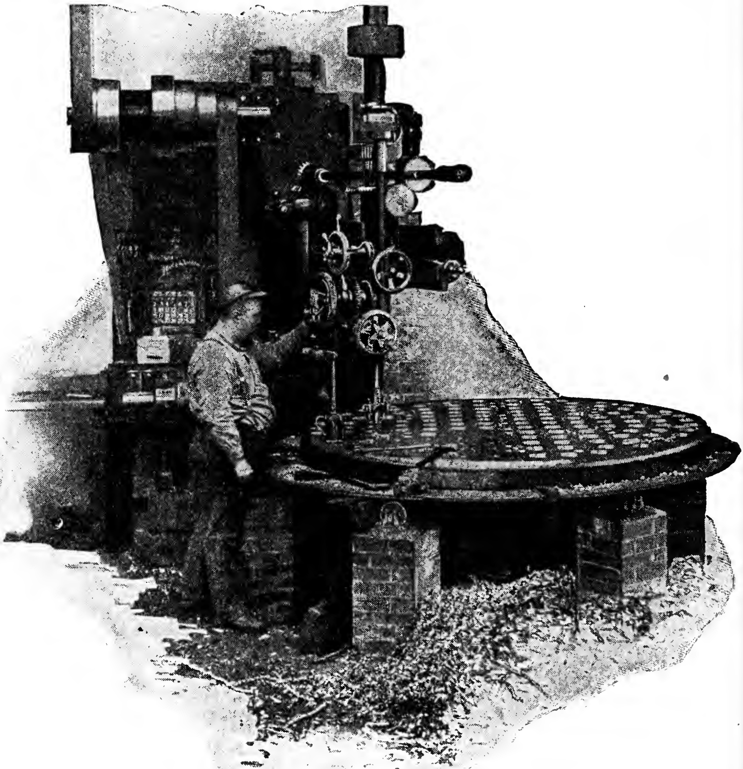


FIG. 4,251.—Drill at work cutting tube holes. A $1\frac{1}{16}$-inch centering hole should be punched as a guide to the cutter and a solid disc should then be cut from the head for each tube, and after being cut the beading side should be slightly countersunk.

Ques. What other precautions should be taken?

Ans. Unequal heating must be guarded against, and accurate allowance must be made for shrinkage by cooling, experience having shown that, when cooled, the contraction may sometimes amount to considerable, rendering the head far from true.

Ques. What operation should be performed after flanging the heads?

Ans. They must always be reheated to a uniform temperature in a furnace; when reheated they are straightened on a face plate while hot, then allowed to cool gradually so as to perfectly anneal and equalize all molecular strain.

The importance of this operation is pointed out in the *Engineering Magazine* as follows: "The microscope, in each experimental series, indicates the same result, viz., that heating at high temperature causes a great development in the size of the crystalline grains, and that reheating to about 1,600 degrees F restores the original structure, or yields an even better one. A structural steel, although good in its normal rolled or forged condition, may easily deteriorate by being heated to a temperature a little above that to which steel is most commonly heated, previously to being rolled or forged. Steel that is made brittle by such heating, or dangerously brittle by exposure to considerably higher temperatures, can be completely restored to the best possible condition without remelting and without forging down to a smaller size. Practically all experimental results show not only that the original good qualities of normally rolled steel can be restored after the material has been made brittle by the exceedingly simple expedient of heating to about 1,600 degrees F. for a very short time, but also that the steel may even be made better than it was originally.

Ques. Why is a faced head necessary, and how should the facing operation be performed?

Ans. A faced edge is essential for perfect caulking. The edge of the head flange should be faced in a boring mill instead of leaving the rough edge untouched or unfinished, as is the ordinary practice.

Some boiler makers face the edge of this flange by hand with hammer and chisel, possibly a slight improvement, but nevertheless invariably resulting in a rough edge. Too many boiler shops lack these machine tools, and as a result a very rough character of work is left on the flange so that inside caulking is impossible.

Ques. How should the tube holes be cut?

Ans. They should be cut from the solid plate by a tool having two cutting edges.

Ques. Describe a highly objectionable yet common method of cutting tube holes.

Ans. The holes are punched to nearly the finished size and then reamed.

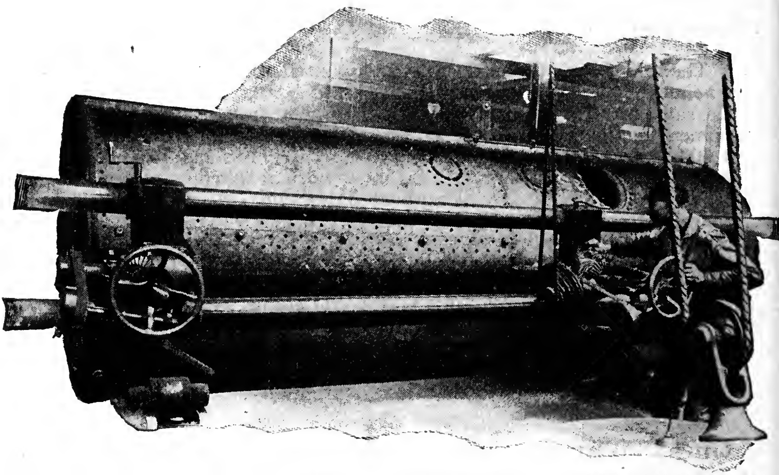


FIG. 4,252.—Drilling rivet holes in boiler shell by gang drill.

This process is objectionable, even for small rivet holes because it upsets the molecular arrangement of the metal with resulting damage to the plate. Evidently this does not occur where the holes are drilled, hence, **drilled** *holes should be specified.*

Ques. What operation should be performed on the man hole frames and man hole flange in the tube head?

Ans. They should be flanged in, and the seat for the gasket and cover should be faced.

The man hole frames and the plates should be made of the same material as the boiler, and the frame should be at least 13/16-inch thick, to insure ample strength in order to fully compensate for the material cut out of the shell. The flange, when faced to receive the gasket, should have width

Fig. 4,253.—How the seats of manhole covers are faced.

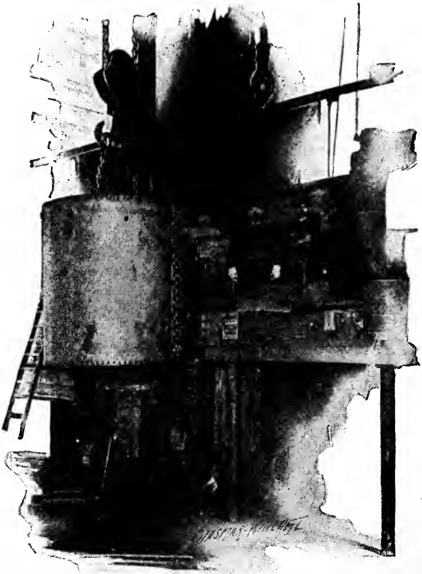


FIG. 4,254.—Hydraulic riveter. Rivets should be driven by hydraulic pressure in so far as possible, and headed up full and true with heads in line, preferably of button shape. No form of riveting compares with the work done by the hyrdaulic riveter. The full pressure can be applied throughout the full length of the stroke so that the rivet is properly upset, thoroughly filling the hole from end to end, and also squeezing the plates close, and holding them for *several* seconds while the rivet is contracting or cooling off. While apparently all methods of hydraulic riveting are the same, there are, however, two distinct methods. The start is the same; the finish is different. The results vary as widely as their costs. ***First method:*** Ordinarily, pressure is applied, the rivet formed and the pressure then immediately released, whereupon the work is considered done. No allowance is made for the fact that the hot rivet contracts as it cools. Even though the rivet completely filled the rivet hole when formed hot under pressure, the metal necessarily contracts as it cools. Hence, as the pressure has been removed, the hole remains unfilled when the rivet assumes its final form after cooling. As a consequence, the plates are held together by rivets smaller than the rivet holes, thus allowing considerable play, often resulting in leaks. ***Second method:*** The best practice is to apply the full pressure for several seconds until the rivet is cold, thus allowing the rivet to cool and shrink under pressure. The plates are squeezed closely together and as the rivet contracts in cooling, the undiminished pressure forces the metal to completely fill the rivet hole *from end to end* during the entire process of contraction until the rivet assumes its final form when cold. As a consequence, the plates are held tightly together by rivets, completely filling the rivet holes, thus preventing any play whatsoever and eliminating leakage. Furthermore, the rivets do not require such intense heat with this method, therefore there is no risk of burned rivets. *The **first** is the ordinary method because it is **cheap**.* A dozen rivets can be drived if the pressure be immediately released while one is being driven where the pressure is kept on until the rivet cools. *Manufacturers who give shop cost precedence over character or quality of work use the first method. Those who aim to do the **best** work regardless of cost employ the **second** method with its consequent greater cost, because a boiler is improperly built if constructed by any other method.*

enough so that a thin, wide gasket can be used over and over again, without cutting or requiring replacing. The finished edge should never be less than ¾ inch thick. If the head be thinner than ¾ inch, it should be brought up by shrinking a ¾×1¼ inch band around the flange, and then the whole faced. If this method be adopted, the finished edge in ¼-inch head is 1¼ inches, and ensures a smooth, wide surface for the gasket. This is greatly appreciated by the man who has to handle the man hole plate. Also by the man who pays the bills for the usual frequent renewal of gaskets caused by cutting on a too narrow seat.

Fig. 4,255.—Multi-tube hole drill. It takes head up to 11½ feet in diameter.

The foregoing operations completed, the shell, heads and butt straps are now ready to be assembled. Having been assembled, they should be bolted together and placed before the gang drills.

Ques. What should be done after the rivet holes have been drilled?

Ans. The shell should be taken apart and all burrs and pieces of cutting left between the plates by the drills should be removed. The shells must then be reassembled, closely bolted and the plates pressed close together by hydraulic pressure. The rivets are then driven, as shown in fig. 4,254.

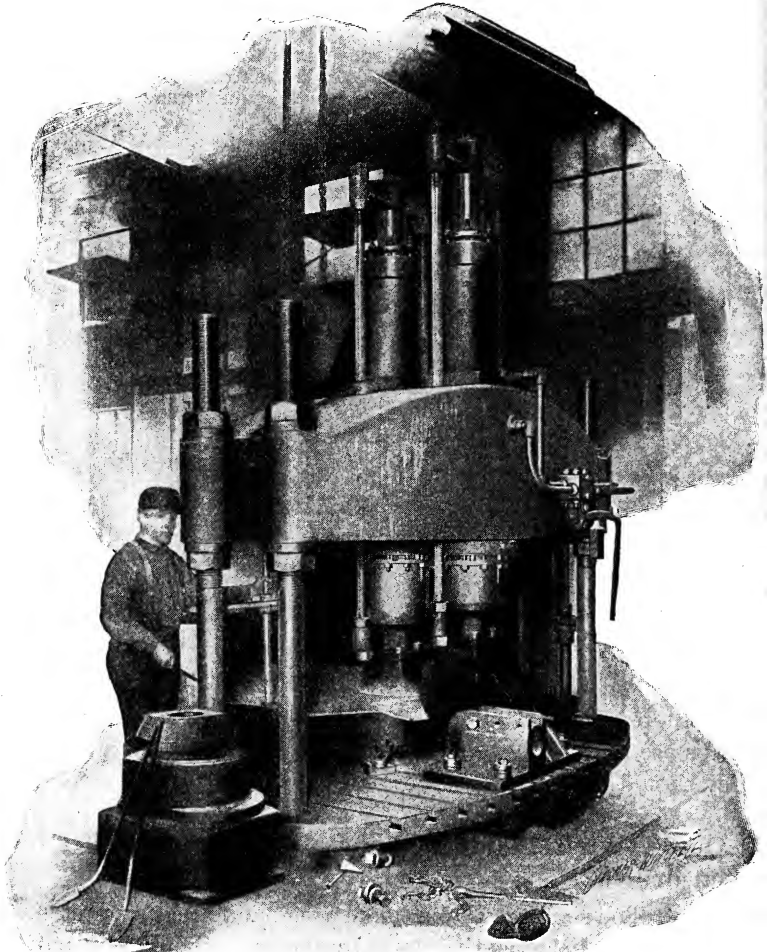


FIG. 4,256.—Hydraulic press.

Ques. Describe the operation of caulking.

Ans. This should be done outside and inside with a round nose tool so as to avoid all danger of having the plates crack or split in any way. A great tendency exists in the usual practice to "over drive," which results in splitting the edge of the plate.

The round nose tool will not cut the under plate, where square nose tools are liable to. A crack made by these tools, small at first, may finally open up and be very dangerous.

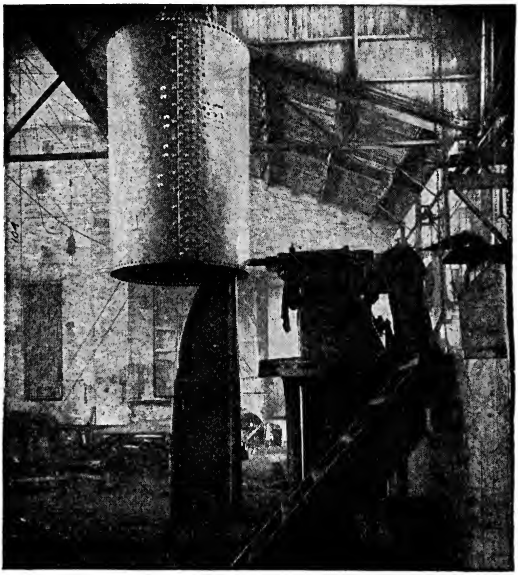


FIG. 4,257.—Hydraulic riveting machine in Freeman & Sons Shop.

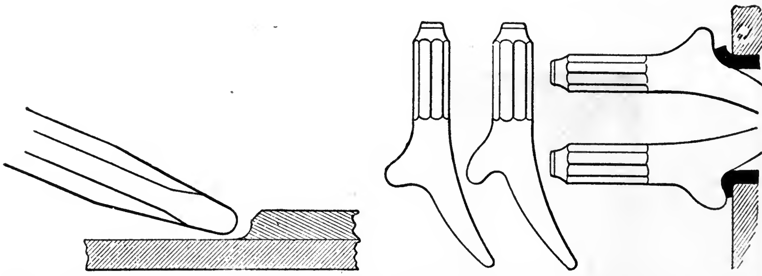
Ques. How should the tube be expanded?

Ans. With a Dudgeon (roller) expander.

By using a roller expander, the tube is uniformly enlarged and its outer surface brought into solid bearing metal to metal, with the entire inner surface of the tube hole in the sheet. After expanding, the tubes should be *beaded* down at each end.

Ques. What precaution should be exercised in beading tubes?

Ans. Great care should be taken that the metal is not so fatigued by the process as to set up cracks or badly weaken the tube ends.



Figs. 4,258 to 4,262.—Caulking and heading tools and method of use. Care must be exercised when caulking the seams between the outside rows of rivets when thin cover plates are used in triple and quadruple riveted joints, particularly where the rivets are spaced with long centers. There is great danger from the thin sheet springing up between the rivets while the caulking is going on. Considerable care and skill must be exercised to prevent this and at the same time produce a sound, perfect caulked joint. Similar care must also be exercised even when using heavy cover plates, as the danger from "springing" also exists, although perhaps to slighter extent than with thin plates.

NOTE.—Experiments clearly demonstrate that the operation of beading the tubes greatly increases their holding power. The Hartford Boiler Insurance Co. say, in this connection, in a report on an explosion: "This explosion serves to emphasize the importance of beading or flaring the tube ends of boilers, for if the tube in this boiler had been flared or beaded it is not likely that the explosion would have occurred without signs of distress first making themselves visible."

***A.S.M.E. Boiler Code.**—Selection of Materials.*

1. Specifications are given in these Rules for the important materials used in the construction of boilers, and where given, the materials shall conform thereto.

2. Steel plates for any part of a boiler when exposed to the fire or products of combustion, and under pressure, shall be of firebox quality as designated in the Specifications for Boiler Plate Steel.

3. Steel plates for any part of a boiler, where fire box quality is not specified, when under pressure, shall be of fire box or flange quality as designated in the Specifications for Boiler Plate Steel.

4. Braces when welded, shall be of wrought-iron of the quality designated in the Specifications for Refined Wrought Iron Bars.

5. Manhole and handhole covers and other parts subjected to pressure and braces and lugs, when made of steel plate, shall be of fire box or flange quality as designated in the Specifications for Boiler Plate Steel.

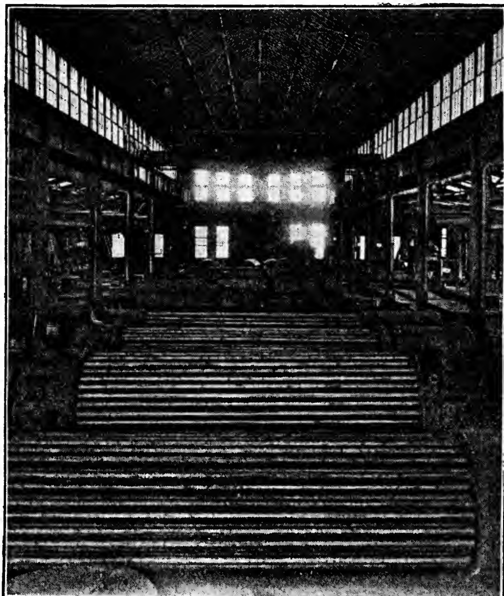


Fig. 4,263.—Interior of Wickes boiler shop showing boilers in various stages of construction.

***A.S.M.E. Boiler Code.**—Selection of Materials—continued.*

6. Steel bars for braces and for other boiler parts, except as otherwise specified herein, shall be of the quality designated in the Specifications for Steel Bars.

7. Stay bolts shall be of iron or steel of the quality designated in the Specifications for Staybolt Iron or in the Specifications for Staybolt Steel.

8. Rivets shall be of steel or iron of the quality designated in the Specifications for Boiler Rivet Steel or in the Specifications for Boiler Rivet Iron.

9. Cross pipes connecting the steam and water drums of water tube boilers, headers and cross boxes and all pressure parts of the boiler proper over 2-inch pipe size, or equivalent cross-sectional area, shall be of wrought steel, or cast steel of Class B grade, as designated in

A.S.M.E. Boiler Code.*—Selection of Materials—continued.*

the Specifications for Steel Castings, when the maximum allowable working pressure exceeds 160 pounds per square inch.

10. Mud drums of boilers used for other than heating purposes shall be of wrought steel, or cast steel of Class B grade, as designated in the Specifications for Steel Castings.

11. Pressure parts of superheaters, separately fired or attached to stationary boilers, unless of the locomotive type, shall be of wrought steel, or cast steel of Class B grade, as designated in the Specifications for Steel Castings.

CHAPTER 73

FURNACES

The term furnace may be defined as *that part of the boiler designed for burning the fuel.* There are two general classes of furnace:

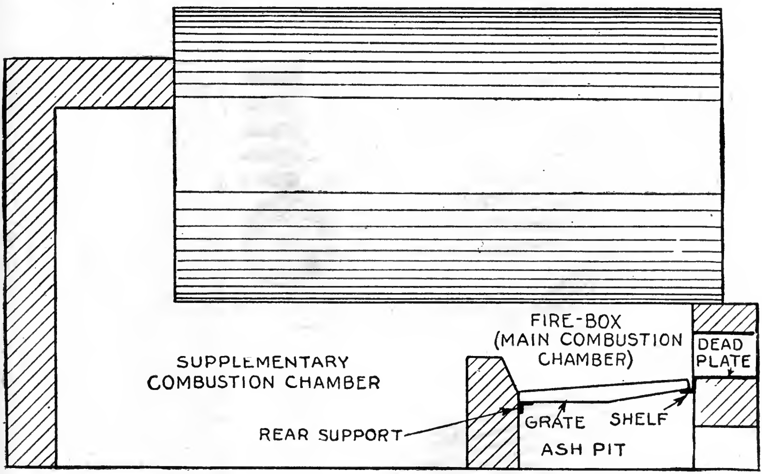
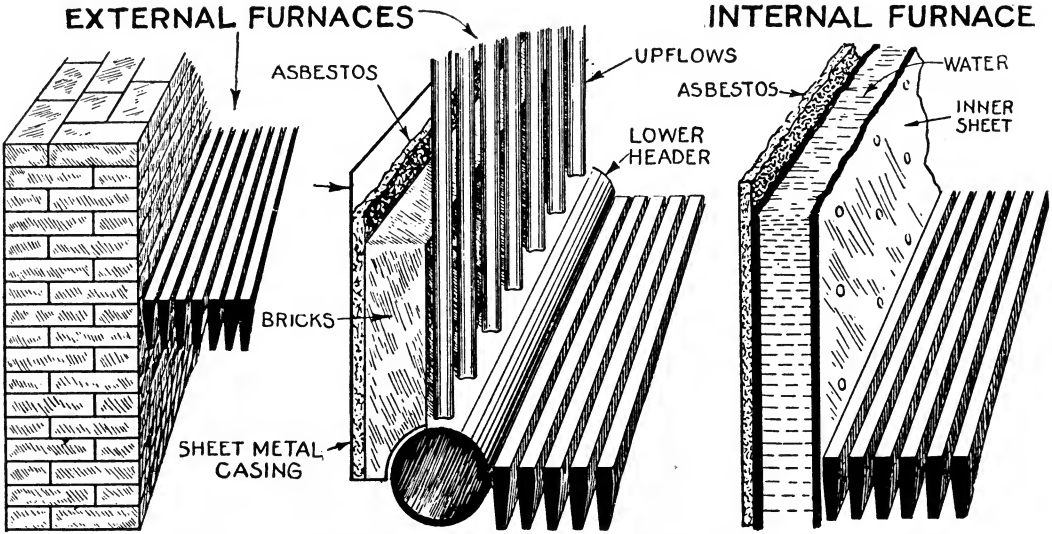


FIG. 4,264.—Horizontal tubular boiler, showing details of externally fired furnace.

1. Internally fired,
2. Externally fired,

according as the furnace is located *inside* the boiler, that is, surrounded by heating surface, or, *outside* or apart from the boiler proper.



FIGS. 4,265 to 4,267.—External and internal furnaces or "fire boxes" showing different kinds of enclosing walls. Fig. 4,265, ordinary brick setting; fig. 4,266, combination brick and "water" wall as used on some water tube boilers and consisting of, first the up-flow connections which absorb some of the heat, next a row of fire brick, behind which is a sheet steel casing with asbestos board; fig. 4,267, water wall, of internal "fire box" boilers. ***Evidently*** all the heat passing through the inner sheet is absorbed by the layer of water, except the small amount which passes through the insulating covering. Although internal furnaces, since they are surrounded by the water, are very efficient in transmitting the heat to the water, the relatively cold surfaces tend to deaden the fire adjacent to the walls.

The principal parts and appendages of a furnace as shown in fig. 4,050 are:

1. The fire box.

This is the furnace proper being the chamber, immediately above the grate, in which the constituents and part of the gases of the fuel are consumed; the main combustion chamber.

2. The grate.

Composed of alternate bars and spaces to support the fuel and admit the air necessary for combustion.

3. The front support; *dead plate*.

This consists of the bottom of the door frame which extends back a little way and drops down, forming a shelf for the support of the front ends of the grate bars. In some cases door frame extends back some distance, forming the *dead plate*, upon which bituminous coal may be piled when first fired so as to assume the character of coke before it is thrust back into the fire; thus providing for the gradual distillation and combustion of its gases.

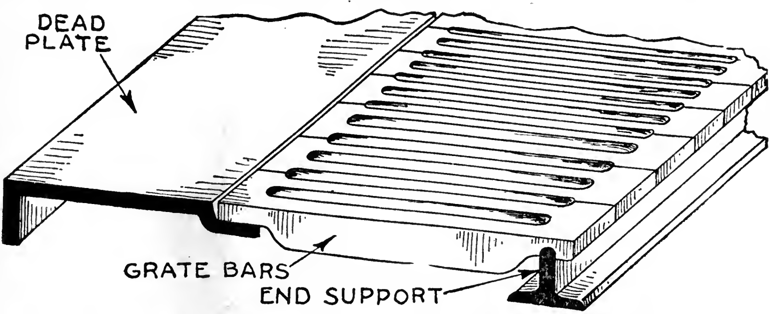


FIG. 4,268.—Detail of dead plate and grate bar.

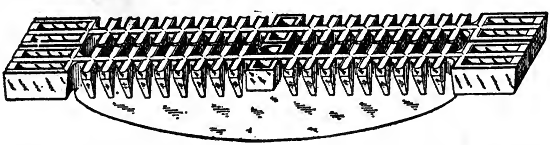


FIG. 4,269.—Fish bone type of grate bar. The illustration shows two of these bars side by side.

4. The rear support; *bridge wall*.

At the rear ends of the grate bars is a barrier of fire brick or equivalent, having a shelf attached to it to support the rear ends of the grate bars and built up several inches above the grate bars to prevent the fuel being carried past the grate in firing or by the draught, and to quicken the draught by contracting the section through which the gases flow. Sometimes the bridge wall or *bridge* consists of a casting extending across the back of the furnace and supported by attachment at the sides. This supports the back ends of the grate bars, as already referred to, and also a wall of fire brick.

5. Supplementary combustion chamber.

In some boilers there is at some intermediate point in the passage between the grate and chimney, an enlargement or chamber, the purpose of which is to assist combustion; that is, the portion of the gases not completely burned in the fire box or **main** *combustion chamber*, passes into the supplementary combustion chamber where combustion is completed, otherwise if the ignited gases passed direct to the comparatively cold heating surface they would in some cases be cooled below the ignition temperature and extinguished, resulting in a loss. The supplementary combustion chamber is generally and erroneously called the *combustion chamber*, as though it were the principal place where combustion takes place. It should be understood that it is simply an additional space or adjunct to the fire box or main combustion chamber.

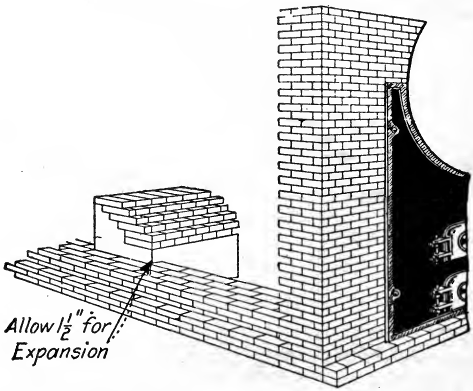


FIG. 4,270.—Detail of setting showing construction of bridge wall.

6. The ash pit.

This serves the double purpose of a receptacle for the ashes and a passage for the air supply.

The Fire Box.—The size of the fire box will depend on the quality of the fuel and quantity burned per hour. Usually the fire box is too small, and where there is no supplementary combustion chamber, it should be of very liberal dimensions.

For anthracite furnaces, the volume of the fire box can run nearly form regardless of the source of the coal, since all anthracites have reasonably near the same characteristics, however, for bituminous coals, the size must vary with the amount of volatile matter and ash, as well as with the rate of combustion.

The fire box may be a rectangular chamber as in locomotive boilers, or have cylindrical walls with corrugations, as in corrugated furnaces.

In the externally fired types, the sides consist 1, of fire brick forming a part of the brick "setting," as in stationary boilers, or 2, of sheet iron lined with asbestos board and numerous water tubes or pipes, as in marine types of water tube boiler.

The Grate.—This is made up of numerous so called grate bars.

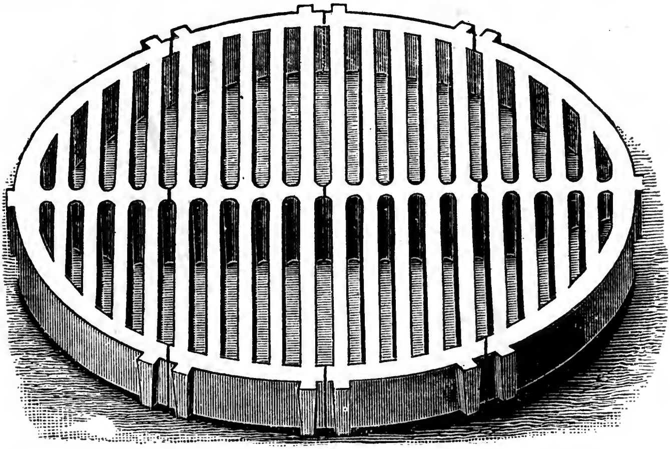


Fig. 4,271.—Plain circular grates for vertical boilers made in from 2 to 4 sections for 20 to 60 inch boilers, grate diameter 14½ to 52 inches. The standard air space is ⅜ inch.

These serve the double purpose of holding the fuel while it burns and of admitting sufficient air so that it can burn.

Evidently to secure satisfactory combustion the grate bars must be suited to the fuel used, that is, the air spaces, must not be so large as to allow the fuel to fall through to the ash pan, and there must be sufficient extent of air space to admit the necessary amount of air to the fuel.

The great variety of fuels used gives rise to numerous type of grates and grate bars.

According to the method of handling the fuel grates may b classed as:

1. Stationary.
2. Shaking.
4. Dumping.
5. Combined shaking and dumping.

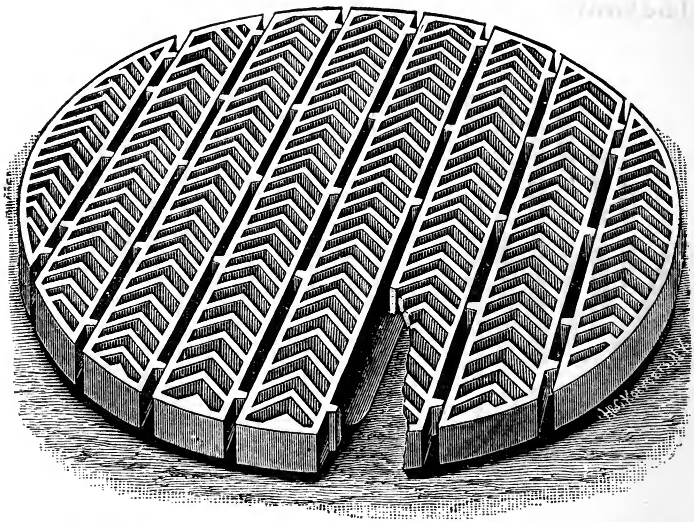


FIG. 4,272.—Herring bone grate or Tupper grate for vertical boilers, 30 to 60 inch. Gra diameters 23 to 52 inches, 4 to 8 sections.

6. Revolving.

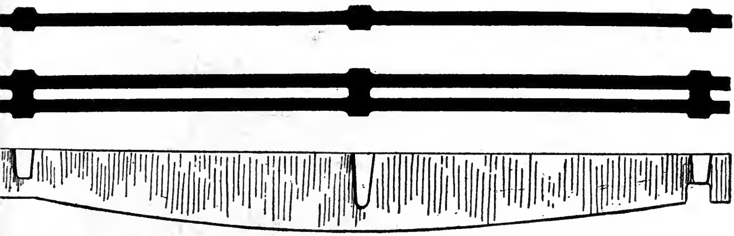
There are also a multiplicity of grate bar types, the standar forms are known as:

1. Ordinary or straight.

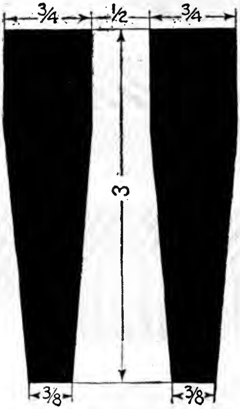
This bar, as shown in the accompanying cuts, consists of one or more stri of metal called *fingers*, separated by air spaces. The objections to this ty of bar is that it is more liable to warp than the other types and gives less air space.

2. Tupper or herring bone.

It is used fur both coal and saw dust, and is considered the best all around grate bar. Its shape, as shown in fig. 4,279, gives it stiffness, thus reducing the tendency to warp.



IGS. 4,273 to 4,275.—One and two finger plain straight grate bars.



3. Sheffield or oblique.

In this bar alternate transverse metal strips and air spaces run diagonally across, as shown in fig. 4,067; it is a modification of the tupper or herring bone bar.

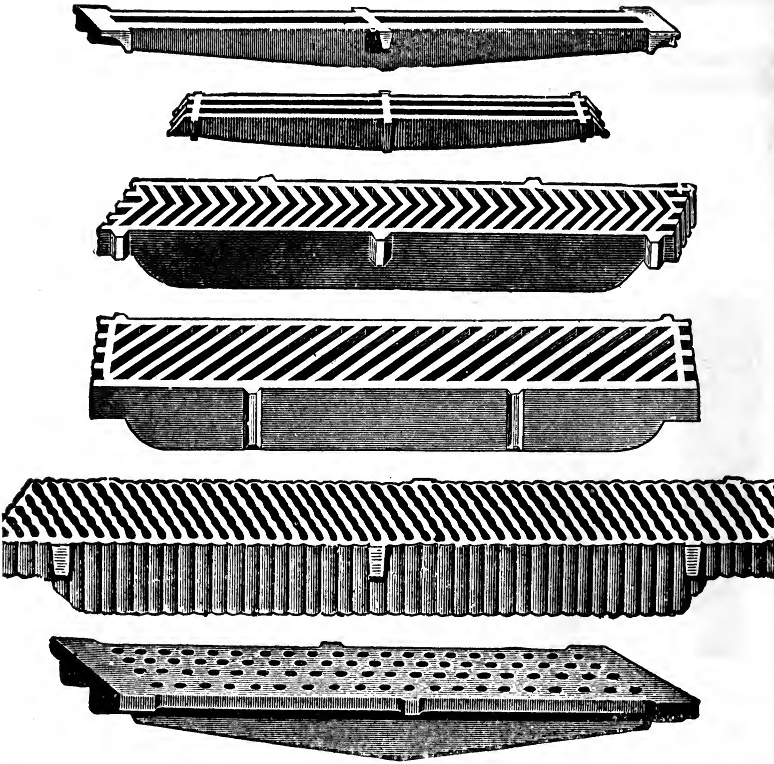
4. Saw dust.

For burning saw dust or the finest sizes of anthracite known as rice

IG. 4,276.—Section through two finger straight bar, showing proportions. The bars should not be more than three feet long and should be thiner at the bottom than at the top. To maintain constant air spaces even after the top surfaces have worn down, the fingers are made the same thickness for about 1 inch from the top, being tapered from that point to the bottom of the bars, one about 3 inches deep in the middle, depending on the length and width, and have distance pieces at the center as at the ends to prevent twisting. The illustration shows ½-inch air spaces. The size of the spaces and width of bar will depend on the kind of fuel used, varying for coal for ¼ to 1 inch, depending on the size of the lumps.

coal, flat or raised plates, as shown in fig. 4,282, are used, having tapering holes about ½ inch in diameter at the upper surface. As usually constructed an air space is obtained equal to about 25 per cent. of the grate area. A larger space would be desirable, but it is difficult to get without allowing the fuel to fall through.

The various grate bars just described are constructed of cast iron which is the best material for bars. The ribs or fingers are

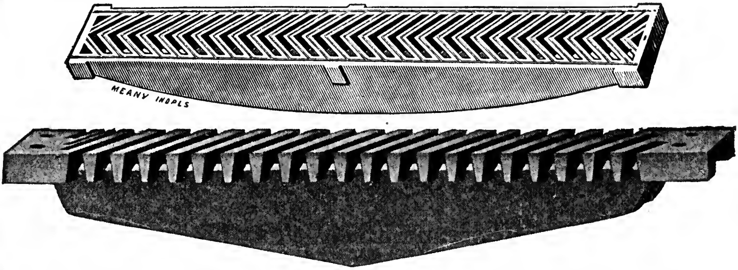


FIGS. 4,277 to 4,282.—Various grate bars. Fig. 4,277, two finger (double) bar with straight ends; fig. 4,278, three finger (triple) bar with taper ends; fig. 4,279, Tupper or herring bone bar with plain finger tops; fig. 4,280, obtuse or diagonal bar; fig. 4,281, Mahoney corrugated obtuse or diagonal bar; fig. 4,282, perforated bar for refuse burners in saw and planing mills.

of tapered cross section, giving a wider opening between the bars at the lower end, for free flow of air and cooling. Distance lugs are cast on the sides of the bars to maintain proper spacing.

Ques. How much air space is provided?

Ans. The total area of the air spaces is usually made from 30 to 50 per cent. of the grate area.



FIGS. 4,283 and 4,284.—Various grate bars. Fig. 4,283 Kelly herring bone or Tupper bar with recessed finger faces. These recesses become filled with ashes, which not only protect the surface from the intense heat of the incandescent coals but prevent slag from adhering to the metal. Fig. 4,284 Kelly bar with raised transverse fingers.

NOTE.—***Grates.*** It is difficult to select a grate that will be exactly suitably for all the different grades of coal likely to be used in a plant. The kind and quality of coal does not usually change greatly in any particular plant except under abnormal conditions. Fine coal low in ash, requires narrow openings, and fine coal high in ash, wider openings; coarse coal low in ash also calls for wider openings. By adopting suitable widths of openings for different coals the fires may be kept in good condition with the least amount of work and attention. ***Air spaces.*** The percentage of air space ordinarily is not of as much importance as the size of the air spaces. The percentage of air space is usually rather low in grates designed for burning the finest or smallest sizes of coal. Since such coal requires a much stronger draught than coarse coal, the percentage of air space may be less than for the coarse coal and still prove to be highly economical, because of the saving of coal, especially when thin fires are carried, by preventing loss into the ash pits.

Air Space and Draught Needed at Chimney

(According to the Southern Engineer.)

Kind of fuel.	Draught needed. ins. of water.	Width of air space ins.	Kind of fuel.	Draught needed. ins. of water.	Width of air space ins.
Straw	.2	¼	Pea	.5 to .8	⅜
Wood	.3	¼	Run of mine	.6 to .9	⅜
Sawdust	.35	¼	Slack	.6 to .9	⅜
Peat, light	.4	¼	Slack, small	.7 to 1.1	¼
Peat, heavy	.5	¼	Dust	.8 to 1.1	¼
Sawdust & small coal	.6	¼	Semi anthracite	.9 to 1.2	¼
Lump	.4 to .7	¾	Breeze and slack	1. to 1.3	¼
Egg	.4 to .7	¾	Breeze and dust	1.2 to 1.5	¼
Nut	.5 to .8	½	Anthracite slack	1.3 to 1.8	¼

Ques. What is understood by the term grate area?

Ans. The amount of surface (expressed in square feet) presented by the grate bars upon which the coal may be piled.

This means not only the area of the metal but that of the air spaces as well

Ques. How wide are the air spaces?

Ans. For fine sizes of anthracite the spaces are as narrow as 3/8 inch, and for different grades of coal vary in width up to 1 inch wide

Ques. How long should bars be made?

Ans. Not longer than three feet.

Ques. What important precaution should be taken in setting grate bars?

Ans. Ample space should be provided for expansion.

Cast iron exposed to continued heat becomes permanently expanded 1½ to 3 per cent. of its length, hence grate bars should be allowed about 4 per cent. play for expansion.

Ques. Mention a peculiar shape sometimes given to the top of grate bars, and why?

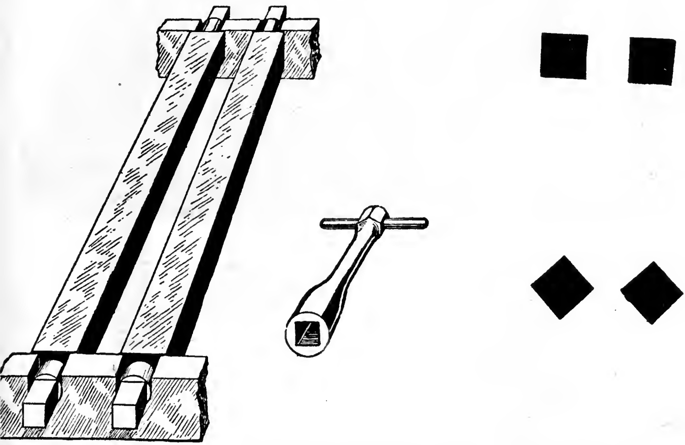
Ans. Cast iron bars often have a shallow groove running along the top. This fills with ashes and tends to prevent clinker adhering to the bar; it also acts as a coating to protect the bar from the intense heat of the incandescent coals.

Ques. What may be said of wrought iron bars?

Ans. They are used in locomotive and marine boilers, when they are subjected to hard usage. Although the fusing point of wrought iron is higher than that of cast iron, wrought iron bars bend and twist more than cast bars. Figs. 4,285 to 4,288 show some types of wrought iron bar.

There are, as in the case of cast bars, numerous types of wrought iron bars. Some boilers are fitted with wrought bars of square section, while in other bars of round section, or built up construction are used as shown in the accompanying cuts.

Rocking or Shaking Grates.—In order to reduce the labor f breaking up clinkers, various forms of rocking grate have been levised. This form of grate moreover, avoids the necessity of requently opening the fire doors to slice the fire, which results n the admission of cold air that not only chills the boiler and



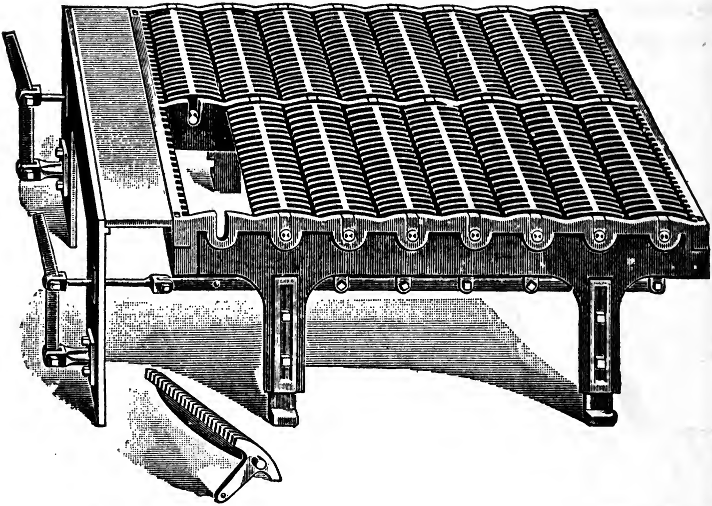
IGS. 4,285 to 4,288.—Wrought iron grate bars and wrench. Fig. 4,285 plain bar made of iron of square section. These bars may be turned back and forth to shake the fire by means of the wrench, fig. 4,286, and may be placed in parallel positions, fig. 4,287, for large air spaces, or in oblique positions, fig. 4,288, for small air space. On page 2,409 is shown a built up bar composed of wrought iron plates spaced by thimbles or distance pieces and riveted or bolted as shown.

urnace, reducing economy, but which is injurious to the fire rick lining, causing it to chip off freely.

In locomotives rocking grates are necessary because of the igh rate of combustion and consequent necessity of keeping he fire in good condition.

The simplest form of rocking grate is composed of plain bar of square section as shown in fig. 4,286, by means of a T wrench each bar may be turned back and forth.

Fig. 4,289 shows a typical form of rocking grate. Each bar is pivoted at the sides and has an arm extending down and pivoted to a horizontal lever.

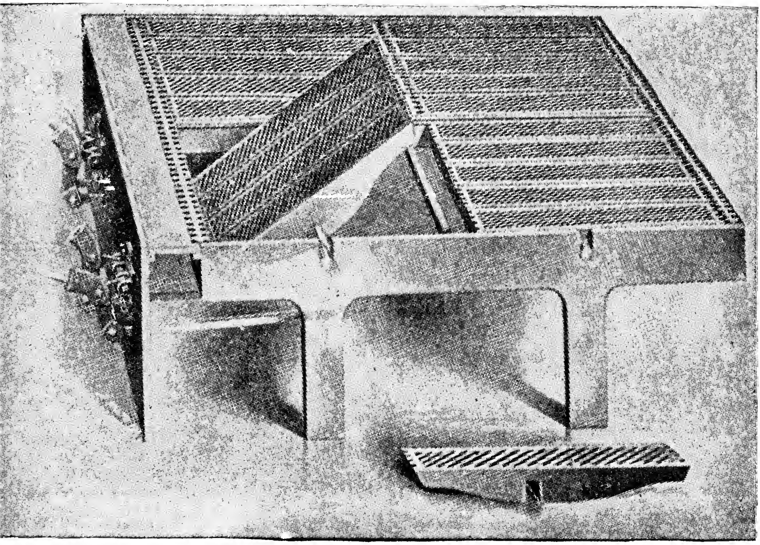


Figs. 4,289 and 4,290.—Manhattan rocking grate and detail of bar. ***In construction*** each section or bar has an arm projecting downward and pivoted to a horizontal bar which in turn is connected to the vertical shaking lever seen at the left. Moving the shaking bar back and forth causes the grate bars to "shake" or rock through a small angle, thus allowing ashes to fall through to the ash pit.

When this lever is moved back and forth by the shaking bar outside of the brickwork, the grate bars rotate through a small angle, thus clearing the bottom of the fuel bed.

Shaking and Dumping Grates.—Some grates are so arranged that in addition to shaking, the fuel may be dumped. Such grates are particularly useful on heating boilers where, because of intermittent operation or lack of attention, the fire frequently is extinguished, making it necessary to dump the fuel.

Fig. 4,297 shows a grate of this type. The bars may be shaken vigorously or gently as may be desirable, according to the condition of the fire, having a motion of 4 inches up and down without opening the spaces between the bars any further than when the grate is locked level, no unburnt fuel can drop through it.



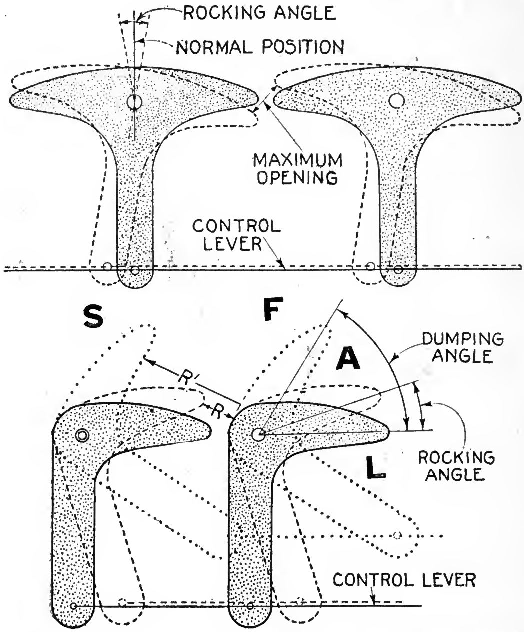
FIGS. 4,291 and 4,292.—Manhattan dumping grate. This grate is similar in principle to ths rocking grate shown in fig. 4,289, there being several sections in each dumping unit and the control levers are so geared that the units may be tilted through a much greater angle than when provision is made only for rocking, thus dumping the fuel.

The filing movement of the bars, owing to the fact that they set in the frame eccentrically, cuts the ashes entirely off the bottom of the fire, making it possible to maintain the free circulation of air through the fire.

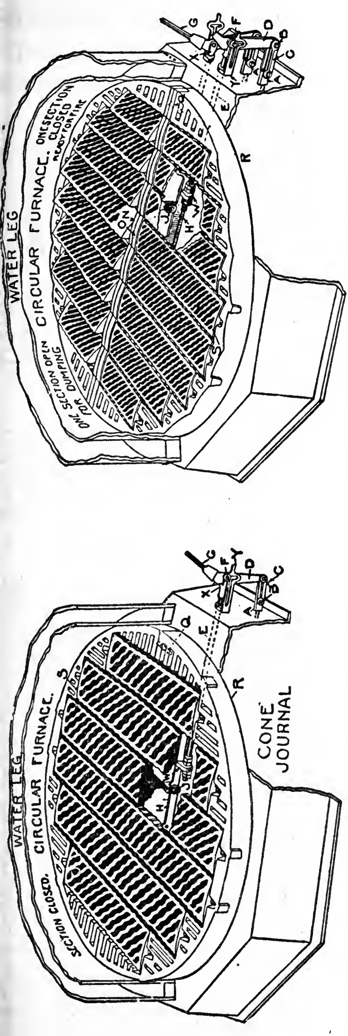
When it is desirable to dump the residue of the fire, the shaking lever is pressed downward until the bars are thrown to such an angle that the entire contents of the fire box drop through between the openings, which are then about 4 inches wide, into the ash pit. These grates are installed in 1, 2 or 4 sections, according to the size of the fire box.

Smoke Preventing Devices.—Where smoke exists, the con ditions of the furnace are such as to give **incomplete** *combustion* hence *smoke indicates* **waste** *of fuel.*

To avoid the production of smoke the temperature of the gase must be kept above the *ignition point* until after the union o carbon and hydrogen with oxygen is complete. This require a proper amount of air supply, sufficient room and time for th chemical operation to be performed, and also **provision** t



FIGS. 4,293 and 4,294.—Difference between *rocking* and ***combined rocking and dumpin*** grates. Fig. 4,293, rocking grate; fig. 4,294, combined rocking and dumping grate. I fig. 4,293 the bars are T shape. Position M, of the control lever corresponds to the horizont or normal position of the bars. ***To rock or shake*** the grate, the control lever is moved t position S and back an equal distance on the other side of the normal position. The pos tion of the bars corresponding to position S of the lever are shown in dotted lines, giving main opening large enough to pass ashes and small or crushed clinkers. In fig. 4,294 th bars are L shape and inverted: L is normal position; A, end of shaking movement; and F, en of dumping movement. The maximum opening for shaking and dumping being equal to and R^1 respectively.



FIGS. 4,295 and 4,296.—Mahoney single and double section circular ***combined*** *rocking and dumping* grate with corrugated diagonal bars for vertical boilers. Made in single sections for boilers 24 to 42 inches, and in double sections for boilers 42 to 72 inches.

prevent the gases being chilled during the process, as by coming into contact with the relatively cold heating surface of the boiler.

Numerous arrangements have been devised for preventing smoke such as:

1. Large combustion chamber.

2. Supplementary combustion chamber.

3. Baffle plates.

4. Brick checker work.

5. Supplementary air supply.

6. Dutch oven.

7. Down draught furnace.

The effect of large combustion chambers and of supplementary combustion chambers has already been explained, both tend to improve the combustion.

Baffles Plates.—Most water tube boilers have over the furnace, a roof built up of sectional tubing extending from the front header to a trifle beyond the bridge wall. The object of this tile roof is 1, to protect the hot gases from immediate contact with the comparatively cold tubes, thus securing better combustion

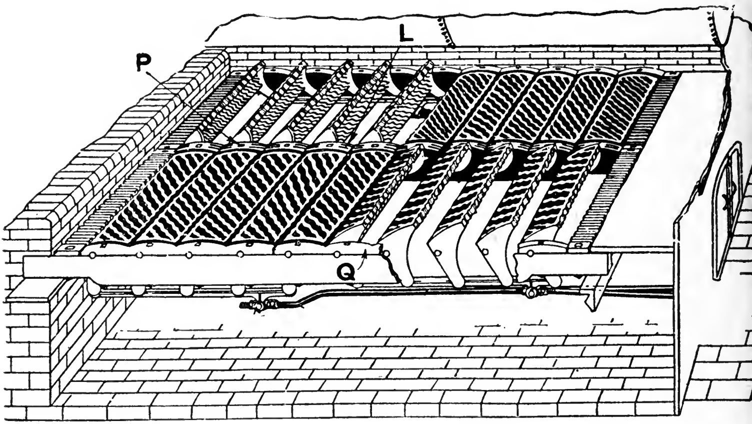
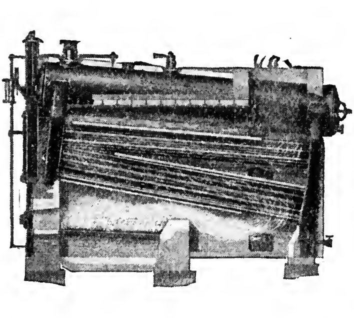
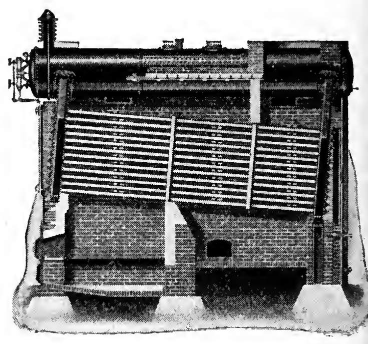


FIG. 4,297.—Mahoney premier ***combined rocking and dumping grate.*** Air space for any size coal and arranged in from 1 to 8 sections.





FIGS. 4,298 and 4,299.—Casey-Hedges horizontal water tube boilers, illustrating 1, horizontal (fig. 4,298) and 2, vertical (fig. 4,299) baffles. The horizontal baffles are arranged for two passes, being adjustable to suit draught conditions. The lower row of tubes is completely encased in tile, forming an incandescent roof over the furnace, giving Dutch oven effect. The vertical baffles (fig. 4,299) is arranged for three passes; this method is sometimes modified for four passes taking the gases off from the bottom.

and 2, to protect the tubes from the intense heat directly over the furnace. With this arrangement almost smokeless operation is obtained with little or no excess of air.

Figs. 4,298 and 4,299 show the tiling in detail and fig. 4,300, location of same on boiler. The equivalent of this is sometimes provided in tubular boiler settings in the form of an arched wall over the furnace as shown in figs. 4,304 to 4,307.

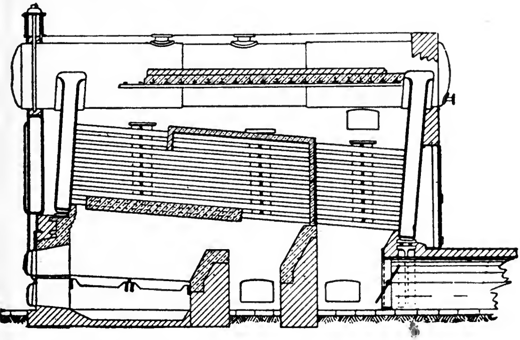


FIG. 4,300.—Casey-Hedges horizontal water tube boiler with combination horizontal and vertical baffles. When this method of baffling isused, the gases are usually taken off at the bottom or back end. It will be noted that the boiler has a "Dutch oven" effect due to the fact that the baffle tile surrounding the lower row of tubes form an incandescent reverberatory top for the furnace.

Brick Checker Work.—The object of any arrangement of this sort is to act as a heat reservoir so that combustion will take place within a highly heated passages, and to thoroughly mix the air with the combustible gases. An example of checker

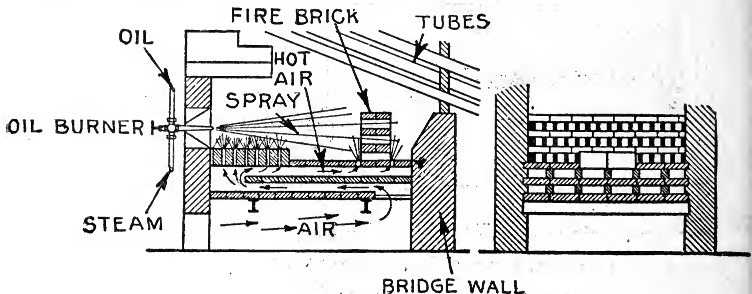
NOTE.—When horizontal baffles are used, the tube section is split up in two banks, and the baffling arranged so that the gases circulate through each bank, eliminating short circuiting, which is common to most types of boilers employing the single horizontal pass through the tubes. Boilers of the horizontal baffle type are provided with hollow stay boltsin the headers, through which the soot and ashes may be blown off the heating surface of the boiler. In the vertical baffle type, there is provided the necessary vertical baffles, of the very best grade of fire tile. These baffles are held in place with heavy cast iron backing-up plates. There is also provided a lintel plate for carrying wall above rear baffle, and side dusting doors for blowing the soot and ashes from the tubes. In the vertical baffle type boiler, the tubes are inclined one inch to the foot, the steam drum setting horizontally. The vertical baffle type of boiler can be modified to suit various conditions.

NOTE.—In the Casey Hedjes horizontal water tube boiler with horizontal baffles is arranged so that there are two passes of the hot gases through tubes, and not one, as in most horizontal baffled water tube boilers. The baffles are so arranged that they can bead justed to suit draught conditions. The tubes are divided into two banks, an upper and lower bank. The lower bank is inclined two inches to the foot. The lower bank of the tubes being the hottest, in consequence the circulation is most rapid, therefore, the necessity of the increased inclination. The upper row of tubes and drum are inclined one inch to the foot. The boiler is supported at the front end by a beam and column suspension. At the rear end it rests on cast iron columns with expansion plates and rollers. This construction permits the boiler to expand and contract in any direction without interfering with the brick work. A superheater may be installed in the space between the upper and lower bank of tubes.

work is shown in figs. 4,092 and 4,093, showing an oil burning furnace as suggested by the designers of the Sterling boiler.

Supplementary Air Supply.—Perfect combustion requires a certain amount of air, all of which may be admitted through the grate, or part delivered at some point beyond the grate, the object of this supplementary air supply is to secure a thorough mixture of preheated air and gases.

Ques. What is the advantage of preheating the air?



FIGS. 4,301 and 4,302.—Checker work baffles as applied to a front feed oil burning furnace without grate.

Ans. The affinity of heated air for carbon being much greater than that of cold air, it raises the intensity of combustion.

When heated air is employed, it is deprived of its oxygen within a very short travel, the combustion is thereby more concentrated and localized at the focus where the heat has to be applied and to do its work. This is favorable to economy of fuel, because combustion and high temperature beyond the point where heat has to be applied are useless.

Figs. 4,308 to 4,310 show various arrangements for introducing supplementary air supply by means of perforated bridge walls.

Dutch Oven Furnace.—This consists of a boxlike extension to the boiler setting proper. The grate is entirely surrounded by fire brick except the exit side to boiler heating surface. There is a fire brick arch or tile above the grate and since this and the

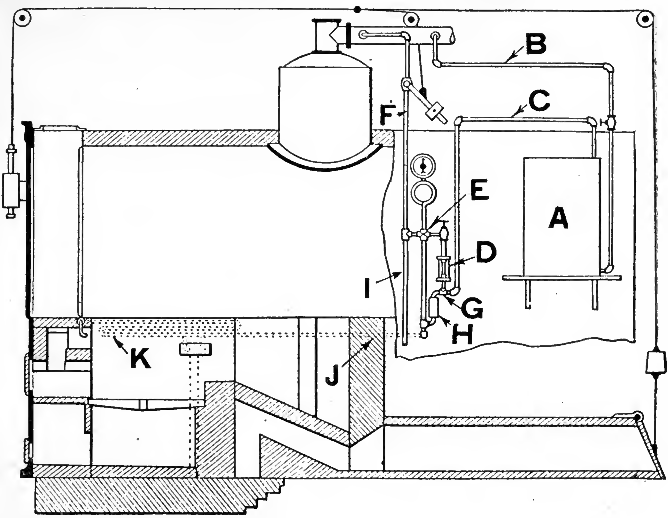


FIG. 4,303.—Puddington smokeless furnace designed to supply automatically the proper amount of heated air to mix with the volatile gases and floating carbon distilled from a charge of green coal in the fire box, the temperature being such that the gases are ignited and burned, thus securing perfect combustion and preventing smoke. To accomplish this a large passageway is constructed under the furnace and the air supply is drawn through it to the fire box, the supply being controlled by a damper, operated by mechanism that is actuated by the opening and closing of the fire doors. At the rear end of the fire box, is the mixing pocket which becomes incandescent and, in passing through which, the air and gases become thoroughly mixed. Beneath this pocket and in heating relation thereto, is located a large air chamber, into which the air passageway from the rear of the combustion leads and from which connection is made under the furnace to the air chamber over the fire doors. When the fire door is opened, jets of combustible gas are projected downward and to the rear over the fuel bed, thoroughly intermixing the hot air and the gases and at the same time acting as a torch to cause ignition of the mixture. Located at some suitable point is a tank A, containing petroleum or other hydrocarbon and connected at the bottom with the steam pipe B. A pipe C, leads from the upper portion of this tank to the lower end of a sight feed device D, from the upper end of which a pipe leads to a pipe E. Joining with this pipe E, is a pipe F, which leads from the steam space in the boiler. Between the sight feed device and the pipe C, is a valve, connected with a plunger in the cylinder H. This cylinder is connected with the pipe E. A spring tends to hold the valve closed, while the pressure on the piston from the pipe E, tends to open it. I, represents a drain pipe leading from the pipe E, but normally closed. Leading from the lower end of the pipe E, is a pipe J, which is embedded on one of the walls of the furnace and forms a retort alongside of the fire box, being coiled back and forth on itself, as shown at K. Leading from this coil, a pipe extends crosswise within the brick work above the air chamber, and extending downwardly from this pipe are a number of branch pipes terminating in nipples, which freely occupy the discharge openings in the wall and point rearward and downward toward the fire box. When the steam is admitted from the boiler to the pipe F, the back pressure of the fluid in the pipe J, acting against the piston in the cylinder H, opens the valve and admits oil to the pipe E. The oil and steam pass together through this pipe and through the retort where the mixture is heated sufficiently to decompose the steam, making carbon monoxide and hydrogen, which is discharged into the furnace as previously described.

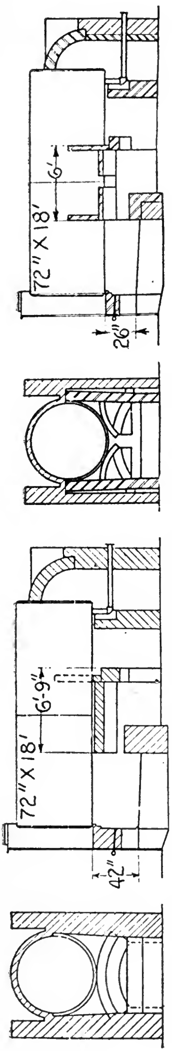
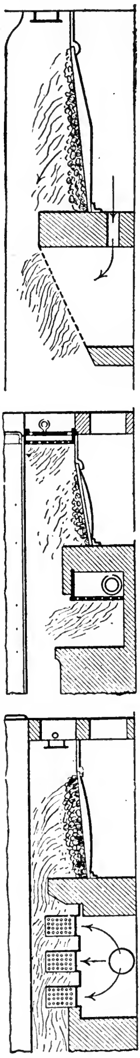


FIG. 4,304 to 4,307.—Single and double arch furnaces which have proven successful.



FIGS. 4,308 to 4,310—***Supplementary*** *air supply* introduced through perforated walls giving Argand burner effect.

other fire brick present intensely hot surfaces for the burning gases to strike against as they rise from the fuel bed, hence the combustion is improved.

Fig. 4,103 shows the general arrangement of a Dutch oven furnace.

Ques. For what kinds of fuel is the Dutch oven furnace well adapted?

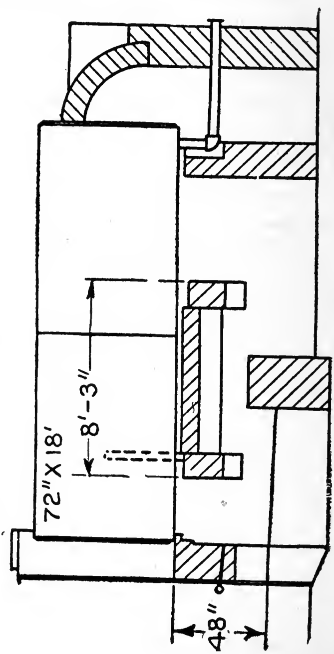


FIG. 4,311.—Furnace baffle or "igniting arch" as applied to a horizontal tubular boiler.

Ans. For refuse fuels such as sawdust, hoggings, spent tan, bagasse, rubber gayule, and refuse from the various kinds of wood extract plants.

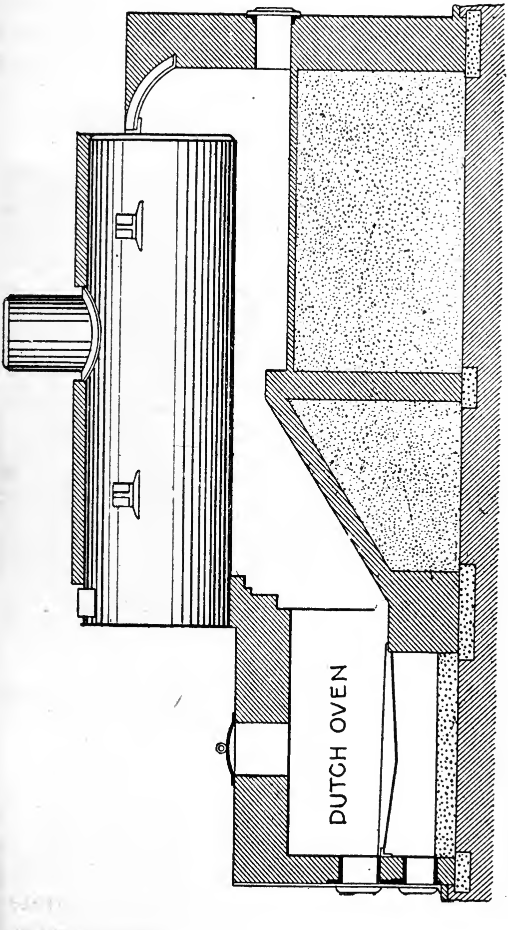


Fig. 4,312.—Dutch oven furnace.

The intense heat generated in the furnace conserves the lowest grades of fuels and refuse which are impossible to burn in an ordinary furnace.

Ques. State some objections to the Dutch oven furnace.

Ans. The additional room required for the setting, and the more intense heat to which the fire brick are subjected.

Down Draught Furnace.—In this furnace there are two grates, one above the other as shown on fig. 4,313. The lower grate consists of the ordinary iron grate bars, while the upper grate is composed of wrought pipes connected to two headers, with proper connections to water space in the boiler for free circulation of water through the tubes, thus protecting them from the intense heat.

In operation fresh coal is fed to the upper grate, and as it becomes partially consumed falls through to the grate below where the combustion is completed.

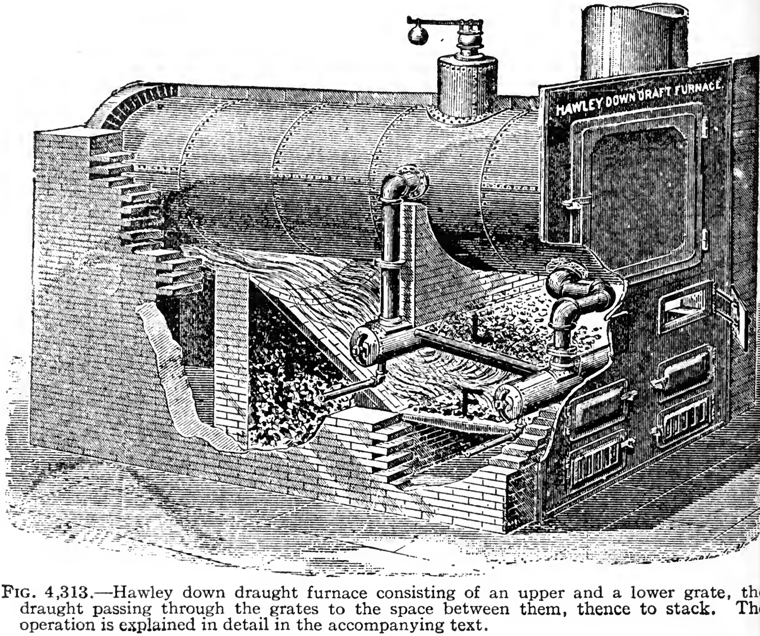


FIG. 4,313.—Hawley down draught furnace consisting of an upper and a lower grate, the draught passing through the grates to the space between them, thence to stack. The operation is explained in detail in the accompanying text.

Ques. Explain the draught.

Ans. The draught is *upward* through the lower grate as in an ordinary installation, and *downward* through the upper grate because the passage to the chimney is from the space between the grates.

Ques. Explain the combustion.

Ans. The volatile gases are carried down through the bed of fuel on the upper grate and are burned in the space below where they meet the hot air drawn upward from the lower grate. A large proportion of the air for combustion enters the upper grate door.

Test on down draught furnaces show that from 30 to 45 pounds of coal per square foot of grate can be burned with satisfactory results.

Ques. What size of rear drum should be used for the down draught grate, and why?

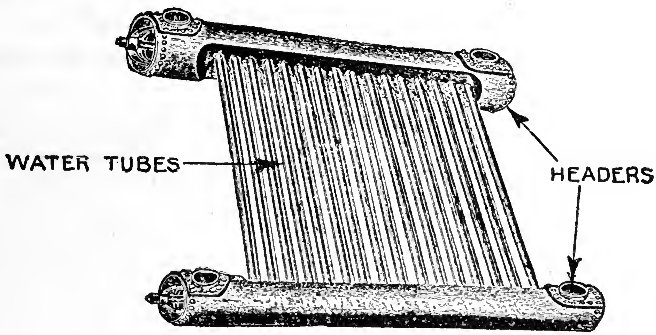


FIG. 4,314.—Down draught water grate as used with Hawley down draught furnace.

Ans. One large enough to insert a man hole in the head to permit examination of the pipes.

By attaching a stick to a candle and passing it through the pipe opening in the small drum, a man in the large drum can ascertain the condition of each pipe.

Ash Pit.—The depth of the ash pit is limited by the height of the grate above the floor at which the firing can be conveniently done. This height should not be more than about 20 inches.

Doors are put on ash pits (except on air tight ash pits for forced draught), because of the mistaken idea that it is the proper device for regulating the draught. The door has an impossible duty to perform, if it be closed, especially when cleaning the fire the grate becomes overheated and rapidly deteriorates.

Ques. How is the best way to induce a fireman to regulate the draught by the damper in the stack and not by the ash pit doors?

Ans. Remove the ash pit doors.

Ques. How should the ash pit be constructed?

Ans. It should be arranged to hold a pool of water several inches deep.

Water should always be kept in the ash pit in order that the vapor arising from same will protect the grate bars from becoming overheated, and **not** because of the general opinion which prevails that this vapor assists combustion.

CHAPTER 74

MECHANICAL STOKERS

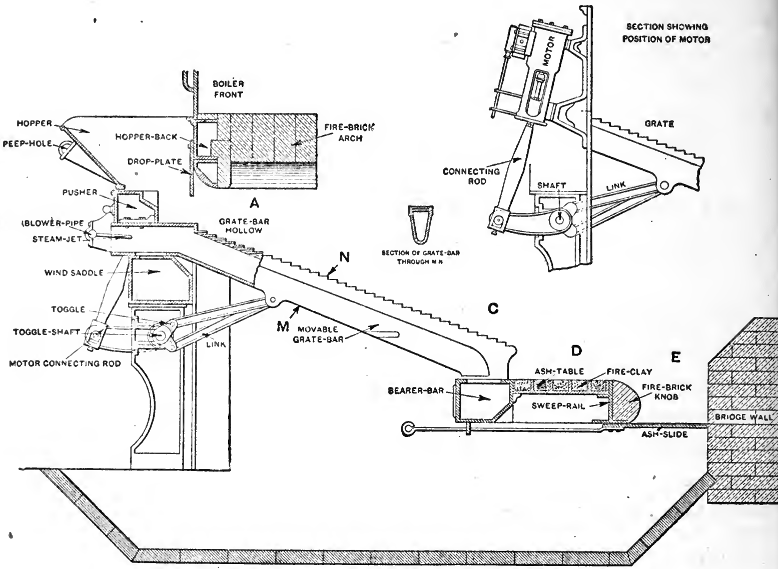
The subject of smokeless combustion is one of increasing importance, not alone for the reason of cleanliness in cities and residence districts, but principally because smoke represents waste due to incomplete combustion, and with the constantly increasing cost of fuel and wages, any device whose use will result in a saving, upkeep and operating expenses considered, must be adopted.

Evidently, with intermittent hand firing, the combustion is neither uniform nor perfect at all times because of the frequent opening of the doors allowing a large excess of air to enter which chills the flame, and the dumping of a quantity of fuel at each firing, resulting in smoke periods until normal combustion conditions are restored. To avoid these losses, mechanical stokers are designed:

1. To maintain a constant feed of the fuel without opening the doors.

2. To automatically clean the grate of ashes and clinker and to effect the full saving possible, automatic auxiliary apparatus is provided to handle the coal and ashes, and to reclaim any good fuel or siftings deposited in the ash pit.

There are a multiplicity of stokers on the market, and they



FIGS. 4,315 and 4,316.—Mechanism of the Wilkinson front-over feed stoker. ***In operation,*** coal of a slack or crushed form having been placed in the hopper, passes under the drop plate (height of same being varied to suit the fineness and nature of the coal burned), than passing on down the grates begins to ignite and coke at A, reaches a higher zone of combustion at N, and at C, is practically at a white heat when a heavy load is being carried. The partly burned out ashes land at D, where they give off all their heat, finally tumbling over on the ash slides at E, whence they are easily removed by pulling out the ash slides. The grate bar, a small section of which is given, weighs from 160 to 210 pounds, according to the size stoker, and length of these bars is proportioned to the grate surface required. This stoker will burn slack, buckwheat and pea anthracite coals, or mixtures of same will also burn successfully bituminous coals of a slack or crushed form. Tests were made by the manufacturer to determine the relative advantage of steam jet, and blower. The trials were made with the use of the steam jets first, and next by the use of a blower driven by an engine, and using the same boiler, same degree of draught, and the same quantity of coal, under the same conditions as near as it was possible to produce them. The test using the steam jet showed an evaporation of 10.15 pounds of water per pound of coal burned on the grate. The test with the blower showed an evaporation of 9.22 pounds of water for every pound of coal burned on the grate, showing a gain of 10 per cent., due to the exclusive use of the steam jet. These results were obtained running the boiler 57 per cent. above its rating. The steam jets protect the grate bars from the intense heat of the fire.

NOTE.—"By increasing the capacity of a battery from 50 to 200 per cent, compared with other methods of firing, the stoker virtually adds that amount to the entire boiler plant (auxiliaries excepted) at only the cost of the stokers themselves. Where land is costly, the saving in ground and buildings alone may more than pay the difference in cost of the stokers, leaving the saving in boilers and the fuel economy as clear gain. Even more important than the saving in over-all cost of plant is the saving in operating cost, comprising both fuel and labor.

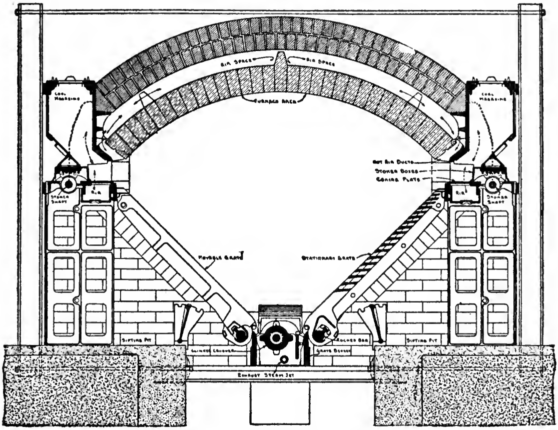


FIG. 4,317.—Murphy side-overfeed stoker. At either side of the furnace, extending from front to rear, is a coal magazine of ample size, into which the coal may be introduced, either mechanically or by hand. At the bottom of this magazine is the coking plate, against which the inclined grates rest at their upper ends. The stoker boxes (shown on page 2,464) operated by segment gears and racks, are moved forward and back upon this coking plate, and push the coal through the throat opening onto the grates. The coking plate is sectional and is cooled by air passing through the duct. extending under same, which conveys air to the rear end of the chamber in the arch. The grates are made in pairs, one fixed, the other movable. The movable grates, pivoted at their upper ends, are moved by a rocker bar (located at their lower ends) alternately, above and below the surface of the stationary grates. ***In operation,*** as the coal leaves the magazine, from which it is fed alternately and intermittently it rests for a short time upon the coking plate; there the volatile gases are driven off and immediately mixed with the heated air admitted through the arch plate air ducts and forming a combustible gas, which is burned as it passes toward the rear of the furnace. The fuel then travels slowly down the inclined grates toward the clinker grinder, receiving the requisite amount of air through the grates to complete the burning process. and by the time it reaches the clinker grinder, the combustion is complete, and the ash and refuse automatically removed and deposited in the ash pit. The speed at which the stoker boxes push the coal into the grates can be easily regulated to conform with the duty required. The grates being pivoted at their upper ends and actuated at their lower ends, have their greatest action at the lower end. and consequently the ability to break up the fuel bed, allowing the air free admission to all parts of the furnace, assures practically complete combustion of the carbon. The clinker grinder can be adjusted according to the amount of ash in the coal, independently of the balance of the mechanism.

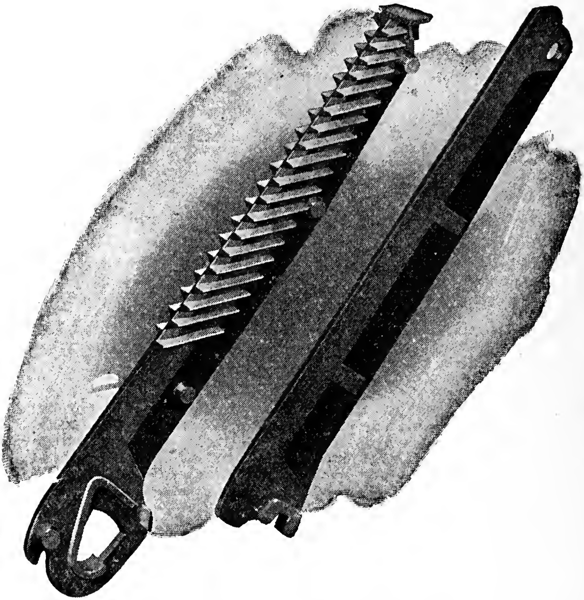
NOTE.—***Murphy stoker drive.*** The furnace is actuated by a reciprocating bar across the front normally driven by an engine. It can also be successfully operated by hand; the fuel fed and the ash removed in the same manner as when controlled by the engine. This prevents any possibility of the furnace or boiler being thrown out of commission by the breaking of any portion of the actuating mechanism. The construction of the furnace is such that it lends itself readily to various methods of operation. The small engine located on either side of the furnace or battery, is that most generally used. The engine adopted by the Murphy Co. is a small, compact, double cylinder, single acting and self-oiling. Quite often, however, it is desired to use an electric drive, which is also a very satisfactory method and has its advantages. A variable speed motor should be used, mounted on a heavy cast iron base, which also supports the bearing for the reducing gears. For large installations, however, it has been found best, in a number of instances, to vary from the above methods, and avoid a large number of small driving units, by providing an over-head shaft and ratchet drive.

may be classed, with respect to the manner in which the fuel is fed, as:

1. Over feed.

   a. Front feed.
   b. Side feed.

2. Under feed.



FIGS. 4,318 and 4,319.—Grate bars of Murphy side-overfeed stoker. Above the coking line the bars are ribbed to prevent the admission of an unnecessary amount of air. These ribs also serve to carry the fine coal before it is coked, and prevent excessive sifting, further down the grate, or below the coking line, these ribs are omitted, thus a liberal air opening is provided where it is most needed.

   a. Inclined grate.
   b. Horizontal grate.

3. Rotary of sprinkler feed.
4. Chain, or traveling grate feed.

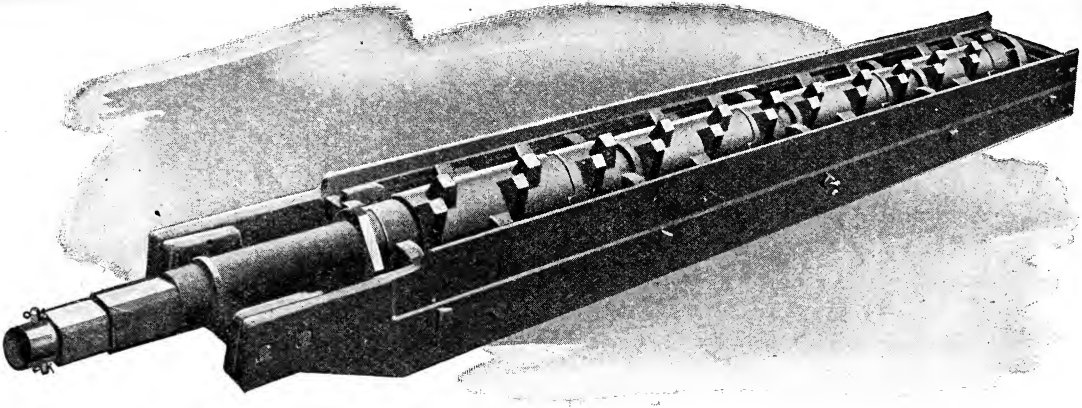


FIG. 4,320.—Murphy single clinker grinder and grate bearer. The grate bearer acts as a support for the lower end of the stationary grate bars, and also carries the rotating clinker grinder. Exhaust steam from the stoker engine is emitted immediately under this bearer, and serves to lengthen the life of these parts, softens the clinker and assists in the cleaning process. The clinker grinder is built of a square steel shaft, on which are slipped small toothed cast iron segments; these are easily and inexpensively renewed in case of wear or breakage. The feed of this clinker grinder is adjustable and can be varied to suit the amount of ash contained in the coal.

Overfeed Stokers.—In the front feed type of over feed stoker, of which the Rover and Wilkinson stokers are examples, there is a step grate, consisting of a series of stepped grate bars, slightly inclined from the horizontal, and a dumping grate at the bottom which receives and discharges the ashes.

The bars are given a slow rocking or sawing motion by means of a small engine or motor. The motion thus imported gradually carries the fuel as it is burned toward the rear and bottom of the furnace. The dumping gates at the bottom of the inclined grates are flat.

During the process of combustion the fuel is coked on the upper portion of the grates, and the volatile gases driven off in this process are ignited and burned in their passage over the bed of burning carbon lower on the grates.

In the second type of over feed stoker, illustrated by the Murphy stoker, the fuel is fed from the sides of the furnace for its full length on to the upper part of the grates inclined downward toward the center.

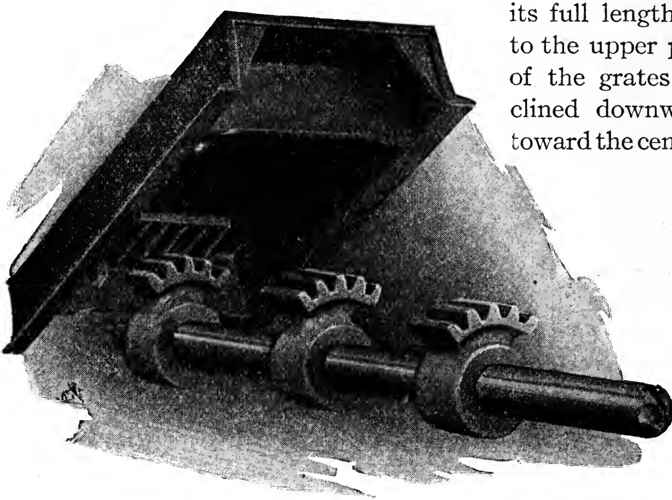


FIG. 4,321.—Murphy stoker box and stoker shaft. These boxes push the coal onto the grates and can be regulated to conform with the duty required.

The inclined grates are moved by rocking bars and the fuel is gradually carried on to the bottom and center of the furnace as combustion proceeds, where a clinker breaker grinds out and removes the refuse.

Ques. For what kind of fuel are over feed stokers adapted?

Ans. Caking coal.

The fires ordinarily carried are comparatively thin, and the movement of the grate bars keeps them broken up and open, thus preventing caking.

Instructions
for
Operating Murphy Overfeed Stoker

To Start Furnace

1. Give new furnace brick work at least a twenty-four hour drying by slow fire.
2. Fill the worm gear oil chambers of the enclosed drive with a heavy oil. Fill all grease cups and oil necessary parts.
3. Open all ash and sifting pit doors and air slides.
4. Unhook links and throw out pawls so that the driving bar cannot move the grates, stoker boxes or clinker bars.
5. Scatter wood and kindling the entire depth of the furnace over the clinker bars and the lower ends of the grates from front to rear.
6. Set the boiler damper about half open and light the fire.
7. Fill the magazines with coal and feed just enough by hand to keep the grates covered. Build up a thin fire.
8. Open the valve on the furnace front which allows exhaust steam to pass beneath the grates and clinker bars.
9. When the fire is thoroughly started and the steam pressure is high enough, start the driving engine.
10. After trying out the movements of the stoker boxes, movable grates and the clinker bars by hand, hook up links and throw in pawls.
11. Break up and level the fire.
12. Regulate the speed of the engine and set the boiler damper for the load required.

The Fire

1. Carry a V-shape fire bed from 3 inches to 8 inches thick.
2. *Do not carry a heavy fire at the lower ends of the grates and over the clinker grinders.*
3. Thickness of fire depends upon the draught, load and kind of coal.
4. Keep a thin fire for low draught or fine coal.
5. Run the driving engine just fast enough to keep the grates covered with coal.
6. If the fire become unbalanced, even up by wrenching in coal by hand, or by stopping the stoker boxes.
7. Wrenching in too much coal at one time will cause smoke and heavy fires.
8. Never poke the fire at the top of the grates where it is coking.
9. When burning coals that require occasional breaking up, roust through the capped roust holes.
10. The roust bar should be pushed in with the hook flat on the grates, and pulled out with the hook cutting the fire.
11. *About once every 2 or 3 hours hook through the middle of the fire so as to break up the clinker bridges.*
12. Slow up or stop the clinker grinders when fire is being ground out into the ash pits.
13. Adjust the speed of the clinker grinders to suit the amount of ash in the coal.
14. If ash clinker, turn on more steam beneath the grates and grinders.
15. The movable grates at the lower end should have a movement of not less than ⅝ inch above and ⅝ inch below the stationary grates.
16. *Clean off the V-wall at the rear of the grates once every 24 hours.*
17. *Do not allow ash pits to fill up with ashes to the clinker bars*

The Draught

1. Don't forget that it takes air to burn coal.
2. Have dampers rigged up so that they can be EASILY handled from the furnace fronts or firing aisle.
3. Regulate the load and steam pressure by changing the opening of the boiler or main damper. Keep the ash and sifting pit doors open.
4. The damper should never be closed tightly or suddenly either by hand or a damper regulator where there is a hot fire in the furnace.
5. If damper regulator be used, there should be not less than .12 of an inch of draught over the fire when the damper is in closed position.

6. Do not use a regulator which operates only in two positions, that is, open and closed. The regulator should vary the damper opening according to the steam pressure.
7. Low draught or sudden checking of the fire will increase the cost of repairs due to the rapid burning out of the brick and iron work.
8. Don't waste coal by using too much draught. Have just enough draught to keep a hot fire, and at the same time carry the load.
9. A draught of about .25 of an inch water suction over the fire will alow operation at boiler rating.
10. *Keep the air passages beneath the coking plates open.*
11. Keep air slides open that let air over the top of the fire arch.
12. Don't apply forced draught apparatus to the furnace without first consulting the Murphy Iron Works.

The Coal Feed

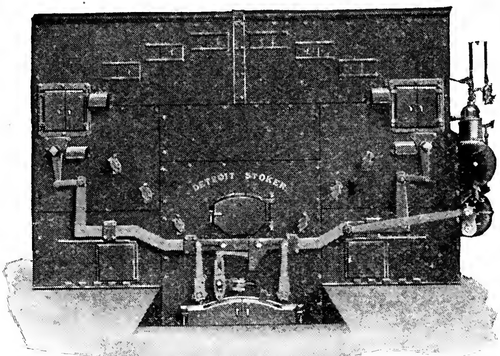
1. Coal should be crushed fine enough so that it will pass through a screen with a 1¼ inch round mesh.
2. The use of lumpy coal causes: *a*. coal to clog in the magazines; *b*. fires in the magazines; *c*. Arch plates and magazine castings to break and burn out; *d*. the breaking of stoker parts; *e*. uneven fires and bare grates, and *f*. extra labor for the firemen.
3. Keep magazines full of coal from front to rear.
4. Very often coal chutes fail to supply coal to the rear of the magazines. Be sure coal chutes are correct.
5. If coal catch afire in the magazine, close the slide and let it empty before filling. See that the air flues beneath coking plates are cleaned out.
6. When burning lumpy coal, close the slides once in a while and let the magazines empty.
7. See that magazine coal slides work freely.
8. Do not let the stoker boxes stand still longer than 15 minutes at a time when magazines are full of coal. When at rest, the boxes should be left pushed in toward the fire.
9. Be sure that the stoker boxes have a stroke ranging from 3 to 3½ inches. If less than 3 in., the coal will not feed properly.
10. The larger size furnaces are equipped with the variable feed stoker arms. Keep the connecting link at the top of the slot in the arm for continual operation. The links to be lowered only when evening up the fires.

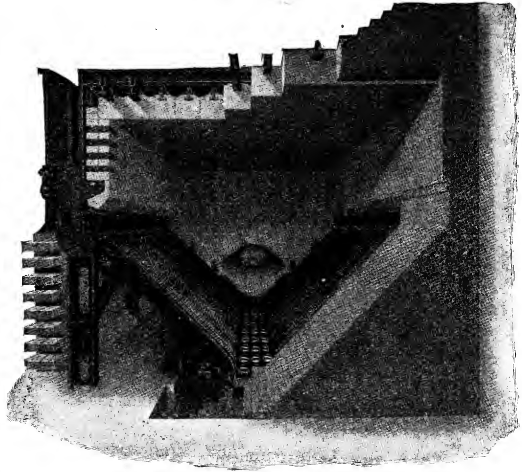
Banking

1. Feed all of the coal out of the magazines.
2. When the top of the grates become bare, pull the fire to the bottom.
3. Unhook the grate rocker links and throw out the clinker bar pawl.
4. Cover with a layer of fresh coal or siftings from beneath the grates.
5. Close the air slides and the ash and sifting pit doors.
6. Close boiler damper just enough so as to barely allow the gas from the fresh coal to escape.
7. Remember when a fire is banked, that every pound of air passing through the furnace and boiler setting carries away heat, which means coal.

When Furnace is Out of Service

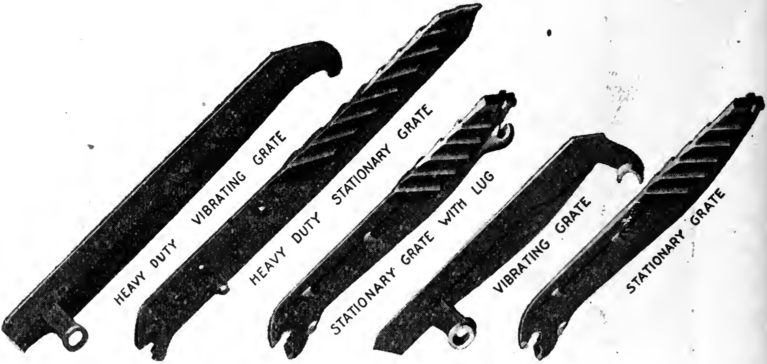
1. See that all of the coal is fed out of the magazines before taking furnace off the line.
2. Close the valve on the steam line to the grates and clinker bars.
3. Keep all doors, slides and dampers which will allow air to enter the setting, closed as much as possible. The admission of air to the flue or stack to which active boilers are connected will seriously affect the draught.
4. Clean out the air ducts of the arch plates.
5. Clean the clinker from the V and front walls.
6. Patch all air leaks in the brickwork.
7. Keep iron and brickwork in proper repair.
8. See that the holes in the perforated steam piping beneath grates and clinker bars are free from dirt and scale.
9. See that the operating mechanism is in working order. The driving bar should have a 12-inch stroke.



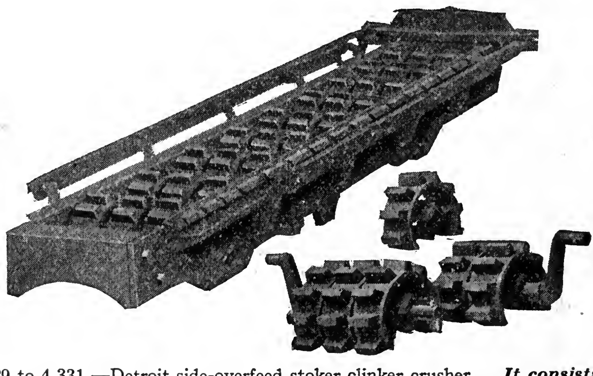


FIGS. 4,322 and 4,323.—Detroit side over feed stoker. Fig. 4,322 front view; fig. 4,323 rear view. ***In operation,*** coal stored on top of stoker feeds by gravity through the magazine, on both sides, to the grate, the fuel bed moves down toward the center of the furnace and the ash and clinker are ground through the clinker crusher to the pit below. The continuous movement of the vibrating grates, and the constant operation of the clinker crusher in the center ,keep the fire clean and complete the burning process. The maker states the advantages of the fire brick arch thus: As the coal comes into the highly heated furnace its volatile matter is distilled off in the form of a gas. The gases thus formed constitute a large portion of the heating value of the fuel. To properly burn these gases, two things are necessary: First, they must be mixed with a proper amount of oxygen obtained from the air; and second, they must be maintained at a high temperature until the oxygen has united with the gases distilled from the coal. In the construction shown above it will be noted that both of these conditions are obtained. The air is supplied in a preheated condition by passing from the front of the stoker through the hollow arch and tuyere openings and enters the furnace immediately above the point where the gas is distilled from the coal. The mixture of air and gas travels under the highly heated arch, thus allowing the combination to take place before the gases come in contact with the boiler surfaces and become chilled. The gas distilled from coal contains a large portion of carbon in combination with other elements, and in this condition the carbon is invisible. Under the influence of heat the carbon is liberated and changes to a solid state, becoming visible in the form of soot or smoke. This is the only source of smoke in the burning of coal. If the fine particles of carbon be brought in contact with oxygen while heated they will unite with the oxygen and form an invisible gas. It will thus be seen that the fire brick roof is necessary in the burning of bituminous coal in order that complete and smokeless combustion may be obtained.

Underfeed Stokers.—There are two types of underfeed stoker: horizontal and inclined. The fuel is fed from underneath, either continuously by a screw, or intermittently by a plunger. The principle upon which these stokers base their



FIGS. 4,324 to 4,328.—Detroit heavy duty and standard grate bars.



FIGS. 4,329 to 4,331.—Detroit side-overfeed stoker clinker crusher. ***It consists of*** heavy interchangeable, cast iron discs with teeth bolted on steel cranks which continuously rotate toward each other. The operation can be regulated to suit the fuel to be burned, and is easily adjusted to suit the conditions while in operation.

claims for efficiency is that the green fuel is fed under the coked and burning coal, the volatile gases from this fresh fuel being

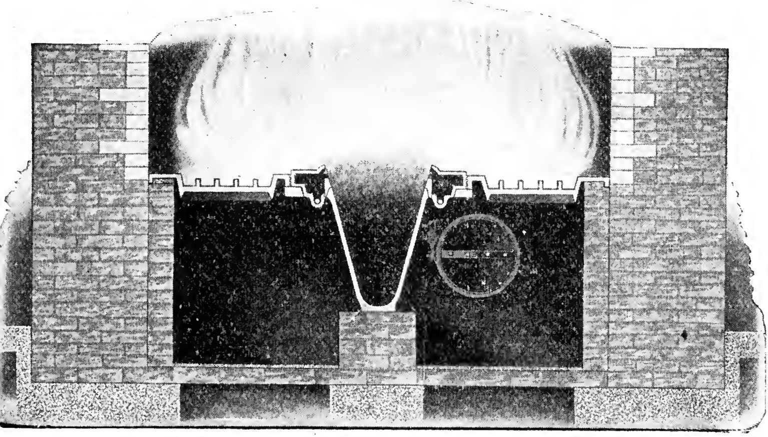


FIG. 4,332.—Jones underfeed horizontal stoker; cross section through furnace with single retort. Air from blower is forced into the sealed ash pit through the duct, the supply being controlled by blast gate in the line. From the ash pit the air passes under pressure through the hollow tuyeres into the furnace. Note that it is introduced above the green fuel but below the fire so that volatile matter driven off during the coking process is thoroughly mixed with air before passing through the incandescent fuel bed.

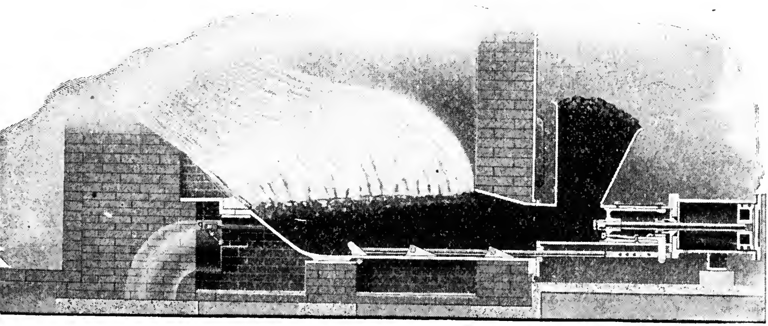


FIG. 4,333.—Jones underfeed horizontal grate stoker; longitudinal section through stoker and furnace. ***In operation,*** steam admitted behind the piston forces the piston and ram forward, carrying a portion of the coal in the hopper to the retort. The pusher rod moves with the ram to carry coal forward in the retort, and thus secures an even distribution of the fuel in the furnace.

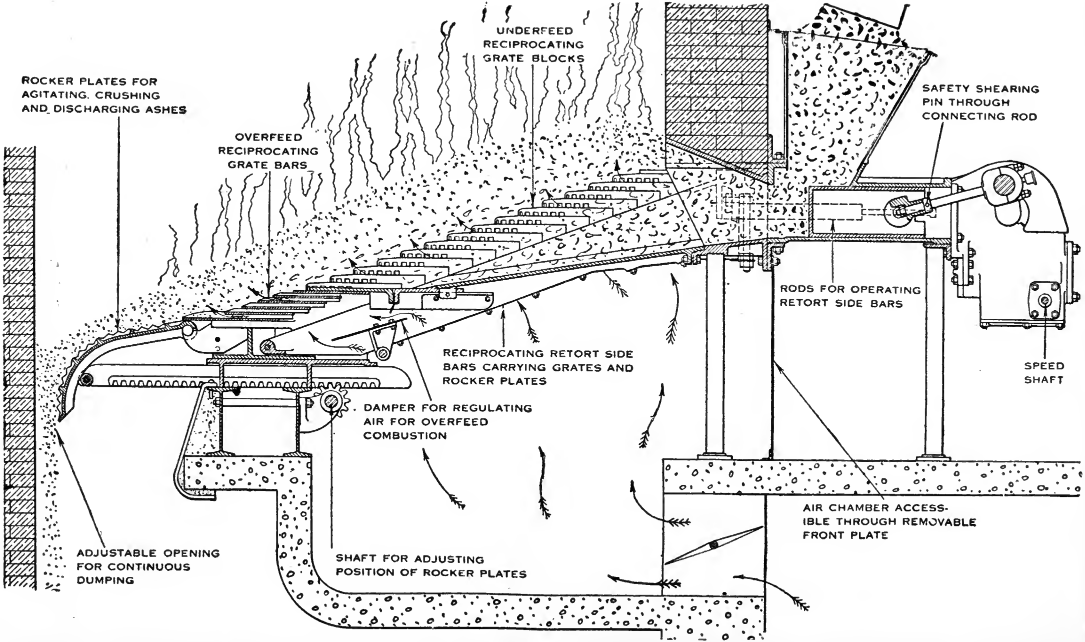
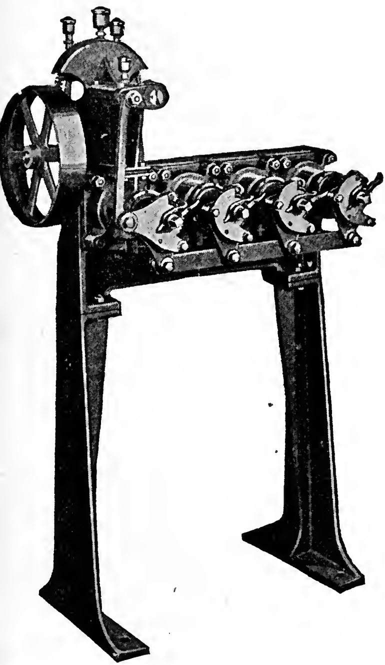


FIG. 4,334.—Riley self-dumping under feed inclined grate stoker. The stoker is a multiple-retort, underfeed stoker with an incline of 20°. Below the retorts, the grate surface is continuous so as to burn fuel completely before it is pushed off the ash supporting plates. The distinctive feature of this stoker is that the sides of the retorts reciprocate relative to the bottoms. This provides a means of moving the fuel uniformly along and out of the retort. It also provides a moving grate surface on to which the fuel is passed as it leaves the retort. The same movement serves to push the refuse across the rocker ash dumping plates where it continuously discharges throu h the adjustable opening next to the bridge wall. To prevent the possibility of a breakdown due to foreign matter in the fuel, each plunger connecting rod has a safety device. This safety device consists of a standard ½″ rivet so placed that it is double sheared when the plunger strikes an obstacle.

heated and ignited in their passage through the hottest portion of the fire on the top. In the horizontal class of underfeed stokers, the action of a screw carries the fuel back through a retort from which it passes upward, as the fuel above is consumed, the ash being finally deposited on dead plates on either side of the retort, from which it can be removed. In the inclined class the refuse is carried downward to the rear of the furnace where there are dumping plates, as in some of the overfeed types. The American underfeed stoker is an example of the horizontal class of underfeed stoker. The principle of operation of this stoker is the same as that of the Taylor stoker.



Ques. What are the advantages of underfeed stokers?

Ans. They are adapted to heavier fire than other stokers.

As they are practically all operated with forced draught (the fan being driven in some cases by the same mechanism as the stoker drive), but a

FIG. 4,335.—Cole automatic valves used with Jones underfeed horizontal grate stoker. Each valve controls the fuel supplied to the furnace by one stoker and each may be adjusted without regard to any of the others. The location of the pointer indicates the rate of feed and nine variations ranging from 0 to 8 are provided. In addition the valve may be operated in emergencies by a crank which fits onto the shaft projecting through the trigger hub.

small amount of draught suction is necessary in the furnace, and, due to the thickness of the fuel bed, air supply is kept at a minimum, with a resulting high CO_2 reading.

Since the plunger and screw feeds both tend to break up the fire, caking coals can be burned with satisfactory results.

Ques. What precaution should be taken with underfeed stokers?

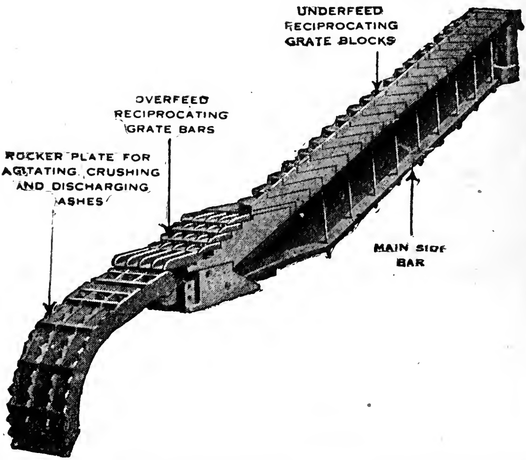


FIG. 4,336.—Grate detail of Riley self-dumping underfeed inclined grate stoker. ***In construction,*** base plates are assembled on through I-beams, which keep them together and carry the weight of the lower end of the grates and fuel bed. The upper end of the grates is carried and motion given by the rods or plungers located at each side of the main feeding rams. The grates are assembled on the retort side bars as shown. These assembled side bars are simply dropped into place and hung on the rods shown in fig. 4,337. There is no accurate fitting or alignment required. The retort bottoms are dropped into place between the side bars and bolted to the cylinder unit at the upper end. The hinged plates between the retort bottoms and sides lay against the sides and prevent sifting. These plates also allow for contraction and expansion.

Ans. The draught should be properly regulated to prevent brickwork troubles, because of the very high temperatures developed in the furnace.

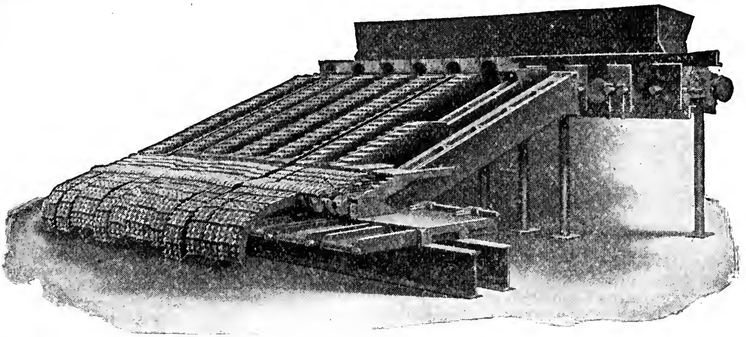


FIG. 4,337.—Riley self-dumping underfeed stoker; view of 9 retort stoker partly assembled, showing independence of unit part. ***In operation*** the fuel is forced up from beneath the point where the air is admitted, and is then burned on a series of inclined retorts. Distillation of the volatile gases takes place in the retorts, after which these gases, mixed with air, pass up through an active bed of burning coke and then through the incandescent fire zone. Instead of stationary tuyeres, the Riley stoker has moving air supplying grate blocks, carried by the reciprocating sides of the retorts. These retort sides also move the overfeed grates which extend across the entire width of the stoker below the retorts. Beyond these are the rocker dump plates, which continuously agitate, crush, and discharge the ash. The travel of these reciprocating parts is adjustable. The upper edges of the reciprocating retort sides carry grate blocks, in the form of narrow grates with side tuyere openings for allowing air to enter the green fuel below the zone of combustion, designed to allow free escape of air without sifting, through of fine fuel. Beyond the end of the underfeed retorts, the overfeed grates extend across the entire width of the stoker. This arrangement permits all the partially burned coke (from which the volatile matter has already been distilled) to come in intimate contact with air at a lower pressure than that in the underfeed section. A lower pressure here prevents excess air blowing through the lighter and more porous fuel bed. At low boiler ratings this air pressure may be cut down to little or nothing. It is regulated by operating the air damper. ***In construction*** base plates are assembled on heavy I-beams, which keep them in alignment and carry the weight of the lower end of the furnace and fuel bed. Each reciprocating unit (the retort side bar) is carried and actuated at its upper end by a heavy rod sliding parallel with the plunger. The grates are assembled on the retort side bars as shown. These assembled side bars are simply dropped into place and hung on the support rods. The retort bottoms fill the space between the side bars and are bolted to the cylinder units at the upper end. The sifting strips are hinged between the retort sides and bottom. They make a flexible light joint which prevents sifting and allows for expansion and contraction.

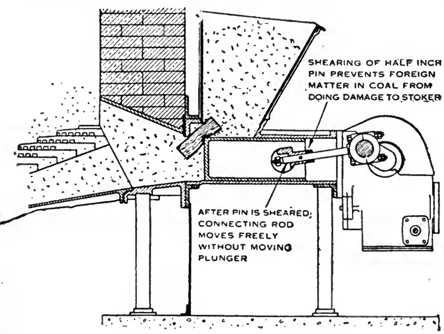


FIG. 4,338.—Detail of Riley self-dumping under feed stoker showing operation of safety connecting rod. ***It consists of*** a ½″ soft steel pin passing through a hardened steel ring on the connecting rod. The thrust of the rod comes on this hardened shearing ring which bears against the sleeve shown at the cross head end. An excessive pressure will double shear this pin between the ring and the rod, and allow the rod to move freely without moving the plunger.

Instructions

for

Operating Riley Underfeed Stokers

Even at the best, operating instructions can only serve as a guide. Individual conditions in the plant should dictate the method of procedure. Only a few fundamental rules can be given to teach the operators some things to do and not to do. Careful study of the operation and performance of the equipment with different coals—loads—air pressures—temperatures, etc. is the best way to determine the conditions that give the most economical results. Stoker operation therefore resolves itself in good common sense, combined with a knowledge of the following.

Lighting Up.—Fill the hopper with coal and feed enough fuel into the furnace to cover the grates of a depth of 3″ or 4″ (this can be most effectively done with a small amount of travel on the grates). If there be no power to operate the stoker, coal should be shovelled in by hand and evenly distributed over the grates. Put kindling and waste on top and near the front wall. Light and turn on the draught until fuel is thoroughly ignited.

If forced draught be not available resort to natural draught by removing the front plate. Do not force the stoker until the entire fuel bed is in a good coked condition.

Fire on Ash Plates.—With some coals it may be necessary to cover the lower end of the grates and rocker plates with ashes. (In starting be especially careful not to get too heavy or too hot a fire on the ash plates. To do so may cause serious burning). Remember the lower end of the furnace is not intended for live coals but ash.

Grate Motion.—After a sufficient amount of ash has accumulated to protect the grates, the moving parts can be put into commission. Always keep plenty of fuel over the grates and use the minimum possible travel for the side bars. One or two inches will usually suffice. Eastern coals as a rule do not require as much travel on the grates as the high ash, high volatile Western coals. When driving the stoker hard it is usually desirable to give the grate additional motion. In any instance care should be exercised to see that the motion is not excessive to carry live coal down onto the rocker plates.

Draught.—Under all conditions of operation there should be a light suction in the furnace. Under no conditions should there be a pressure in the furnace. The suction over the fire should be between .1″ and .25″ water gauge at maximum rating. If the suction be over .25″ in filtration losses will be so great as to defeat economical operation. The correct suction can be maintained by manipulating the flue or stack dampers in conjunction with the air duct dampers.

The pressure under the grates will depend upon the coal used, the thickness of the fuel bed and the rating desired. During normal operation (400 to 500 of coal per retort per hour) 1½ to 2½″ water gauge is usually required; at the highest rating (900 to 1400 of coal per retort per hour) 4″ to 6″ will be required.

By observing the conditions of the fire it is not difficult to determine the draught that will produce the most efficient results. Draught gauges will be found helpful in this connection. The lowest pressure that will give the correct mixture of air and fuel should be used at all rates of combustion. Ordinarily 40 to 50% excess is required. This is necessary so that each particle of combustible may be reached by the proper amount of oxygen.

Fuel Bed.—Keep the fuel bed as near uniform and clinker-free as possible. The thickness depends upon the coal used, rating desired, and draught pressure. With most bituminous coals 18″ to 24″ of fuel over the grates in the underfeed section gives good results. With lignitic coals the thickness and air pressure should be much less. In any instance the coal and air should bear a certain relation to each other which can be easily determined by watching the operation.

The greatest depth and hottest part of the fire should be over the retorts near the front wall. Don't let the crown of the fuel bed work down on the overfeed grates. These grates are intended for the devolatilized fuel. If the fuel bed get too thick, throw the clutch of the gear box until it has burned down to the correct level.

Ash Discharge.—Do not keep ash discharge open any wider than necessary, otherwise the ashes will fall through before all the combustible is burned out of the refuse. The best condition is to keep the rocker plates nearly closed so as to maintain a bridge of ashes over the opening and a thick bed of ashes on the ash plates so as to protect them.

Be careful to keep the ash hopper or ash pit clear of hot refuse so as to prevent overheating of the rocker plates and racks. If necessary to dump hot refuse, be sure to turn on water in order to quench fire in ash pit.

Cleaning. After complete dump, keep the rocker plates closed for the first hour or two (depending on the kind of coal used, and the rate of operation). As soon as the fire appears dirty or well burned out, next to the bridge wall, open the rocker plates about 4″. This will allow the accumulated ash and small clinkers to discharge continuously. Do not open enough to get big holes between rocker plates and bridge wall. After another hour or two of operation (depending on the quality of coal and boiler rating), it may be necessary to open the rocker plates more, in order to discharge an increased amount of ash and clinker.

The opening between the rocker plates and the bridge wall should be just large enough to discharge ashes and small clinkers without leaving a big gap through which cold air from the ash pit may get into the furnace. In other words, as the fires get older, they get dirtier, and you must allow for discharge accordingly. At the end of six hours or longer (depending on the coal and rating), open the rocker plates wide in order to make a clean dump of any big clinkers that may have accumulated Do not delay this opening too long or clinkers may build onto the bridge wall.

If there be any difficulty in dumping after the rocker dump is opened, put extra travel on the rocker plates opposite the obstruction, until it is pushed down.

As soon as the fire is cleaned in this way, close the rocker plates and then follow instructions again. as above. The aim should be to adjust the rocker plates' position as little as possible and still keep the fire clean. With good coal and low ratings. it is possible to run continuously without any change whatever. The above precautions are intended for poor coal and high ratings.

Clinkers.—In case of large clinkers which will not readily dump, you may have to withdraw the rocker plates temporarily in order to let them through. If they be stuck to the bridge wall, or otherwise blocked, do not use a bar, but change the travel of the rocker plate opposite the clinker. To do this effectively put on the maximum travel of about 5″ and let the rocker plate operate this way just long enough to break up the clinker properly. (Do not leave this long travel on any longer than absolutely necessary because otherwise it will bring down too much green fuel from the upper end of the stoker.)

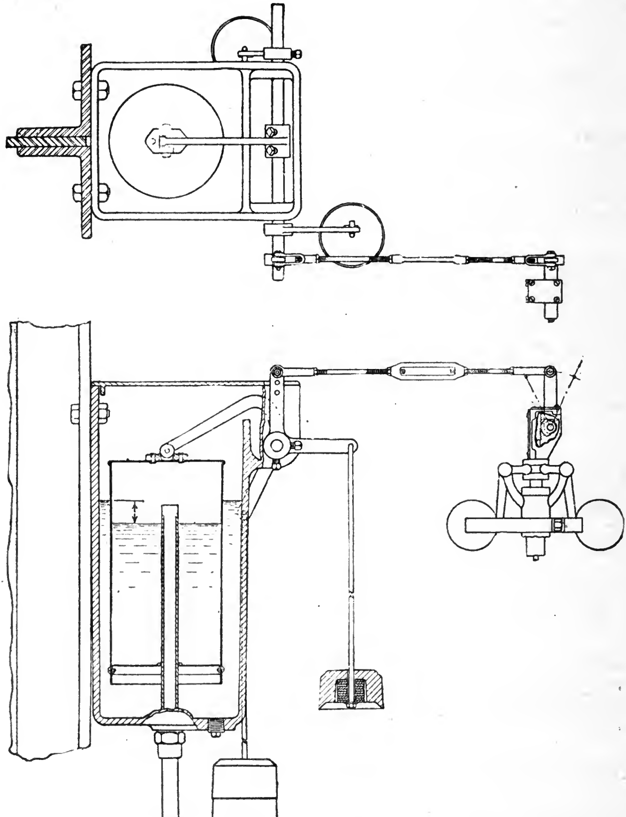
To Bank Fire.—Shut off all air and feed enough coal to the boiler to make the fuel bed as thick as circumstances require. By occasionally feeding a small amount of coal it is possible to maintain the bank over a long period of time (weeks if desired). The consumption of fuel, with the boiler setting tight, will be very small—just enough coal is necessary to take care of radiation losses.

Do not use much travel, if any, on the side bars when banking. With fires banked be sure to have the stroke adjusters in lowest position so that the side bars will stand fully withdrawn.

To Raise Steam from Banked Fire.—Turn on the wind gradually to the required amount, then start side bars with minimum travel. If the fuel bed be heavy, run the stoker with hopper empty so as not to feed in any more fuel until after the side bars have broken up the bed and it has had a chance to burn down to normal thickness.

Lubrication.—Make it a point ot see that gear boxes are kept well lubricated by adding a litt e fresh cylinder oil as needed. Look at these boxes twice a week, also see that all grease cups are used and filled once a week. By doing this you will make things easy for yourself. It is the things that are neglected that cause the trouble.

Rotary or Sprinkler Stokers.—This class of stoker is suitable for small units. Coal passes from a hopper to a revolving



FIGS. 4,339 and 4340.—Riley oil seal pneumatic regulator for controlling speed of stoker engine from the forced draught pressure. ***In construction and operation,*** a ¾-inch wrought iron pipe is connected to main duct. Any variation in pressure in duct communicates itself to plunger, causing it to rise or fall accordingly. This motion is transmitted by means of multiplying levers to a special ball ranger of the throttling governor of stoker engine. Thus when fan speeds up, due to low steam pressure, it increases the air pressure in duct. This in turn causes pneumatic regulator to operate and increases stoker engine speed. In a similar manner engine speed is decreased.

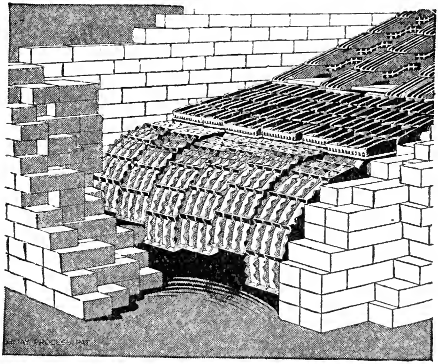


FIG. 4,341.—Riley under feed stoker rocker dump. ***It consists essentially*** of a series of overfeed grates and rocker plates, the latter of which crush and eject the ash. These grate blocks and rocker plates are held in place by side bar frames which in turn are fastened to the main retort side bar so as to move in unison with it. The grate bars are so designed that by removing pins they can be readily slipped in or out of place independently of the rest of the furnace parts. After removing the grate bars the rocker plates are simply lifted out of place. Instead of allowing the ash to be deposited on stationary refuse plates, as heretofore has been customary with all stokers, it is now deposited on rocker plates which move with the retort units, the effect of this motion being multiplied next to the bridge wall where it is most needed. The *constant agitation* of the rocker plates *grinds up* and *discharges the ash;* its motion is positive and continuous and is just sufficient to keep large clinkers from forming. By this method the ash is not allowed to accumulate and fuse into masses and thus the bridge wall and dump plates are kept free from all accumulations, thereby effecting savings in labor and maintenance. The magnitude of the motion (given it by the reciprocating retort sides) may be varied at will and is regulated to suit the clinkering qualities of the coal. It has maximum agitation at the vital point—when the dump is nearly closed; when nearly opened, it has maximum crushing effect so as to aid the operator when in emergency he wishes to make a quick disposal of ash. However this is seldom (if ever) required, as over 95 per cent. of the ash is continuously discharged.

NOTE.—***Control of air and fuel supply in underfeed stokers.*** In small installations it is usually desirable to drive the stokers directly from the fan shaft, by means of suitable shafting with sprocket and chain connections. Where the forced draught fan is driven by steam, it is customary to install a standard damper regulator operating a balanced valve and so connected up that the speed of the fan is controlled by the boiler steam pressure. That is, a drop in steam pressure automatically opens up the steam supply to the fan engine or turbine, until the additional air from the fan has resulted in raising the steam pressure to normal, or vice versa. In case the fan is driven by a variable speed electric motor, a special rheostat control is used, which is also governed by the steam pressure. By these means the steam pressure may be held approximately normal, for the entire range of capacity. Where the fan prime mover consists of a constant speed motor the air supply is regulated by a damper in the fan discharge. This damper can be operated either by hand or by means of a suitable damper regulator. In large plants or for large boiler units it is usually desirable to have a separate prime mover driving the stokers. The air and fuel supply may then be controlled either by hand or automatically. For hand control it is customary to have a panel completely equipped with indicating instruments showing steam pressure, air pressure under grates, draught over fire, rate of coal feed, CO_2, etc. The operator can then tell from his instruments exactly what the conditions of combustion are and can govern the coal feed accordingly.

member which throws or "sprinkles" it on the fire, as shown i fig. 4,345. The principle of this stoker is to give a light uniforn feed of coal at the same rate it is burned.

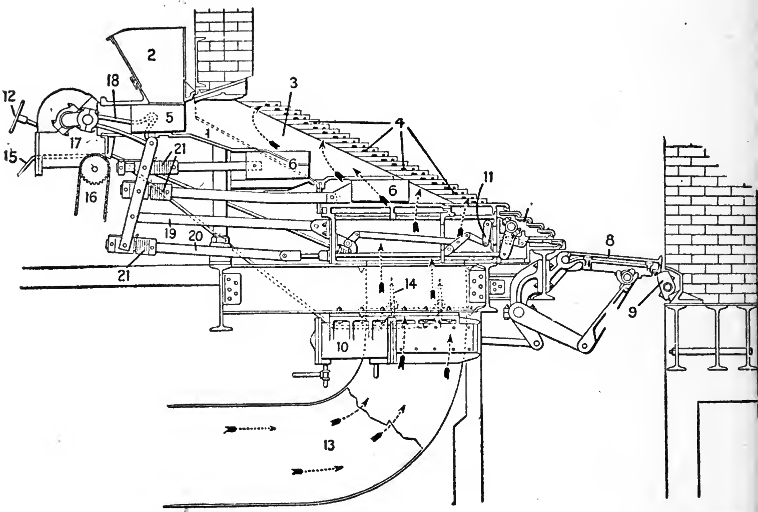


FIG. 4,342.—Taylor underfeed inclined grate stoker with power dump. ***It consists o*** A series of sloping passages 1, called retorts, by which coal enters from the hopper 2; series of cast iron boxes 3, called tuyere boxes, through which air is forced by a fan, and whic are covered by perforated cast iron blocks 4, called tuyeres, through which the air enter the fuel bed; a series of slowly reciprocating rams, driven at variable speed by worm gea from a sprocket shaft. Each retort is served by one feeding ram 5, and one or two dis tributing rams 6, 6. As the coal drops behind them it is pushed upward and backward working to the surface and eventually past the extension grate 7 to the dump plate 8 on which hot refuse accumulates, to be dumped every three to six hours, depend ing on the rate of working. If the rotary ash discharge be used, the dump plate i omitted. The alternating retorts and tuyere boxes just described are furnished, usually in number to fill the width of the setting. The rams are driven in groups, feeding four re torts or less, by sprockets and worm gearing for a drive shaft below the flow. Chain coup lings permit independent drive to equalize the fuel bed. Shearing pins protect the mechan ism from obstructions: The ram stroke is adjustable. In small plants one engine runs bot stokers and fan, with a hydraulic regulation controlling it according to the steam pressure Where separate engines are used, the fan is controlled by the steam pressure and the stoke engine by a diaphragm regulator operated by the air pressure. In large plants separat drives with hand regulation are often preferred, the steam pressure being thereby held con stant. The first effect of the rams, especially the feeding ram, is to push much of the fue upward. Hence result the deep fuel beds, from 2 to 4 feet thick. As the green fuel work slowly to the surface it has ample time to distil, and the escaping gases, rising with the ai from the tuyeres through the incandescent coke above, are thoroughly mingled and bur with an intense, relatively short flame. Working gradually backward and downward, bein pushed constantly by fresh fuel, the burning coke slowly shrinks, till when it reaches the dum plate, little but hot ash and clinker remains. Mechanical draught (1 to 5 inches of water is employed.

The fire doors permit access to the fire for observation and for the correction of any irregularity in the working of the fire bed due to clinker.

When a clinker forms on any part of the grate, its presence is shown by a darker and thicker area caused by the lack of air and by coal on that portion of the bed not burning down as fast as on the rest. The operator can

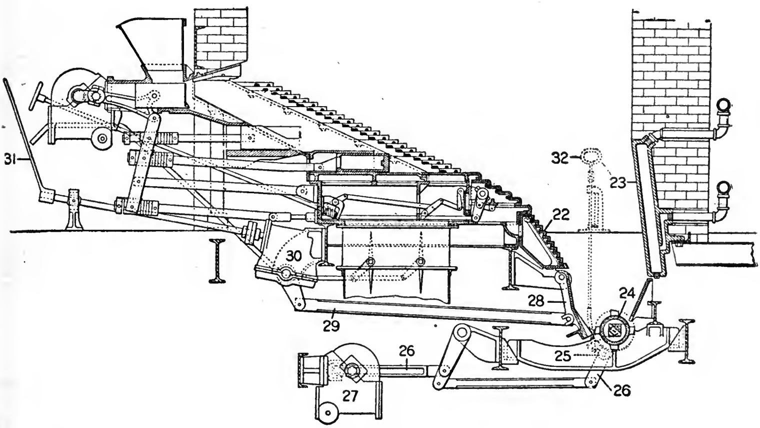


FIG. 4,343.—Taylor underfeed inclined grate stoker with rotary ash discharge. ***The ash discharge consists of:*** 22, extension grate; 23, cast iron water back; 24, crusher; 25, pawl rotating crusher; 26, pawl driving mechanism; 27, worm driving gear; 28, crusher plate; 29, strut supporting crusher plate; 30, worm adjusting gear for crusher plate; 31, adjusting lever; 32, handle controlling effective action of pawl 25. The ash discharge, as shown, has a deep pocket beyond the extension grate, which is filled (and thus sealed) with ashes. At the bottom a toothed crusher, driven at a speed corresponding to the amount of ashes to be discharged, slowly breaks up and expels the ashes. The clearance from crusher to crusher plate is adjustable according to the character of the fuel, but should never be so wide as to spill the ashes and break the seal. The ash discharge requires, however, more head room than the hand or power dump, and the operating conditions must be favorable if the best results are desired.

remedy the condition by removing the clinker with a hook and patching the spot with fresh coal placed with a shovel. Do not attempt to patch by raking live fire over the spot, as to do so tends to form another cluster at the same spot.

Ques. Mention a characteristic of rotary stokers.

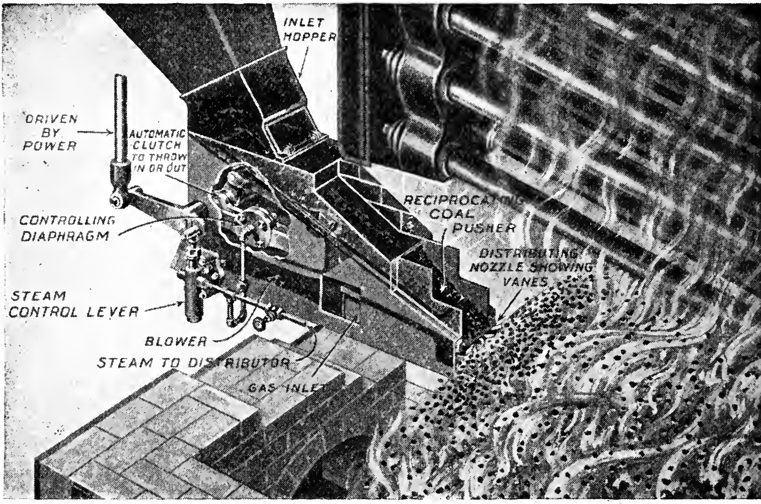


FIG. 4,344.—Parson's automatic fuel distributer or "shovel stoker." Coal is delivered from a hopper or other overhead source of supply. It is fed into an inlet hopper upon a long plate which reciprocates up and down, forming a *reciprocating coal pusher*. This pusher is operated by an arm driven by an eccentric At each movement of this arm driving the pusher a valve operated by the *steam controlling lever* is opened and closed, which admits steam through the pipe marked *steam to distributer* to the *blower*. ***In operation*** each time the pusher moves to advance coal downward toward the fire through the throat of the machine the valve opens and a charge of steam propels the air through the blower which operates through the distributing nozzle, picks the coal off the end of the plate below the pusher and with diverging columns of air scatters the coal in various directions over the bed of fuel. By means of sharp deflections at the corners, as shown, the coal is thrown at right angles to the *distributer* and completely across the fire. The travel of the pusher which controls the amount of coal fed is adjustable. The controlling diaphragm is under boiler pressure feeding more coal with fall of pressure, and less with rise of pressure, this tending to maintain a steady pressure. Evidently every time the blower begins to work, it starts from zero, with each movement of the valve. It quickly mounts to the maximum force and then quickly recedes to zero again. Thus the first body of air striking the first fuel does so with comparatively gentle force, but this force rapidly increases to the maximum and then recedes again to nothing. The first fuel and the last fuel blown away therefore fall immediately in front of the distributer. The coal at the middle of the stroke is flung to the furthest confines of the furnace and every part of the furnace between those two limits is by the progressive rise and fall of the blast, fed automatically with its due proportion of fuel. The argument might be advanced that a machine of this kind using *air* would tend to chill the furnace and interfere with combustion. As a matter of fact, *this is so*, consequently, there is an opening from the interior of the furnace through a fire bricked passage whereby *furnace gas*, unburned and very hot, is drawn in by the action of the blower to the enclosed box in which the blower operates at the bottom of the distributer through the port marked "gas inlet." It is there permitted to mix with a quantity of atmospheric air from outside the boiler setting controlled by a valve, and when the proper proportion of gas and air has been arrived at, that mixture at the proper temperature and of the proper character for combustion is the *gaseous body*, which by the friction of the steam in the blower is caused to do the propelling and distribution of the coal. Thus the furnace, as claimed, is not chilled and also is fed with the proper amount of secondary air for complete combustion within the furnace.

Ans. Its feature of operation is that it carries a thin fire, which should be disturbed with the fire tools as little as possible.

It may be necessary occasionally to remove an accumulation of fine fuel from the dead plate. To do this move part to the first corner of the grate and part behind the pier between the stoker openings. Never shove this material to the center of the fire.

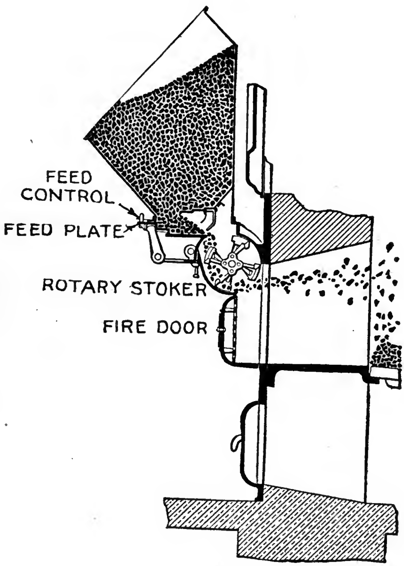


FIG. 4,345.—Rotary or sprinkler stoker. ***In operation*** the revolving member catches the coal as it is fed from the hopper and throws or sprinkles it upon the fire, imitating the operation of a fireman in throwing fuel on the fire with a shovel, but dong so in a more efficient manner.

Ques. When should the stoker be started?

Ans. It should not be started until the fire bed is in a level condition and admitting air uniformly. The stoker will then maintain the bed in a level condition.

If rocking or dumping poles be used do not rock them violently enough to mix the fire and ashes, as this will make clinkers, or may let patches of fire fall through the grate.

Ques. What is the nature of the fuel feed adjustment?

Ans. Since the fuel is spread on the fire every few seconds a comparatively small change of the feed control screw makes considerable difference in the quantity of fuel supplied.

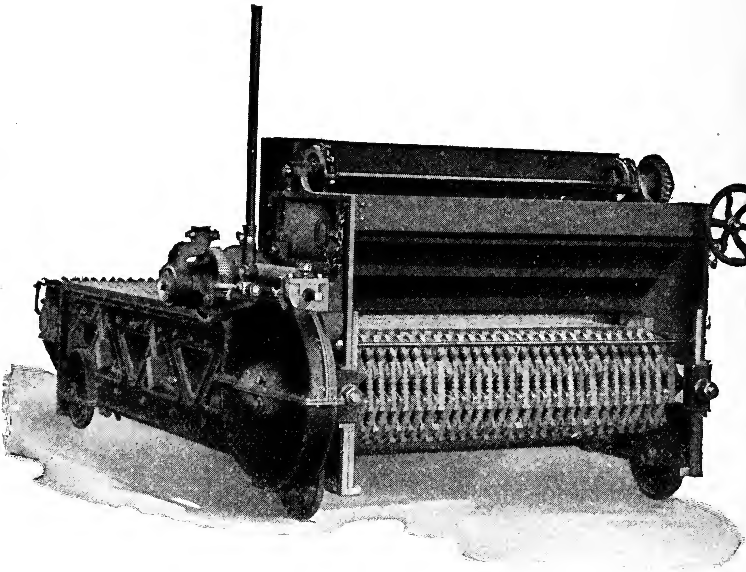


Fig. 4,346.—The Babcock & Wilcox chain grate stoker consists of a grate in the form of an endless chain passing at the front and rear of the boiler furnace over sprockets which are keyed to shafts carried by the stoker frame. The passage of the grate through the furnace is continuous. The stoker is driven through a worm wheel keyed to the front sprocket shaft. The fuel is fed uniformly to the front end of the grate under an adjustable stoker gate. The volatile gases are driven off on the foreward portion of the grate under an ignition arch and are completely consumed in passing over the incandescent fuel bed before striking the boiler heating surface. Combustion is truly progressive. The ash and refuse are discharged automatically and continuously as the grate turns over the rear sprockets. The form of the grate links is such as to allow proper admission of air for combustion. Suitable side seals and a bridge wall water box prevent the admission of large quantities of excess air. The bridge wall water box is connected into the water circulation of the boiler and is part of the regular stoker equipment. The construction of the entire stoker is of such rugged character throughout as to permit continuous operation without the necessity of shut-downs for repair. This stoker is only offered for installation where fuel suitable for chain grate stokers is available.

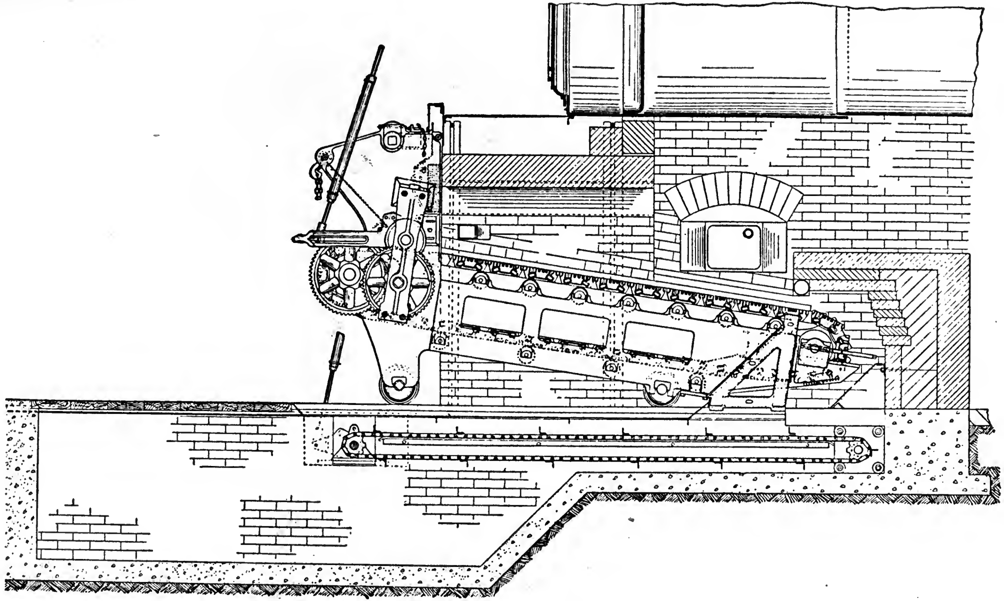


FIG. 4,347.—Green inclined chain grate stoker applied to tubular boiler, and ratchet ash drags which are recommended when ash storage pit under rear of chain grates is impossible or inaccessible. The ash drag requires only 21 inches depth below stoker rails from bridge wall forward to boiler front. An accumulating pit for storage of ashes, sealed by trap door set flush in boiler room floor, is forward of stoker front, which permits convenient access for ash removal. The ash drag *consists of* angle members riveted to a series of endless sprocket chains riding sprockets on front and rear shafts. Tension take up is provided for the front sprocket shaft. A relief spring is placed in the connection between the eccentric on the line shaft driving stokers and the ratchet mechanism driving the front sprocket shaft of ash drag.

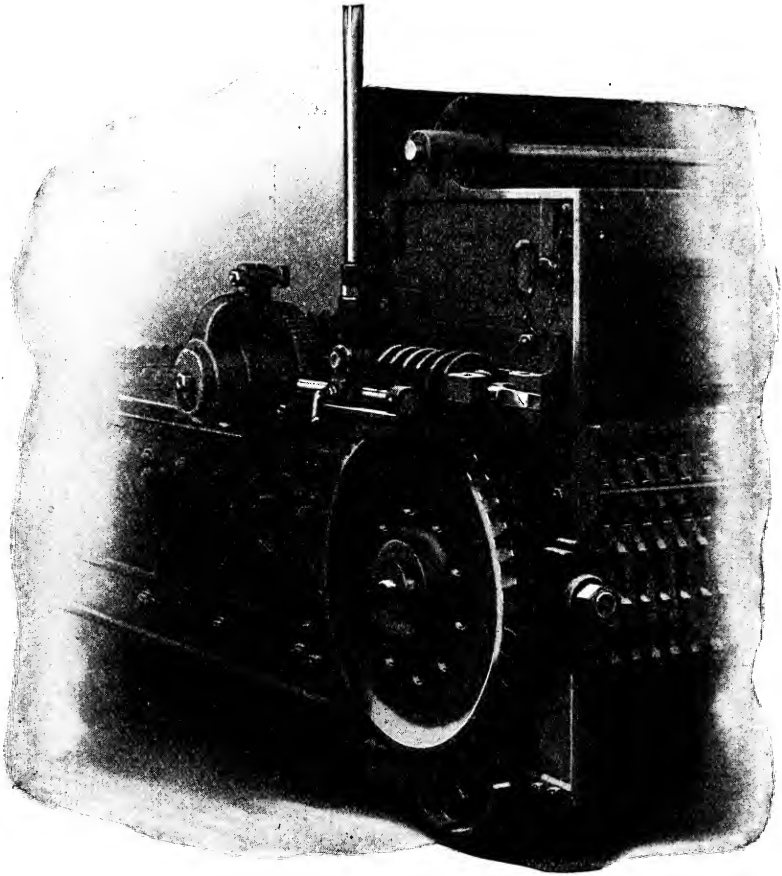


FIG. 4,348.—Driving mechanism of Babcock and Wilcox Chain Stoker with casing removed. The front sprocket shaft is driven by a heavy cast iron worm wheel. This worm wheel engages a cast iron worm secured by fitted taper keys to a worm shaft, the outer end of which is squared, and to the inner end of which is keyed one of a pair of mitre gears. Another mitre gear which engages this is actuated by a ratchet wheel. Long and short tool steel pawls drive this ratchet wheel from a cast iron ratchet arm. A second pair of tool steel pawls prevents the ratchet wheel moving backward. The pawls referred to in each case differ in length by an amount equal to one-half of a tooth of the ratchet wheel, with the result that a that a fineness of feed is possible equivalent to that of a ratchet wheel with twice the number of teeth of that supplied, without the disadvantage of fine teeth on this wheel. The bearings for the driving mechanism are supported by cast iron frames bolted to one cheek piece.

Traveling Grate or "Chain" Stokers.—As implied by the name, these consist of endless grates composed of short sections of bars, passing over sprockets at the front and rear of the furnace. Coal is fed by gravity onto the forward end of the grates through suitable hoppers, is ignited under ignition arches and is carried with the grate toward the rear of the furnace as its combustion progresses. When operated properly, the combustion is completed as the fire reaches the end of the grate and the refuse is carried over this rear end by the grate in making the turn over the rear sprocket. In some cases auxiliary dumping grates at the rear of the chain grates are used with success.

Generally a bridge wall water box or similar device at the rear serves as a seal to prevent the admission of excess air at that point, and in some cases closes up the rear portion of the fire by partly obstructing its passage over the rear of the grate.

Ques. For what class of fuel is the chain stoker well adapted?

Ans. It is well adapted to burning low grades of coal running high in ash and volatile matter.

More stokers of the chain grate type have been devised than of any other one class. For these, observations on practice made by the U. S. Geological Survey indicate that the depth of fire usually carried is 5 inches with western coals and 4 to 4½ inches with eastern coals.

The Department gives as the results of its investigation that in operation of the chain grate it should be run so that volatile matter is all driven off by the time the coal has traveled ⅓ the length of the grate, the travel

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FIG. 4,348.—*Text continued.*

The ratchet arm referred to is driven from an eccentric rod, the radius of whose attachment to the ratchet arm may be changed at will to increase or decrease the amount of feed for each revolution of the eccentric. A spring safety stop in the eccentric rod limits the power which may be transmitted from the eccentric, to prevent breakage in case any foreign object blocks the motion of the stoker. By simply lifting the pawls out of engagement with the ratchet wheel and applying a crank to the squared end of the worm shaft, the grate may be run in or out oy hand. It is one of the requirements in the erection of the stoker that one man be able to operate the grate in either direction with this crank before any power is applied.

along the rest of the grate being used in burning the fixed combustible and heating air for the furnace.

The grate should not be run so fast as to be hot when re-entering the furnace. Variable load may be carried with the chain grate by changing the thickness of fire, speed and damper position to suit the load, but the draught should never be reduced below the certain minimum at which smoke will result.

Ques. Mention one characteristic of operation of chain stokers.

Ans. Cleaning of the fire is continuous and automatic, hence no periods occur when smoke will necessarily be produced.

Ques. What important advantage do chain stokers possess?

Ans. They can be withdrawn from the furnace for inspection or repairs without interfering in any way with the boiler setting, being provided with wheels and track for this purpose.

Instructions

for operating

Babcock & Wilcox Chain Grate Stoker

Generally one operator and one coal passer can handle about ten chain grate stokers. With chain grates either natural or forced draught can be used, althouhg certain coals are not adapted to use forced draught successfully. Chain grates are usually large in area for the boiler, when compared with other types of stokers; the normal forcing capacity averaging 260% of boiler rating, with the combustion rate up to 48 pounds per square foot per hour, with coal suitable for the stoker. With low ash coal, this rate of driving would probably cause the grate to become overheated, and high maintenance cost would result. To obtain best operating results, it is essential that the draught be under control, and that wide open and tight shut positions of the damper be determined and marked, and that dampers operate readily between these positions.

All gate leveling bolts can be adjusted to obtain a uniform fuel bed, but, before making this adjustment to correct an uneven fire, be sure that it is due to the gates and not to other causes. Some settings provide definite arch ventilation, and the openings through the side and curtain walls must be kept clear, and indicate air circulation.

If the ledge plate flanges provided in some settings have been distributed by the settling of the brick work, they should be set to within ⅛ inch of the stoker chain, to cut off air leaks between the chain and furnace wall.

For efficient operation, no unconsumed fuel should be carried over the end of the grate, and frequent gas analyses should be made. A few days' experimenting will determine the proper relation between fuel bed thickness and speed of grate. See that all air openings around the front of the stoker are effectually closed.

If the fire tend to draw away from the gate, decrease the speed, increase the thickness of the fuel or adjust the dampers. The thickness of the fuel bed is shown on the gate indicator. Variation in gate height is necessary with coals varying in fineness and in volatile proportions. It is better to run a thick fire slowly than thin fires rapidly. The average speed should be about 3½ inches per minute. Keep the grate covered by closing the dampers and slowing down the stoker with decreasing load, and vice versa with increasing load. Keep the bottom side of the feed gate tile in line, as an uneven fuel bed makes an uneven fire. Insert new tiles when the old ones are burned or broken down. Dampers should not be entirely closed during operation. A furnace draught of $^1/_{10}$ inch should be the lowest draught permitted.

If the fire tend to pass over into the ash pit, the fuel feed is too fast or too thick, or the furnace is given insufficient draught. The fuel should be just consumed upon reaching the rear turning point. The back end of the grate should never become bare of live coals.

Adhesions usually form on the side walls. About once in 6 hours run a bar under the hopper apron and gate, being careful not to dislodge the gate tile. This should be repeated regularly, as often as necessary to keep the side wall clean and prevent the side links from being burned.

Ashes should not be allowed to accumulate in a pile around the chain. This may tend to overheat it, and burn it out. Neither should the drippings of coal be allowed to accumulate. Put a little back into the hopper at a time, a large amount will act to make holes in the fire. It is not a bad plan to wet the drippings. Do not stop the stoker for any length of time with the hopper full of coal, as the fire will burn forward and injure the gate. Do not run short fires with the damper wide open, as high brickwork maintenance and poor economy will result. Do not try to regulate the fire by opening the doors in the stoker setting. In washing out the boiler, be careful not to wet the stoker arch, as nothing is more injurious. Keep the arch dry. With a coking coal, it is necessary to run a slice bar through the fuel bed occasionally to break it up and permit free passage of air.

If run at proper speed, so that no unconsumed fuel runs over the end, the links at the stoker front can be touched with safety. The speed should be such that all volatile matter will have been driven off the coal by the time it has traveled not more than half the length of the grate.

Varying loads can be easily taken care of by proper regulation of the thickness of the fuel bed and the speed of the grate. The damper will have to be regulated accordingly. Insufficient draught causes smoke in the stack and possibly in the feed hopper. If smoke be noticeable in the feed hopper, allow it to empty and inspect the gate shoes to determine whether they are being burned. If so, allow the hopper to remain empty until the shoes cool off.

To force the fire, open the boiler damper wide, speed up the grate, lower the feed gate and loosen up the coal. A ¾-inch bar with a 6-inch bend at the end can be used. Run it through the furnace with the 6-inch leg flat on the grate. When at the rear, turn the bar completely over and pull it out. Continue until the whole grate has been gone over. Never disturb the top surface of the fuel bed.

To bank the fire, let the hopper empty, stop the grate, partly close the damper, giving $1/10$-inch draught in the furnace, until the fire burns short. Close the damper almost to the smoking point. Loosely bank the coal against the lower edge of the gate, allowing a little air to get through.

At intervals of 5 hours run the grate ahead a little.

To bring a banked fire up to rating, stir up the fuel bed with a bar, partly open the damper, lower the gate to the operative point, fill the hopper and, as soon as the arch is thoroughly heated, start the stoker at a rate that will keep the fuel ignited at the gate. When the grate is completely covered, the damper may be opened and normal operation begun.

CHAPTER 75

OIL BURNERS

The term oil burner may be defined as an *erroneous* title for *any device wherein oil fuel is atomized or vaporized* **previous** *to ignition*. In order that everybody may understand what the author is trying to explain, he will overlook the error and use the common term, oil burner.

Requirements for Burning Oil Fuel.—There are several conditions which must be fulfilled to properly burn oil:

1. Its atomization or vaporization must be thorough.

This requirement is met by the selection of a proper burner.

2. When atomized it must be brought into contact with the requisite quantity of air for its combustion, and this quantity must be at the same time a minimum to obviate loss in stack gases.

3. The mixture must be burned in a furnace where refractory material radiates heat to assist in the combustion, and the furnace must stand up under the high temperatures developed.

4. The combustion must be completed before the gases come into contact with the heating surfaces or otherwise the flame will be extinguished, possibly to ignite later in the flue connection or in the stack.

5. There must be no localization of the heat on certain portions of the heating surfaces or trouble will result from overheating and blistering.

The foregoing requirements are fulfilled:

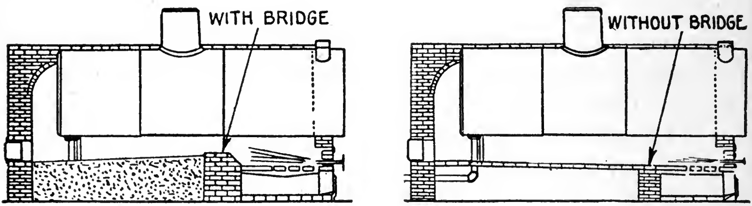
1. By the selection of a proper burner.

2. By properly introducing the air into the furnace, either through checker-work under the burners or through openings around them, and

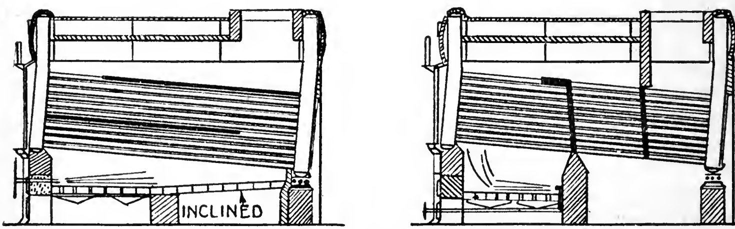
by controlling the quantity of air to meet variations in furnace conditions.

3. By installing a furnace so designed as to give a sufficient area of heated brick work to radiate the heat required to maintain a proper furnace temperature.

4. By giving ample space for the combustion of the mixture of atomized oil and air, and a gas travel of sufficient length to insure that this combustion be completed before the gases strike the heating surfaces.



Figs. 4,349 and 4,350.—Improper and proper furnace design for horizontal tubular boiler. In fig. 4,349 the flame striking the inclined target is directed upward where it can impinge on the metal of the shell and injure same. In fig. 4,350, the flame has a free space the entire length of the boiler.

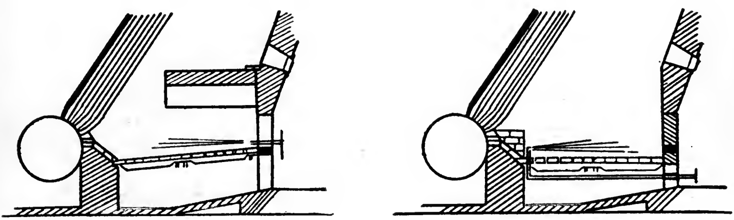


Figs. 4,351 and 4,352.—Arrangement of oil furnace for water tube boilers with horizontal and vertical baffles.

5. By the adoption of a suitable burner in connection with the furnace, meeting the other requirements. A burner must be used from which the flame will not impinge directly on the heating surface and must be located where such action cannot take place. If suitable burners properly located be not used, not only is the heat localized with disastrous results, but the efficiency is lowered by the cooling of the gases before combustion is completed.

Furnace Design.—This is an important feature of any oil burning system, as poor economy is nearly always due to improper furnace conditions. Moreover, upon the design of the furnace depends to a great extent, the capacity of the boiler. With a correctly designed furnace a very high overload may be carried without injuring the boiler.

The practice of using brick arches, checker work, target walls, etc., is unnecessary and is frequently the cause of the burning out of tubes or bagging the boiler. With such arrangement the cost of furnace repairs becomes very high and they are likewise often the cause of interruptions of service.



Figs. 4,353 and 4,354.—Faulty and well designed furnace for Sterling boilers. In fig. 4,353 the flame is liable to impinge on the tubes.

Ques. What is the objection to target walls?

Ans. They not only limit capacity but cause a localization of heat.

Ques. How should the furnace be designed?

Ans. It must be so arranged that the flame will not impinge on either the boiler or brick work.

The disastrous effects of the blow pipe action of the oil flame on the metal of boilers is well known.

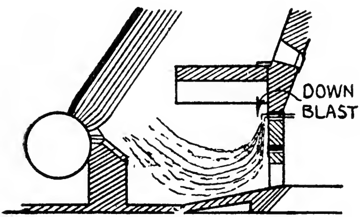
To secure the best results, the furnace must be so arranged that 1, all air must pass through the flame, 2, the atomized oil must be completely burned while suspended in the air, 3, a large surface of brick work must be exposed near the flame, and 4, the flame ought to be distributed over a large aerea.

Ques. What causes the brick work to "melt out?"

Ans. This is due to the intense heat, and sometimes to certain agents, present in some oils which cause a fluxing action.

Points Relating to Oil Burning Plants.—In fitting up a plant for oil burning, the following points are important:

1. Provide ample means for delivering clean hot oil to the burners.



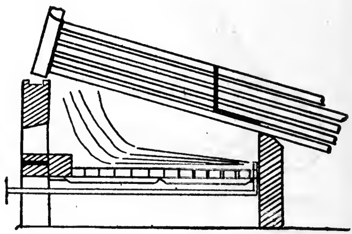


FIG. 4,355.—Down draught arrangement under Sterling boiler.

FIG. 4,356.—Furnace for Babcock and Wilcox boiler.

2. Select a type of burner that will maintain a flame in a cold furnace.

In designing a furnace, practice has shown:

1. That practically all air must pass through the flame.

2. The flame must *not* be allowed to impinge directly on either boiler sheets, tubes or brick work.

3. That the flame produces better results when worked near hot brick.

4. Distribute over as large an area as possible to prevent localization of heat.

5. That every precaution must be taken to guard against excess air.

Oil Burners.—There are a great variety of burners, and they may be classified in several ways.

1. With respect to the gasifying process, as:

   a. Vaporizers.
   b. Sprayers.

2. With respect to the atomizing agent, as:

   a. Air;
   b. Steam.

FIG. 4,357. ***Drooling*** burner. The oil to be atomized passes out and down from the upper passage, where it meets air or steam issuing from the lower passage, and being caught by the rapidly escaping and expanding air or steam is thoroughly sprayed.

3. With respect to the method of spraying, as:

   a. Outside mixing { drooling; atomizer; projector; centrifugal;

   b. Inside mixing { chamber; injector; centrifugal.

What is an outside mixing burner?

One in which oil and atomizing agent meet outside the burner.

Drooling Burner.—The oil supply simply drools or oozes out, at the orifice over and on to the steam or air jet as in figure 4,357. *In operation,* as the steam or air issues forth it expands within the layer or film of oil which is being carried into the furnace.

Atomizer Burner.—The oil is brought through an orifice from which it is swept off by a brush of steam or air as in fig. 4,358. It is the principle made use of in the ordinary cologne spraying devices.

Fig. 4,358. ***Atomizer*** burner. The oil is brought through an orifice directly across the path of the jet of air or steam and is "brushed" off by the latter and sprayed.

Projector Burner.—The oil is pumped to the oil orifice and from there is caught by a passing gust of steam and is blown off as in fig. 4,359.

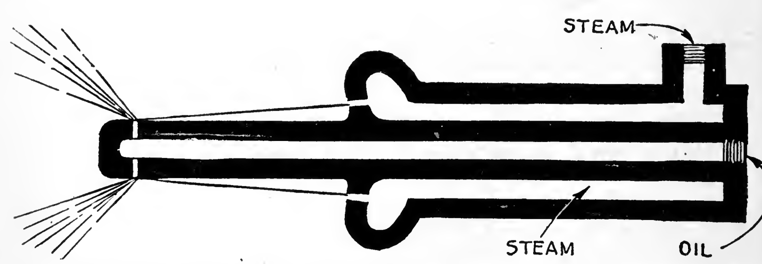


Fig. 4,359. ***Projector*** burner. The oil is pumped to the oil orifice and caught by the air or steam jets which are located some distance back of the oil orifice.

Outside Centrifugal Burner.—The oil is lead through the hollow spindle of a disc, which is rotated at high speed by a jet of steam acting on vanes attached to the circumference of the disc, and, overflowing onto the disc at its center, is hurled off the disc by centrifugal force and ignited by a torch, producing a ring of flame as in fig. 4,360.

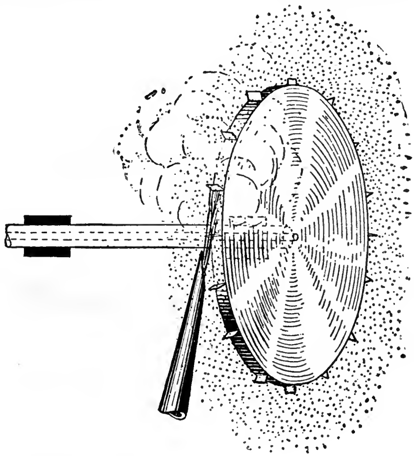


FIG. 4,360. Outside centrifugal burner.

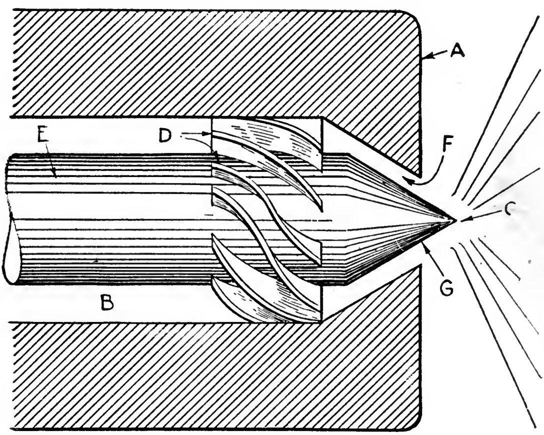


FIG. 4,361. Inside centrifugal burner. ***In construction,*** at the end of the pipe A, that conveys the oil, the oil passage B, is tapered down to the opening C, through which the oil is discharged. The ser.es of slanting vanes D, on the rod E, deflect the oil and break it up into a number of currents, each of which has a whirling motion as it enters the space F, around the end G, of the rod. The centrifugal force due to the whirling motion given by the vanes causes the spray to spread on leaving the burner as shown by the diverging lines.

These separate currents are intermingled at the orifice and on emerging spread out in diverging lines.

What is an inside mixing burner?

One in which the oil and atomizing agent meet inside the burner.

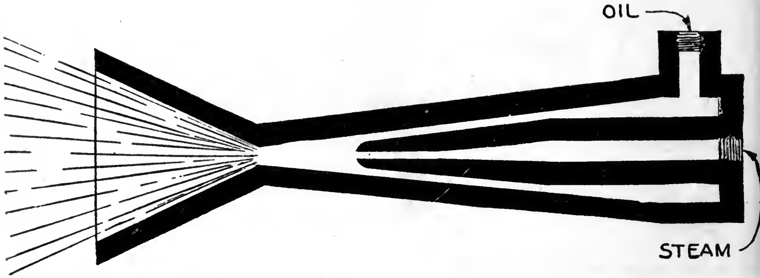


FIG. 4,362. ***Injector*** inside mixing burner.

Inside Centrifugal Burner.—In the end of the pipe near the nozzle is placed a series of slanting vanes as shown in fig.4,361 which deflect the oil and break it up into a number of currents, each of which has a whirling motion.

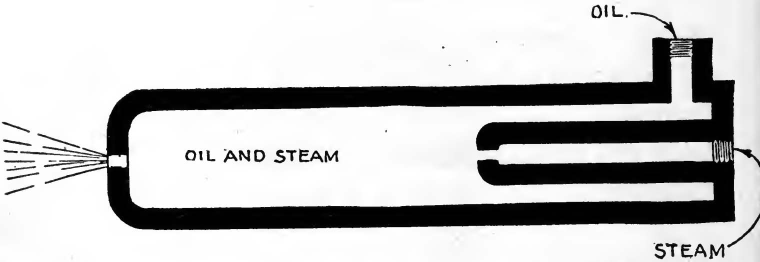
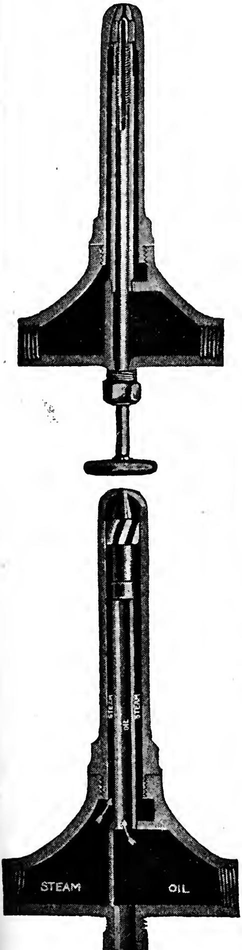
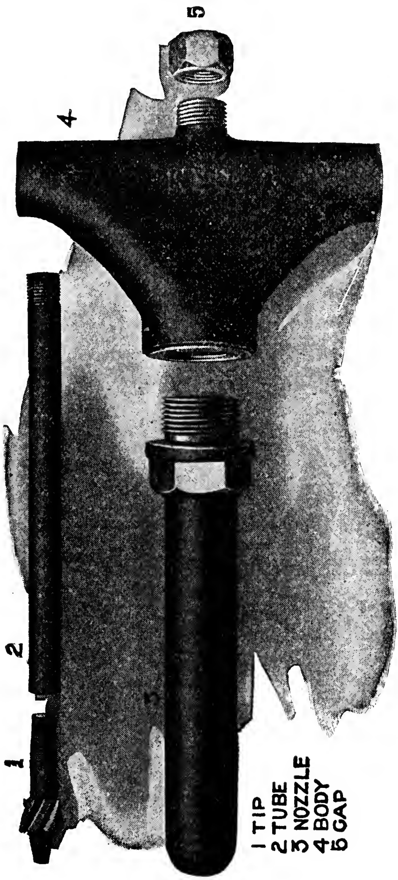


FIG. 4,363. ***Chamber*** burner. The oil and steam are more or less mixed before issuing from the burner. With this burner the oil is heated before leaving the burner.

Injector Burner.—The principle here employed is similar to the injector used for boiler feeding. *In operation*, the steam and oil mingle within cone shaped passages and, as a mixture, pass through a contracted nozzle and then outward through a reversed flaring cone, as in fig. 4,362.

Chamber Burner.—The oil and steam are more or less mingled within the body of the burner as in fig.4,363 and pass out from the tip or nozzle as a mixture, and then, owing to the expansion of the steam, the oil is rapidly broken into minute particles.



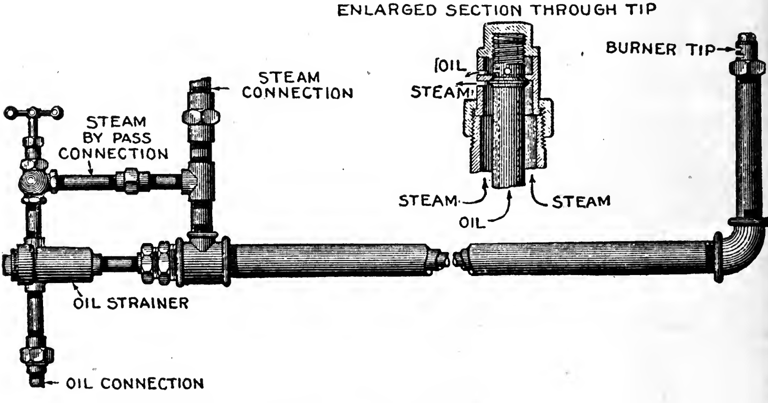


FIGS. 4,364 to 4,370.—Gem burners and parts. Fig. 4,364 regular Gem; fig. 4,365, improved Gem; figs. 4,366 to 4,370, ***parts:*** 1, tip; 2, tube; 3, nozzle; 4, body; 5, gap. In figs. 4,364 and 4,365 oil enters at one side of the burner and steam at the other, surrounding the inner oil tube heats the oil as it passes through. The jet formed at the outlet atomizes the oil. A whirling motion is given the steam by a whirl placed near the outlet. The improvement in fig. 4,365 consists of a needle valve which admits of a closer regulation of the oil supply. This burner is adapted especially for small boilers.

So Called Mechanical Burners.—These burners are properly termed centrifugal burners. In these burners the oil is given a whirling motion, preferably, within the burner tip. This is done either by forcing the oil through a passage of helical form or by delivering it tangentially to a circular chamber from which there is a central outlet. The oil is fed to these burners under a pressure which varies with the make of the burner and the rates at which individual burners are using oil.

The oil particles fly off from such a burner in straight lines in the form of a cone rather than in the form of a spiral spray, as might be supposed.

Where, in the spray burners, air is ordinarily admitted through a checker-work under the burner proper, with the mechanical burner, it is almost universally admitted around the burner.

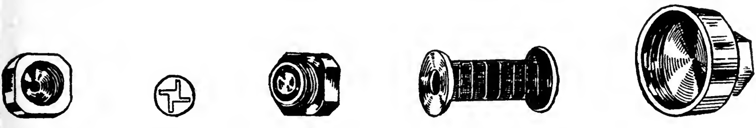


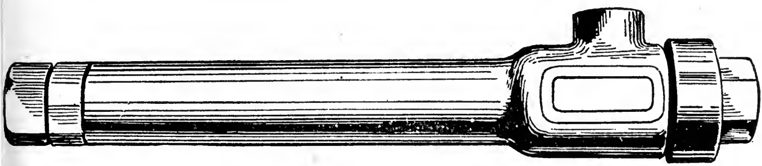
FIGS. 4,371 and 4,372. Peabody burner and pipe connections.

Steam Consumption of Burners.—The Bureau of Steam Engineering, U. S. Navy, made in 1901 an exhaustive series of tests of various oil burners that may be considered as representing, in so far as the performance of the burners themselves is concerned, the practice of that time. These tests showed that a burner utilizing air as an atomizing agent, required for compressing the air from 1.06 to 7.45 per cent of the total steam generated, the average being 3.18 per cent. Four tests of steam atomizing burners showed a consumption of 3.98 to 5.77 per cent of the total steam, the average being 4.8 per cent.

Improvement in burner design has largely reduced the steam consumption, though to a greater degree in steam than in air atomizing burners. Recent experiments show that a good steam atomizing burner will require approximately 2 per cent of the total steam generated by the boiler operated at or about its rated capacity. This figure will decrease as the capacity is increased and is so low as to be practically negligible, except in cases where the question of loss of feed water is all important.

There are no figures available as to the actual steam consumption of mechanical atomizing burners but apparently this is small if the requirement be understood to be entirely apart from the steam consumption of the apparatus producing the forced blast.





FIGS. 4,373 to 4,378. Peabody burner and parts. Oil is delivered under pressure to an annular channel cut into the face of a nozzle upon which is screwed a tip having a very small central chamber communicating with a discharge orifice. Between the nozzle and the tip a thin washer or chamber disc is inserted and held firmly in place. This has a hole in the center corresponding with the diameter of the central chamber of the tip, and small slots or ducts, extending tangentially from the edges of the central opening outward toward the periphery of the washer, long enough to overlap the annular channel of the nozzle and put it in communication with the central chamber. The effect is that, when the burner is assembled with the washer in place, oil is delivered through the ducts tangentially to the central chamber where it rapidly revolves and almost immediately is discharged through the orifice in the tip. The burner is connected as shown in fig. 4.311.

Capacity of Burners.—As rated by manufacturers, burners may be obtained in sizes ranging from one, to over four hundred horse power. The question of capacity of individual burners is largely one of the proper relation between the number of burners used and the furnace volume.

In some recent tests with a Babcock & Wilcox boiler of 640 rated horse power, equipped with three burners, approximately 1,350 horse power was developed with an available draft of the .55 inches at the damper or 450 horse power per burner. Four burners were also tried in the same furnace but the total steam generated did not exceed 1,350 horse power or in this instance 33‸ horse power per burner.

From the nature of mechanical atomizing burners, individual burners hav‸ not as large a capacity as the steam atomizing class. In some tests on a Bab‸ cock & Wilcox marine boiler, equipped with mechanical atomizing burners the maximum horse power developed per burner was approximately 105 Here again the burner capacity is largely one of proper relation between fur‸ nace volume and number of burners.

Furnace Design.—Too much stress cannot be laid on the im‸ portance of furnace design for the use of this class of fuel. Pro‸ vided a good type of burner be adopted, the furnace arrangemen‸

Fig. 4,379. Peabody and Irish impeller or air register. In a paper read before the Society o‸ Naval Architects and Marine Engineers, Mr. Peabody says: "Great delicacy is required i‸ introducing the air for combustion, very slight changes affecting the results in unsuspecte‸ ways, and while almost any method may result in smokeless combustion, maximum econom‸ and capacity can be secured only by careful and intelligent design. It is not necessary t‸ give the air a whirling motion but, judging from our rather exhaustive experiments, bette‸ gas analyses are secured, lower air pressures are required, and less refinement of adjustmen‸ is needed if the air be brought into contact with the oil spray with the right sort of a twist We have found the impeller plate, illustrated on this page, most effective in accomplishin‸ this mixture, and our most satisfactory results have been obtained with it."

and the method of introducing air for combustion into the furnac‸ are the all important factors. No matter what type of burner b‸ used, satisfactory results cannot be secured in a furnace no‸ suited to the fuel.

What are the chief points to consider in furnace design?

The furnace should be of such shape, volume and arrangement that the combustion of the gases is completed in the body and that the gases are suitably retarded so that all possible heat is absorbed by the heating surface.

How should the burners be located?

They should be so placed that the products of combustion,

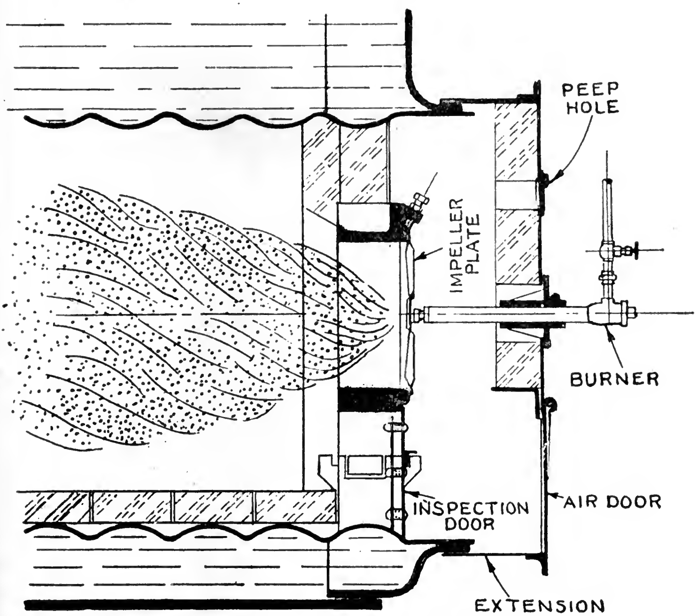


FIG. 4,380. Peabody mechanical burner as applied to a Scotch marine boiler.

as they leave the oil, burning first, do not impinge on the cold tubes and metal of the boiler.

It is important to keep the side and bottom burners far enough from the side and bottom walls to prevent the formation of heavy masses of carbon by the oil spray, as these masses will eventually produce poorer combustion.

The flames from mechanical atomizing burners have a less velocity of projection than those from steam atomizing burners and if introduced into the higher end of the furnace, should not lead to tube difficulties provided they are properly located and operated. This class of burner also will give the most satisfactory results if introduced so that the flames travel in the direction of increase in furnace volume.

Operation of Burners.—When burners are not in use, or when they are being started up, care must be taken to prevent the oil

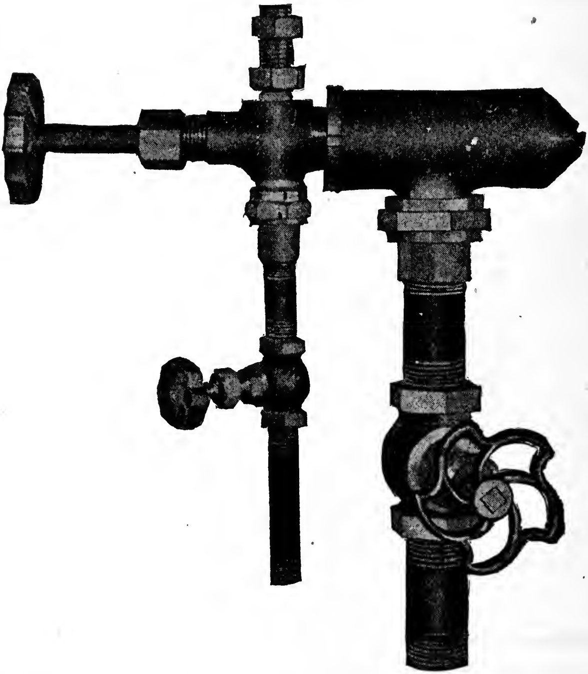


FIG. 4,381. Monarch all brass burner. It is a combination burner for either "high or low" pressure, and is adjusted by the center lock nut working backward or forward. The feed pipes are regulated with standard valves and the oil adjusted by needle valve.

flowing and collecting on the floor of the furnace before it is ignited. In starting a burner, the atomized fuel may be ignited by a burning wad of oil soaked waste held before it on an iron rod. To insure quick ignition, the steam supply should be cut down. But little practice is required to become an adept at lighting an oil fire. When ignition has taken place and the furnace brought to an even heat, the steam should be cut down to the minimum amount required for atomization. This amount can be determined from the appearance of the flame. If sufficient steam be not supplied, particles of burning oil will drop to the

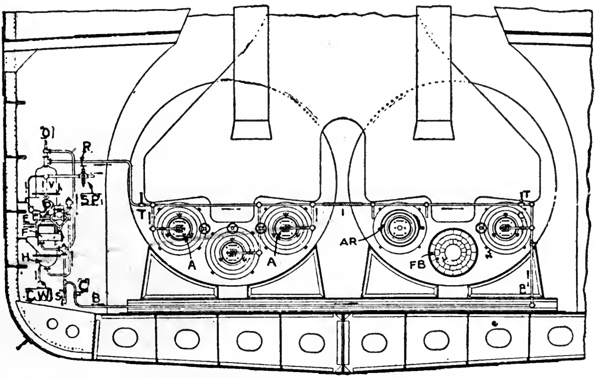


FIG. 4,382. ***Koerting*** oil burning installation for Scotch boilers. The outfit comprizes: A, centrifugal oil sprayer; B, circulating line of heating; C, Cock; E, exhaust of pump; F, filter; H, oil heater; O, safety valve; P, steam pump; R, reducing valve; S, oil supply line; T, thermometer; V, air vessel; AR, air register; CW, condensed water; FB, fire brick; SP, steam pressure line. The full section of the furnace is used, the grate being unnecessary. Therefore there is a gain in heating surface. The heating and resulting expansion is equal, and all the water surrounding the tubes is correspondingly heated. The short fire clay lining in the furnace serves as a protection against the intense temperature of the oil flame, and enables the boiler to be readily set to work after a short interruption; the oil ignites on the incandescent fire-clay.

furnace floor, giving a scintillating appearance to the flame. The steam valves should be opened just sufficiently to overcome this scintillating action.

Air Supply.—From the nature of the fuel and the method of burning, the quantity of air for combustion may be minimized. As with other fuels, when the amount of air admitted is the minimum which will completely consume the oil, the results are the best. The excess or deficiency of air can be judged by the

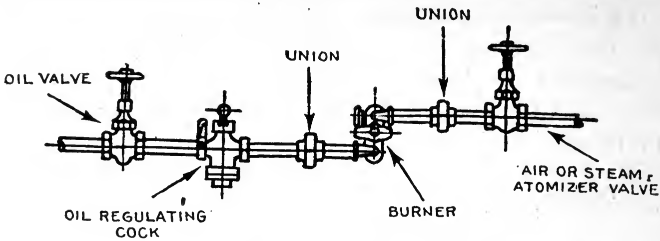


FIG. 4,383. Correct method of connecting ***Best*** atomizer valve (air or steam), also regulating cock and oil cut out valve.

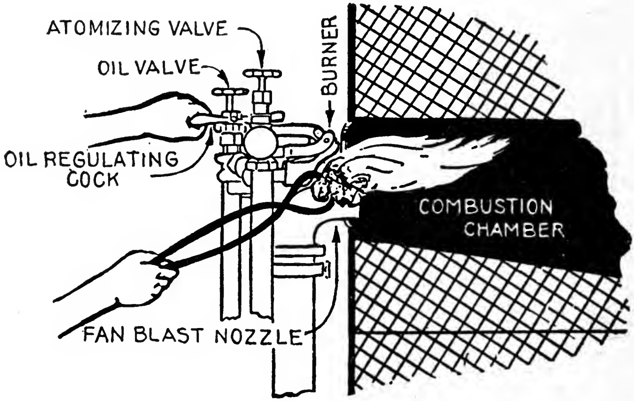


FIG. 4,384. Correct method of starting ***Best*** oil burner. Open furnace door and keep it open until the brick work shows red. Saturate well a piece of cotton waste as large as a fist with kerosene, light it and hold with pair of tongs under nose of burner. Open atomizer valve slightly. As the flame from the burning waste draws into the combustion chamber, open full the globe valve on the oil line, then carefully turn on the oil by means of the oil regulating cock. Always be sure that there is flame from the burning waste entering the combustion chamber until the combustion chamber is above the igniting temperature of the fuel, after which the furnace can be heated to the required temperature by turning on more oil and air through the burner, also be feeding blast air through the blast nozzle above referred to. Be careful not to feed too much air or it will not only cool down the furnace, but will scale or oxidize the metal. Control oil supply so that no smoke is emitted from furnace. A clear heat should be kept in furnace, which is obtained either by cutting off a little oil or adding more air, preferably at blast nozzle, as blast air is cheaper than compressed air. After furnace is at required heat, no flame should appear at the doors or waste gas vents in the top furnace, save a green haze, which is simply the consumed gases passing away. Never allow any obstruction to stop up the vents in top of furnace. The deflection air blast simply keeps the heat from the operator, also helps to retain it in the furnace. Blast air from 2 oz. to 8oz. is sufficient. Dry steam or compressed air of from 15 lbs. up is used for atomizing the fuel. Oil pressure in all cases must be less than that of the atomizing agent. Tar or heavy oil should always be heated by means of a steam coil in the storage tank. Never regulate oil with a globe valve but with an oil regulating cock.

appearance of the stack or by observing the gases passing through the boiler settings.

What are the air supply indications?

A perfectly clear stack indicates excess air, whereas smoke indicates a deficiency.

How is the proper air supply best gauged?

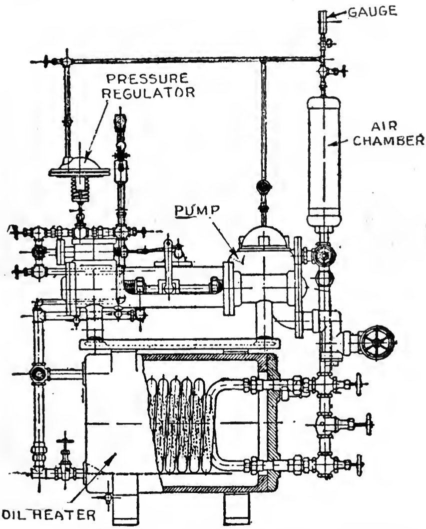


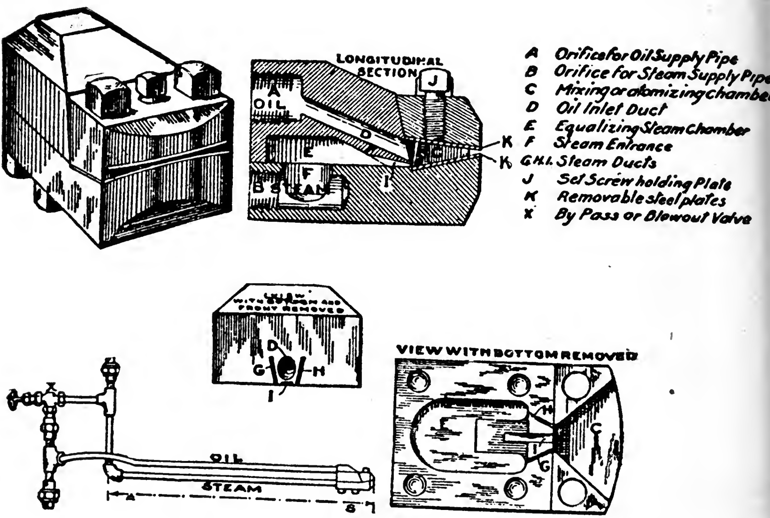
FIG. 4,385. Lockett automatic fuel outfit. ***The heating*** is done by means of a brass coil through which the discharge from the pumps is led. The exhaust from the pumps being used to heat the oil. A live steam connection is also provided so that the oil may be heated to any desired temperature. To provide against danger in case the live steam connection is allowed to remain open when the pumps are not running, a safety valve is provided on the steam chamber. A closed oil relief valve is provided to prevent excessive oil pressure. The governor, air chamber and pump discharge chamber are provided with purge pipes to prevent any possible gas accumulation.

By running near the smoking point with a slight haze in the gases.

A slight variation in the air supply will affect the furnace conditions in an oil burning boiler more than the same variation where coal is used, and for this reason it is of the utmost importance that flue gas analysis be made frequently on oil burning boilers.

With the air for combustion properly regulated by adjustment of any checkerwork or any other device which may be used, and the dampers carefully set, the flue gas analysis should show, for good furnace conditions, between 13 and 14 per cent, of CO_2 with either no CO or but a trace.

In boiler plant operation it is difficult to regulate the steam supply to the burners and the damper position to meet sudden and repeated variations in the load. A device has been patented which automatically regulates by means of the boiler pressure the pressure of the steam to the burners, the oil to the burners and the position of the boiler damper. Such a device has been shown to give good results in plant operation where hand regulation is difficult at best, and in many instances is unfortunately not even attempted.



FIGS. 4,386 to 4,390. ***Hammel*** inside mixing oil burner. ***In operation,*** oil enters at A, flows through D, into the mixing and atomizing chamber C; steam enters at B, passes through F, E, and then through three small slots, G, H, and I, into mixing chamber C, where it meets the oil, and as these small steam jets cut across the oil stream at an angle, the energy of the steam is fully utilized and the burner requires only about 2 per cent or less of the amount of steam generated by the boiler, the heavy hydrocarbons are completely atomized, the light hydrocarbons are vaporized, and the completed mixture issues from the burner and ignites like a gas flame.

Efficiency with Oil.—As pointed out in enumerating the advantages of oil fuel over coal, higher efficiencies are obtainable with the former. With boilers of approximately 500 horse power

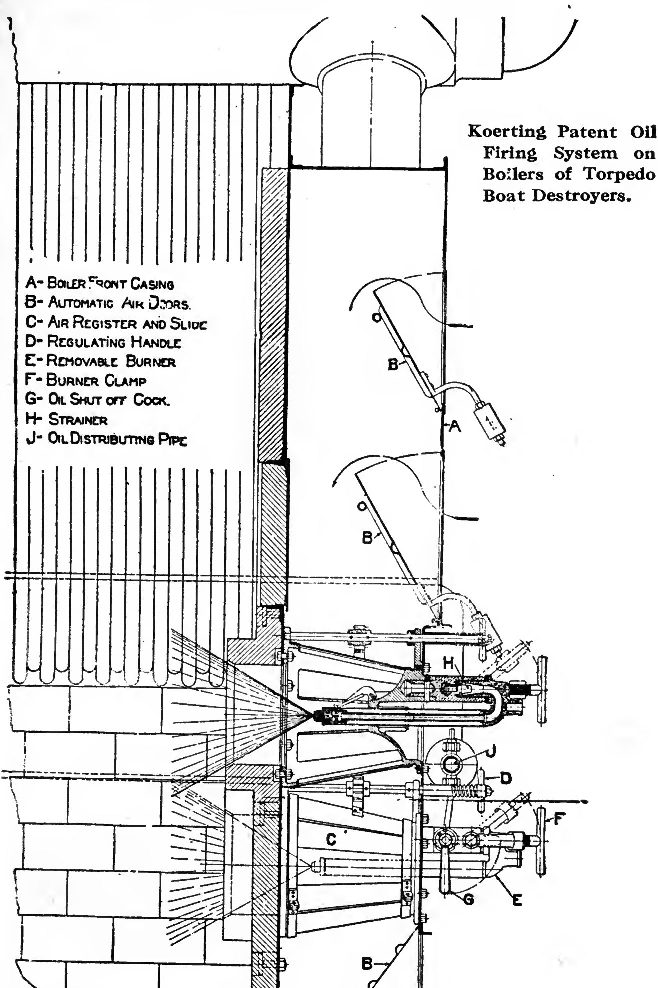


FIG. 4,391. Schutte and Koerting oil burning system as applied to boilers of torpedo boat destroyers.

equipped with properly designed furnaces and burners, an efficiency of 83 per cent is possible or making an allowance of 2 per cent for steam used by burners, a net efficiency of 81 per cent. The conditions under which such efficiencies are to be secured are distinctly test conditions in which careful operation is a prime requisite.

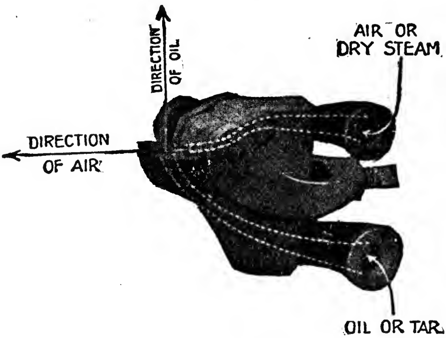


FIG. 4,392. ***Best*** high pressure type burner, for light or heavy oil, or tar. ***In operation,*** the air or steam meets the oil at right angles. By releasing the set screw in yoke and raising the lips, any obstruction that might find its way through the air line can be blown out.

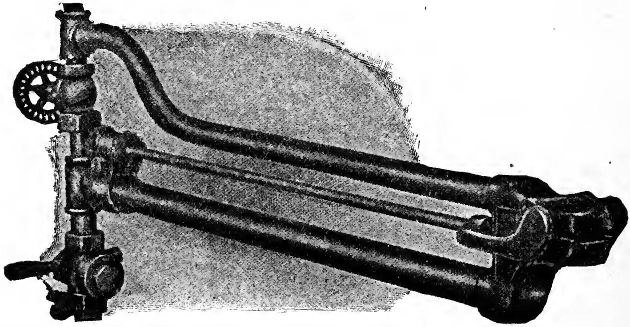
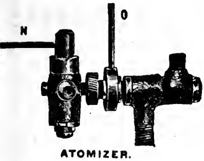
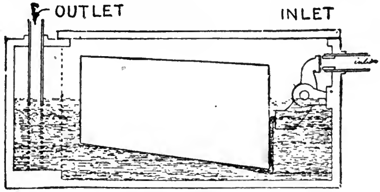
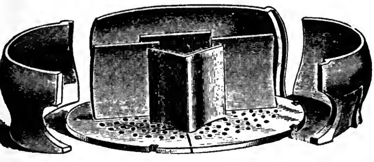
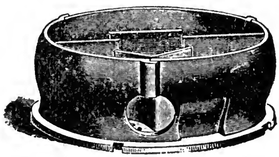


FIG. 4,393. ***Best*** burner mounted for boiler. The burner is connected to piping of sufficient length to go through the front setting of boiler. By means of the by pass valve any foreign substances that may enter the oil pipes can be blown out. The atomizer lip is hinged and held tight against the body of the burner, but means are provided for raising the lip to blow out the atomizer pipe in case any foreign substance such as scale, red lead, etc., should lodge therein. This can be accomplished without removing the burner from boiler.

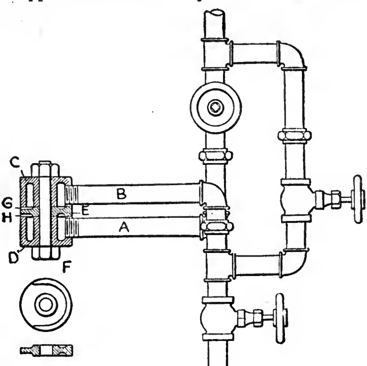




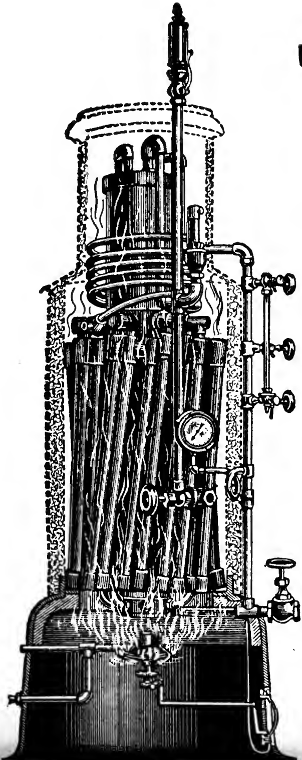
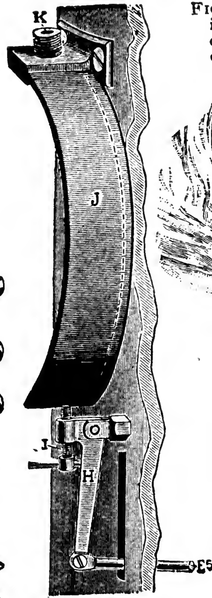


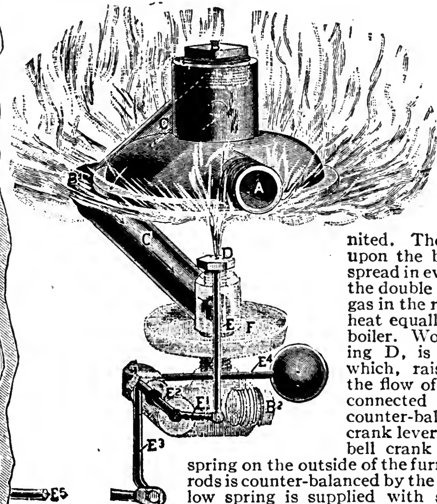


FIGS. 4,394 to 4,397.—Racine oil burning system for small vertical boilers up to 20 horse power. Fig. 4,394 burner; fig. 4,395 oil trap; figs. 4,396 and 4,397 fire box disassembled showing deflecting plates, and assembled. In fig. 4,395 when the oil level is reached the supply is cut off by the float rising and closing the oil level. The outlet to the burner being above the oil level, and the oil supplied to the burner by the vacuum created there can be no overflow.



FIGS 4,398 to 4,400.—Slot oil burner with renewable disc. The steam pipe A, and oil pipe B, are made of such length as to bring the tip of the burner to the proper point in the furnace. The burner consists of two cup shaped castings C and D, separated by a narrow disc E. The three pieces are of the same diameter and are held together firmly by the central bolt F. As shown in the separate views, the disc E, has its rim cut away on both sides for about one-third of its circumference. Thus, when it is bolted between the castings C and D, two slots G and H, are formed, extending about one-third of the way around the burner. The oil flows through the upper casting C, and drools over the edge of the disc E, from the slot G. The steam flows through the lower casting D, and escapes through the slot H, meeting the oil and spraying it so as to produce a wide fan shaped flame. The greater part of the wear due to erosion comes on the disc E, which can be renewed when badly worn. The arrangement of the regulating valves for oil and steam and of the by pass for cleaning is similar to that already described.

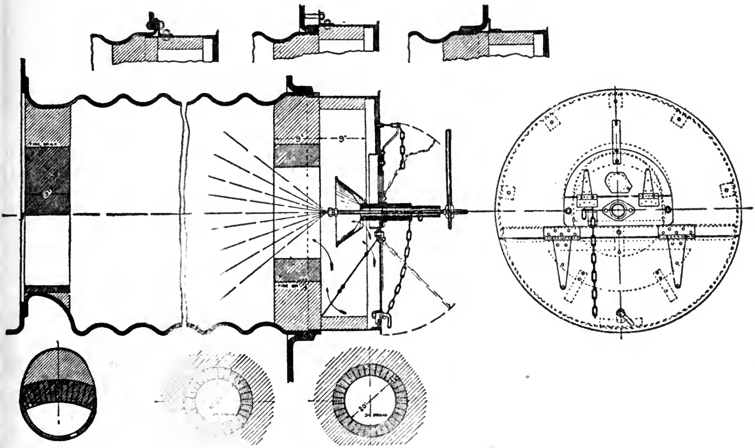





FIGS. 4,401 to 4,403. ***Vaporizing*** or ***gas*** type burner and method of installing in small marine boiler. It is designed for naphtha, benzine, gasoline or other light hydrocarbons or ordinary headlight oil, of 150° test. ***In operation,*** the oil is supplied through a pipe to the vaporizing retort indicated by the letter A. In its passage through the fire box and this retort it is converted into a vapor or gas, which burns without odor, soot or residuum. From the top of the retort A, the gas is conveyed through an elbow pipe C (as shown by arrows) to the mouth of the burner, where it escapes through a small opening D (made adjustable) and is ignited. The flame striking centrally upon the bottom of the retort A, is spread in every direction, thus serving the double purpose of generating the gas in the retort and distributing the heat equally to every portion of the boiler. Working into this small opening D, is a shut off plunger, E, which, raised or lowered, controls the flow of the gas. This plunger is connected by means of a rod E^1, counter-balanced rock shaft E^2, bell crank lever E^3, connecting rod E^5, to bell crank lever H, and to a hollow spring on the outside of the furnace. The weight of these rods is counter-balanced by the rod and ball E^4. The hollow spring is supplied with steam at boiler pressure through a small pipe at opening K. The saucer F, is for oil or alcohol used in raising the proper heat under retort at starting, and until sufficient gas is manufactured for its own reproduction; a matter of three or four minutes. The burner is furnished with removable plugs BB^1, and B^2, to facilitate cleaning. Rock shaft E^2, is furnished with stuffing box G, to prevent leakage. It will readily be seen that the straightening of the spring, caused by an increase of pressure in the generator, operates directly on the plunger by means of the adjusting screw I, bell crank lever H, and intermediate connections; thus perfectly establishing the relation between steam pressure and fire. Should the steam pressure rise, the plunger would close off the flow of gas correspondingly, and vice-versa, thereby regulating the heat of the fire. The plunger cannot, however, shut off the flow of gas entirely; a small orifice is always left, enough to keep the burner and generator hot; and in this way, the trouble and annoyance from having to relight the fire after every stop is avoided.

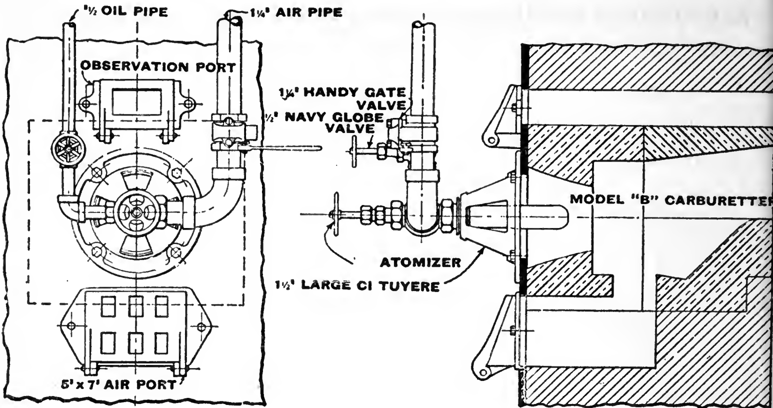
With furnace conditions that are not conducive to the best combustion, this figure may be decreased by from 5 to 10 per cent.

In large properly designed plants, however, the first named efficiency may be approached for uniform running conditions, the nearness to which it is reached depending on the intelligence of the operating crew.



FIGS. 4,404 to 4,411. Furnace front for Dahl mechanical oil burning system. This system has been adopted by many of the Pacific coast steamship companies, and was the first mechanical system to successfully operate with the heavy California oils. The burner is simple, having only a few parts, consisting of a tip, atomizer, strainer, tube and valve. ***The operation*** of the burner is regulated by the pressure of the oil line, rather than the valve of the burner. The furnace front as shown is so arranged that the burner passed through a pipe on the end of which is a cone or deflector which can be adjusted by moving it in or out to insure the proper quantity of air just when it is needed. The front is extended so that the whole length of the furnace is utilized and the brickwork is so fitted that repairs and examination can be made without removing it.

It must be remembered that the use of oil fuel presents to the careless operator possibilities for wastefulness much greater than in plants where coal is fired, and it therefore pays to go carefully into this feature.



FIGS. 4,412 and 4,413. Typical setting of Billow, class DM, atomizer in connection with model G1 carburetter. The observation port above the tuyere block enables the operator to examine the condition of the fire through a mica window without exposure to the heat or glare of the flame. The air port below the carburetter permits controlling the air supply to furnace and tuyere block and the tuyere controls the amount of air entering around the atomizer.

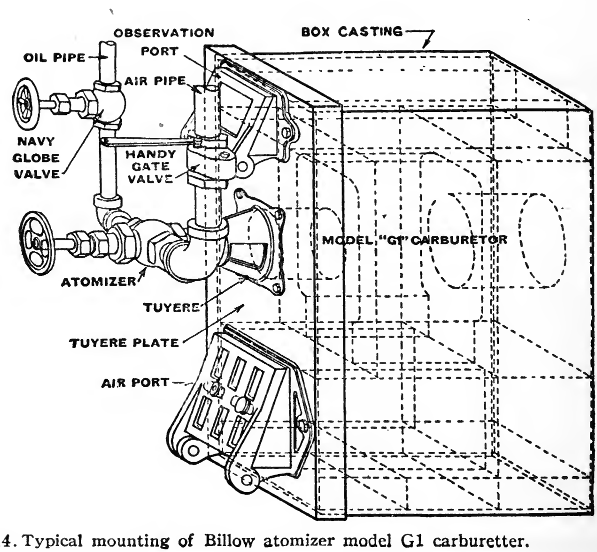
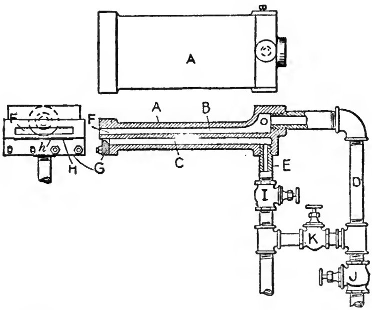


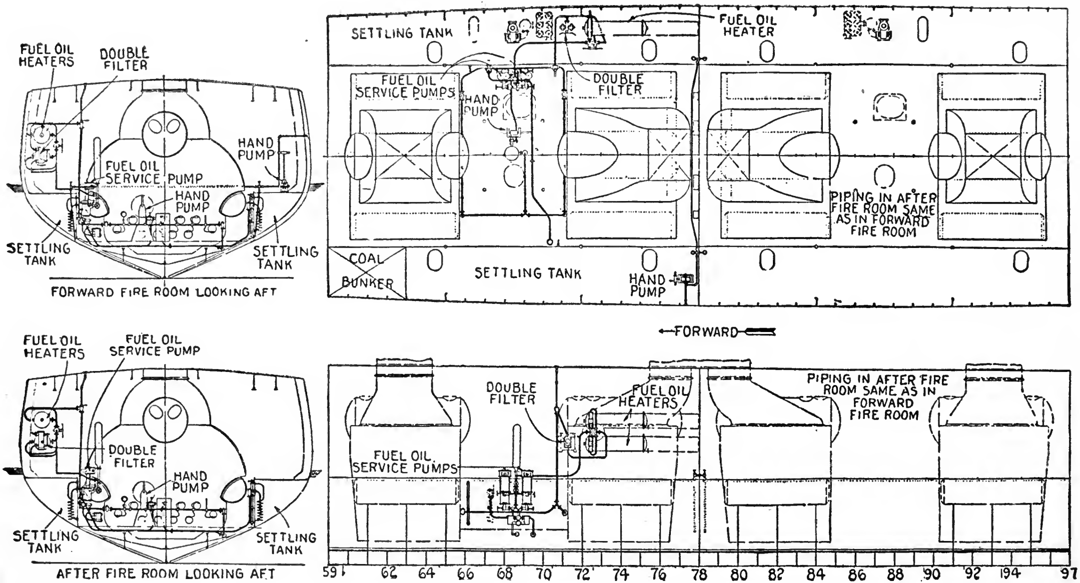
FIG. 4,414. Typical mounting of Billow atomizer model G1 carburetter.

Water-gas Tar.—Water-gas tar, or gas house tar, is a by-product of the coal used in the manufacture of water gas. It is slightly heavier than crude oil and has a comparatively low flash point. In burning, it should be heated only to a temperature which makes it sufficiently fluid, and any furnace suitable for crude oil is in general suitable for water-gas tar. Care should be taken where this fuel is used to install a suitable apparatus for straining it before it is fed to the burner.

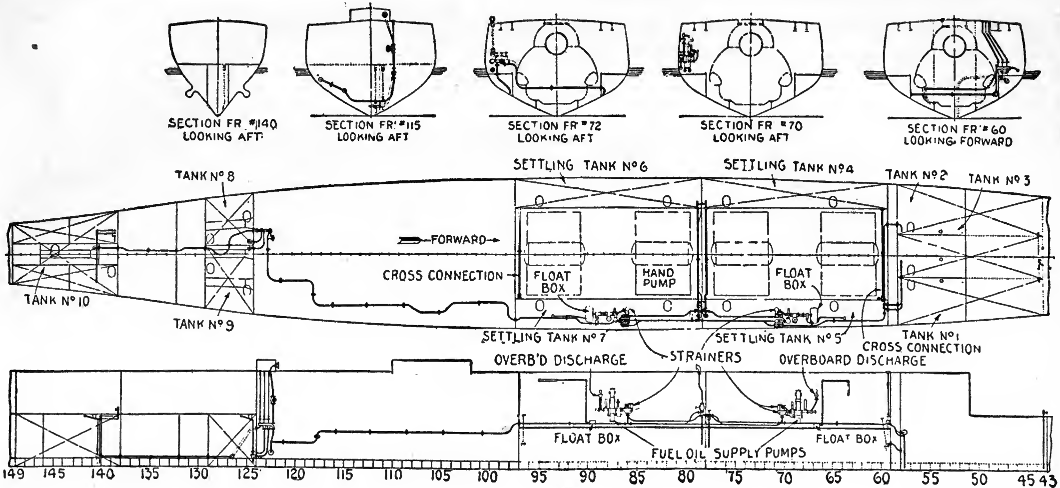


FIGS. 4,415 to 4,417.*Booth* oil burner with pipe connections. The body of the burner consists of a box-shaped casting A, that is set horizontally. It contains two passages, B and C, oil being admitted to the former through the pipe D, and steam to the latter through the pipe E. The oil flows outward through the wide, shallow slot F, at the tip of the burner and drools downward across the end. An adjustable steel plate G, is bolted across the steam orifice. This plate has a long notch cut in the top edge, forming the outlet H, for the steam, and on the inside it is beveled so as to direct the steam upward toward the orifice. The escaping steam sweeps along the under side of the burner tip, and in expanding, sprays the oil that runs down from the upper slot. The bolts that hold the plate G, in place, pass through long vertical slots in the plate, and this construction allows the plate to be moved up or down to give the desired depth of slot H. This adjustment, of course, is made when the burner is disconnected and not in use. The arrangement of the piping is simple. The supply of steam is brought to the burner through the pipe E, the flow being regulated by the valve I. In the same way a valve J, in the oil line D, is used to control the rate of flow of the oil. Between the oil pipe and the steam pipe is inserted a short connection fitted with a valve K. This serves as a by pass to admit steam to the oil passage when it becomes necessary to clean out the passage. The oil valve J, and the steam valve I, are first closed and then the by pass valve K, is opened. The steam rushes through the oil passage, and its heat and its cutting action together scour the passage clean. The steam passage may be cleaned by removing the plate G, completely, and allowing steam to blow through at full pressure. The passages in the burner are straight and fairly large to avoid frequent clogging.

It would appear from experiments that such a combination gives satisfactory results from the standpoint of both capacity and efficiency, if the two fuels are burned in separate furnaces. Satisfactory results cannot ordinarily be obtained when it is attempted to burn oil fuel in the same furnace as the primary fuel, as it is practically impossible to admit the proper amount of air for combustion for each of the two fuels simultaneously.



FIGS. 4,418 to 4,428. Diagram showing arrangement of oil piping of ***U. S. S. Patterson.*** As described by the Bureau of Steam Engineering: "The system comprises storage tanks forward and aft, and two settling tanks in each fire room, abreast of the boilers, together with the necessary pumps, oil heaters, strainers, etc. In each fire room there are one light service supply pump, two duplex pressure pumps and two oil heaters, each of sufficient size to heat all the oil used in same compartment to the desired temperature. For raising steam with no source of power available, a hand pump is provided in each fire room, of suitable size to supply oil at necessary pressure to two burners. From the bottom of each forward storage tank a pipe is led to the suction and filling manifold in the forward fire room. A similar manifold is provided in the engine room connected to pipes from the after group of storage tanks. From each manifold a combined suction and discharge pipe is led to the combined suction and discharge manifold at each supply pump. There are Macomb strainers in both suction and discharge connections between the manifolds and the pumps. The supply pumps



FIGS. 4,418 to 4,428. *Text continued.*

normally draw from the storage tanks and discharge into the settling tanks, which are cross-connected in each fire room for maintaining the same oil level in both tanks. In order to prevent overflowing the settling tanks, the starboard tank in each fire room is fitted with a float, which actuates a chronometer valve in the steam line to the supply pump, automatically shutting it down when the oil in the tank has reached a predetermined height. The supply pumps are also arranged for transferring oil from the forward to the after storage tanks and vice versa. They are also fitted to draw from the settling tanks and to discharge overboard when cleaning tanks. These pumps can also discharge oil to another vessel in emergency, via the deck filling connections. All tanks are filled from the deck via supply pumps, combined suction and discharge pipes. Extending from just below the mid-depth of each settling tank, with end surrounded by a steam coil, a suction pipe is led to the service pumps, in same compartment and fitted with strainers, at pumps. The service pumps discharge through strainers and heaters, the latter arranged with by pass to the oil burners. Large air chambers are provided on the pumps' discharge. The cut out valves to the burner lines, across boiler fronts, are fitted for emergency operation from the deck above. A hand pump is also provided in the after fire room for freeing the settling tanks of water and discharging same overboard."

Burning Oil in Connection with Other Fuels.—Considerable attention has been recently given to the burning of oil in connection with other fuels, and a combination of this sort may be

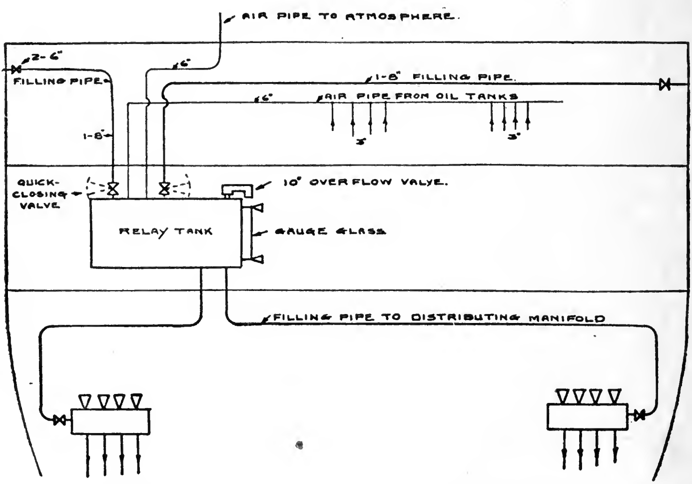


FIG. 4,429. Diagram of filling pipes and relay tanks U. S. S. Pennsylvania. Two 6-in. pipes with valves are located on each side of the ship, connecting with one 8-in. filling pipe on each side, which runs to the relay tank. The latter is fitted with a removable cover and a large (10-in.) overflow closed by a relief valve with a very light spring. Filling pipes lead from the relay tank to the storage tanks, and it is evident that the greatest pressure which can be put on the latter is that due to the head from the relay tank, which can be reduced to a smaller amount by suitably locating such tank. The vent pipes from the storage tanks lead into the relay tank, which is fitted with a common vent pipe leading to the atmosphere and covered at the end with wire gauze. The supply pipes to the relay tanks are fitted with quick closing valves and the relay tank is equipped with a gauge glass to mark the level of the oil. Also an annunciator at the relay tank, operating from the "pneumercators" fitted in the storage tanks, gives warning when the latter are 95% full. On the relay tank which is used only in filling and not for permanent storage, the fitting of a gauge glass is no doubt justified, but the use of fittings of any kind on the outside of the tanks below the oil level is in general very bad practice, and should be avoided where possible. Floating suctions, in storage tanks, for taking the oil from a point near the surface are no longer considered necessary, the usual practice being to use a high and low suction, *i. e.*, two pipes either separate or connected through a manifold, one taking the oil from a level 12 to 18 inches from the bottom of the tank and the other from a point within a few inches of it—not more than four inches. The upper suction is used for regular service, and at all times except in emergency—or when the supply is very low or when the low suction is employed to pump overboard water or very dirty oil which has accumulated at the very bottom of the tank.

advisable either with the view to increasing the boiler capacity to assist for heavy demands, or to keep the boiler in operation

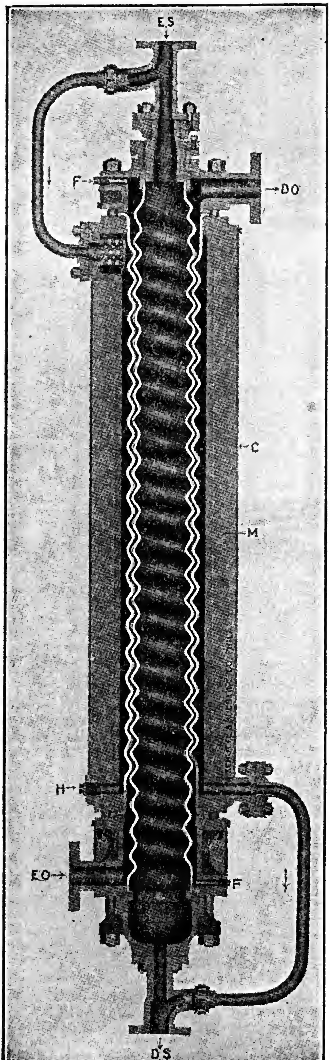


FIG. 4,430. *Schutte and Koerting* film oil heater. In this heater (invented by Lovekin) oil is forced in a thin film between two steam heated surfaces of such shape that the oil is continually being mixed or stirred in passing through the heater.

where there is the possibility of a temporary failure of the primary fuel.

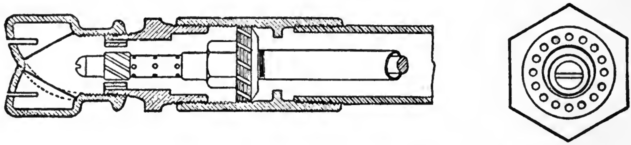
Conversion of vessels for use with coal or oil.—While the U. S. Navy has definitely adopted oil fuel for all classes of service and the later vessels are constructed without provision for coal bunkers, it may appear of advantage to the mercantile vessel owner to be ready to use either fuel. This can be easily accomplished if means are provided for carrying coal fuel.

The change of the boilers consists merely of removal of the burners and oil piping, air controling mechanism and special brickwork that may have been used, and substitution of a few necessaries, such as grate bars and fire doors.

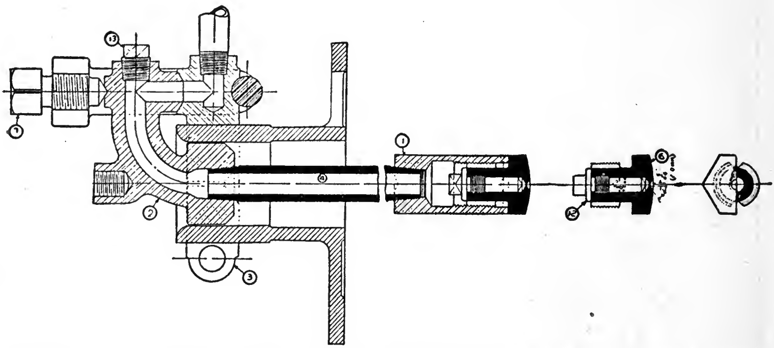
Where steam atomizing burners are used, the grate bars and bearers are usually retained while burning oil, and merely covered with a protecting layer of fire brick.

The changes in the bunkers also are simple, if proper precautions are taken beforehand.

Mr. George Simpson, the well known naval architect, gives the following rules for arranging the bunkers for alternate use with either fuel:



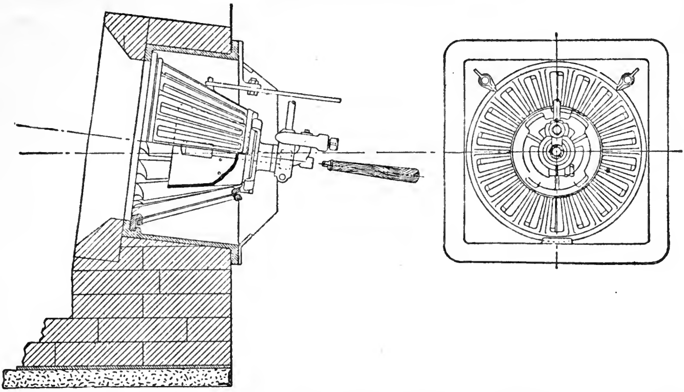
FIGS.4,431 and 4,432.*Staples and Pfeiffer* flat flame inside mixing atomizer; a type extensively used for marine work on the Pacific coast.



FIGS.4,433 to 4,435.***Bailey burner. In construction*** a quick detachable coupling fastened with a yoke is used to hold the burner in position and a wooden handle may be screwed into the burner elbow to facilitate handling. A steel tube is screwed into the coupling casting and on the other end of the tube is screwed a composition nozzle which is adapted to receive a steel tip provided with a central chamber ⅜-in. in diameter. A special plug of adjustable length is screwed into the end of the chamber, so that the actual volume of the chamber in which the oil is given its rotary motion is adjustable. Grooves in the threaded portion of the tip are provided for delivering the oil under pressure to an annular space just outside the central chamber. Oil passes to the central chamber through two small openings or round channels drilled in the tip at an angle of about 45° to a plane at right angles to the axis of the burner. These channels are tangential to the sides of the central chamber, so that as the oil enters the chamber it acquires a rapid whirling motion and issues from the orifice in the tip in a finely divided conical spray.

Specification for Coal or Fuel Oil Bunker

General Description.—"The cross bunker to be arranged adjacent to the fire room and to consist of two thwartship oil tight bulkheads of a predetermined capacity. There shall be a center line oil tight bulkhead dividing the cross bunker into port and starboard compartments, and in addition there shall be partial swash bulkheads extending throughout the upper half of the bunker."



FIGS. 4,436 and 4,437. ***Bailey air control*** as fitted to the Babcock and Wilcox boilers on the S. S. Malsonia. It consists of a cast iron grid of the shape of a truncated cone, the walls of which are cored so as to provide channels for the admission of the air. The passages are curved to give the air a rotary motion. Outside this grid there is a cover which may be revolved by means of a lever; this cover is slotted to correspond with the air passages in the truncated cone, and thus serves as a means for regulating the quantity of the entering air or for closing it off entirely. Inside the cast iron grid there is another truncated cone of different dimensions designed to protect the tip of the burner from direct impact of the air; this is shown partly in section in the drawing. The burner is installed through the small end of the truncated cone, and in this particular design the burner is inclined slightly upward from the horizontal line in order to give an upward sweep to the spray as it enters the furnace. The design is adapted to operate natural draft, but not forced draft.

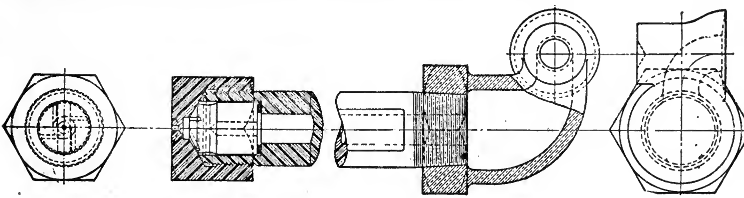
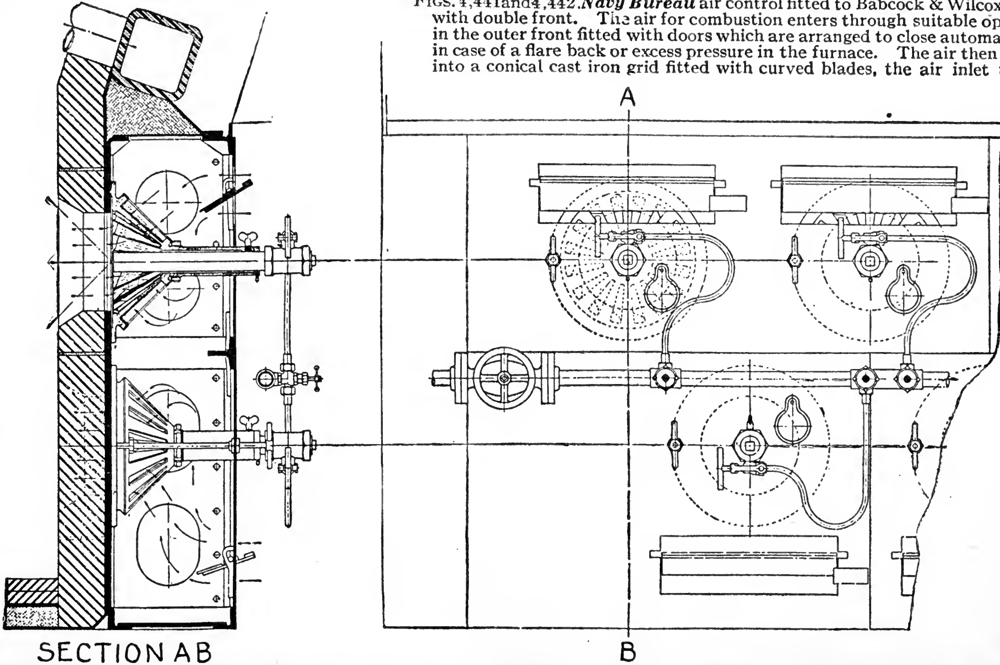


FIG. 4,438 to 4,440 ***Navy Bureau*** standard burner (designed by Lieut. Starr). The oil passes directly into a heavy steel tube, the end of which is recessed to receive a steel plug which is chamfered, on the end which faces the tip of the burner, at an angle of about 26° with a plane at right angles to the axis of the burner. The extreme end of the plug is faced off smooth to give a flat surface which corresponds in diameter with a recess in the steel tip, which in turn communicates with the outlet orifice through a small conical chamber. On the conical face of the plug four grooves are cut which are tangential to the chamber in the tip. The oil reaches the outer ends of these tangential channels by passing through a hole drilled in the center of the plug which communicates with another hole drilled at right angles to same, thus delivering the oil to an annular chamber formed by a recess machined in the side of the plug. The steel tip itself screws on to the end of the oil pipe in such a way as to provide a large chamber to receive the plug, which latter was originally intended to be movable in the direction of the axis of the burner, the idea being that this "floating" plug would be held tightly against the tip ordinarily by the pressure of the oil, but in case of dirt getting into one of the tangential channels, the pressure would force it through by driving the plug back slightly from its seat on the tip. In practice it has been found necessary, however, to use a small lead gasket to hold the plug firmly against the tip, as the oil pressure could not always be depended upon to do this.

FIGS. 4,441 and 4,442. *Navy Bureau* air control fitted to Babcock & Wilcox boiler with double front. The air for combustion enters through suitable openings in the outer front fitted with doors which are arranged to close automatically in case of a flare back or excess pressure in the furnace. The air then passes into a conical cast iron grid fitted with curved blades, the air inlet to the grid being controlled by a rotating shutter of suitable form on the exterior of the same. This is operated by means of a small gear wheel connected with a shaft which extends through the outer front and is provided with a handle, as shown in the drawing. The burner is installed through a sleeve which connects with the grid casting or may be made an integral part of same. It will be noted that the burner tip extends well into the interior of the cone and no protecting device around the tip is used. The Navy Department has granted permission to the ship builders or other interested parties for the free and unrestricted use of the Bureau design of burner and air control, and it is being fitted in many installations.



"The hatchway shall consist of a coaming 24" in height plated over the top and arranged with two oil hatches.

Oil tight Bulkheads.—"The oil tight bulkheads must be suitably stiffened with vertical stiffeners and webs, as well as horizontal girders, the scantlings and arrangement being as required by Lloyd's Rules for oil tight work. The center line bulkhead should extend from inner bottom to coaling hatch with plating and stiffeners to Lloyd's requirements.

Hatchway.—"A steel cover on top of the 24" coaming forming the hatchway shall be arranged with hinges and drop bolts to enable the whole of cover to be readily opened up for coaling purposes, and when carrying oil this cover will be arranged with a lamp wick gasket and the cover screwed down and made oil tight. In addition there shall be two small oil hatches

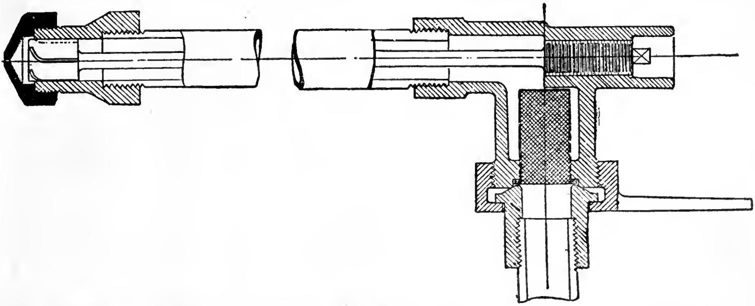
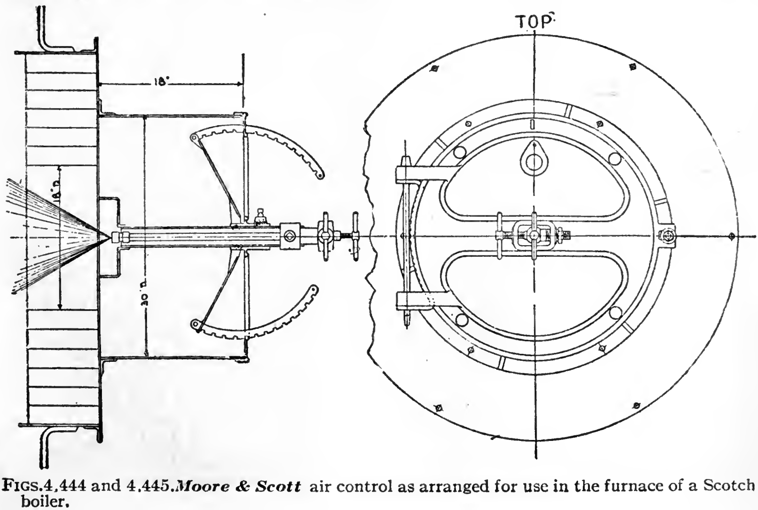


FIG. 4,443. ***Moore & Scott*** burner. The oil is delivered to the chamber communicating with the discharge orifice, through oil passages cut in the sides and on the end of a plug which is adjustable in the direction of the axis by means of a spindle passing completely through the burner; a special strainer is used and the union for connecting the oil piping is fitted with a special means for detaching quickly.



FIGS. 4,444 and 4,445. ***Moore & Scott*** air control as arranged for use in the furnace of a Scotch boiler.

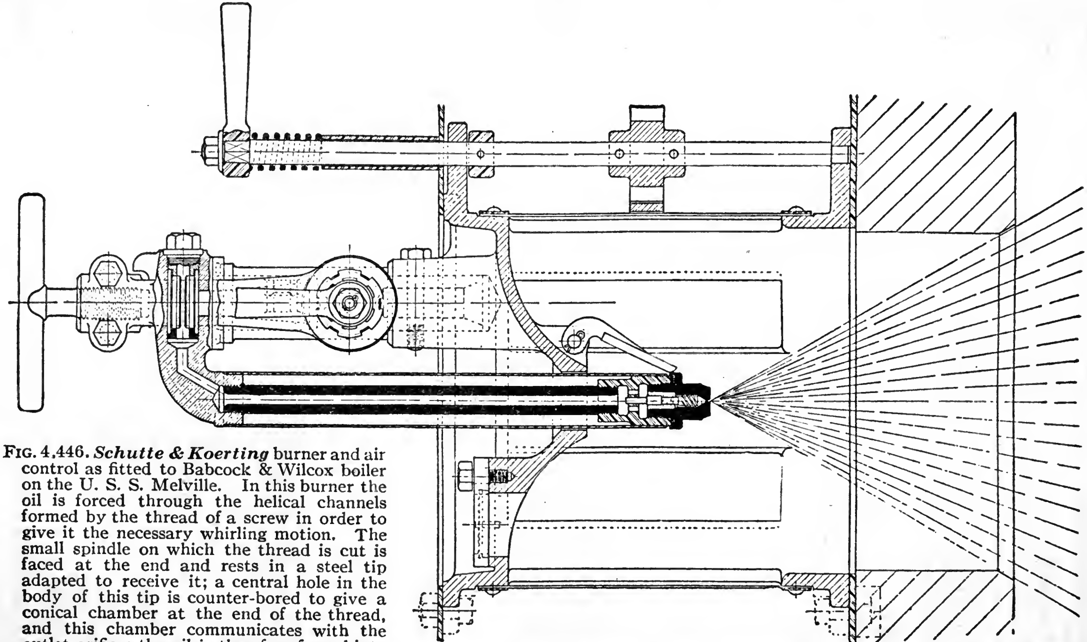


FIG. 4,446. *Schutte & Koerting* burner and air control as fitted to Babcock & Wilcox boiler on the U. S. S. Melville. In this burner the oil is forced through the helical channels formed by the thread of a screw in order to give it the necessary whirling motion. The small spindle on which the thread is cut is faced at the end and rests in a steel tip adapted to receive it; a central hole in the body of this tip is counter-bored to give a conical chamber at the end of the thread, and this chamber communicates with the outlet orifice; the oil is therefore forced into the small conical chamber with the rotary motion due to the action of the thread. The end of the spindle opposite the helical thread is squared in section and fits into a square hole in the nozzle of the burner, which prevents the spindle rotating when in operation. The air admission chamber is cylindrical in shape and is provided with longitudinal openings parallel with the axis of the burner, which admit the air for combustion. These openings are covered by an adjustable sheet iron cylinder, which fits on the outside, and the air is controlled by rotating this cover. The air is not given a whirling motion. In order to obtain the best mixtures and prevent pulsations, a high air pressure is usually carried and the air forced through restricted openings at high velocity.

on the main hatchway cover arranged so as to be readily opened and fitted with peep holes and ventilators.

Coal Doors.—"The stokehold bulkhead to be arranged with coal doors of the usual dimensions, the frames of which shall be secured with bolts and nuts so as to be readily removable when changing over to oil, and a steel plate cover substituted and set up on a lamp wick gasket, or alternatively, the plate may be riveted in place and caulked.

Fuel Oil System.—"The fuel oil system shall consist of a high and a low suction in each tank led to Warren or other suitable oil fuel pumps with the usual arrangement of heaters, duplex strainers, meters and thermometers, the whole system being cross connected and interchangeable so that the break down of one pump need not put that particular unit of the system out of commission, but can be connected up with the other pump and these pumps so cross connected that each can handle its own or opposite system.

Finally.—"Generally there is no practical difficulty in arranging a cross bunker for the

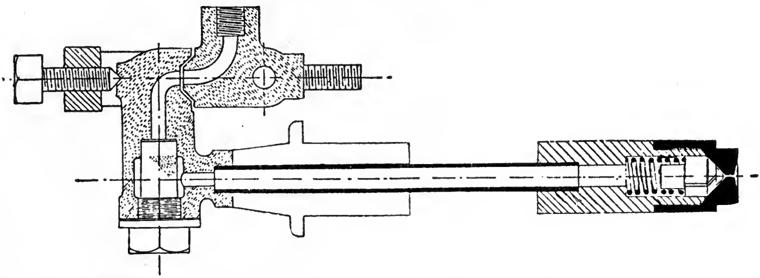


FIG. 4,447. ***White burner;*** extensively used in merchant vessels on the Atlantic coast. The mechanism for giving the oil a whirling motion consists of a plug which seats against the inner surface of the tip and is held in position by a spring. Oil passes along the grooves cut in the cylindrical portion of the plug and then along the corresponding grooves cut in the conical end, which are so arranged as to deliver the oil tangentially to the central chamber in the tip and at an angle of about 45° to a plane at right angles to the axis.

NOTE.—***Corrosion due to oil.*** Certain grades of the heavier oils contain considerable sulphur and the question is frequently asked whether or not corrosion from this cause may result. At the opening of the Beaumont fields, particularly, there were many, who on general principle, prophesied rapid deterioration of boiler surfaces, without giving due thought to the fact that certain kinds of coal having a larger sulphur content than the oil had for years been used for fuel without serious trouble. Experience has demonstrated that sulphur in oil has no bad effect on boilers, except in cases of neglect, when pitting may occur under certain conditions, the same as with coal. Corrosion of copper heating coils has, however, been noticed in the presence of sulphur bearing oils, and for this reason it is the recognized practice to use steel coils. Brass and bronze fittings may be used, however, with safety, both in pumps and on pipe lines, and doubtless brass heater tubes could be employed if desired.

NOTE.—***Oil piping for U. S. Naval Service.*** The piping specified is seamless drawn steel, with flanges expanded on. The joints are scraped and made up metal to metal. Manila paper gaskets are allowed on suction piping. Screwed fittings are used on connections under ¾-in. For merchant service extra heavy welded iron or steel pipe is used, with screwed joints and with extra heavy galvanized iron fittings. Flanges are screwed on the pipe and manila paper or card board is used for gaskets, or special oil proof packing, of which there are several kinds in the market. Rubber is not allowable on account of sulphur in the oil. Copper piping is not used on account of the sulphur, but brass and composition fittings, valves, unions, etc., may be used safely. The suction piping should be large, the Newport News rule for designed velocity of Mexican oil through suction pipes being not over twenty feet per minute, the oil being heated to reduce the viscosity to about 300° Engler. For discharge pipe lines they consider 100 feet per minute allowable in small pipes, the viscosity being reduced to 15° Engler or under.

stowage of either coal or fuel oil provided the hatchway is made large enough and arranged with a steel cover. Care should be observed in arranging the wing swash plates that they shall only extend for the upper part, thus permitting the coal to gravitate freely to the bunker doors.

"With a system such as has been outlined in the foregoing, a change over from one fuel to the other can be made in a few hours."

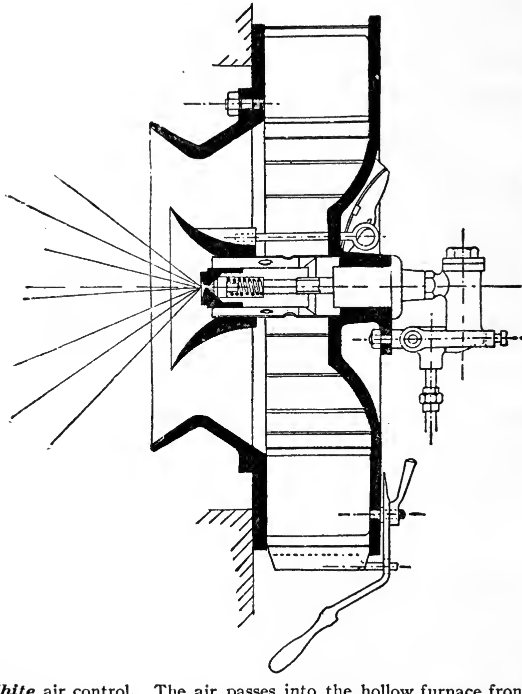


FIG. 4,448. ***White*** air control. The air passes into the hollow furnace front through ducts which give it a rotary motion, and the metal work of this part is intentionally exposed to the radiant heat of the furnace for the purpose of heating the air before it enters the furnace. The flaring sleeve around the burner is adjustable in the line of the axis of the burner and it will be noticed that a small amount of air is admitted directly around the tip through the opening in the sleeve. It is claimed that the "Venturi meter" effect of the portion of the apparatus where the air enters the furnace is of benefit in promoting combustion.

NOTE.—***Valves.*** For valves on suction lines designed for viscous oils, the gate valve is preferable, on account of reduced friction. On delivery lines, globe valves of a regrinding type give satisfaction. There is no occasion to use needle valves. Where fine regulation is required, as in some cases with steam atomizers, there are several types of valve which open gradually on slotted or "V" shaped passages which give better and more consistent results than the needle type. All valves for high pressure work should be extra heavy with bonnets screwed over, not into, the valve body. Specially designed and packed plug cocks may be used in small sizes for quick action.

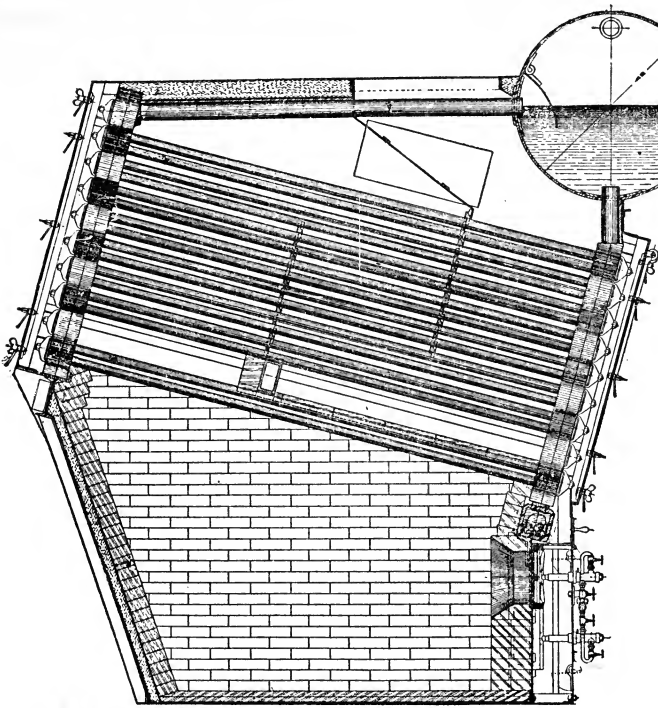


FIG. 4,449. Sectional view of ***Babcock & Wilcox*** marine boiler showing furnace and ***Peabody oil burners***. The reverberating brick baffle on the bottom group of tubes direct the gases to the rear of the furnace, in which direction it will be noted that the furnace increases in height and volume. Moreover, the oil is injected into the furnace along lines nearly parallel or at a slight angle with the tubes which promotes a very even distribution of the flame along the bottom row of tubes.

NOTE.—***Stowage on board.***—By no means the least of the advantages of oil over coal is its adaptability for storage in almost any part of the vessel—in the ordinary bunker space, or in tanks remote from the fireroom, or in double bottoms. Special precautions must be taken to prevent and to detect leakage from the tanks. Special riveting is employed and frequently coffer dams are built around the oil tanks. Coffer dams around the oil tanks are recommended but not insisted upon by any of the Classification Societies, except where "low flash point" oils are allowed, ***i. e.***, oils having a flash point below 150° F. In other words, while oil is easily handled, the feasibility of its use on shipboard depends primarily on the ability to keep it where it is stowed until it is pumped to the burners. In deep tanks, swash plates are installed to prevent undue motion of the liquid in the tanks when partly filled. Expansion trunks are provided to allow for increase in volume due to heating; vent pipes are carried above the decks to carry away vapor given off by the oil. These are fitted with goose necks at the top covered with wire gauze, and sometimes in destroyers or vessels of low freeboard the vents have special automatic valves at the end instead of the simple goose neck, for discharging vapor and at the same time preventing water from entering the tanks.

Strainers.—The comparatively small orifice of the mechanical sprayer necessitates special care being taken in straining the oil. Most makes of burner are fitted with individual strainers, that used in the Peabody burner being shown in fig. 4,378.

The spool is wrapped with three turns of brass netting of 40 to the inch mesh, fastened with No. 20 gauge brass wire.

Furnace Walls.—In laying up brick walls and flooring of oil furnaces, provision should be made for expansion, but it is worth noting in this connection, that there is a great difference in the coefficient of expansion of fire brick. It is possible to secure highly refractory brick and tiles made of material which expands but slightly, not over $\frac{1}{16}$ in. in 9 in.

The Babcock & Wilcox Company uses a light wash for making joints, composed of 15 parts (by weight) of fire clay, 5 parts of carborundum sand, and 1 part silicate of soda.

The special high temperature cements on the market are a needless expense for new work but are very effective for repairs, where they find a special field of usefulness.

It is a good idea to throw a few old glass bottles into the furnace to make a glaze on the bottom surface and fill the cracks.

NOTE.—***Sounding pipes*** for measuring depth of oil in the tanks are provided. These should be of ample size, anything less than $2\frac{1}{2}$ in. being unreliable for deep tanks in which viscous Mexican oil is carried. It is advisable to drill small holes in these pipes to give free access to the oil at all depths, as it is possible for some difference in density to exist at the various levels, if the oil has been standing for some time. Heavier oil at the bottom would give an erroneous reading if the sounding pipe were open at the bottom end only.

NOTE.—***In closed tanks*** the combined area of the vents and sounding pipes must be sufficient to provide an adequate overflow in the case of too rapid filling, which might put an undue pressure on the tank. For this reason, when tanks in the lower part of the vessel, such as the double bottoms, are used for oil, it is advisable to fill through a system of relay tanks which eliminates the danger of a large "head" of oil exerting a heavy pressure on the storage tanks.

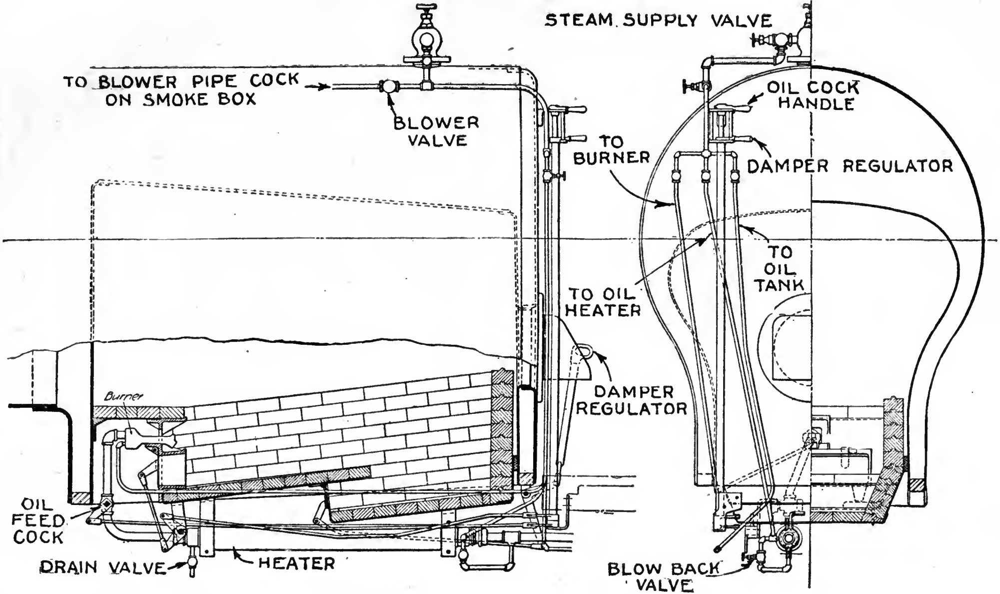


FIG. 4,450.—Arrangment of Baldwin locomotive oil burner equipment. ***It consists of*** an injector or atomizer through which the oil is fed into the furnace, a suitable fire pan replacing the regular ash pan of a coal burner, and an arrangement of fire brick for protecting the lower parts of the furnace sheets from the direct action of the flame. The supply of oil may be carried either on the tender or on the locomotive. The flow of oil is controlled by a plug cock in the feed pipe. A heater may be placed in this pipe line as it is essential to have the oil warm enough to insure a steady flow to the burner. In order to insure complete combustion and fill the fire box with flame, it is necessary to spray the oil into the furnace usually by means of a steam jet. The fire pan is supported in the bottom of the furnace and is lined throughout with fire brick. Where necessary, fire clay and asbestos are used to insure an air tight joint between the pan and the furnace walls. The front and of the pan proper is some distance back of the front water leg the intervening space being bridged over by a steel plate covered with fire brick. The damper

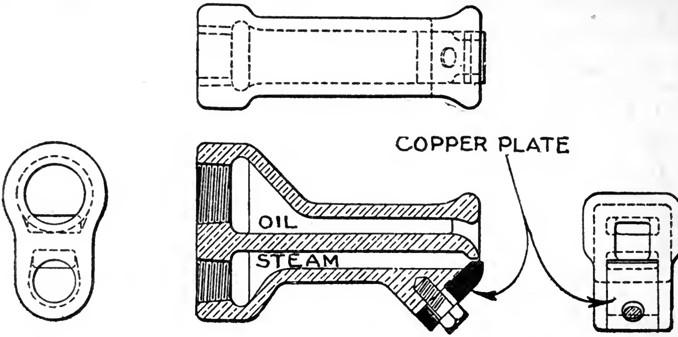


FIG. 4,451.—Baldwin oil burning locomotive burner. It consists of a brass casting provided with an adjustable copper plate as shown. The end of the burner is so shaped that the stream of oil is discharged downward, meeting the steam jet before the velocity of the latter has materially decreased.

FIG. 4,450.—*Text continued.*
is at the front end of the fire pan. The damper has an opening near the top through which the oil is injected. A second damper, admitting air in a horizontal direction is placed in the pan at mid-length. Admission of air above the fire is effected through the fire hooded fire door. The bottom of this hood is mounted on trimmings for rotary motion to regulate draught. The fire is observed by a peep hole which is also used to introduce sand into the furnace to scour or clean the tubes of soot. The crude petroleum used is a heavy black liquid and must be warmed to insure a steady flow to burner. The heater provided for this purpose consists of a long steam jacketed pipe through which the oil flows. The oil feed cock is placed between the heater and the burner. The control handles for oil feed and damper regulation are located in the cab. There is an automatic plug cock in the pipe line which closes in case engine and tender become disconnected. The oil tank in the tender is arranged to fit into the fuel space so that by lifting the tank out, the tender can be adapted to coal fuel.

NOTE.—***How to fire oil burning locomotives.*** The following rules are important: ***Filling oil tanks.*** Torches must not be brought nearer than ten feet from tank. In filling tank leave margin of 2 ins. for expansion of the oil. After filling clamp down manhole cover. ***Starting fire.*** A locomotive having 20 lbs. steam pressure can operate its own blower and atomizer. See that bottom of fire box in front of burner is free from carbon or obstructions. Open front damper and start blower. Now open atomizer valve long enough to blow out any condensate, and after closing throw in some lighted waste in front of burner. Open atomizer sufficiently to carry oil to the burning waste, and then regulator until the oil is known to be spouted from the burning waste. Determine this by observation through fire door or sand hole. After oil is ignited carefully regulate atomizer and oil valve so that all oil passing through burner is being consumed. *Don't turn on too much oil.* If fire go out, do not attempt to relight it from the heated brick as there is danger of an explosion. If in starting up, wood be used to generate the necessary 20 lbs. steam power, place wood carefully in fire box. ***Combustion indications.*** A fire having a bright, clear color denotes proper combustion; while a fire burning with a dark smoky flame indicates the reverse. Black smoke should be avoided. ***Adjustment of burner.*** The burner should be adjusted so that the blaze will not strike the top, bottom, or side of the arch before striking the flash wall to avoid black smoke. ***Handling atomizer blowers and dampers.*** A slight change in atomizer adjustment will often produce good results when an engine is not steaming well. When firing up with oil, the blower must be used; in running use blower as little as possible, as it is detrimental to the tubes and stay bolts. When throttle is closed reduce atomizer at once so that it will just keep oil from dropping into bottom of the pan. ***Sanding tubes.*** They should be cleaned out well after leaving terminal, or after standing. Continue sanding as long as black smoke issues from stack. ***General hints.*** Use as little blower, as little sand, and as little atomizer as possible.

CHAPTER 76

BOILER SETTINGS

Most writers in treating of boiler settings begin and *stop* with the setting for a horizontal return tubular boiler. Although this is the most elaborate setting it is by no means the only kind of setting. Accordingly, no chapter or book on settings is complete which is devoted exclusively to horizontal tubular boiler settings, nor is the arrangement logical which begins with this most complicated form of setting.

Boilers are either *self-contained*, or require brick work or equivalent to enclose the furnace and combustion passages leading to the tubes.

The self-contained class require no "setting" in the ordinary sense of the term, but to enlarge the scope of this chapter, the author defines **setting** as *a support or foundation for a self-contained boiler*, or *a mass of brick work or equivalent comprising the foundation and enclosure for furnace and combustion passages of an externally fired boiler, together with the necessary iron fixtures or trimmings, exclusive of grate.*

Marine Boiler Settings.—These consist simply of members designed 1, to support the weight of the boiler, and 2, to hold the boiler firmly in place. The important problem which presents itself is to distribute the weight by rigid supports over a considerable portion of the hull to prevent undue strains coming on the latter. This is particularly important in the case of lightly constructed vessels such as high speed yachts.

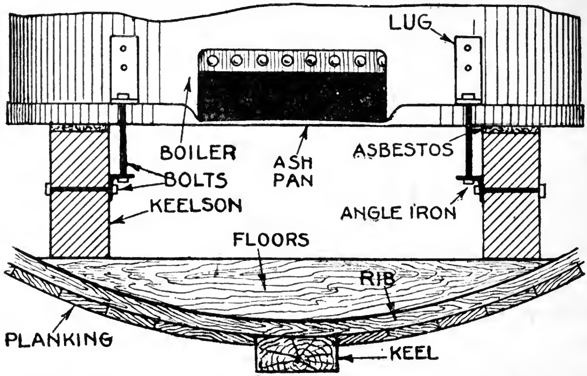
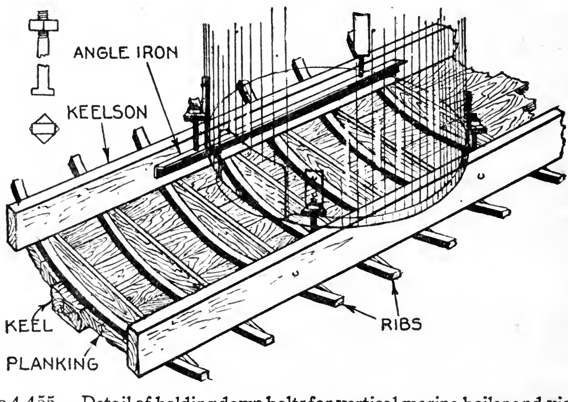


FIG. 4,452.—Setting for marine vertical boiler, showing method of securing the holding down bolts to the keelsons without weakening the latter. By attaching these bolts to angle irons fastened to the keelsons along the neutral axis no wood is cut away in other parts, thus the stiffness of the keelson, which is so essential, is not impaired.



FIGS. 4,453 to 4,455.—Detail of holding down bolts for vertical marine boiler and view of setting or bed so arranged as to distribute the weight over a large area. The two keelsons are connected rigidly together by cross members, the structure resting on the floors (see fig. 4,452) and reinforced by angle irons, to which the holding down bolts are attached. This arrangement avoids the use of lag screws and gives a very strong light weight construction. For large boilers there may be four keelsons, the inner two being extended aft to form the bed for the engine. The longer these keelsons, the better, as it adds stiffness to the hull and distributes the weight of the boiler over a large area.

Figs. 4,452 to 4,455 show one form of setting or bed for vertical boiler. As shown, no wood is cut away for the holding down of bolts, except at the neutral axis, thus the stiffness of the supporting members is not reduced. Where boilers are supported by wooden members, a liberal thickness of asbestos board should be provided between the wood and metal to protect the wood from the heat.

Western River Boiler Settings.—A peculiar characteristic of the power plants for Western river steam boats is that the boiler is placed on deck instead of at a lower level near the bottom. This

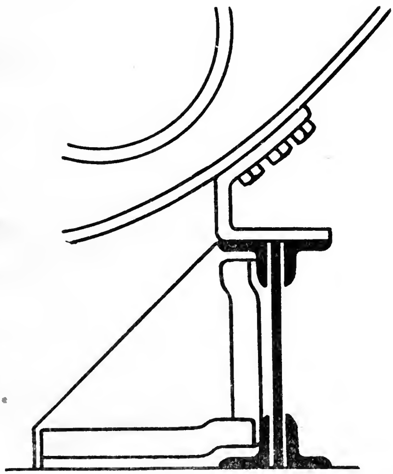


FIG. 4,456.—Horizontal marine boiler saddle. The weight of the boiler is supported on saddles or bearers which are attached to the structure of the ship. There are several of these saddles on each side of the boiler, each extending a little distance longitudinally to give a firm bearing.

necessitates some form of deck reinforcement to support the weight.

Both self-contained and externally fired boilers are commonly used, the former class being in favor for small and medium sized boats, the two types in general being the locomotive and gun boat boilers

Locomotive boilers are mounted on longitudinal skids which makes a good footing for distributing the weight, as shown in fig. 4,451.

On gunboat boilers saddles are used in place of skids, the weight being transmitted through these to longitudinal beams, reinforced by cross guy rods, as shown in fig. 4,456.

Stationary Vertical Boiler Setting.—This being a self-contained boiler, the setting consists simply of a foundation suffi-

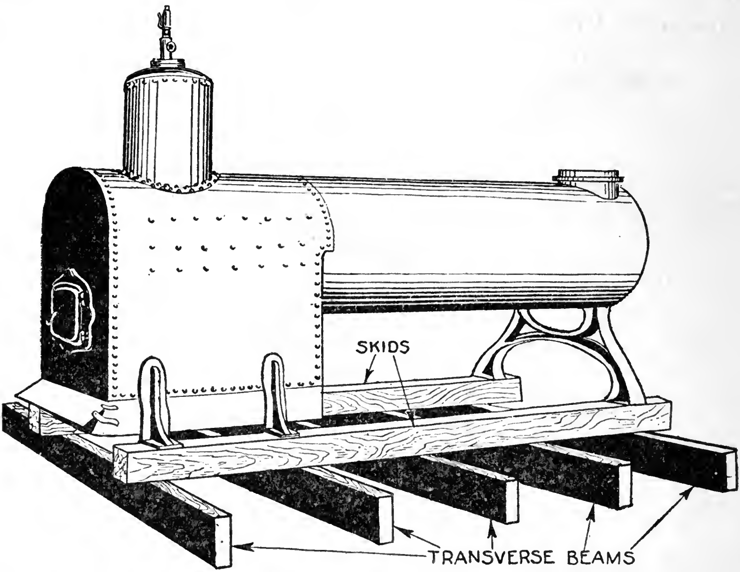


FIG. 4,457.—Setting for locomotive boiler as installed on Western river steamboats. The skids which come with the boiler provide an excellent means of distributing the weight of the boiler over a number of the transverse deck beams.

ciently strong to support the boiler. Either concrete or brickwork may be used. The setting may be either solid as in fig. 4,461 or hollow as in fig. 4,459 and 4,460.

Horizontal Return Tubular Boiler Settings.—This type of boiler requires an elaborate setting, as the latter forms the furnace and combustion chambers, and with lug supports, carries the weight of the boiler. The setting consists of:

1. Foundation.
2. Enclosing walls.
3. Bridge wall.

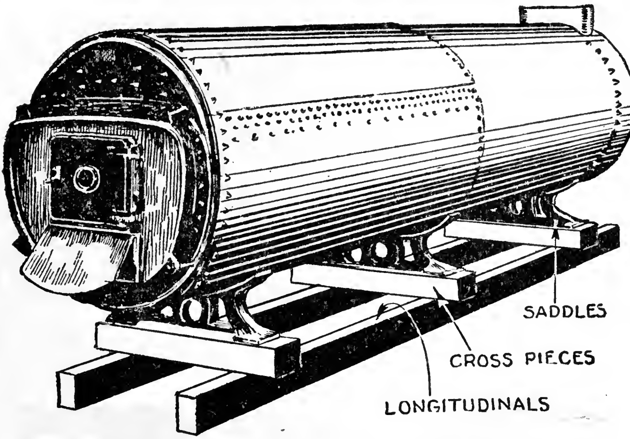
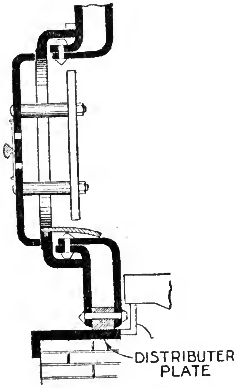


Fig. 4,458.—Setting for gunboat boiler as installed on Western river steamboats. The boiler rests on saddles which in turn are supported by cross pieces placed on top of longitudinal beams, the latter being stiffened by guy rods. ***In erection*** these guy rods should be carefully adjusted by means of the turnbuckle so that the load will be equally divided.

4. Combustion chamber.
5. Top covering.
6. Arch.
7. Trimmings.

Foundation.—In selecting the location of a boiler it is



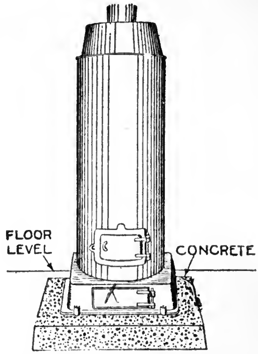
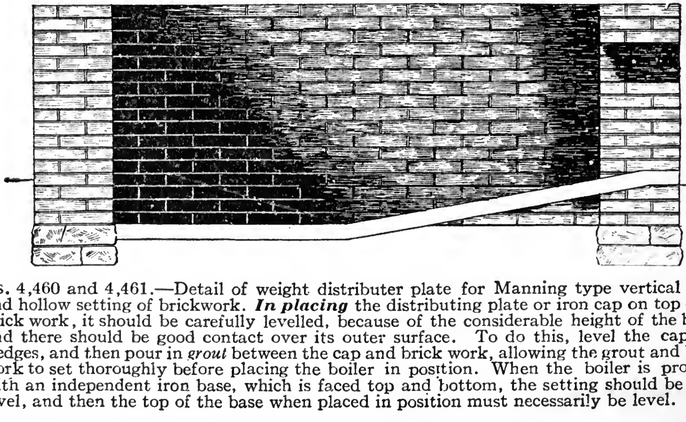


FIG. 4,459.—Solid concrete setting or foundation for stationary vertical boiler having cast iron base or ash pit. The top of the foundation should be slightly larger than the base of the boiler, and should slope outward so as to obtain additional area for a firm support. The excavation should extend down to firm earth. Sand makes a good foundation bed over soft earth, if the earth be of a quality that will retain the sand in position. Where the earth is too soft to support the weight, a considerable area is excavated to liberal depth below the first line, then a bed is prepared of stones, sand, or concrete, the latter being preferred.



FIGS. 4,460 and 4,461.—Detail of weight distributer plate for Manning type vertical boiler and hollow setting of brickwork. ***In placing*** the distributing plate or iron cap on top of the brick work, it should be carefully levelled, because of the considerable height of the boiler, and there should be good contact over its outer surface. To do this, level the cap with wedges, and then pour in *grout* between the cap and brick work, allowing the grout and brickwork to set thoroughly before placing the boiler in position. When the boiler is provided with an independent iron base, which is faced top and bottom, the setting should be made level, and then the top of the base when placed in position must necessarily be level.

important to consider the nature of the soil upon which it is to rest, because unless a firm foundation be provided, trouble is quite sure to result in the way of cracked setting walls and leaky steam pipe joints caused by sprung piping when the foundation settles.

The required size and shape of the foundation will depend on the bearing power of the soil, the weight of the setting plus the weight of the boiler

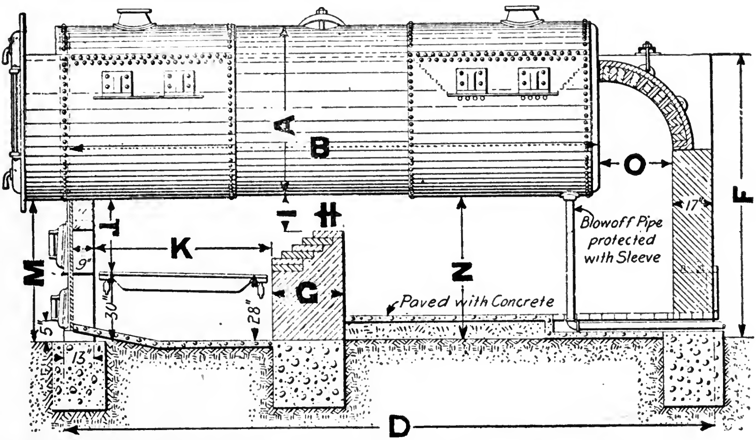
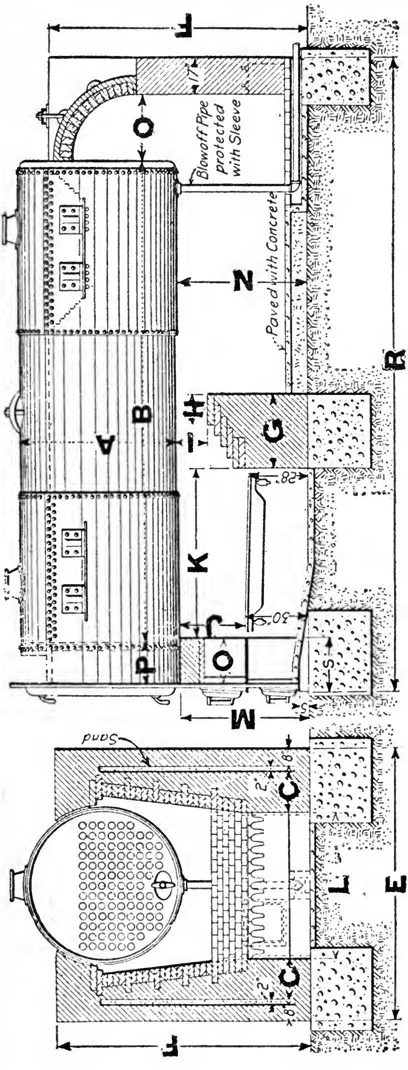


Fig. 4,462.—Setting design for overhanging front boiler. The dimension letters refer to the accompanying table of dimensions for boiler setting.

when full of water and fitted with such accessories as rest on the foundation. With a boiler resting directly on the side walls of the setting the side wall footings may be assumed to bear the entire weight of the boiler as a uniformly distributed load. Except where the soil is poor it will not be necessary to make the width of the footings more than 8 inches greater than the thickness of the setting walls.

Figs. 4,462 to 4,464 show settings for overhanging and flush front boilers, the various dimensions, as indicated by the reference letters being given in the accompanying table, from which the size of foundation for any size boiler is easily obtained.

Allowing a factor of safety of 10 the bearing power of the poorest kind



FIGS. 4,463 and 4,464.—Setting design for flush front boiler. The dimension letters refer to the accompanying table of dimensions for boiler setting.

of rock is estimated at 18 tons per square foot while the bearing power of the strongest rock, such as granite, runs as high as 150 tons per square foot. Thus any kind of rock makes the finest of natural foundations. All that is necessary is to level the rock off roughly and put down a thin mat of concrete upon which to build.

Ques. What is the nature of clay?

Ans. It varies in character from hard slate or shale, which will sustain practically as much pressure as rock, to soft, moist clay which will flow from under comparatively moderate loads of one ton or less per square foot.

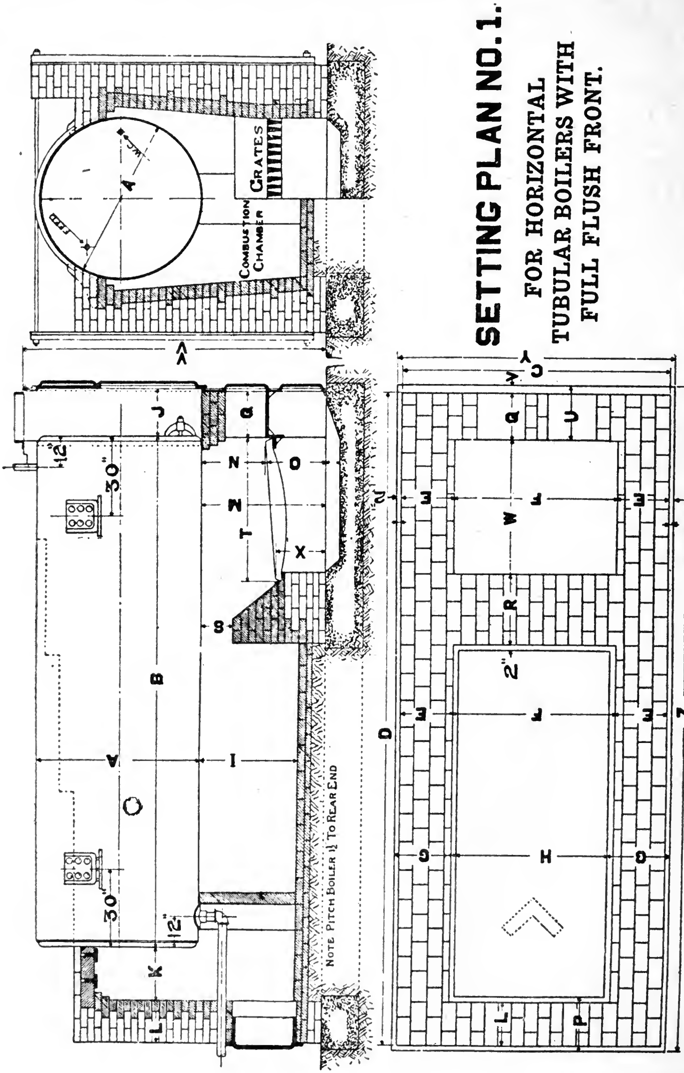
Ques. Will the softer clays sustain the weight of any ordinary boiler?

Ans. Yes, when in thick, horizontal beds and not too wet nor undermined by springs.

Dimensions for Boiler Setting

Horsepower on a Basis of 10 Sq. Feet of Heating Surface per Horsepower: 3-inch Tubes	3½-inch Tubes	4-inch Tubes	A. Diameter of Boiler in Inches	B. Length of Tubes, Feet	Number of Tubes of Each Diameter	C. Thickness of Inside Furnace Walls, Inches	E. Over-all Width of Setting, Feet and Inches	F. Height from Floor Line to top of Setting Wall, Feet and Inches	G. Thickness of Bridgewall Inches	H. Width of top of Bridge-wall, Inches	I. Top of Bridgewall to Shell of Boiler, Inches	J. Top of Grates at Front to under side of shell, Inches	K. Length of Furnace, Inches	L. Width of Furnace, Inches	M. Floor Line to Bottom of Shell at Front, Inches	N. Floor Line to Bottom of Shell at Rear, Inches	O. Distance bet. tube sheet and Rear Wall, Inches	Approx. wgt. of boiler and water with allowance for piping and brick covering on top of shell and flue, lbs	Approx. ratio between grate and heating surface when 3-inch tubes are used	Number of Fire-brick required to set one boiler	For Overhanging Fronts Only: Number of Red-brick required to set one boiler	For Overhanging Fronts Only: D. Over-all length of Setting Walls at Floor Line Feet and Inches	For Flush Fronts Only: P. Depth of Smoke Box, Inches	For Flush Fronts Only: Q. Thickness of Front Wall, Inches	For Flush Fronts Only: R. Over-all Length of Setting Walls at Floor Line, Feet and Inches	For Flush Fronts Only: S. Thickness of Front Wall at Floor Line, Inches
53	48	44	48	12	50-3" 38-3½"	17	8'-0"	8'- 0"	21½	9	10	26	48	42	56	55	22	16,000	1 to 35	1900	12,500	15'-11"	15	17	16'-10"	21
61	56	51	48	14	30-4"	17	8'-0"	8'- 0"	21½	9	10	26	54	42	56	55	22	18,000	1 to 35	2100	14,000	17 -11"	15	17	18'-10"	21
72	63	51	54	14	60-3" 44-3½"	17	8'-6"	8'- 6"	21½	9	12	26	54	48	58	57	24	23,000	1 to 35	2200	15,500	18'- 1"	16	18	19'- 1"	22
83	72	58	54	16	30-4"	17	8'-6"	8'- 6"	21½	9	12	28	54	48	58	57	24	25,500	1 to 40	2500	16,500	20'- 1"	16	18	21'- 1"	22
99	88	86	60	16	72-3" 54-3½"	17	9'-0"	8'- 8"	26	9	12	28	60	54	58	57	26	32,500	1 to 40	2600	17,000	20'- 3"	16	18	21'- 3"	22
110	99	96	60	18	46-4"	17	9'-0"	8'- 8"	26	9	12	28	66	54	58	57	26	35,500	1 to 40	2800	18,500	22'- 3"	16	18	23'- 3"	22
130	118	108	66	16	98-3" 74-3½"	17	9'-6"	9'- 6"	26	14	12	30	72	60	60	59	26	38,000	1 to 40	2850	18,500	20'- 3"	1	19	21'- 4"	23
147	132	121	66	18	60-4"	17	9'-6"	9'- 6"	26	14	12	30	78	60	60	59	26	41,500	1 to 40	3100	20,000	22'- 3"	17	19	23'- 4"	23
163	149	131	72	16	124-3"	21½	10'-9"	9'-10"	30½	14	12	30	72	66	60	59	28	47,500	1 to 45	3050	23,500	20'- 7"	18	20	21' -9"	24
183	167	147	72	18	96-3½"	21½	10'-9"	9'-10"	30½	14	12	30	84	66	60	59	28	51,000	1 to 45	3300	26,000	22'- 7"	18	20	23'- 9"	24
203	185	164	72	20	74-4"	21½	10'-9"	9'-10"	30½	14	12	30	90	66	60	59	28	56,000	1 to 45	3600	27,500	24'- 7"	18	20	25'- 9"	24
188	175	161	78	16	144-3"	21½	11'-3"	10'- 6"	30½	14	12	34	72	72	64	63	28	50,000	1 to 50	3300	25,500	20 - 7"	20	22	21 -11"	26
211	197	181	78	18	114-3½"	21½	11'-3"	10'- 6"	30½	14	12	34	78	72	64	63	30	54,500	1 to 50	3600	27,500	22'- 7"	20	22	23'-11"	26
234	218	201	78	20	92-4"	21½	11'-3"	10'- 6"	30½	14	12	34	84	72	64	63	30	59,000	1 to 50	3900	29,500	24'- 7"	20	22	25'-11"	26
260	242	221	84	18	180-3" 142-3½"	21½	12'-3"	11'- 0"	30½	14	14	34	84	84	64	63	30	62,500	1 to 50	3850	29,000	22'- 7"	20	22	23'-11"	26
288	268	245	84	20	114-4"	21½	12'-3"	11'- 0"	30½	14	14	34	90	84	64	63	30	68,000	1 to 50	4150	31,500	24'- 7"	20	22	25'-11"	26
310	284	267	90	18	210-3" 168-3½"	21½	12'-9"	11'- 4"	35	14	14	36	84	90	66	65	32	65,000	1 to 55	4000	30,500	22'- 9"	22	24	24'- 3"	28
334	315	297	90	20	140-4"	21½	12'-9"	11'- 4"	35	14	14	36	90	90	66	65	32	70,000	1 to 55	4350	33,000	24'- 9"	22	24	26'- 3"	28
353	320	302	96	18	248-3" 190-3½"	21½	13'-3"	11'- 8"	35	14	14	36	84	96	66	65	34	70,000	1 to 55	4150	31,500	22'- 9"	22	24	24'- 3"	28
392	354	336	96	20	158-4"	21½	13'-3"	11'- 8"	35	14	14	36	90	96	66	65	34	76,000	1 to 60	4500	34,000	24'- 9"	22	24	26'- 3"	28

NOTE:—In using this table for setting boilers, particular attention must be paid to the fact that dimensions F, J, M, and N must conform to the dimensions of the front furnished with the boiler and dimensions K and L with the grates furnished. On flush fronts, dimensions Q, R, and S depend on dimension P, and these dimensions must be changed to conform to any changes that may be necessary in P The column giving the number of common brick required refers to the overhanging front style of setting, and for flush fronts there should be added 500 to 2500 brick, depending on the size of the boiler.



FIGS. 4,465 to 4,467.—Brownell setting plan No. 1 for horizontal tubular boilers with flush front *supporting* or *under mounted setting*.

DETAILS SETTING PLAN No. 1

No. of Front	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	V V	W	X	Y	Z	No. of Fire Brick	No. of Common Brick above Floor Level	No. of Cubic Feet Concrete Foundation 18 In. Deep
REFERENCE LETTERS ON DIAGRAMS																														
	In.	Ft.	In.	Ft. In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	Ft. In.			
350	36	8	57	11-4½	10	37	14	33	30	12½	16	13	39¾	19¾	20	17	12	18	10	36	16	4	84	33½	18¾	61	11-10½	1,200	3,000	76
	36	10	57	13-4½	10	37	14	33	30	12½	16	13	39¾	19¾	20	17	12	18	10	36	16	4	84	33½	18½	61	13-10½	1,400	4,000	85
	36	12	57	15-4½	10	37	14	33	30	12½	16	13	39¾	19¾	20	17	12	18	12	42	16	4	84	39½	18¼	61	15-10½	1,500	4,500	95
450	44	10	78	14-1	17½	43	21½	39	30	14¾	18	17½	42¾	21¼	21½	21½	12	21	12	36	16	4	92	33½	20	82	14-7	1,700	5,600	120
	44	12	78	16-1	17½	43	21½	39	30	14¾	18	17½	42¾	21¼	21½	21½	12	21	12	42	16	4	92	39½	19¾	82	16-7	1,800	6,900	130
	44	14	78	18-1	17½	43	21½	39	30	14¾	18	17½	42¾	21¼	21½	21½	12	21	12	48	16	4	92	45½	19½	82	18-7	1,900	7,000	145
550	48	12	78	16-1	14½	49	18½	45	30	14¾	18	17½	42¾	20¼	22½	21½	12	24	12	42	16	4	96	39½	20½	82	16-7	2,000	7,500	135
	48	14	78	18-1	14½	49	18½	45	30	14¾	18	17½	42¾	20¼	22½	21½	12	24	12	48	16	4	96	45½	20¼	82	18-7	2,300	8,000	150
650	54	14	93	18-9½	19	55	23	51	30	16½	20	22	47¾	25¾	22	26	15	24	15	48	19½	4½	108	45½	20	97	19-4	2,500	10,800	170
	54	16	93	20-9½	19	55	23	51	30	16½	20	22	47¾	25¾	22	26	15	24	15	54	19½	4½	108	51½	19¾	97	21-4	2,800	11,900	180
750	60	16	99	20-9½	19	61	23	57	30	16½	20	22	46	24	22	26	18	26	15	54	22½	4½	112	51½	19¾	103	21-4	3,000	12,500	210
850	66	16	105	21-0½	19	67	23	63	30	17½	22	22	52½	28	24½	26	18	26	18	54	22½	4½	126	51½	22¼	109	21-7	3,400	14,500	220
	66	18	105	23-0½	19	67	23	63	30	17½	22	22	52½	28	24½	26	18	26	18	60	22½	4½	126	57½	22	109	23-7	3,600	16,000	230
950	72	16	119	21-4½	23	73	27	69	30	19½	24	22	54	30	24	26	18	30	18	54	22½	4½	135	51½	21½	123	21-11	3,700	20,500	255
	72	18	119	23-4½	23	73	27	69	30	19½	24	22	54	30	24	26	18	30	18	60	22½	4½	135	57½	21¼	123	23-11	3,900	23,000	270
1050	78	18	125	23-4½	23	79	27	75	36	19½	24	22	54	30	24	26	18	30	22	60	22½	4½	138	57½	21¼	129	23-11	4,200	23,500	275
	78	20	125	25-4½	23	79	27	75	36	19½	24	22	54	30	24	26	18	30	22	66	22½	4½	138	63½	21	129	25-11	4,600	24,000	295
1150	84	18	131	23-7	23	85	27	81	36	21	24	22	54	30	24	26	18	30	24	60	23	5	146	57½	21	135	24-2	5,000	25,000	300
	84	20	131	25-7	23	85	27	81	36	21	24	22	54	30	24	26	18	30	24	66	23	5	146	63½	20¾	135	26-2	5,500	27,000	325

NOTE—The depth of foundation given above should not be followed where the condition of soil requires a greater or lesser depth, but is sufficient where a solid footing can be obtained at this depth. Dimensions given above apply to suspended or lug settings with or without domes.

Ques. What precaution should be taken with footings?

Ans. They should be made deep enough to extend below the first line which in most localities is not greater than five feet.

Ques. Are coarse gravel and sand desirable materials?

Ans. Coarse gravel in a thick layer is a very fine foundation and it will withstand pressures up to 8 or 10 tons per square foot Fine sand if saturated with water, makes a poor foundation if there be any tendency for the water to drain away easily. Dry

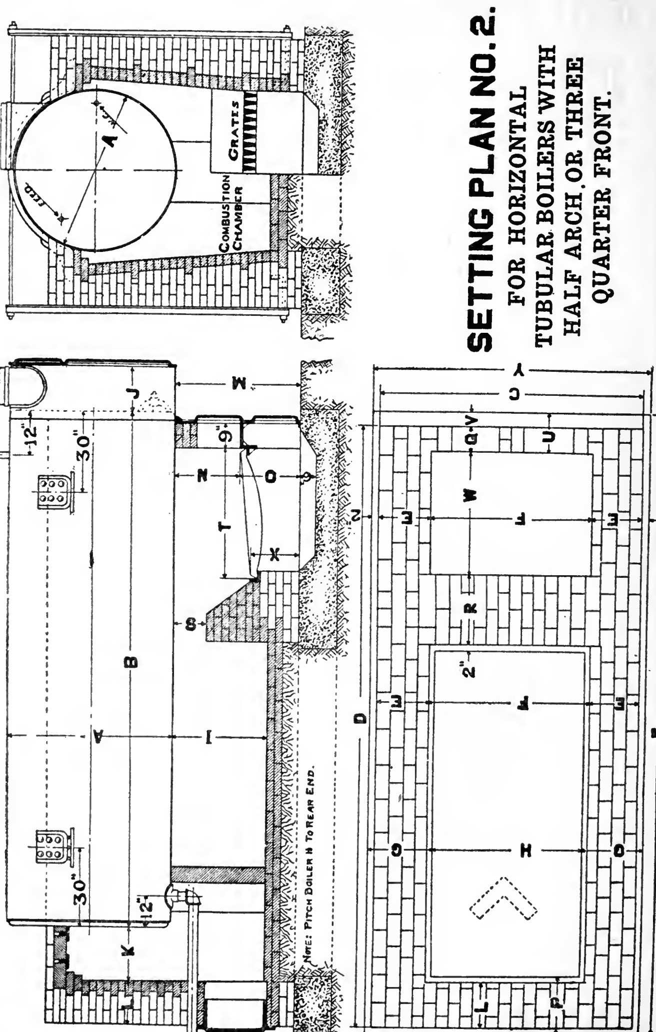


FIG. 4,468 to 4,470 —Brownell setting plan No. 2 for horizontal tubular boilers with half arch and three-quarter front *supporting* or *under mounted setting*.

DETAILS SETTING PLAN No. 2

No. of Front	REFERENCE LETTERS ON DIAGRAMS																									No. of Fire Brick	No. of Common Brick above Floor Level	No. of Cubic Feet Concrete Foundation 18 In. Deep
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z			
	In.	Ft.	In.	Ft. In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	Ft. In.			
200	36	8	57	10-1	10	37	14	33	30	12½	16	13	40	20	20	17	9	18	10	36	14	5	33½	18½	61	10-8	1,000	2,600	75
	36	10	57	12-1	10	37	14	33	30	12½	16	13	40	20	20	17	9	18	10	36	14	5	33½	18½	61	12-8	1,200	2,900	82
	36	12	57	14-1	10	37	14	33	30	12½	16	13	40	20	20	17	9	18	12	42	14	5	39½	18	61	14-8	1,300	3,300	90
300	44	10	78	12-8	17½	43	21½	39	30	14¾	18	17½	46½	24	22½	21½	9	21	12	36	14	5	33½	21	82	13-3	1,500	5,200	115
	44	12	78	14-8	17½	43	21½	39	30	14¾	18	17½	46½	24	22½	21½	9	21	12	42	14	5	39½	20½	82	15-3	1,700	6,000	125
	44	14	78	16-8	17½	43	21½	39	30	14¾	18	17½	46½	24	22½	21½	9	21	12	48	14	5	45½	20½	82	17-3	1,800	6,600	135
	48	12	78	14-8	14½	49	18½	45	30	14¾	18	17½	46½	24	22½	21½	9	24	12	42	14	5	39½	20½	82	15-3	1,900	6,800	130
	48	14	78	16-8	14½	49	18½	45	30	14¾	18	17½	46½	24	22½	21½	9	24	12	48	14	5	45½	20½	82	17-3	2,000	7,300	145
400	54	14	93	17-2	19	55	23	51	30	16½	20	22	48½	24	24½	26	9	24	15	48	14	5	45½	22½	97	17-9	2,400	10,000	160
	54	16	93	19-2	19	55	23	51	30	16½	20	22	48½	24	24½	26	9	24	15	54	14	5	51½	22	97	19-9	2,600	11,300	170
	60	16	99	19-2	19	61	23	57	30	16½	20	22	48½	24	24½	26	9	26	15	54	14	5	51½	22	103	19-9	2,700	11,700	200
500	66	16	105	19-4	19	67	23	63	30	17½	22	22	50½	26	24½	26	9	26	18	54	14	5	51½	22	109	19-11	3 000	14,000	210
	66	18	105	21-4	19	67	23	63	30	17½	22	22	50½	26	24½	26	9	26	18	60	14	5	57½	22	109	21-11	3,200	15,000	220
	72	16	119	19-6	23	73	27	69	30	19½	24	22	50½	26	24½	26	9	30	18	54	14	5	51½	22	123	20-1	3,500	19,500	245
	72	18	119	21-6	23	73	27	69	30	19½	24	22	50½	26	24½	26	9	30	18	60	14	5	57½	22	123	22-1	3,800	22,000	260
1050	78	18	125	21-6	23	79	27	75	36	19½	24	22	54	30	24	26	9	30	22	60	14	5	57½	22½	129	22-1	3,900	23,000	265
	78	20	125	23-6	23	79	27	75	36	19½	24	22	54	30	24	26	9	30	22	66	14	5	63½	22	129	24-1	4,100	23,500	270
1150	84	18	131	21-6	23	85	27	81	36	21	24	22	54	30	24	26	9	30	24	60	14	5	57½	21½	135	22-1	4,500	24,000	290
	84	20	131	23-6	23	85	27	81	36	21	24	22	54	30	24	26	9	30	24	66	14	5	63½	21	135	24-1	4,700	25,000	310

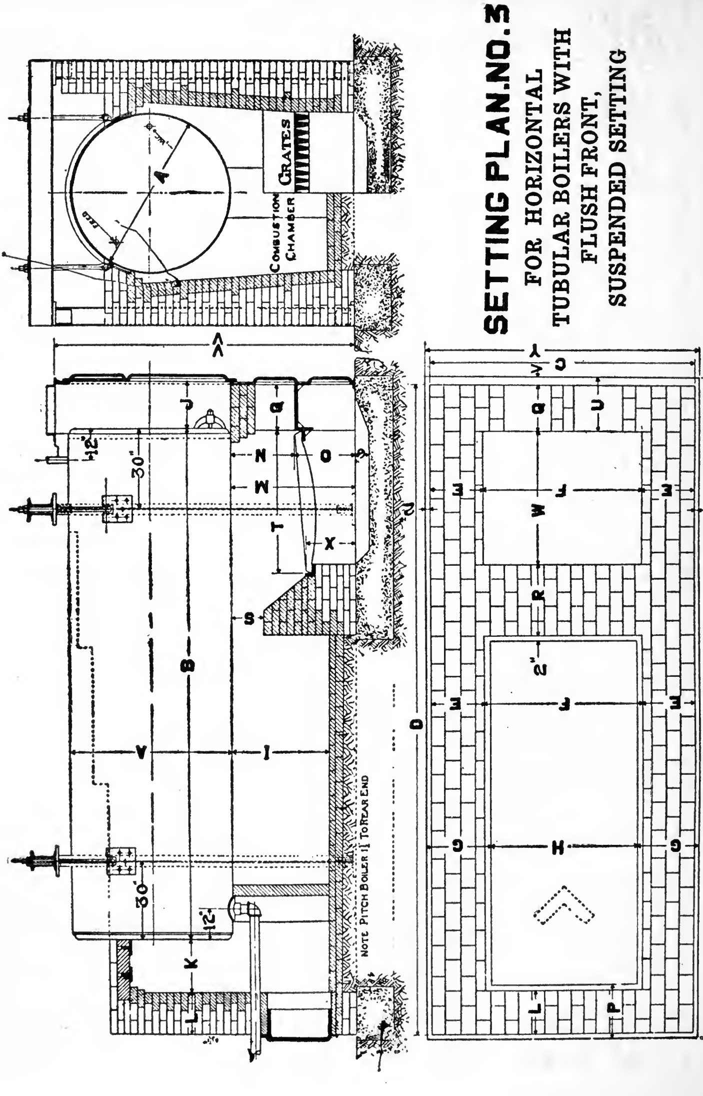
NOTE—The depth of this foundation given above should not be followed where th condition of soil requires a greater or lesser depth, but is sufficient where a solid footing can be obtained at this depth. Dimensions given above apply to suspended or lug settings with or without domes.

sand will withstand from 2 to 4 tons pressure per square foot.

Ques. What must be done, in case of mud, silt or quick sand?

Ans. If in a thin layer, it may be possible to excavate to the gravel, clay or rock substratum and carry the foundations down to rest on this firm ground beneath. In thick layers it is often necessary to drive piles and cap them with a mat of concrete to carry the load.

Where the soil is not too soft a good foundation may be made by laying a solid sheet of concrete, 2 or 3 feet thick, over the entire area beneath the boiler, suitably reinforced with iron



FIGS. 4,471 to 4,473.—Brownell setting plan No. 3, for horizontal tubular boilers with flush front, *suspended setting.*

DETAILS SETTING PLAN No. 3

No. of Front	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	VV	W	X	Y	Z	No. of Fire Brick	No. of Common Brick above Floor Level	No. of Cubic Feet Concrete Foundation 18 In. Deep
	In.	Ft.	In.	Ft. In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	Ft. In.			
350	36	8	57	11-4½	10	37	14	33	30	12½	16	13	39¾	19¾	20	17	12	18	10	36	16	4	84	33½	18¾	61	11-10½	1,200	3,000	76
	33	10	57	13-4½	10	37	14	33	30	12½	16	13	39¾	19¾	20	17	12	18	10	36	16	4	84	33½	18½	61	13-10½	1,400	4,000	85
	33	12	57	15-4½	10	37	14	33	30	12½	16	13	39¾	19¾	20	17	12	18	12	42	16	4	84	39½	18¼	61	15-10½	1,500	4,500	95
450	44	10	78	14-1	17½	43	21½	39	30	14¾	18	17½	42¾	21¼	21½	21½	12	21	12	36	16	4	92	33½	20	82	14-7	1,700	5,600	120
	44	12	78	16-1	17½	43	21½	39	30	14¾	18	17½	42¾	21¼	21½	21½	12	21	12	42	16	4	92	39½	19¾	82	16-7	1,800	6,900	130
	44	14	78	18-1	17½	43	21½	39	30	14¾	18	17½	42¾	21¼	21½	21½	12	21	12	48	16	4	92	45½	19½	82	18-7	1,900	7,000	145
550	43	12	78	16-1	14½	49	18½	45	30	14¾	18	17½	42¾	20¼	22½	21½	12	24	12	42	16	4	96	39½	20½	82	16-7	2,000	7,500	135
	48	14	78	18-1	14½	49	18½	45	30	14¾	18	17½	42¾	20¼	22½	21½	12	24	12	48	16	4	96	45½	20¼	82	18-7	2,300	8,000	150
650	54	14	93	18-9½	19	55	23	51	30	16½	20	22	47¾	25¾	22	26	15	24	15	48	19½	4½	108	45½	20	97	19-4	2,500	10,800	170
	54	16	93	20-9½	19	55	23	51	30	16½	20	22	47¾	25¾	22	26	15	24	15	54	19½	4½	108	51½	19¾	97	21-4	2,800	11,900	180
750	60	16	99	20-9½	19	61	23	57	30	16½	20	22	46	24	22	26	18	26	15	54	22½	4½	112	51½	19¾	103	21-4	3,000	12,500	210
850	66	16	105	21-0½	19	67	23	63	30	17½	22	22	52½	28	24½	26	18	26	18	54	22½	4½	126	51½	22¼	109	21-7	3,400	14,500	220
	66	18	105	23-0½	19	67	23	63	30	17½	22	22	52½	28	24½	26	18	26	18	60	22½	4½	126	57½	22	109	23-7	3,600	16,000	230
950	72	16	119	21-4½	23	73	27	69	30	19½	24	22	54	30	24	26	18	30	18	54	22½	4½	135	51½	21½	123	21-11	3,700	20,500	255
	72	18	119	23-4½	23	73	27	69	30	19½	24	22	54	30	24	26	18	30	18	60	22½	4½	135	57½	21¼	123	23-11	3,900	23,000	270
1050	78	18	125	23-4½	23	79	27	75	36	19½	24	22	54	30	24	26	18	30	22	60	22½	4½	138	57½	21¼	129	23-11	4,200	23,500	275
	78	20	125	25-4½	23	79	27	75	36	19½	24	22	54	30	24	26	18	30	22	66	22½	4½	138	63½	21	129	25-11	4,600	24,000	295
1150	84	18	131	23-7	23	85	27	81	36	21	24	22	54	30	24	26	18	30	24	60	23	5	146	57½	21	135	24-2	5,000	25,000	300
	84	20	131	25-7	23	85	27	81	36	21	24	22	54	30	24	26	18	30	24	66	23	5	146	63½	20¾	135	26-2	5,500	27,000	325

NOTE—The depth of foundation given above should not be followed where the condition of soil requires a greater or lesser depth, but is sufficient where a solid footing can be obtained at this depth. Dimensions given above apply to suspended or lug settings with or without domes.

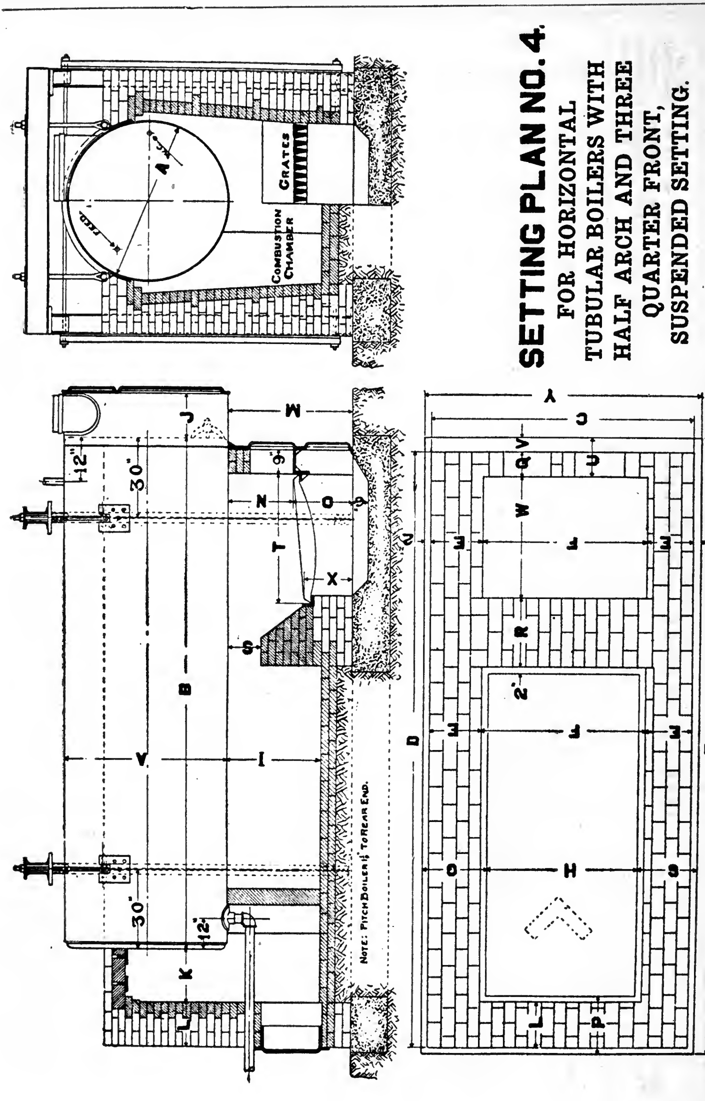
rods or old rails imbedded in the concrete. This gives a large bearing area and the load is so distributed that the pressure per square foot is not so great as to cause settling.

Ques. What is the usual limit of pressure on the soil?

Ans. Two tons per square foot.

Accordingly, the ordinary footings such as shown in figs. 4,463 and 4,464, are sufficient, except where the soil consists of made, or filled in ground, quicksand or soft wet clay. For moderately firm clay a footing sole under the entire area of the boiler, as already described, will prove satisfactory.

Where there is doubt as to the nature of the soil it is advisable to call in someone who is competent to give good advice rather than risk future trouble due to poor foundations.



FIGS. 4,474 to 4,476.—Brownell setting plan No. 4, for horizontal tubular boilers with half and three quarter front, *suspended setting.*

DETAILS SETTING PLAN No. 4

No. of Front	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	No. of Fire Brick	No. of Common Brick above Floor Level	No. of Cubic Feet Concrete Foundation 18 In. Deep
	REFERENCE LETTERS ON DIAGRAMS																												
	In.	Ft.	In.	Ft. In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	Ft. In.			
200	36	8	57	10-1	10	37	14	33	30	12½	16	13	40	20	20	17	9	18	10	36	14	5	33½	18½	61	10-8	1,000	2,600	75
	36	10	57	12-1	10	37	14	33	30	12½	16	13	40	20	20	17	9	18	10	36	14	5	33½	18½	61	12-8	1,200	2,900	82
	36	12	57	14-1	10	37	14	33	30	12½	16	13	40	20	20	17	9	18	12	42	14	5	39½	18	61	14-8	1,300	3,300	90
300	44	10	78	12-8	17½	43	21½	39	30	14¾	18	17½	46½	24	22½	21½	9	21	12	36	14	5	33½	21	82	13-3	1,500	5,200	115
	44	12	78	14-8	17½	43	21½	39	30	14¾	18	17½	46½	24	22½	21½	9	21	12	42	14	5	39½	20½	82	15-3	1,700	6,000	125
	44	14	78	16-8	17½	43	21½	39	30	14¾	18	17½	46½	24	22½	21½	9	21	12	48	14	5	45½	20½	82	17-3	1,800	6,600	135
	48	12	78	14-8	14½	49	18½	45	30	14¾	18	17½	46½	24	22½	21½	9	24	12	42	14	5	39½	20½	82	15-3	1,900	6,800	130
	48	14	78	16-8	14½	49	18½	45	30	14¾	18	17½	46½	24	22½	21½	9	24	12	48	14	5	45½	20½	82	17-3	2,000	7,300	145
400	54	14	93	17-2	19	55	23	51	30	16½	20	22	48½	24	24½	26	9	24	15	48	14	5	45½	22½	97	17-9	2,400	10,000	160
	54	16	93	19-2	19	55	23	51	30	16½	20	22	48½	24	24½	26	9	24	15	54	14	5	51½	22	97	19-9	2,600	11,300	170
	60	16	99	19-2	19	61	23	57	30	16½	20	22	48½	24	24½	26	9	26	15	54	14	5	51½	22	103	19-9	2,700	11,700	200
500	66	16	105	19-4	19	67	23	63	30	17½	22	22	50½	26	24½	26	9	26	18	54	14	5	51½	22	109	19-11	3,000	14,000	210
	66	18	105	21-4	19	67	23	63	30	17½	22	22	50½	26	24½	26	9	26	18	60	14	5	57½	22	109	21-11	3,200	15,000	220
	72	16	119	19-6	23	73	27	69	30	19½	24	22	50½	26	24½	26	9	30	18	54	14	5	51½	22	123	20-1	3,500	19,500	245
	72	18	119	21-6	23	73	27	69	39	19½	24	22	50½	26	24½	26	9	30	18	60	14	5	57½	22	123	22-1	3,800	22,000	260
1050	78	18	125	21-6	23	79	27	75	36	19½	24	22	54	30	24	26	9	30	22	60	14	5	57½	22½	129	22-1	3,900	23,000	265
	78	20	125	23-6	23	79	27	75	36	19½	24	22	54	30	24	26	9	30	22	66	14	5	63½	22	129	24-1	4,100	23,500	270
1150	84	18	131	21-6	23	85	27	81	36	21	24	22	54	30	24	26	9	30	24	60	14	5	57½	21½	135	22-1	4,500	24,000	290
	84	20	131	23-6	23	85	27	81	36	21	24	22	54	30	24	26	9	30	24	66	14	5	63½	21	135	24-1	4,700	25,000	310

NOTE—The depth of this foundation given above should not be followed where the condition of soil requires a greater or lesser depth, but is sufficient where a solid footing can be obtained at this depth. Dimensions given above apply to suspended or lug settings with or without domes.

Ques. How are the footings proportioned for boilers supported by columns?

Ans. As practically the entire load is concentrated on the column footings they must be made large enough to distribute the pressure over such area that the pressure per square foot comes within a safe limit.

NOTE.—"***The best way*** to learn how to do mason work is to observe that which is being demolished. A man was employed in a growing establishment that removed a great many buildings, foundations, etc., and had the opportunity to study the result of different methods. He has seen brick walls pushed over. In some, the bricks have been broken and when these were cleaned it required a large amount of labor. In others, when the wall fell the bricks all separated readily and were cleaned with little trouble. When the first were laid the bricks were wet, or there was cement in the mortar. In some cases the voids between the bricks were only partially filled and the wall came to pieces easily although the mortar adhered to the bricks. Observing the above, engineers have called for bricks to be wet except during freezing weather, and also are careful that plenty of mortar shall be used and that cement shall be added."—*Crane.*

Foundation Material.—Concrete is the material now used almost universally for foundations. The best concrete is made with broken stone or gravel with a cement sand mortar for the binder.

The usual proportions for foundation work are as follows: one part cement, two and one-half parts sand and five parts broken stone or gravel, whichever be more available or cheaper to obtain. A good standard brand of cement should be used. Cement comes in barrels of 400 pounds or in bags of 100 pounds.

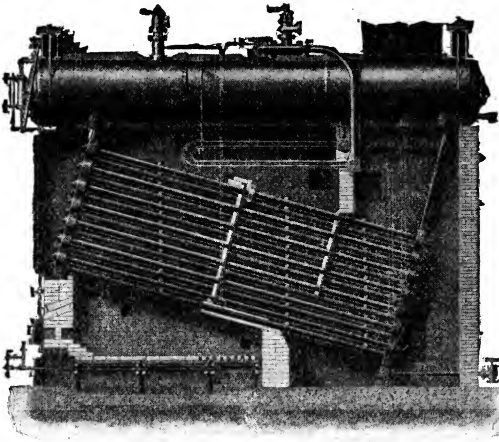


FIG. 4,477.—Babcock and Wilcox water tube boiler and setting. Type W.I.F. having inclined headers.

The sand should be clean, that is, free from loam or earthy matter, and the particles should be sharp (not smooth cornered or round) and of fairly uniform size.

The broken stone or gravel should be free from dust or dirt and not greater than 2 inches in size.

The following quantities are required to make one cubic yard of concrete

NOTE.—***Laying Out the Foundations.***—As a general rule the boiler manufacture supplies a drawing showing the design and dimensions of the setting. From this and from the character of the soil the foundations may be laid out. If no drawing be furnished, the design may be taken from the accompanying designs and dimension tables, which represent standard practice.

having the above mentioned proportions: 1.26 barrels of cement (5 bags), .48 yard of sand and .96 yard of broken stone or gravel.

When the foundations have been laid out, figure the number of cubic feet of concrete required and divide by 27 to get the cubic yards. Then, multiply by the above figures to find the amounts of the different materials required for the job.

When worked by hand the concrete is usually mixed in batches of about one yard. A measuring box is used for the sand and stone. This usually has no bottom and is about 36 by 36 by 18 inches in size.*

Ques. How should the concrete be put in the foundation trenches or forms?

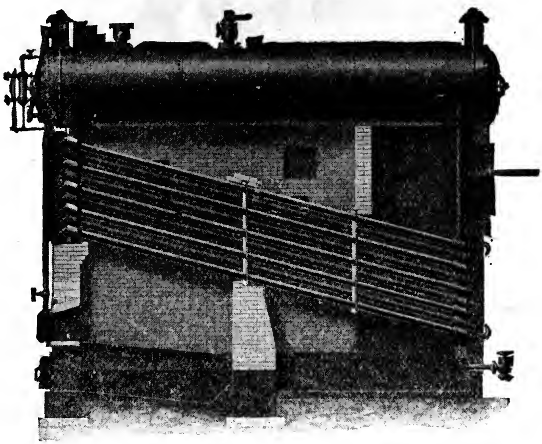


FIG. 4,478.—Babcock and Wilcox water tube boiler and setting. Vertical header type.

* NOTE.—***The Measuring Box*** is placed on the mixing board and filled twice with stone and then in a different spot one boxful of sand is measured out. The measured sand is then spread out in a layer about 4 inches thick and 5 bags of cement are sprinkled uniformly over the dry sand. Next, the cement and sand are turned over thoroughly three or four times with a shovel or hoe so that they become thoroughly mixed. The stone is then spread out and the sand cement mixture thrown over it. Then, this whole mass is turned several times until it is thoroughly mixed. Finally, the mixture is smoothed out and hollowed in the middle to form a crater and into this water is sprinkled from either a bucket or hose. As the water is being thrown into the crater the sides are shoved in to soak up the water. Enough water should be used to make the entire mass like a thick mud, but not so much as to wash the cement or sand out. The mass should be turned two or more times until it is thoroughly wet all through. The concrete is then ready to be put into the foundation trenches or forms as the case may be.

Ans. It should be spread out in layers about 6 inches thick and not all dumped in one spot or corner a foot or more deep.

Gentle poking or tamping will help to work the concrete into place and make it dense and well bonded. After the concrete has started to set it should not be distrubed.

Ques. How much time is required for the concrete to set?

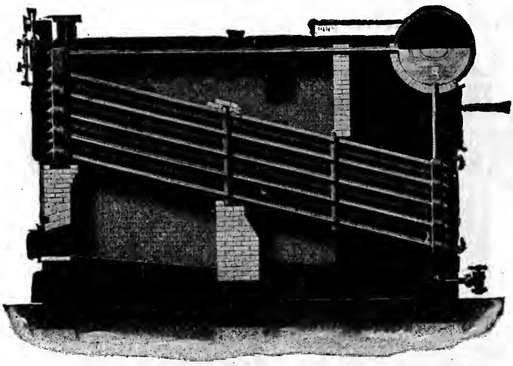


Fig. 4,479.—Babcock and Wilcox water tube boiler and setting. Cross drum type with vertical headers, designed for low head room. This type is also built with inclined headers.

Ans. From 24 to 96 hours depending upon the kind of concrete used.

Its full strength is not reached for several weeks. At least one week should elapse before the brick work of the setting is started in order to allow the concrete to get hardened safely.

Blocking the Boiler.—After completing the foundation, the next step is to put the boiler in place. It is first raised by jack screws or levers to the height at which it is to set, and blocked there by cribbing made of short pieces of timber as shown in fig. 4,480.

Another method of supporting the boiler during erection is by means of barrels. Two good barrels are sufficient for boilers up to 66 inches by 16 feet in size. Blocks should be placed above and below the barrels so the load will be spread evenly over the staves.

Enclosing Walls.—The difference in first cost between a good job and a poor job is comparatively slight and once paid for there is an end to it. If a boiler setting be carefully built with good

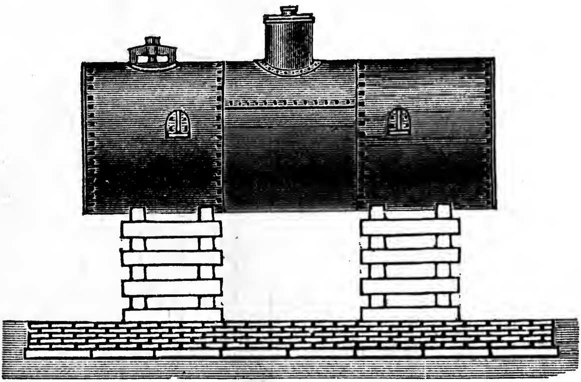
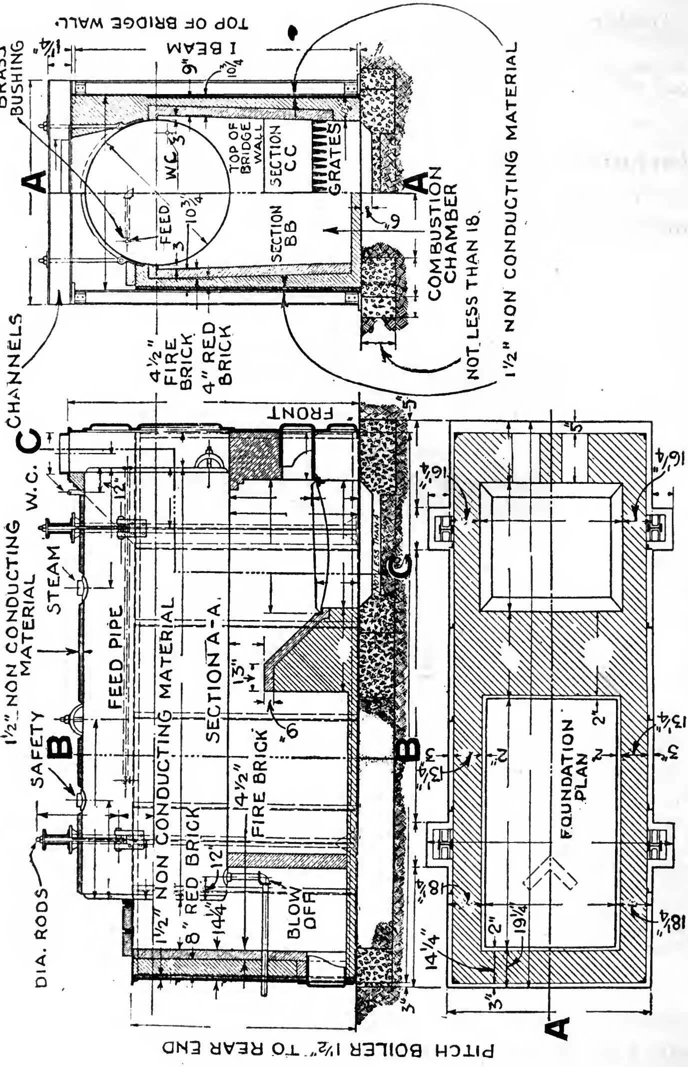


FIG. 4,480.—Boiler blocked up ready for setting. When the boiler is to rest on the setting walls it should be blocked up about an inch higher than its final position so that the side walls may be finished without difficulty after which the boiler may be lowered into position. The boiler front should not be required to carry any of the weight of the boiler, hence there should be about ½ inch clearance between the bottom of the shell and the front. The boiler should be inclined toward the rear so as to cause it to drain through the blow off easily and to give a little extra depth of water over the rear end of the tubes. If the front end of the boiler be set about 1 inch higher than the back, the desired slope will be obtained. In leveling the boiler crosswise, the top row of tubes should be taken to gauge by and not the faces of the steam nozzle flanges. If the nozzle flanges be but slightly out of true with the tubes the difference can probably be made up in the packing of the joint. If they be considerably out of true special, flanges may be used in making up the joints. It is preferable to have the tubes level rather than the flanges. The reason for this is that with unlevel tubes it is necessary to carry a higher water line than ordinary in order not to expose the high tubes and this is unsatisfactory as it cuts down the steam space.

material it should last practically as long as the boiler, but if poorly built with poor material it may not last a year.



FIGS. 4,481 to 4,483.—Brownell setting plan No. 5, ***box type setting.***

Poor construction means cracks and air leaks, the worst enemies to efficient boiler performance, causing useless waste of fuel.

The exterior of the walls should be hard burned brick, and the lining of furnace and combustion chamber of fire brick. The walls may be made either solid or with a central air space, the latter being always much to be preferred and costing but little more than the solid wall. The side walls and back walls are made of the same thickness, the front wall being somewhat thinner. They are either carried up the same thickness from top to bottom, or may be tapered somewhat from the grate up to the supporting brackets of the boiler, in order to give more room for the hot gases to circulate on each side of the shell.

Ques. What precaution should be taken in laying the fire brick lining?

Ans. Care should be taken to lay it so that it can be replaced without taking down the outer walls of the setting, but it must be bonded into the brick work so that it will not peel off.

It is advisable to line the entire setting with fire brick rather than only the furnace portion as is sometimes done. The reason for this is that a fully lined setting will stand up much longer and give far greater satisfaction under overload operation. The tendency of modern practice is to use fewer boilers and work them harder; hence, a fully lined setting is a good investment.

The better the quality of the fire brick used, the more economical the job will ultimately prove.

NOTE.—***The Common Brick*** used in a boiler setting should be dense, sound, well burned and of uniform dimensions; they should be selected with an eye to strength and durability rather than beauty. The sand used in the mortar should be clean and sharp and free from pebbles; if necessary, it should be screened before use. The lime and cement should be of good standard brand. For laying red brick below the ground line, a straight cement mortar is best. The mixture should be three parts sand to one part cement with enough water to make the mortar easily workable. For red brick above the ground line use a mortar of one part lime to four parts sand. This mortar must not be used while hot as the result of slacking the lime. The quality of lime mortar is much improved by the use of well slacked lime. The lime should be slacked for at least six weeks before using and longer if possible. The brick should be carefully laid with no unfilled spaces in the joints whatever. The joints should be as small as possible, ⅜ or, even better, ¼ inch. Each brick should be solidly bedded in the mortar and all vertical joints should be filled solidly. This is a most imortant point and should be insisted upon as otherwise wasteful air leaks and cracked walls will result. Every fifth course of brick should be a header course.

NOTE.—***Fire Brick*** vary greatly in quality and price. For boiler setting work it seems to be good economy to get the best fire brick obtainable. The greater price will be made up for by the greater life of the lining and the saving in shut downs and the cost of repair work.

Ques. What kind of mortar is used in laying fire brick?

Ans They are laid without mortar.

Ques. How are the joints sealed?

Ans. Fire clay is used as a filler material.

This should be mixed with enough water to make it as thin as a grout.

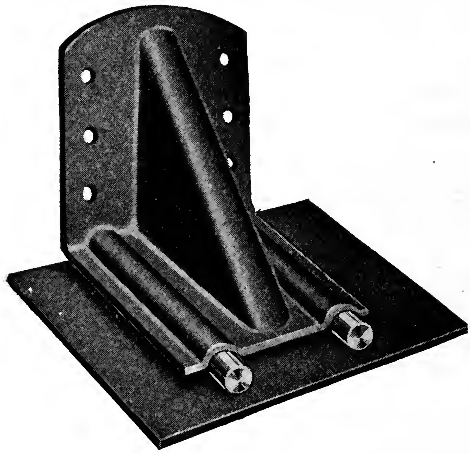


FIG. 4,484.—Casey-Hedges two roller pressed steel side lugs and bearing plate. A commonly used yet objectionable method of supporting the boiler. In some states there are boiler laws which prohibit the supporting of boilers of large diameter by means of side lugs resting on the boiler walls. When boilers are furnished with side lug construction, the pressed steel type of lug is recognized as the best.

The brick should be laid by dipping them in the fire clay mixture and then rubbing and shoving them into place. It is even advisable after this to tap the brick with a mallet or hammer and block of wood so that each brick will come into actual contact with its neighbors.

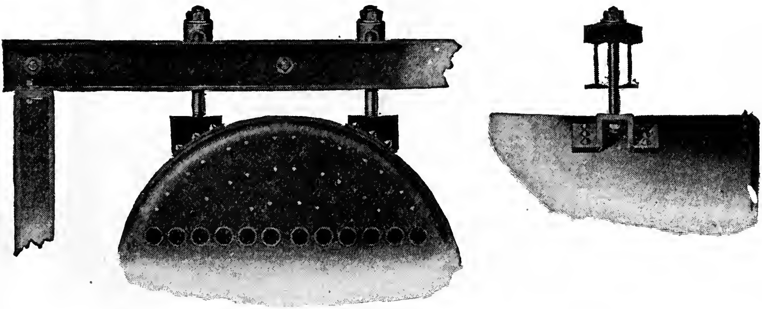
NOTE.—Some engineers line the furnace with brick laid in the same manner as the wall, that is, with bricks running lengthwise of the setting and every fifth or sixth row laid as headers bonding back into the main wall. If well laid, this construction may work well, but the preferable method is to use all brick as headers, that is, with the ends toward the inside of the wall, this construction being employed for the sides of the furnace above the grate and for the combustion chamber to a point about 2 feet back of the bridge wall. This avoids the falling out of the stretcher rows of brick and produces a construction in which, if bricks fall out or chip off they may be burned end for end and still be serviceable for a long time.

Ques. Should the brick work touch the boiler at any part?

Ans. No.

There should be a clearance of 1 inch between the top of the walls and the shell of the boiler. This space must be packed with asbestos rope or plastic asbestos.

Especial care must be taken to allow ample clearance around the connection to the water column as otherwise the pipes are liable to be broken.



Figs. 4,485 and 4,486.—Casey-Hedges I beam and column suspension. By its use the boiler is free to expand and contract without disturbing the brick work, the weight of the boilers being carried by the I beams, which rest on the supporting columns at the side instead of the brick work, as in the old style side lug method, which is positively dangerous. The trouble of brick work cracking and the boiler settling is reduced to a minimum, and at the same time the columns act as buckstays and hold the side walls. The use of hollow cast iron columns, round square, should be discouraged. The centers of such columns are made with cores that are liable to shift in casting and the columns are necessarily subject to many imperfections that are invisible to the eye.

Ques. Why should not the brick work touch the boiler at any part?

Ans. To allow for expansion of the boiler.

Provision for Expansion.—Since boilers are longer (and larger in diameter) when hot than when cold it is necessary to provide 1, space between the setting and boiler (as just mentioned), and 2, a flexible support to prevent cracking of the brick work.

When the boiler is supported by the brick work, expansion is usually provided for by placing rollers under the rear supporting legs as shown in figs. 4,487 and 4,488.

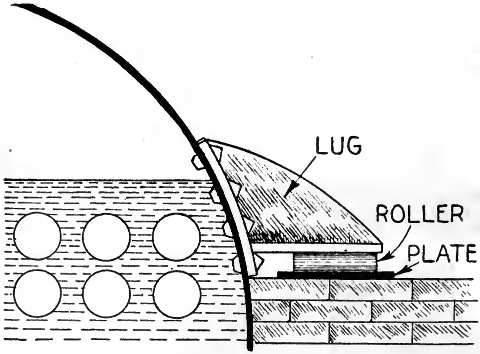


FIG 4,487.—The usual but objectionable method of providing for expansion on lug supported boilers. It will be seen that no provision is made for transverse expansion of the shell consequently the side walls must "breathe" with the boiler, which tends to produce air leak by cracking and loosening the mortar.

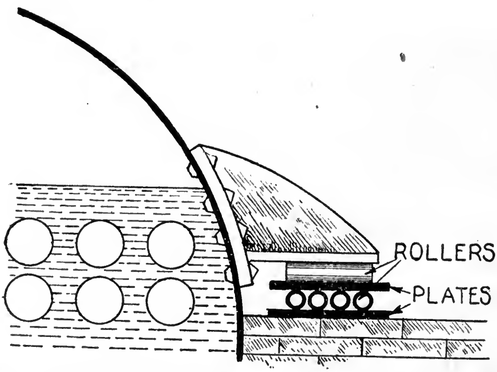


FIG. 4,488.—Approved method of providing for expansion on lug supported boilers. The two sets of rollers placed at right angles to each other form a universal joint, allowing free movement both endwise or crosswise.

The reason for putting the rollers at the rear end instead of the front end is because the front end rests upon the brick work and accordingly should not move. The author objects to the arrangement shown in fig. 4,487, in that it does not provide for lateral expansion.

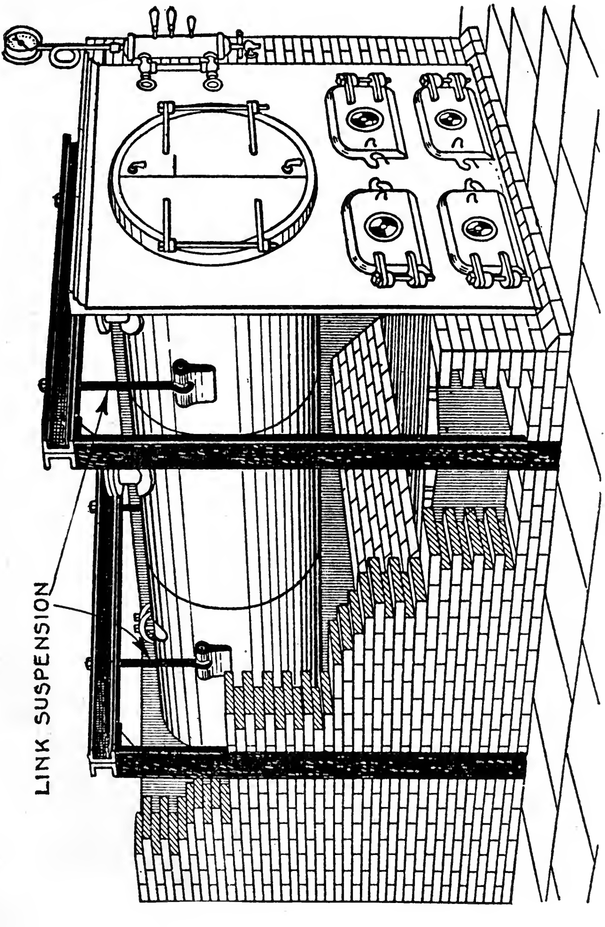
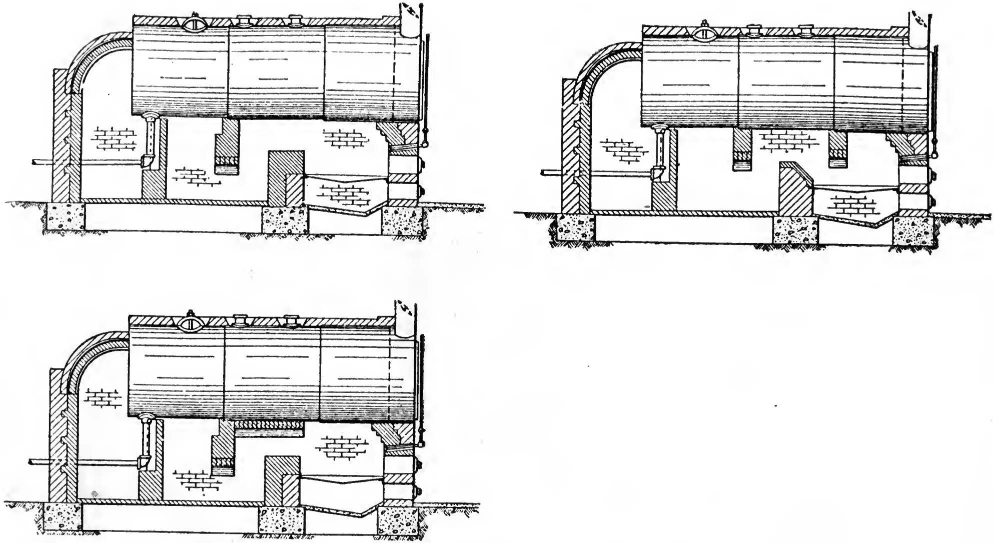


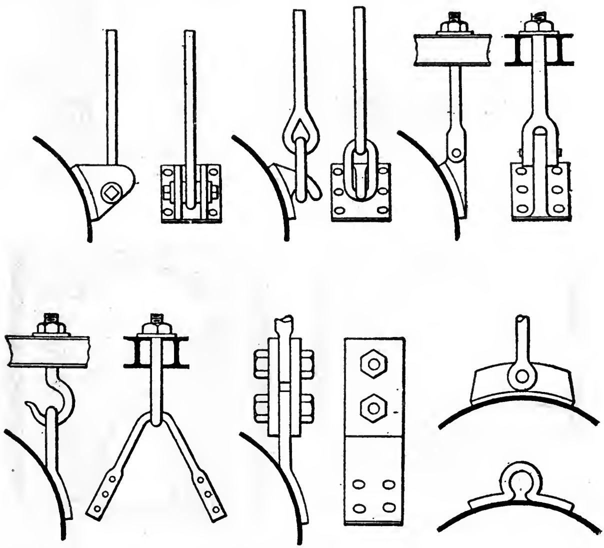
FIG. 4,489.—Method of providing for expansion by link suspension. As may be seen, the weight of the boiler is carried by the steel work, thus relieving the brick work of this duty. The side columns may be either of solid channel iron or built up from angles and lattice work, and channel bars are carried across the top of these columns as shown. The boiler is suspended from these channels by suspension links or rods arranged with nuts and washers, permitting easy leveling and adjustment of the height of the boiler.



FIGS. 4,490 to 4,492.—***Various arches.*** Fig. 4,490 shows the simplest form of arch originally used in connection with steam jets to keep down smoke in the furnace; while it broke up the gases and mixed them to a certain extent, it did not provide sufficient temperature at the point of mixture. Two arches were then used, one, as shown in fig. 4,491, back of the bridge wall, and the other at about the same height and the same distance in front of the bridge wall, but this construction also had its shortcomings, so the single arch bridge wall furnace with single span deflection arch was developed and has been used with success in connection with high volatile coals. From experience, it has become evident that in order to burn high volatile coals, draught is more essential than high temperatures. It has also been found that a "cool" furnace, one having direct radiation from the fire to the heating surface, not only increases efficiency and capacity by increasing heat absorption, but reduces the liability to dense smoke because the volume of volatile gases passing off is at no time in excess of the capacity of the furnace to take care of it. As a result, in the furnace shown in fig. 4,492, there is provided a zone of high temperature back of the bridge wall and which maintains the gases at or above the igniting temperatures. A deflection arch is provided as shown, against which the high temperature gases impinge. A sufficient quantity of air is necessary to mix in this high temperature zone with the volatile gases and furnish the the necessary oxygen for complete combustion.

In bricking up around the lugs a recess must be left large enough so that the lugs will not touch the brick work in any spot. In fact, the brick work should not touch the boiler at any point.

Another method of providing for expansion, and one well adapted to long boilers is by link suspension as shown in fig. 4,489. This consists of two pairs of side columns with cross beams to which are attached suspension links having their lower ends attached to the boiler and supporting same.

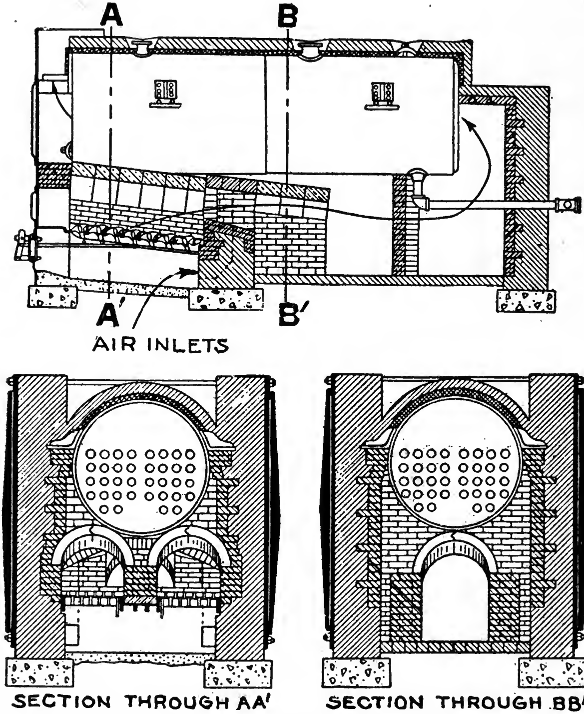


FIGS. 4,493 to 4,504.—Various forms of suspension links.

Bridge Wall.—This is a most important part of the setting. Unless it be located in the right place and be of the right thickness and height, more or less trouble may result in the way of overheated sheets, especially if there be a girth seam near.

The wall must be strong enough to withstand the thrust of the firing implements used in cleaning the fire, and must be thick enough that the joints do not loosen by this action.

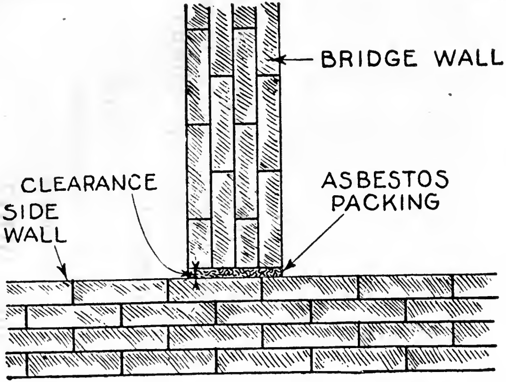
Experience shows that the best results are secured with a bridge wall perfectly flat on top as shown in fig. 4,489 and not built circular to follow the curve of the boiler shell. The distance between the bottom of the shell and the crest of the bridge wall should be not less than 10 inches. The crest of the wall should be one or one and a half fire brick lengths wide according to the table on page 2,537.

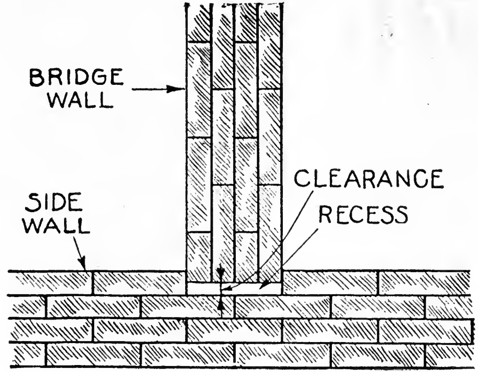


FIGS. 4,505 to 4,507.—Double arch furnace with mixing arch, a form of combustion chamber well suited where high volatile coals are burned.

Each course below should be set out as shown in fig. 4,462, so that the front face slopes forward at an angle of about 45 degrees until the full thickness of the wall is reached.

The bricks on the sloping face and on the front of the crest should be laid as headers, as shown, in order that an accidental poke with a fire iron will not be likely to knock any off. Some engineers prefer that these brick be cut beveled on the front so as to present a smooth surface on the slope





FIGS. 4,508 and 4,509.—Two methods of joining bridge wall to side walls to allow for expansion. The bridge wall may be built with a one-inch clearance space between its ends and the side walls, as in fig. 4,508, and this clearance space packed with asbestos rope, or it may be extended into a recess in the side walls as in fig. 4,509, allowing a clearance of 1½ inches in the recess for expansion.

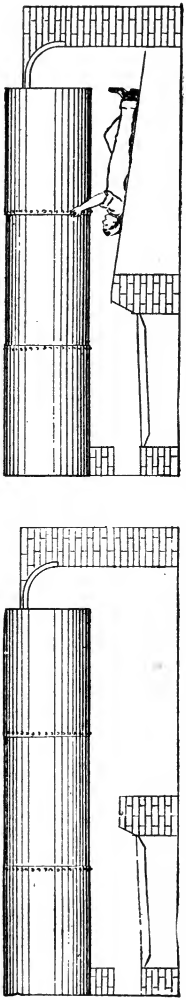
of the bridge wall as shown in fig. 4,489. There is practically nothing to be gained by this as the clinkers adhere just as readily to such a surface as they do to the square corners of the uncut brick.

Ques. How should the bridge wall connect with the side walls?

Ans. It should be free to expand as shown in fig. 4,508 or fig. 4,509.

If this be not done, the expansion of the bridge wall will crack out the side wall of the setting.

Combustion Chamber.—The space between the bridge wall and rear end of the boiler, commonly called the combustion chamber, may extend down to the floor line,



Figs. 4,510 and 4,511—Horizontal and sloping floor combustion chambers showing features of each.

or be reduced in size by a wall sloping from the top of the bridge wall to the floor level at the rear of the boiler as respectively shown in figs. 4,510 and 4,511.

It is thought by some that the extra space due to the first construction is useful as a reservoir for heated gases, breaking up the rapid current which would otherwise flow in a line parallel to the bottom of the boiler and thence through the tubes to the chimney, not giving out as much heat as would be the case if this volume of hot gases could be interrupted in its passage and proceed with a slower movement, but Barr considers this argument far fetched and probably not true. He further states that boiler tests with both types of combustion chamber give practically the same results.

It should be noted that with a sloping floor in the combustion chamber, it is difficult to properly inspect the girth seams of the boiler.

The best and cheapest construction for the combustion chamber is that shown in fig. 4,510 (for dimensions see figs. 4,462 to 4,464). The floor should be made of concrete just the same as the ash pit floor.

Ques. What important provision should be made in the rear end of the combustion chamber?

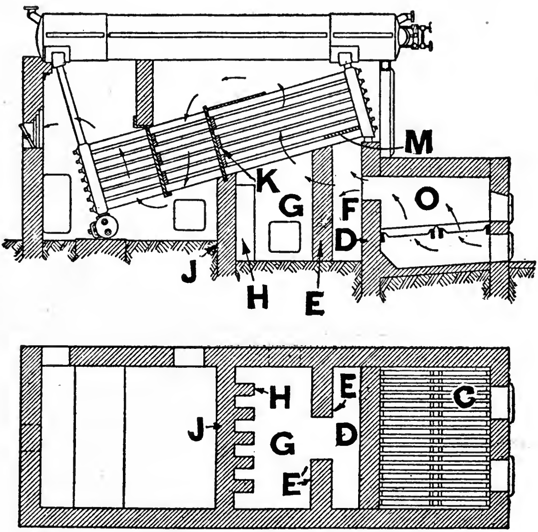
Ans. The blow off pipe should be protected from the intense heat at this point.

Ques. Why?

Ans. To prevent the formation of steam in the pipe, and prevent the sediment adhering to the pipe.

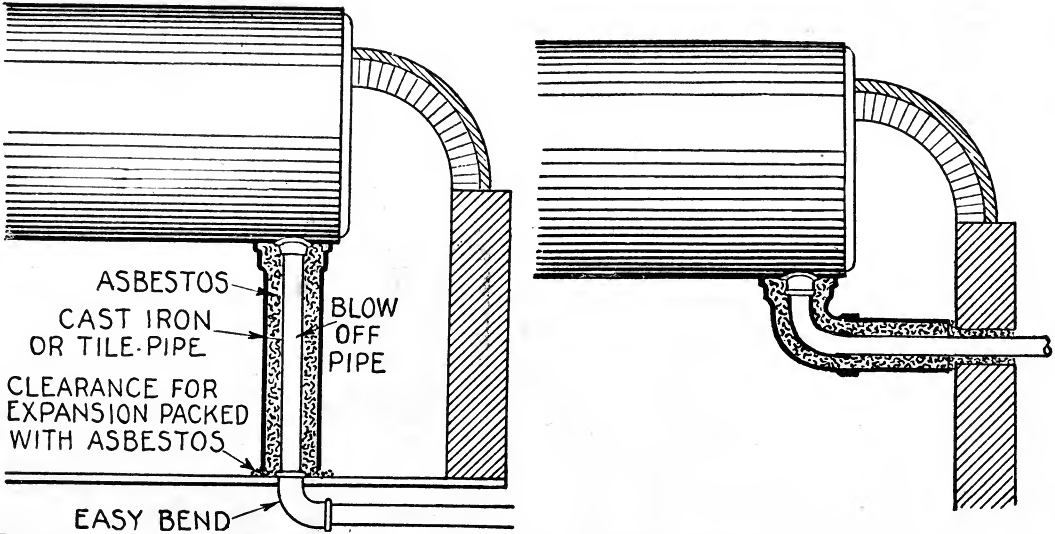
Ques. How should the blow off be piped and protected?

Ans. The blow off outlet at the rear end of the boiler should run vertically downward to the bottom of the floor and pass out under the flow level. The length of pipe in the combustion



FIGS. 4,512 and 4,513.—Kent wing wall furnace designed to secure smokeless combustion. ***In construction*** C, is a fire chamber or oven, built of brick and extending in front of the boiler, where the fuel is burned either on the ordinary grate or by means of a mechanical stoker. D, is an ordinary bridge wall. E,E′, are two tall vertical walls called wing walls, built some distance in the rear of the bridge wall. G, is a combustion chamber, H,H, are several piers of firebrick projecting into the chamber, G, from the rear wall J,K, is an ordinary baffle, and M, is a tile roof to the chamber, F, to prevent the gases in that chamber reaching the tubes until after they have passed through the narrow vertical passage between the wing walls, E,E′.

chamber should be covered with asbestos or other insulating material and enclosed in a cast iron or tile pipe, the object being to keep the blow off pipe as cool as possible.



FIGS. 4,514 and 4,516.—Two arrangements for the blow off connection. The first or vertical rim is preferable, but for convenience, the pipe may be carried out horizontally above the floor line and will be satisfactory if properly protected. The object aimed at is to keep the pipe cool as possible preventing the formation of steam, and avoiding baking of the sediment in the pipe. Use easy bends instead of close elbows, and have the outer casing large enough for a liberal thickness of asbestos between casing and blow off pipe.

Sometimes it is more convenient to have the pipe pass out of the setting above the floor line. As with the other arrangement special provision must be made to protect the pipe.

Back Connection.—The opening between the back wall and rear end of the boiler is covered either by a flat plate or some form of arch construction.

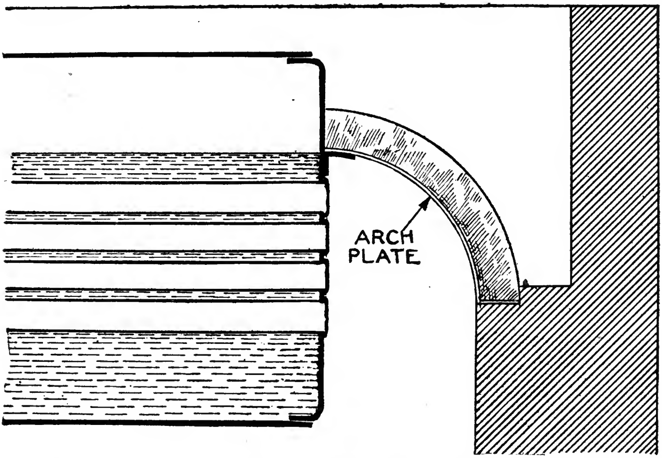


FIG. 4,516.—Ordinary arch back connection with *inside* cast iron arch plate. The objection to this construction is that the cast iron plate is exposed to the intense heat.

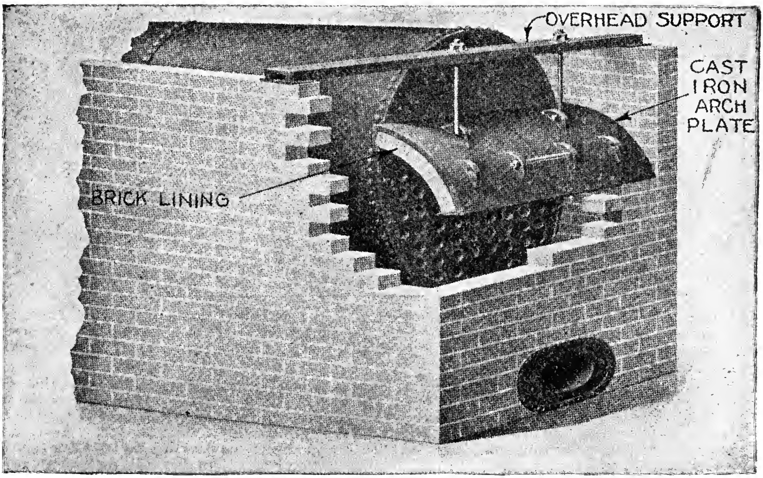


FIG. 4,517.—Monarch arch back connection with *outside* cast iron arch plate; view showing construction and method of support. ***In construction*** fire brick are placed in an arch-shaped casting mould and molten iron run over the back and ends of the arch. As the iron cools after being poured into the mould around the brick. it shrinks slightly and takes a firm grip on the brick, pressing them tightly together so as to form a practically solid arch—a very excellent construction.

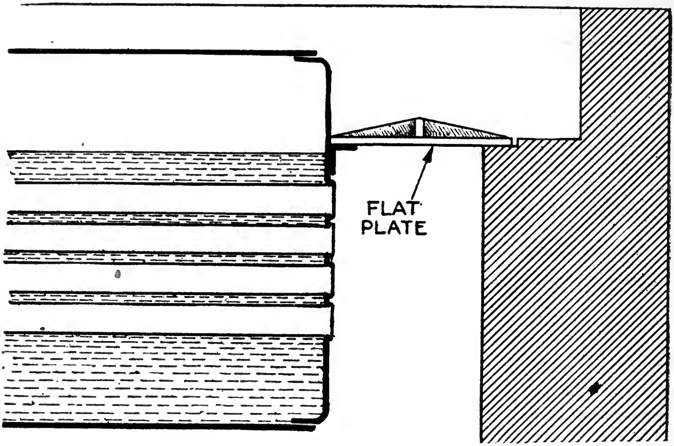


FIG. 4,518.—Flat plate back connections. This construction affords easy access to the bac end of the boiler and plenty of light but is objectionable in that *the metal is not protected fro the heat.*

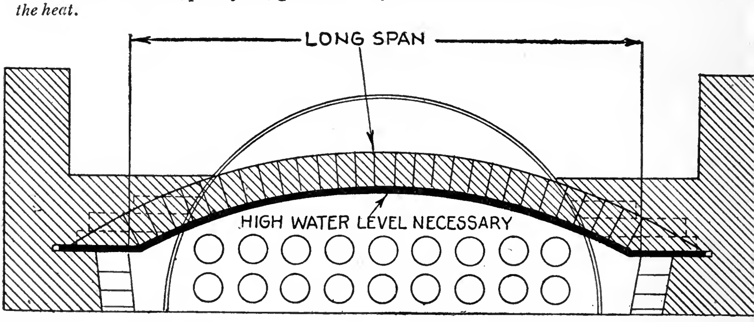


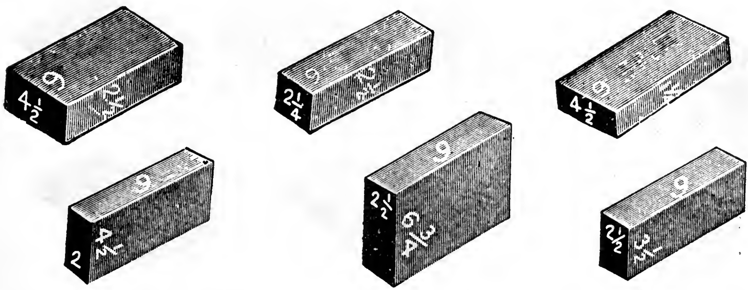
FIG. 4,519.—Long span arch back connection. In this construction the arch springs fro the two side walls, and of necessity must be almost flat. It is objectionable because: its almost flat shape is an element of weakness, and 2, a higher water level must be carrie

NOTE.—Until recently it has been almost universal practice to construct the side wal of the setting with an air space, usually located 8 inches back from the outside face of the wa and 2 inches wide. As the result of some experiments conducted a short time ago at the fu testing plant of the United States Geological Survey in Pittsburg it was found that the ordina air space of a boiler setting has but little effect in preventing the flow of heat from the furnac In fact a solid wall is more efficient in reducing radiation losses than one built with an air spac The air space has the advantage, however, that if a crack develop in the inner part of th wall, it seldom extends to the outer part and hence the bad effects of a crack clear through a avoided. The best construction seems to be with the air space filled with loose sand, ash crushed brick. Thus, if the inner part of the wall crack, the crack will not extend clear throug and, at the same time, the filling in the air space acts as a good heat insulator and serves prevent any air leaks into the furnace.

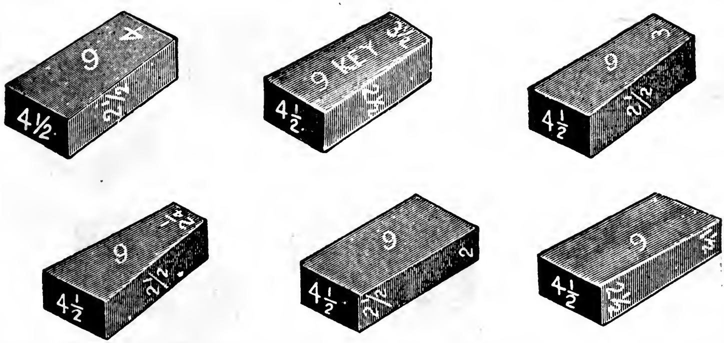
Fig. 4,518 shows the flat plate connection. Such arrangement lasts but a short while because the iron quickly burns out.

Another construction is to spring a long span arch between the side walls as shown in fig. 4,516. This arch must be almost flat so that it will not extend above the water line nor block off too many of the tubes at the sides. On account of being almost flat it is structurally weak. It must be very carefully made in the first place and even at that it will not last very long, especially if the boiler must be forced occasionally.

The best construction is to spring a half arch between the back wall of the setting and the boiler shell as illustrated in figs. 4,516 and 4,517.



FIGS. 4,520 to 4,525.—Standard 9-inch firebrick shapes. Fig. 4,520, 9-inch; fig. 4,521, soap; fig. 4,522, No. 1 split; fig. 4,523, No. 2 split; fig. 4,524, large 9-inch; fig. 4,525, small 9-inch.

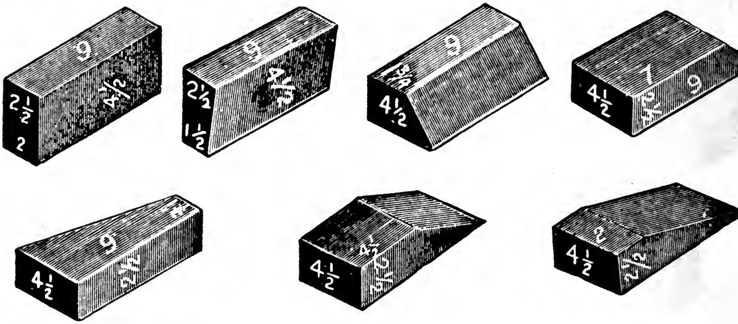


FIGS. 4,526 to 4,531.—Standard 9-inch firebrick shapes. Fig. 4,526, No. 1 key; fig. 4,527, No. 2 key; fig. 4,528, No. 3 key brick; fig. 4,529, No. 4 key brick; fig. 4,530, No. 1 wedge; fig. 4,531, No. 2 wedge.

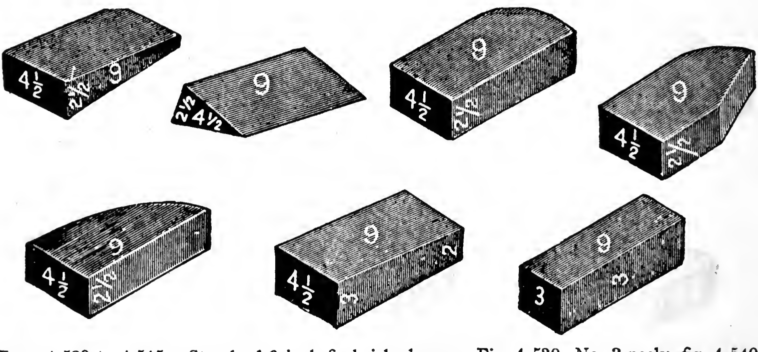
With this design the gases have plenty of room and are guided in a natural sweep and with the least resistance to the tubes. Also, the straight line of the arch at the boiler shell affords ample protection against over. heating that part of the head which is above the water line.

The bricks of this arch must be supported in some manner although no iron should be exposed to the direct impingement of the gases. Fig. 4,519 shows a very excellent arch construction.

Ques. What precaution must be taken with back connections?



Figs. 4,532 to 4,538.—Standard 9-inch firebrick shapes. Fig. 4,532, No. 1 arch; fig. 4,533, No. 2 arch; fig. 4,534, side skew; fig. 4,535, end skew; fig. 4,536, skew back; fig. 4,537, No. 1 neck; fig. 4,538, No. 2 neck.



Figs. 4,539 to 4,545.—Standard 9-inch firebrick shapes. Fig. 4,539, No. 3 neck; fig. 4,540, feather edge; fig. 4,541, No. 1 jamb; fig. 4,542, No. 2 jamb; fig. 4,543, No. 3 jamb; fig. 4,544, bull head; fig. 4,545, checker.

Ans. The joints must be made tight by covering with earth or equivalent, otherwise cold air will enter and lower the temperature of the gases passing into the tubes.

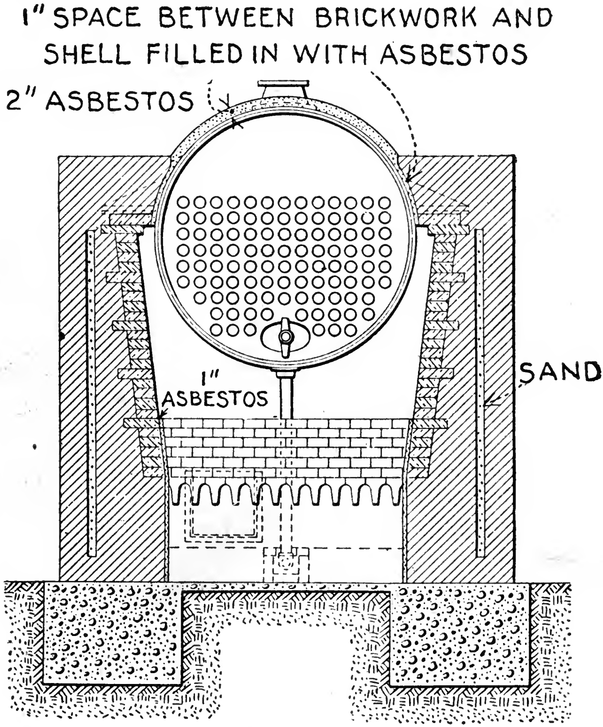


FIG. 4,546.—Approved method of covering the top of boiler for those who insist on covering the top instead of following the more advanced and sensible practice shown in figs. 4,552 and 4,553.

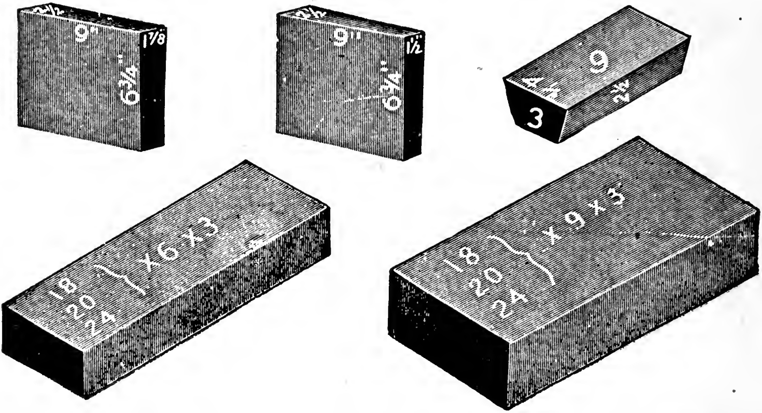
Top Covering.—The usual but questionable method of constructing the top of a boiler setting is to cover the top of the boiler with some form of insulating material.

There are three methods of covering the top of the boiler shell. When the brick are laid coat them over with a grout of one part cement and one part sand to a thickness of at least ¼ inch. Although this is the cheapest and probably the most durable construction, it has but slight value for heat insulation.

A more efficient method in this respect and one which is also fairly cheap is the use of a good grade of asbestos in fairly thick layers.

The best covering to use from the heat saving point of view is 85 per cent. magnesia, 2 or 3 inches thick, finished off with a hard cement layer on the outside.

Ques. What precaution should be taken before covering a boiler?



FIGS. 4,547 to 4,551.—Standard 9-inch firebrick shapes. Fig. 4,547, large No. 1 wedge, 102 brick to the circle 5 feet inside, 6 feet 6 inches outside diameter; fig. 4,548, large No. 2 wedge, 63 brick to the circle, 2 feet 6 inches inside, 4 feet outside diameter; fig. 4,549, edge arch, small diameter for larger stock linings, and 2½-inch pipe linings; fig. 4,550, checker tile; fig. 4,551, checker tile, mill tile.

Ans. The boiler should be operated first to ascertain if there be any leaks at the joints.

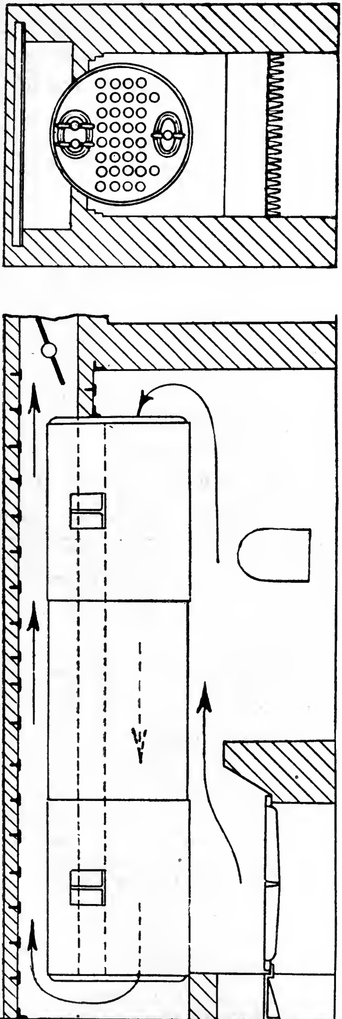
Jacket Covering.—The practice of covering boiler tops with insulating material indicates either a lack of nerve or knowledge or simply the result of blindly following the example of others without using individual reasoning in the matter.

A jacket of hot gases over the top of the boiler, as shown in figs. 4,552 and 4,553 is frequently employed, and affords complete protection against radiation of heat from the top of the boiler.

This feature has been seriously opposed because of the supposed liability of the hot gases passing over the top of a boiler shell to cause overheating, especially in the interval between starting a fire under a cold boiler until steam forms.

According to Barr: "The overheating of the top sheets so far as the writer (Barr) is aware, has never occurred, nor ought it to be expected in any properly designed boiler setting not using a powerful fan blast. No injury could occur to the shell at a temperature below red heat (900° F.), and it is scarcely possible that any such temperature, or more than the half of it, ever reaches the top portion of the shell of a boiler not under steam.

In any boiler setting in which the ratio of heating surface is 30 to 1, employing natural draught there is probably no danger whatever that the top of the sheets will ever become overheated."



FIGS. 4,552 and 4,553.—Boiler setting with jacketted top covering; the correct method of enclosing the top of the shell when economy is of any consequence. As will be seen, the hot gases after passing through the combustion chamber and tubes, traverse the top of the shell, thus avoiding the heat loss through the ordinary top covering.

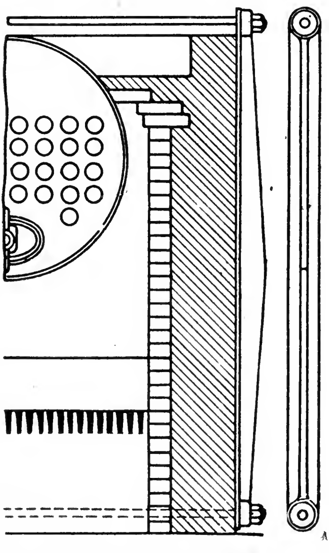
Buck Staves.—In order to prevent the spreading of the furnace walls, they are reinforced by cast iron upright members known as buck stays, as shown in figs. 4,554 and 4,555. These are of T shape and for proper stiffness the web should be from 4 to 6 inches deep, depending on the diameter of the boiler. They are usually placed 4 or 5 feet apart on the side walls.

Boiler Fronts.—These are made in many different styles, almost every maker having some peculiar points in design. There are four general types:

1. Flush front.
2. Overhanging front.
3. Cutaway front.
4. Breaches front.

The flush front is one of the earliest forms of fronts, and though it often gives good satisfaction, yet it is liable to certain accidents.

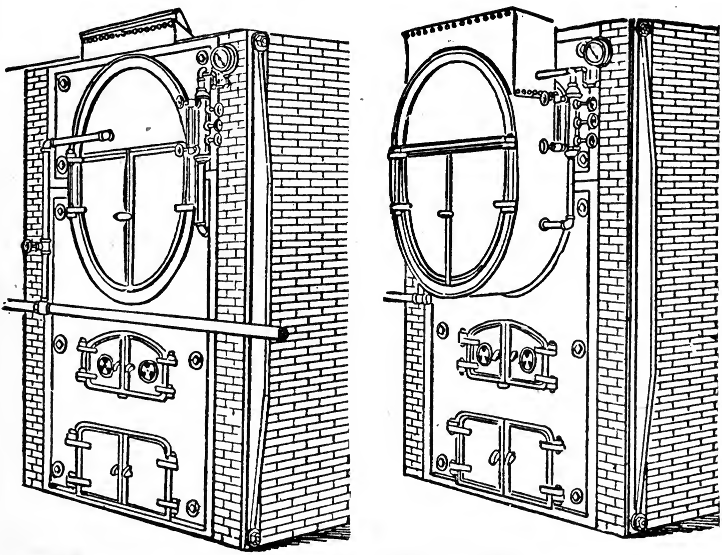
The front of the smoke arch in this form of setting as shown in fig. 4,556, is flush with the front of the brick work, and the dry sheet just outside of the front head is built into the brick work. The heat from the fire, striking through the brick work, impinges on this sheet, which is unprotected by water on the inside. So long as the furnace walls are in proper condition the heat thus transmitted should not be sufficient to give trouble; but after



Figs. 4,554 and 4,555.—*Buck stave* or reinforcing member for boiler setting. *As shown*, the buck staves arranged in pairs are held firmly in place against the brick work by stay rods, which extend from side to side of the furnace at top and bottom. Buck staves are commonly made of cast iron. Their use is to prevent the spreading of the furnace walls and they should accordingly be rigid. To secure rigidity the web should be from 4 to 6 inches deep. Buck staves are usually placed 4 to 5 feet apart on the side walls.

running some time bricks are very apt to fall away from over the fire door, and thus expose portions of the dry sheet to the direct action of the fire, causing it to be burned or otherwise injured by the heat, and perhaps starting a leak around the front row of rivets when the head is attached to the shell.

In the overhanging front, as shown in fig. 4,557, this tendency is prevented by setting the boiler *in such a manner that the dry sheet projects out into the boiler room.*



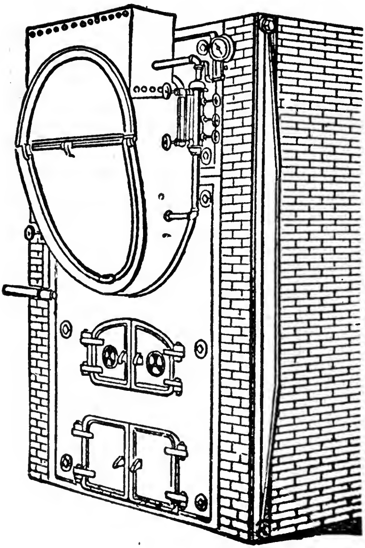
FIGS. 4,556 and 4,557.—Various boiler fronts. Fig. 4,556, flush front; fig. 4,557, overhanging front.

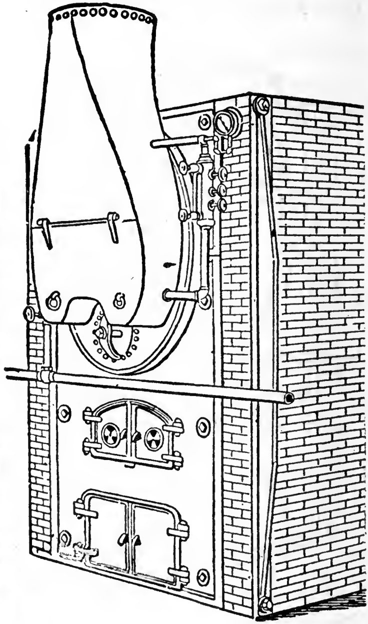
If the brick work over the fire door fall away when a boiler is set in this manner, the only effect is to slightly increase the heating surface. No damage can be done, since the sheet against which the heat would strike is protected by water on the inside.

The objection is sometimes raised against the projecting front, that it is in the way of the fireman. To meet this point and yet preserve all the advantages of this kind of front, the cut away style, shown in fig. 4,558, has come into use.

In this form the lower portion or the front sheet is cut obliquely away, so that at the lowest point the boiler projects but little beyond the brick work.

It will be noticed that in the flush and overhanging fronts, the doors





FIGS. 4,558 and 4,559.—Various boiler fronts. Fig. 4,558, cut-away front; fig. 4,559, breeches front for man hole.

open sidewise, swing about on vertical hinges; in the cutaway front the best way to arrange the tube door is to run a hinge along the top of it, horizontally, and to have the door open upward. With such a disposition of things the door is not easy to handle. For the purpose of support a hook and chain, hanging from the roof should be provided.

The front shown in fig. 4,559 consists of sheet iron breeching that comes down over the tubes and receives the gases of combustion from them.

A man hole is shown under the tubes. This, of course, is not an essential feature of the breeching, but it will be seen that man holes can readily be put below the tubes on fronts of this kind, in such a manner as to be very convenient of access.

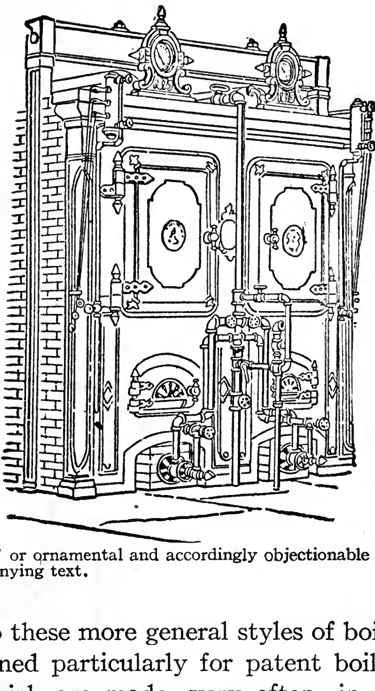
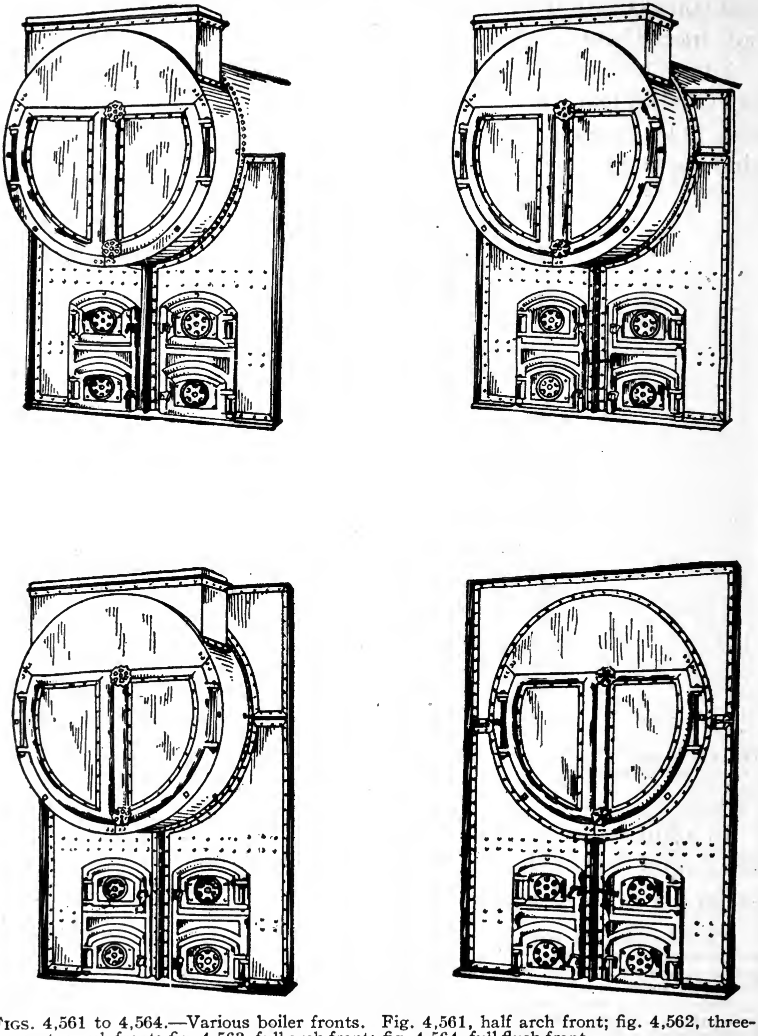


FIG. 4,560.—A "fancy" or ornamental and accordingly objectionable boiler front for reasons given in the accompanying text.

In addition to these more general styles of boiler fronts, there are fronts designed particularly for patent boilers, water-front boilers, etc., which are made, very often, in ornamental and

NOTE.—Sectional plate steel is extensively used for boiler fronts. This sectional method of construction prevents any tendency toward cracking, the necessary allowance for expansion and contraction being provided. As constructed by the Casey-Hedges Co., steel fronts are made of steel plate with cast iron doors and frames. The fronts are reinforced with large angles to prevent their buckling and distorting. The edge of the front is fitted with angles presenting a neat and attractive appearance. Steel fronts may be made with any special door combination, width or height desired.



FIGS. 4,561 to 4,564.—Various boiler fronts. Fig. 4,561, half arch front; fig. 4,562, three-quarter arch front; fig. 4,563, full arch front; fig. 4,564, full flush front.

attractive designs. To the engineer, however, *a* **plain** *front is the most attractive*, as his common sense tells him that *the extra time and expense put into fancy fronts had better be applied to the boiler proper or parts under pressure*.

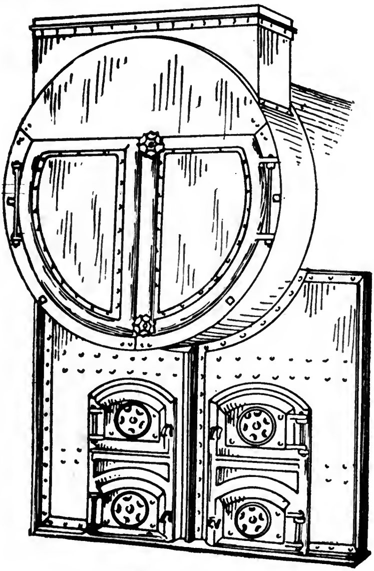


FIG. 4,565.—One-quarter, or *so-called* half arch front.

Ques. What is a full flush front?

Ans. An iron front containing the furnace doors and cleaning doors, and extending the full height of the setting as shown in fig. 4,561.

Ques. What is a three-quarter arch front?

Ans. An iron front for an extended shell boiler embracing the shell to a level three-quarters of its vertical diameter as shown in fig. 4,564.

Ques. What is a half arch front?

Ans. An iron front for an extended shell boiler, enclosing the front end up to level of center of boiler as shown in fig. 4,562.

Ques. What is a so-called half arch front?

Ans. An iron front for an extended shell boiler embracing the shell up to a level lower than the center of the boiler, as shown in fig. 4,565.

These so called half arch fronts usually extend to about one-quarter the vertical diameter, and accordingly would be appropriately called a one-quarter front.

Fire Doors.—On internally fired boilers these are usually fitted to cast iron frames bolted to the shell of the boiler. The

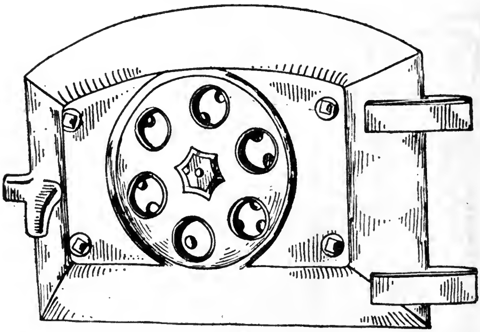


FIG. 4,566.—Walsh and Weidner fire or ash door.

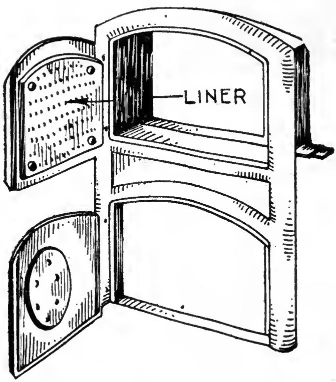


FIG. 4,567.—Walsh and Weidner door frame, showing fire and ash doors with liner and ventilator.

door and frame should have planed surfaces to make a tight joint and the hinges should be very strong to withstand rough usage. A perforated cast iron plate or lining is provided to protect the door from the intense heat. The plate is attached to the door by bolts passing through distance pieces.

Fig. 4,566 shows detail of a fire or ash door for a horizontal tubular boiler and figs. 4,567, door frame with fire and ash doors in position.

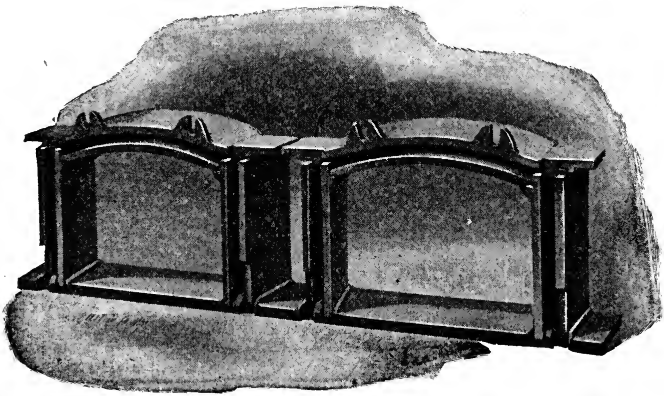
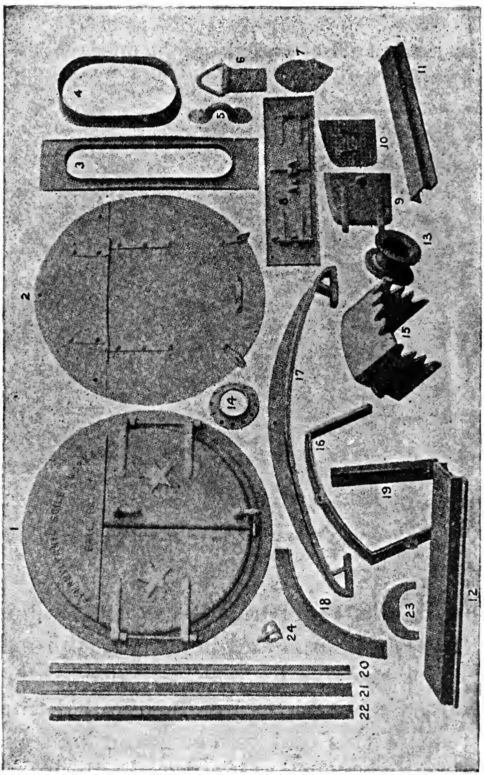


FIG. 4,568.—Bigelow cast iron removable type of arch and jamb.

Linings for Fire Door Openings.—Fig. 4,568 illustrates a cast iron removable type of arch and jamb. It is provided with inner removable check pads and arches, arranged so that these parts may be removed when burned out without disturbing the brick work. Instead of this cast iron construction sometimes a fire brick arch and jamb is used as shown in fig. 4,593. Whereas this form is better adapted to withstand the heat it is subject to injury from knicks with the fire tools.

Miscellaneous Iron Parts.—In addition to the fixtures



FIGS. 4,569 to 4,592.—Some miscellaneous fittings used for boiler setting. 1, cast iron smoke box frame and doors opening right and left; 2, 1/4 inch steel smoke box door opening up; 3, cast iron oval stack plate for full front; 4, steel smoke stack saddle used on smoke box of half-front boilers; 5, pressed steel loop for top of boiler used for suspending boilers; 6, triangular loop for side of boiler used for suspending boilers; 7, plate steel loop or ear for side of boiler used for suspending boilers; 8, ash pit frame and doors for open bottom fire box boilers; 9, cast iron fire door for full or half front; 10, perforated cast iron liner for fire door;

already described there are several other iron parts or trimmings required to complete the "setting."

Fig. 4,594 shows a stack casting which serves as a base for a wrought iron chimney or to receive a pipe connecting with a brick chimney at one side. This plate is for a full flush front and is anchored in the brick work immediately back of the fire front.

For an extensive shell boiler the arrangement shown in fig. 4,595 is used instead of the stack plate just described.

Figs. 4,569 to 4,592 show some miscellaneous fittings.

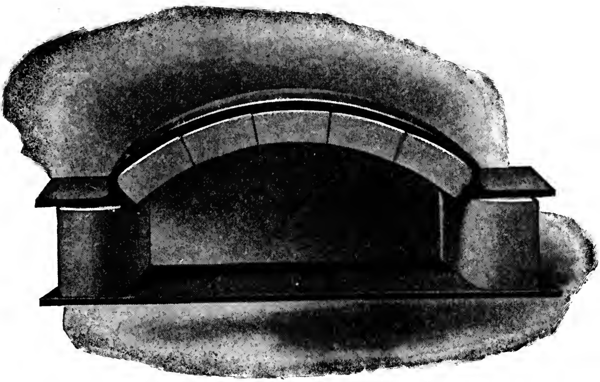


FIG. 4,593.—Bigelow firebrick arch and jamb.

Bricks Required for a Setting.—To estimate the number of brick in a wall, multiply the length of the wall by the width and height all in inches, and divide by 82 for common brick, or by 116 for firebrick. The quotient will be approximately the number required.

If the lining of the furnace is to be made all headers, as already mentioned, multiply the fire brick required for that part of the wall by 2.6, or multiply the area to be laid in square feet by 12.

FIGS. 4,569 to 4,592.—*Text continued.*

11, dead plate for half arch front; 12, dead plate for full arch front; 13, combination nozzle, consisting of pressed steel threaded flange, extra heavy nipple, and faced and drilled heavy cast iron flange, all securely screwed together; 14, pressed steel flange; 15, arch plate, sometimes termed casings, or flame plate, 14 inches deep, for supporting fire brick around fire doors of full fronts; 16, arch plate or casing, for supporting one course of brick around fire door openings on half fronts; 17, rear arch bar, Hartford pattern, for lining with fire brick; 18, rear arch bar, curved pattern, to rest on back wall; 19, rear arch bar, straight pattern; 20, bearing bar, rear end grates; 21, bearing bar, for rear arch; 22, bearing bar, for center of grates; 23, man hole bridge; 24, hand hole plate, bolt and bridge complete.

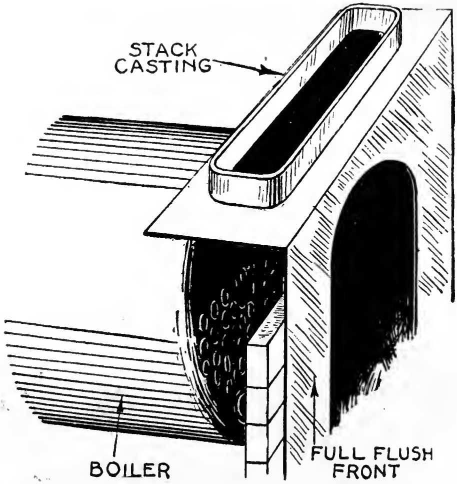


FIG. 4,594.—Stack plate casting for flush end boiler, full flush front. The smoke box is formed by the brickwork of the setting.

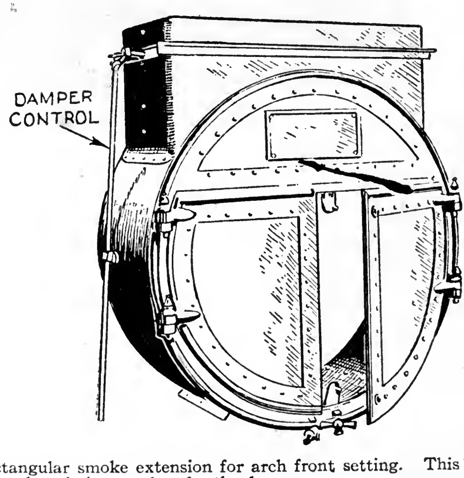


FIG. 4,595.—Rectangular smoke extension for arch front setting. This serves both for the connection to stack and also as a box for the damper.

In estimating the material needed for a boiler setting, 250 pounds of lump lime and 1 cubic yard of sand will be required for each thousand bricks in the walls, and from 800 to 900 pounds of fire clay for each thousand fire brick in furnace linings.

The number of brick required for various settings may be obtained without calculation from the accompanying tables.

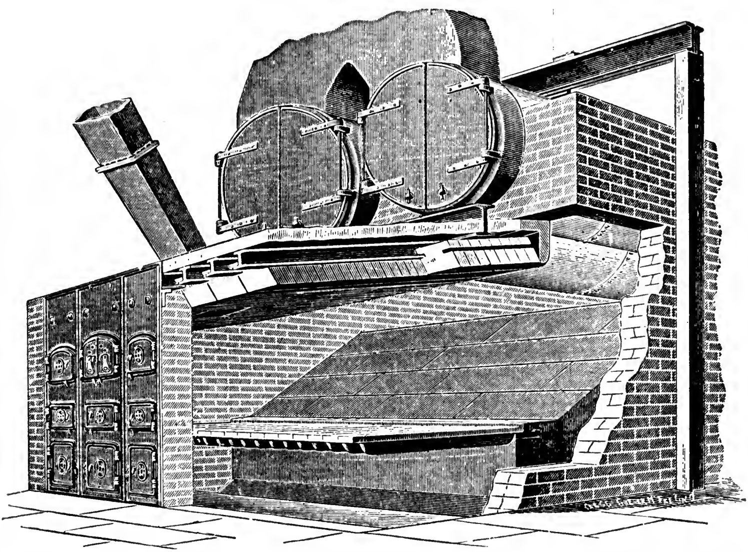
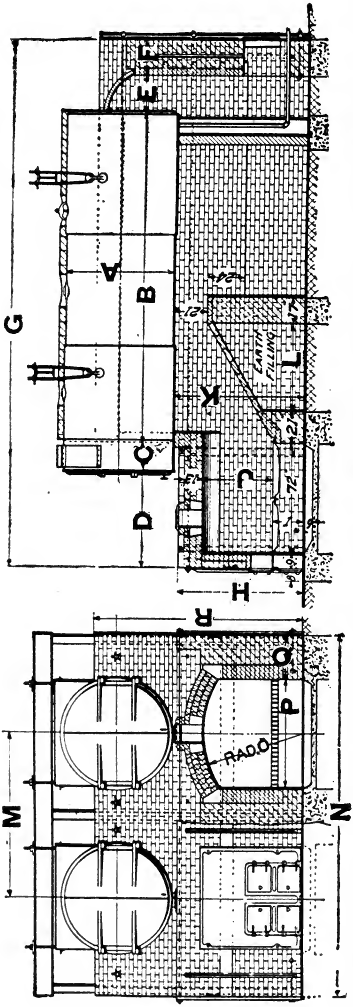


Fig. 4,596.—Quinn's flat top Dutch oven furnace (Walsh and Weidner). This type of furnace is especially fitted for Dutch ovens burning damp or bulky fuel. There are two layers of tile with the air space between for cooling the suspension beams and the tile.

Dutch Oven Setting.—The general proportions for a Dutch oven setting are given in the accompanying table and figs. 4,597 and 4,598.

The number of common brick specified is estimated on the basis of 18

DUTCH OVEN SETTING FOR TWO BOILERS



FIGS. 4,597 and 4,598.—Chandler and Taylor Dutch oven setting. Fig. 4,597, end elevation and oven cross section; fig. 4,598, longitudinal section through one boiler. The reference letters refer to the accompanying table.

brick per cubic foot and allowance must be made for breakage and cutting.

The number of fire brick includes sufficient for headers every sixth course.

When grate length is 66 inches or longer, grates are furnished in two lengths with center bearing bar.

The wall under the boiler at the front should extend back at least eight inches beyond the circular row of rivets to protect them from the fire.

The boiler front should be placed in position with its anchor rods and properly plumbed before building the brick work. Be careful not to spring the front casting out of shape by drawing up too tightly with bolts. This will spring the front and the doors will not fit properly.

The open space between side walls and boiler should be covered over at a distance four inches below the wings or suspension loops in order to properly protect them from the hot gases.

The number of common brick required for a single boiler is approximately 60 per cent. of what is required for the double setting as given in the table below.

The number of fire brick required for a single boiler is one-half the number specified for double setting in the table on page 2,583.

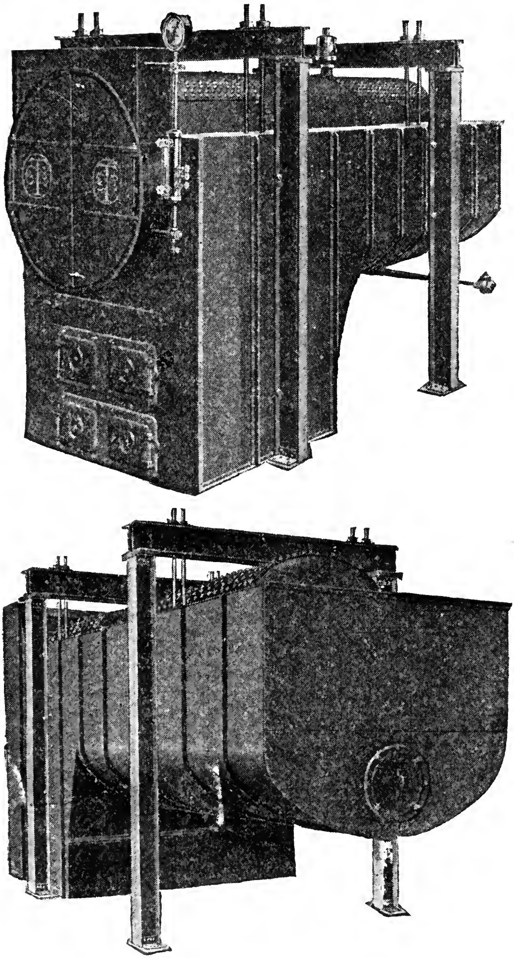
DUTCH OVEN SETTING FOR TWO BOILERS

Size Boiler. A × B (IN × FT)	Depth of Smoke Box. C (IN.)	End of Smoke Box to Face of Setting. D (FT)	D (IN.)	Span of Back Arch. E (IN.)	Thickness of Back Wall. F (IN.)	Over All Length of Setting. G (FT)	G (IN.)	Height of Dutch Oven. H (FT)	H (IN)	Floor Line to Top of Grates. I (IN.)	Height of Fire Box. J (IN.)	Floor to Boiler Shell. K (FT.)	K (IN.)	Distance Between Bridge Walls. L (FT.)	L (IN.)	Boiler Centers. M (FT.)	M (IN.)	Width of Setting. N (FT.)	N (IN)	Radius of Arch. O (IN)	Width of Furnace at Grates. P (IN)	Thickness of Side Wall at Grates. Q (IN)	Height of Side Walls. R (FT.)	R (IN)	Common Brick Above Grade.	Fire Brick.	Width of Setting for One Boiler. (FT.)	(IN.)
54 x 14	14	5	7	20	24	24	5	6	7	Standard height, 20" Special height, 24"	42	6	11	4	0	7	6	16	8	49	55	27½	10	4	30000	6400	9	2
54 x 16	14	5	7	24	24	26	9	6	7		42	6	11	4	6	7	6	16	8	49	55	27½	10	4	32600	6800	9	2
60 x 16	15	5	6	24	24	26	9	6	9		44	7	1	4	6	8	0	17	8	55	61	27½	10	10	34500	7400	9	8
60 x 18	15	5	6	24	24	28	9	6	9		44	7	1	5	0	8	0	17	8	55	61	27½	10	10	36700	7800	9	8
66 x 16	16	5	5	24	24	26	9	6	10		45	7	2	4	6	8	6	18	8	61	67	27½	11	3	37000	8000	10	2
66 x 18	16	5	5	24	24	28	9	6	10		45	7	2	5	0	8	6	18	8	61	67	27½	11	3	38500	8200	10	2
72 x 16	17	5	4	24	24	26	9	7	0		47	7	4	4	6	9	0	19	8	67	73	27½	11	8	39000	8400	10	8
72 x 18	17	5	4	24	24	28	9	7	0		47	7	4	5	0	9	0	19	8	67	73	27½	11	8	41000	8800	10	8
72 x 20	17	5	4	24	24	30	9	7	0		47	7	4	6	0	9	0	19	8	67	73	27½	11	8	43000	9200	10	8
78 x 18	18	5	3	24	24	28	9	7	1		48	7	5	5	0	9	6	20	8	73	79	27½	12	0	42000	9000	11	2
78 x 20	18	5	3	24	24	30	9	7	1		48	7	5	6	0	9	6	20	8	73	79	27½	12	0	44200	9400	11	2

Where it is desired to set two boilers in a battery without any intervening wall, it is advisable to build the furnace in two parts. The width of the combined furnaces is too great for a single arch to be practicable.

When boilers are set with walls between them, these dividing walls should be 22 inches thick for boilers 48 inches in diameter and smaller and 28 inches thick for boilers 54 inches in diameter and larger.

Settings with Steel Casings.—In order to reduce the losses in efficiency that exists in all brick boiler settings and to eliminate expensive repairs without increasing the original cost, the steel casing type of setting as shown in figs. 4,599 and 4,600 has been designed. This consists of a sheet steel casing which entirely surrounds the brick work. It is lined with a heavy layer of insulating material, inside of which there is one course of red and one of firebrick in the combustion chamber and two courses of firebrick in the fire box. This casing is put together and stiffened with steel angles which insure a rigid construction and prevent any possibility of warping. It is also bolted to the steel "I" beam columns which support the boiler.



FIGS. 4,599 and 4,600.—Chandler and Taylor steel or steam boat casing setting.

The casing is set up and fitted in the manufacturer's shops and shipped in knocked down form so that it is a simple matter for anyone to reassemble it wherever it is to be installed.

CHAPTER 77

CHIMNEYS AND STACKS

The object of a chimney is to create a draught and to carry off the waste products of combustion.

The *force required* to produce the draught depends upon the quality of the fuel, the method of firing, thickness of the fuel bed, design of the furnace, length and cross section of the gas passages, height and construction of the chimney and its location with respect to neighboring buildings, hills; also the direction and velocity of the wind which may be blowing.

The *force available* for producing the draught depends upon

1. The height and cross section of the chimney.
2. The difference in temperature between the hot gases in the chimney and the cold air outside.

Ques. Why does a chimney draw?

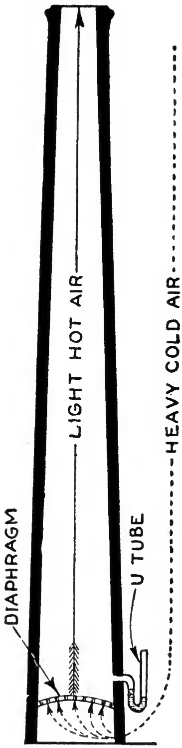
Ans. It draws because the hot air in the chimney is lighter than the surrounding cold atmosphere, which endeavors to force its way into the chimney from below in order to restore the balance of pressure.

Ques. How does air enter a chimney?

Ans. 1, through the grate bars (*primary* air supply); 2, sometimes through special inlet passages between the furnace and the heating surface (*secondary* air supply), and 3, through leaks in the setting, if there be any.

Ques. How does the intensity of the draught vary?

Ans. About as the square root of the height.



Ques. Upon what does the required intensity of draught depend?

Ans. Upon the character of the fuel and desired rate of combustion.

It is least for wood and greatest for the fine low grade of fuel.

Draught Calculation.—The term *draught* may be defined as *the difference in pressure available for producing a flow of the gases of combustion*.

Prof. Peabody explains the action of gases in a drawing, very clearly, as shown in fig. 4,601.

If the gases within a stack be heated, each cubic foot will expand, and the weight of the expanded gas per cubic foot will be less than that of a cubic foot of the cold air outside the chimney. Therefore, the unit pressure at the stack base due to the weight of the column of heated gas will be

FIG. 4,601.—Action of hot gases in a chimney; cause of draught.—"To get an idea of the production of draught by a chimney, we may consider the conditions that would exist if a chimney were filled with hot air and closed at the bottom by a horizontal partition or diaphragm. The pressure of the air at the top of the chimney, due to the atmosphere above that level, is the same on the gases inside the chimney and the air outside. The pressure on the diaphragm at the bottom is the sum of the pressure at the top of the chimney and of the pressure due to the column of hot air in the chimney. At the under side of the diaphragm the pressure will be that at the top of the chimney plus the pressure due to a column of cold air as high as the chimney. This difference of pressure is considered to be the draught, in all theories of the chimney. It may be readily calculated for an assumed set of conditions. For an actual chimney the draught or difference of pressure inside and outside the chimney may be shown by a U tube partially filled with water, and having one end connected to the inside of the chimney and the other open to the air. The water rises in the leg connected with the inside of the chimney; the difference of level measures the draught."—*Peabody*.

less than that due to a column of cold air. This difference in pressure, like the difference in head of water, will cause a flow of the gases into the base of the stack. In its passage to the stack the cold air must pass through the furnace or furnaces of the boilers connected to it, and it in turn becomes heated. This newly heated gas will also rise in the stack and the action will be continuous.

The intensity of the draught, or difference in pressure, is usually measured in inches of water. Assuming an atmospheric temperature of 62° Fahr. and the temperature of the gases in the chimney as 500° Fahr. and, neglecting for the moment the difference in density between the chimney gases and the air, the difference between the weights of the external air and the internal flue gases per cubic foot is .0347 pound, obtained as follows:

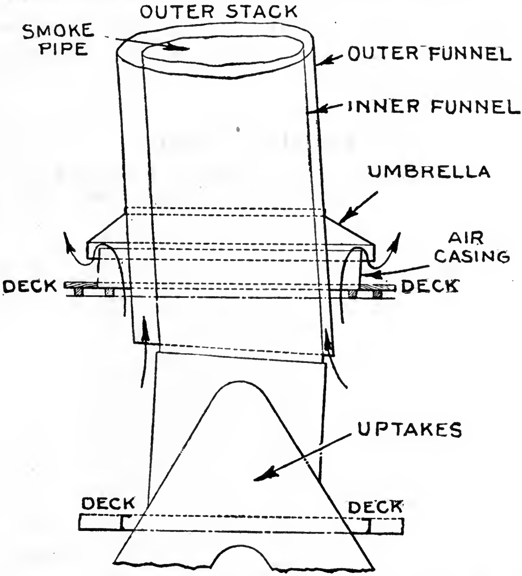


FIG. 4,602.—Marine funnel or stack. ***It is made*** of sheet metal riveted and in best practice there is an inner and outer funnel with air space between. This tends to prevent loss of heat by radiation keeping the temperature of the gases as high as possible. Around the base of the stack is fitted an additional air screen or passage, known as the *air casing*, which serves to ventilate the fire room and protect the neighboring part of the ship from the heat radiated by the funnel. The air casing is protected from the weather by a sloping ring of metal attached to the funnel and known as the *umbrella*.

Weight of a cubic foot of air at 62° = .0761 pound
Weight of a cubic foot of air at 500° = .0414 pound
Difference = .0347 pound

Therefore, a chimney 100 feet high, assumed for the purpose of illustration, would have a pressure exerted on each square foot of its cross sectional area at its base of .0347 × 100 = 3.47 pounds.*

* NOTE.—In this calculation, no allowance has been made for the compression of air in the lower layers due to the pressure caused by the weight of the upper layers, because the same thing happens both inside and outside of the stack and accordingly for simplicity may be disregarded.

As a cubic foot of water at 62° weighs 63.32 pounds, an inch of water would exert a pressure of 62.32 ÷ 12 = 5.193 pounds per square foot. The 100-foot stack would, therefore, under the above temperature conditions, show a draught of 3.47 ÷ 5.193 or approximately .67 inches of water.

The theoretical formulæ deducted by Peclet, Rankine, and later by Professor Gale and others, are of much interest to the scientist, but the engineer in designing a chimney still clings to empirical formulæ deducted from current successful practice.

The following table for Babcock and Wilcox's gives the available draught in inches that a stack 100 feet high will produce when serving boilers of various horse powers with the methods of calculations for other heights.

Available Draught for 100 Foot Stacks

Assuming stack temperature of 500° Fahr. and 100 lbs. of gas per *h.p.*
For other heights of stack multiply draught by height ÷ 100

Horse Power	Diameter of Stack in Inches														
	36	42	4S	64	60	66	72	78	84	90	96	102	108	114	120
100	.64														
200	.55	62													
300	.41	55	.61												
400	.21	.46	.56	.61											
500		.34	.50	.57	.61										
600		.19	.42	.53	.59										
700			.34	48	.56	.60	.63								
800			.23	.43	.52	.58	.61	.63							
900				.36	.49	.56	.60	.62	.64						
1000				.29	.45	.53	.58	.61	.63	.64					
1100					.40	.50	.56	.60	.62	.63	.64				
1200					.35	.47	.54	.58	.61	.63	.64	.65			
1300					.29	.44	.52	.57	.60	.62	.63	.64	.65		
1400						.40	.49	.55	.59	.61	.63	.64	.65	.65	
1500						.36	.47	.53	.58	.60	.62	.63	.64	.65	.65
1600						.31	.43	.52	.56	.59	.62	.63	.64	.65	.65
1700							.41	.50	.55	.58	.61	.62	.64	.64	.65
1800							.37	.47	.54	.57	.60	.62	.63	.64	.65
1900							.34	.45	.52	.56	.59	.61	.63	.64	.64
2000								.43	.50	.55	.59	.61	62	.63	.64
2100								.40	.49	.54	.58	.60	.62	.63	.64
2200								.38	.47	.53	.57	.59	.61	.62	.64
2300								.35	.45	.52	.56	.59	.61	.62	.63
2400								.32	.43	.50	.55	.58	.60	.62	.63
2500									.41	.49	.54	.57	.60	.61	.63

Horse Power	Diameter of Stack in Inches							
	90	96	102	108	114	120	132	144
2600	.47	.53	.56	.59	.61	.62	.64	.65
2700	.45	.52	.55	.58	.60	.62	.64	65
2800	.44	.50	.55	.58	.60	.61	.64	.65
2900	.42	.49	.54	.57	.59	61	.63	.65
3000	.40	.48	.53	.56	.59	.61	.63	.64
3100	.38	.47	.52	.56	.58	.60	.63	.64
3200		.45	5?	.5	.58	.60	.63	.64
3300		.44	.50	.54	.57	.59	.62	.64
3400		.42	.49	.53	.56	.59	.62	.64
3500		40	.48	.52	.56	58	.62	.64
3600			.47	.52	.55	.58	.61	.63
3700			.45	.51	55	.57	.61	.63
3800			.44	.50	.54	.57	.61	.63
3900			.43	.49	.53	.56	.60	.63
4000			.42	.48	.52	.56	.60	.62
4100			.40	47	.52	.55	.60	.62
4200			.39	.46	.51	.55	.59	.62
4300				.45	50	.54	.59	.62
4400				.44	.49	.53	.59	.62
4500				.43	.49	.53	.58	.61
4600				.42	.48	.52	.58	.61
4700				.41	.47	.51	.57	.61
4800				.40	.46	51	.57	.60
4900					.45	.50	57	.60
5000					.44	.49	.56	.60

FOR OTHER STACK TEMPERATURES ADD OR DEDUCT BEFORE MULTIPLYING BY HEIGHT ÷ 100 AS FOLLOWS*

For 750 Degrees F. Add .17 inch.	For 650 Degrees F. Add .11 inch.	For 550 Degrees F. Add .04 inch.	For 400 Degrees F. Deduct .09 inch.
For 700 Degrees F. Add .14 inch.	For 600 Degrees F. Add .08 inch.	For 450 Degrees F. Deduct .04 inch.	For 350 Degrees F. Deduct .14 inch.

*Results secured by this method will be approximately correct.

Draught (***Rust Engineering Co.***).—Chimneys are required for two purposes: 1, to carry away gases; 2, to produce draught.

The first requires the size or area and the second, the height. The height and diameter of a chimney depend upon the following: 1, amount of fuel burned; 2, nature of fuel burned; 3, kind of boiler used; 4, design of flue; 5, arrangement of flue with respect to boilers; 6, use of accessories; 7, altitude of plant above sea level.

It is impossible to develop a formula which will take all the above into consideration. The usual practice of determining the proper proportions of chimneys is to compute the greatest sectional area necessary to carry away gases without undue frictional loss and determine the height of shaft necessary to produce the draft required by the installation.

The diameter of a chimney is dependent upon the horse power of the boilers; and the height upon the draught required. One formula determining the diameter of a chimney is:

$$\text{diameter} = 4.9 \times (\text{boiler horse power})^{2/5}$$

In installations where stokers are used, the area is usually increased about one-third; this allows for leakages, improper operating conditions, etc.

Draught is the difference in pressure per unit of area between a column of hot gas inside the chimney and an equivalent column of air on the outside. When gases are heated they expand; and therefore, the weight of the heated gas per cubic foot, at the base of the chimney, will be less than that of an equivalent volume of cold outside air. The difference in pressure, due to this difference in weight, forces the cold air into the furnace, where it is heated, and passes up the chimney. The action thus becomes continuous.

The intensity of draught or the difference in pressure is measured in inches of water and may vary from 0 inch to 2 inches or more. Intensity of draught is given by the following formula:

$$f = .518\ H \times P \times \left(\frac{1}{T_o}\ \frac{1}{T_c}\right)$$

f = draught in inches of water
H = height of chimney in feet
P = atmospheric pressure in pounds per square inch
T_o = absolute temperature of outside air
T_c = absolute temperature of gases inside chimney

To facilitate the use of this formula it is assumed that P = atmospheric pressure at sea level or 14.7 pounds pressure per square inch. The absolute temperature of the outside air = 520 degrees Fahr.

The formula then reduces to

$$f = H \times .518 \times 14.7 \times \left(\frac{1}{520} - \frac{1}{T_c}\right)$$

from which

$$f = K \times H$$

$$\text{Where } K = .518 \times 14.7 \times \left(\frac{1}{520} - \frac{1}{T_c}\right)$$

The following table gives values for K for different chimney temperatures:

Temperature Constants

Temp. gases inside chimney	Constant	Temp. gases inside chimney	Constant
350	.0053	700	.0081
400	.0058	750	.0084
450	.0063	800	.0086
500	.0067	850	.0088
550	.0071	900	.0091
600	.0075	950	.0093
650	.0078	1,000	.0094

The intensity of draught, as determined by the above formula, is a theoretical value which can never be observed with a recording device. However, by approximating ideal condition, that is, closing the ash pit doors of the boiler and in other ways preventing leakage, the draught at the base of the chimney will be approximately the same as the theoretical draught. The actual draught represents the pressure necessary to force the gases through during the most adverse conditions.

Loss of Draught

The losses in draught may be summarized as follows: 1, through furnace or fuel bed; 2, through boiler; 3, through flues; 4, through turns in flues; 5, through economizers; 6, due to velocity; 7, due to friction.

Loss of Draught Through Furnace or Fuel Bed.—This loss varies greatly. If the particles of fuel be large, it requires less draught to complete combustion than when the particles of fuel are small. For instance, in the case of soft coal, particles of which are comparatively large, much less draught is required to force the air through spaces between the coal than in the case of anthracite coal whose particles are small.

The following represents the draught required to force air through the fuel bed for different kinds of coal, assuming 25 pounds of coal burned per square foot of grate surface per hour.

Anthracite and bituminous slack...........	.6 to .7 inches
Pennsylvania bituminous..................	.3 to .4 "
Indiana bituminous.......................	.2 to .3 "

Loss of Draught Through Boilers.—This depends upon the type of boiler and also the method of baffling. The loss also depends upon the percentage of rating upon which it is run. Under average conditions the loss of draught through the boiler is equal to from .25 inch to .30 inch when the boiler is running at a normal rate or 100 per cent.; .30 inch to .35 inch at 150 per cent.; .65 inch to .75 inch at 200 per cent. of its rated capacity.

Loss of Draught Through Flues.—The loss of draught through flues is usually determined by experiment. For average conditions we may assume that the loss of draught through an unlined steel flue is equal to .10 inch per 100 lineal feet of flue and for brick lined or masonry flues .10 inch per 50 lineal feet of flue.

Loss of Draught Through Turns in Fues.—This may be taken as equal to .05 inch for each right angle turn through which the gases pass.

Loss of Draught Through Economizer.—This varies between wide limits but for ordinary purposes we may assume that the loss is .1 inch to .25 inch.

Available Draught.—The available draught is equal to the theoretical draught less the amount lost by velocity and friction within the chimney itself. Through experiment it has been found that under average conditions the available draught is equal to 80 per cent. of the theoretical draught, hence,

$$f = .8K \times H$$

where f equals available draught in inches of water.

The available draught should always be at least equal to or greater than the sum of the losses through the fuel bed, boilers, flues, turns and economizers.

Height of Chimney.—This dimension is equal to

$$H = \frac{f}{.8K}.$$

The height of a chimney then is found by determining the losses through the fuel beds, boilers, flues, turns, and economizers, and dividing this sum by .8 of the constant for the temperature of the gases inside the chimney.

Diameter of Chimneys.—The diameter of a chimney varies directly as the square root of the horse power of the boilers and inversely as the fourth root of the height.

$$H.P. = 3.33 \times E \times \sqrt{H}$$

$$\text{Whence } E = \frac{H.P.}{3.33\sqrt{H}}.$$

$$\text{and } D = \frac{\sqrt{H.P.}}{1.62\sqrt[4]{H}} + .33$$

where D = actual inside diameter in feet.—*Rust Engineering Co.*

NOTE.—***Chimneys with Forced Draught.*** When natural, or chimney, draught only is used, the function of the chimney is, to produce such a difference of pressure or intensity of draught, between the bottom of the chimney and the ash pit as will cause the flow of the required quantity of air through the grate bars and the fuel bed, and the flow of the gases of combustion through the gas passages, the damper and the breachings and 2, to convey the gases above the tops of surrounding buildings and to such a height that will not become a nuisance. With forced draught the blower produces the difference of pressure, and the only use of the chimney is that of conveying the gases to a place where they will cause no inconvenience; and in that case the height of the chimney may be much less than that of a chimney for natural draught. With oil or natural gas for fuel, the resistance of the grates and of the fuel bed is illiminated, and the height of the chimney may be much less than that of one desired for coal firing. When oil or gas is substituted for coal, and the chimney is a high one, it may be necessary to restrict its draught power by a damper or other means in order to prevent its creating too great a negative pressure in the furnace, and thereby too great an admission of air. which will cause a decrease in efficiency.—*Kent.*

Size of Chimneys.—The following table shows the height of water column due to unbalanced pressure or draught in a chimney 100 feet high for various temperatures inside and outside of the chimney.

The table which follows is a modification of Kents' table and is calculated from his formula. It is in convenient form for approximate work, and provided no unusual conditions are encountered, it is reliable for the ordinary rates of combustion with bituminous coals.

Draught for Various Chimney Temperatures.
(In fractional inches of water)

Temperature in the Chimney	Temperature of the External Air—Barometer, 14.7 Pounds per Square Inch										
	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°
200	.453	.419	.384	.353	.321	.292	.263	.234	.209	.182	.157
220	.488	.453	.419	.38	.355	.326	.298	.269	.244	.217	.192
240	.520	.488	.451	.421	.388	.359	.330	.301	.276	.250	.225
260	.555	.528	.484	.453	.420	.392	.363	.334	.309	.282	.257
280	.584	.549	.515	.482	.451	.422	.394	.365	.340	.313	.288
300	.611	.576	.541	.511	.478	.449	.420	.392	.367	.340	.315
320	.637	.603	.568	.538	.505	.476	.447	.419	.394	.367	.342
340	.662	.638	.593	.563	.530	.501	.472	.443	.419	.392	.367
360	.687	.653	.618	.588	.555	.526	.497	.468	.444	.417	.392
380	.710	.676	.641	.611	.578	.549	.520	.492	.467	.440	.415
400	.732	.697	.662	.632	.598	.570	.541	.513	.488	.461	.436
420	.753	.718	.684	.653	.620	.591	.563	.534	.509	.482	.457
440	.774	.739	.705	.674	.641	.612	.584	.555	.530	.503	.478
460	.793	.758	.724	.694	.660	.632	.603	.574	.549	.522	.497
480	.810	.776	.741	.710	.678	.649	.620	.591	.566	.540	.515
500	.829	.791	.760	.730	.607	.660	.630	.610	.586	.559	.534

The table is figured on a consumption of 5 pounds of coal burned per hour per boiler horse power developed, this figure giving a fairly liberal allowance for the use of poor coal and for a reasonable overload. When the coal used is a low grade bituminous of the Middle or Western States, it is strongly recommended that these sizes be increased materially, such an increase being from 25 to 60 per cent., depending upon the nature of the coal and the capacity desired. For the coal burned per hour for any size stack given in the table, the values should be multiplied by 5.

A convenient rule for large stacks, 200 feet high and over, is to provide 30 square feet of cross sectional area per 1,000 rated horse power.

Stack Sizes by Kents Formula

(Assuming 5 lbs. of coal per horse power)

Diameter Inches	Area Square Feet	Height of Stack in Feet — Commercial Horse Power: 50	60	70	80	90	100	110	125	150	175	Side of Equivalent Square Stack Inches	Diameter Inches
33	5.94	106	115	125	133	141	149	. .	. .	. .	. .	30	33
36	7.07	129	141	152	163	173	182	. .	. .	. .	. .	32	36
39	8.30	155	169	183	196	208	219	229	245	. .	. .	35	39
42	9.62	183	200	216	231	245	258	271	289	316	. .	38	42
48	12.57	246	269	290	311	330	348	365	389	426	460	43	48
54	15.90	318	348	376	402	427	449	472	503	551	595	48	54
60	19.64	400	437	473	505	536	565	593	632	692	748	54	60
66	23.76	490	537	580	620	658	694	728	776	849	918	59	66
72	28.27	591	646	698	747	792	835	876	934	1023	1105	64	72
78	33.18	700	766	828	885	939	990	1038	1107	1212	1310	70	78
84	38.48	818	896	968	1035	1098	1157	1214	1294	1418	1531	75	84

Diameter Inches	Area Square Feet	Height of Stack in Feet — Commercial Horse Power: 100	110	125	150	175	200	225	250	Side of Equivalent Square Stack Inches	Diameter Inches
90	44.18	1338	1403	1496	1639	1770	1893	2008	2116	80	90
96	50.27	1532	1606	1713	1876	2027	2167	2298	2423	86	96
102	56.75	1739	1824	1944	2130	2300	2459	2609	2750	91	102
108	63.62	1959	2054	2190	2392	2592	2770	2939	3098	98	108
114	70.88	2192	2299	2451	2685	2900	3100	3288	3466	101	114
120	78.54	2438	2557	2726	2986	3226	3448	3657	3855	107	120
126	86.59	2697	2829	3016	3303	3568	3814	4046	4265	112	126
132	95.03	2970	3114	3321	3637	3929	4200	4455	4696	117	132
144	113.10	3554	3726	3973	4352	4701	5026	5331	5618	128	144
156	132.73	4190	4393	4684	5131	5542	5925	6285	6624	138	156
168	153.94	4878	5115	5454	5974	6454	6899	7318	7713	150	168

In the above table the following formula is used: $H.P. = 3.3\,(A - .6\sqrt{\ })\sqrt{H}$, in which A = area in sq. ft. and H = height in feet. For pounds of coal burned per hour for any given size of chimney, multiply the figures in the table by 5.

Calculation of Chimney for Battery of 5,000 Horse Power Boilers.—The following calculation is submitted by the Heine Chimney Co. In order to determine the size of chimney to handle any given horse power, it is first necessary to determine the volume of gas to be handled. The volume of flue gas is dependent upon the combustible matter of the fuel, the non-combustible matter being taken out of the furnace in the form of ashes. Assuming the following:

1	pound of combustible	14,500 *B.t.u.*
24	pounds of flue gas generated per pound of combustible (100% excess air)	
1	pound of flue gas at mean stack temperature	25 cu. ft. gas
	Efficiency of boilers (assumed)	60%

33,000 *B.t.u.* assumed as horse power equivalent

we may express the number of cubic feet of gases discharged per second per horse power hour as follows:

$$\frac{33{,}000 \times 24 \times 25}{14{,}500 \times .60 \times 3{,}600} = .635$$

The velocity of the gases may then be expressed as follows:

$$V = \frac{4 \times .635 \times HP}{D^2 \times \pi} = \frac{.81 \times HP}{D^2}$$

when

V = Velocity in feet per second
D = Diameter in feet
HP = Horse power

In the case herein specified, the number of horse power to be developed is—5,000.

Arbitrarily we assumed

$$D = 12'\ 0''$$

Substituting these values in the velocity formula, we have

$$V = \frac{.81 \times 5{,}000}{12^2} = 28.20 \text{ feet per second}$$

The draught losses in the chimney are made up of three items

First, the head, or pressure, required to maintain the velocity of discharge;

Second, the head, or pressure, required to overcome the friction of the walls;

Third, the head, or pressure, required to overcome the velocity head loss due to the right angle intake bend.

Combining the formulæ which may be deduced from these various losses, we find that the total losses in the chimney amount to

$$.00051—V^2$$

This formula is based on the assumption of the following:

atmospheric pressure..................	14.7 pounds
atmospheric temperature..............	60 degrees F.
mean stack temperature..............	500 degrees F.
density of chimney gases compared with air..............................	1.04

Losses in the breeching are generally assumed as being equal to .001 per foot in length, this being based on a rule which gives very good results.

Right angle bend losses are usually assumed as one-third of the stack loss per bend.

A loss of .25 through Stirling type boilers is a good conservative figure which we will assume in these calculations. (Boiler losses vary somewhat, being least with a tubular and highest with a Babcock baffling.)

For hand fired boilers, a draught of .2 in. over the fire is usually advocated. Should you figure on using stokers, a draught of at least 35 in. over the fires is usually called for by the stoker people.

Applying the above losses to the conditions, we derive the following:

Stack losses .00051 V^2	.423
Breeching losses (say)	.1
Two bend losses	.1
Boiler losses (Babcock baffling)	.3
Fire losses (stokers)	.35
	1.273

The above figures indicate the amount of draught necessary in each instance in addition to the furnace draught that is required to maintain the given rate of combustion.

The draught due to one foot of height when the gases have a temperature of 500 degrees F., with atmospheric temperatures at 60 degrees F., is .0064 inch of water. The height of the chimney required to produce the above draught is, therefore,

$$\frac{1.273}{.0064} = 200 \text{ feet}$$

We have in the above instances, assumed figures which we believe, will check closely with general conditions. They were made upon the assumption that the stack would be placed at the end of the battery of boilers and that the breeching would have a straight run over the boilers into the stack without any additional turns.—*Heine Chimney Co.*

Size of Chimneys (*Kent*).—The effective area of a chimney for a given power requirement varies inversely as the square root of the height. The actual area, in practice, should be greater, because of retardation of velocity due to friction against the

Size of Chimneys for Steam Boilers

Diameter Inches	Area Sq. Feet	Effective Area	HEIGHT OF CHIMNEY — COMMERCIAL HORSE POWER OF BOILER: 50 ft.	60 ft.	70 ft.	80 ft.	90 ft.	100 ft.	110 ft.	125 ft.	150 ft.	175 ft.	200 ft.	225 ft.	250 ft.	275 ft.	300 ft.	Equiv't Square Ch'n'y Side of Square
24	3.14	2.08	49	54	58	62	66											22
27	3.98	2.78	65	72	78	83	88											24
30	4.91	3.58	84	92	100	107	113	119										27
33	5.94	4.48		115	125	133	141	149	156									30
36	7.07	5.47		141	152	163	173	182	191	201								32
39	8.30	6.57			183	196	208	219	229	245								35
42	9.62	7.76			216	231	245	258	271	289	316							38
48	12.57	10.44				311	330	348	365	389	426							43
54	15.90	13.51					427	449	472	503	551	595						48
60	19.64	16.98					536	565	593	632	692	748						54
66	23.76	20.83						694	728	776	849	918	981					59
72	28.27	25.08						835	876	934	1023	1105	1181	1253				64
78	33.18	29.73							1038	1107	1212	1310	1400	1485	1565			70
84	38.48	34.76							1214	1294	1418	1531	1637	1736	1830	1919	2005	75
90	44.18	40.19								1496	1639	1770	1893	2008	2116	2219	2318	80
96	50.27	46.01								1713	1876	2027	2167	2298	2423	2541	2654	86
102	56.75	52.23								1944	2130	2300	2459	2609	2750	2884	3012	91
108	63.62	58.83								2190	2392	2592	2770	2939	3098	3249	3393	96
114	70.88	65.83									2685	2900	3100	3288	3466	3635	3797	101
120	78.54	73.22									2986	3226	3148	3657	3855	4043	4223	107
132	95.03	89.18									3637	3929	4200	4455	4696	4925	5144	117
144	113.10	106.72									4352	4701	5026	5331	5618	5893	6155	128
156	132.73	125.82										5542	5925	6285	6624	6948	7256	138
168	153.94	146.50										6454	6899	7318	7713	8090	8449	149
180	176.71	168.74										7433	7946	8429	8884	9318	9732	160
192	201.06	192.56											9068	9619	10138	10633	11105	170
204	226.98	217.94											10263	10885	11475	12035	12569	181
216	251.47	244.90												12233	12894	13523	14123	191
228	283.53	273.53													14396	15099	15768	202
240	314.16	303.53														16761	17505	213

5

For pounds of coal burned per hour for any given size of chimney, multiply the figures in the table by 5.

walls. On the basis that this friction is equivalent to a layer of dead air 2 inches thick over the whole interior surface, and that a commercial boiler horse power requires the combustion of an average of 5 pounds of coal per hour, we have the following formulæ:

$$E = A - 0.6\sqrt{A} \qquad d = 13.54\sqrt{E} + 4''$$

$$H.P. = 3.33\,E\sqrt{H} \qquad H = \left\{\frac{0.3\,H.P.}{E}\right\}^2$$

in which H.P. = horse power; H = height of chimney in feet; E = effective area and A = actual area in square feet; d = diameter of chimney in inches. The constant, 3.33, is an average value obtained by plotting the results obtained from numerous examples in practice.

The table of chimney sizes on page 2,598, was calculated by means of the formulæ just given.

It should be noted that the figures in the table correspond to a coal consumption of 5 pounds of coal per horse power per hour. This liberal allowance is made to cover the contingencies of poor coal being used, and of the boilers being driven beyond their rated capacity. In large plants, with economical boilers and engines, good fuel and other favorable conditions which will reduce the maximum rate of coal consumption at any one time to less than 5 pounds per horse power per hour, the figures in the table may be multiplied by the ratio of 5 to the maximum expected coal consumption per horse power per hour. Thus, with conditions which make the maximum coal consumption only 2.5 pounds per horse power per hour, the chimney 300 feet high × 12 feet diameter should be sufficient for 6,155 × 2 = 12,310 horse power. (See table.)

In this connection, however, it should be observed that fuels, temperatures, flues, type of boilers, economizers, and other accessories, may have a very decided influence on the proper size.

Chimneys for Oil Fuel.—The chimney requirements when oil fuel is used are very different from those for coal. Considerably less draught is required for oil fuel, but this is somewhat offset by the lower temperature of the gases entering the chimney.

Since the volume cf gases for an oil fired boiler is less than with coal, less chimney area is required, the necessary area may be taken as approximately 60% of that for coal.

In designing chimneys for oil fuel excessive draught must be avoided.

The reason for this is that, aside from a slight decrease in temperature at reduced loads, the tendency, due to careless firing, is toward a constant

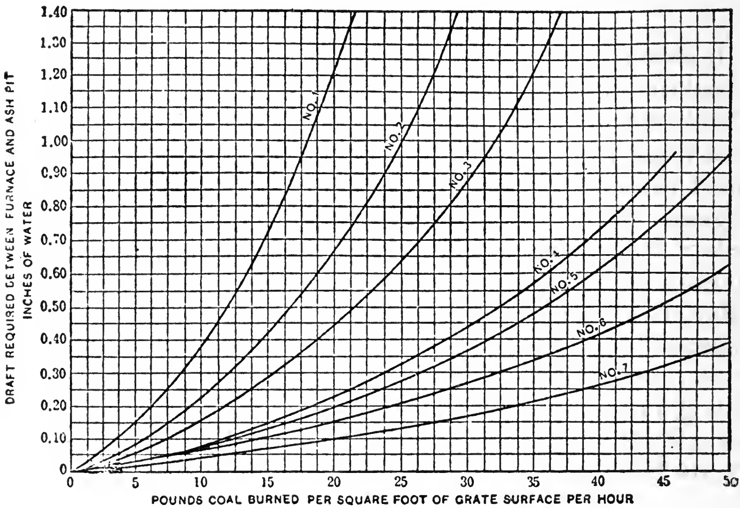


FIG. 4,603.—Curves showing relation between lbs. of coal burned per sq. ft. of grate surface per hour and draught required between furnace and ash pit.

gas flow through the boiler regardless of the rate of operation, with the corresponding increase of excess air at light loads. With excessive stack height, economical operation at varying loads is almost impossible with hand control.

With automatic control, however, where stacks are necessarily high to take care of known peaks, under lighter loads, this economical operation becomes less difficult. For this reason the question of designing a stack for a plant where the load is known to be nearly constant is easier than for a plant where the load will vary over a wide range. While great care must be taken to avoid excessive draught, still more care must be taken to assure a draught suction within all parts of the setting under any and all conditions of operation.

It is very easily possible to more than offset the economy gained through low draught, by the losses due to setting deterioration, resulting from such lack of suction. Under conditions where the suction is not sufficient to carry off the products of combustion, the action of the heat on the setting brick work will cause its rapid failure.

The table which follows gives chimney sizes and horse power, which they will serve for oil fuel. The table is, in modified form, one calculated by Weymouth, being the result of exhaustive study of data pertaining to the subject and will ordinarily give satisfactory results.

Stack Sizes for Oil Fuel

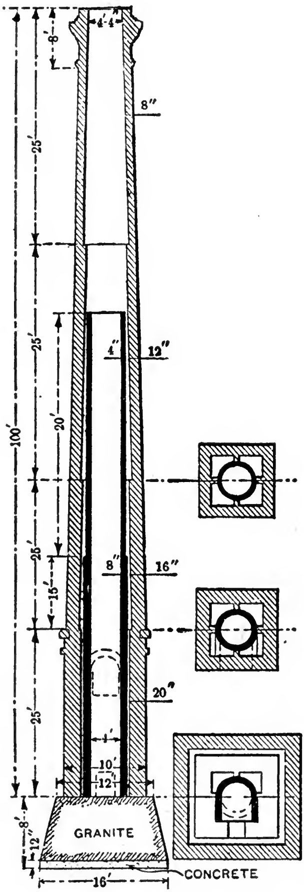
(Adapted from C. R. Weymouth's table, *Trans. A.S.M.E., Vol. 34*).

Diameter Inches	Height in Feet Above Boiler Room Floor					
	80	90	100	120	140	160
33	161	206	233	270	306	315
36	208	253	295	331	363	387
39	251	303	343	399	488	467
42	295	359	403	474	521	557
48	399	486	551	645	713	760
54	519	634	720	847	933	1000
60	657	800	913	1073	1193	1280
66	813	993	1133	1333	1480	1593
72	980	1206	1373	1620	1807	1940
84	1373	1587	1933	2293	2560	2767
96	1833	2260	2587	3087	3453	3740
108	2367	2920	3347	4000	4483	4867
120	3060	3660	4207	5040	5660	6160

Figures represent nominal rated horse power. Sizes as given good for 50 per cent overloads.

Based on centrally located stacks, short direct flues and ordinary operating efficiencies.

Chimney Construction.—The materials used are commonly brick, concrete, and steel plate. Since the weight of the chimney must be supported on a small area, the foundation becomes an important consideration and should be built only under the direction of an experienced engineer, according to the design furnished by the chimney builder.



It must be evident that on account of the great height of a chimney as compared with its diameter any settling of the foundation will throw the chimney considerably out of plumb and render it unstable, hence great care should be taken to secure a rigid foundation.

Usually the foundation can be built cheaper by the owner than by the chimney contractor, because concrete work is going on for the boiler setting, etc., and the entire job may be done at the same time, whereas the contractor would have to secure men temporarily and have his own foreman supervise the work.

Ques. How large should a concrete foundation be made?

Ans. It should be of such size that the pressure due to the weight of the chimney will not exceed one ton per square foot.

If the ground be of stiff clay or well packed loam the load may be twice this value.

FIGS. 4,604 to 4,607.—Proportions for 100 foot chimney (not drawn to scale.)

Ques. How is the weight of a chimney computed?

Ans. It is figured on the basis of: 160 to 170 pounds per cubic foot for granite masonry; 120 to 130 pounds per cubic foot for brick work; 140 pounds per cubic foot for concrete; 150 pounds per cubic foot for reinforced concrete.

Proportions.—A common rule for brick chimneys is to

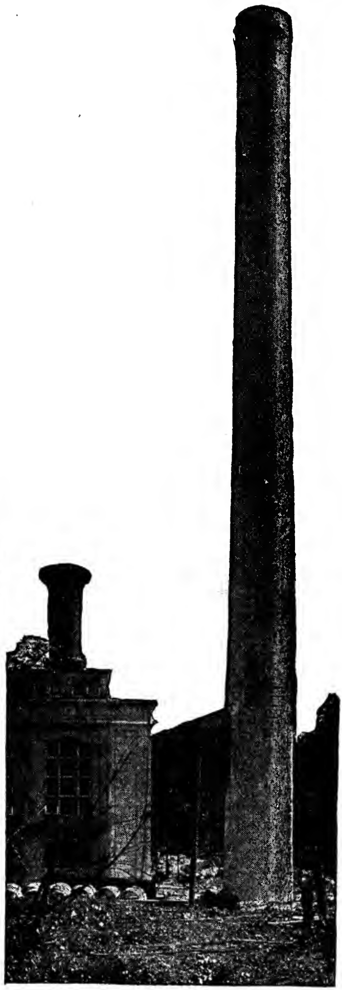
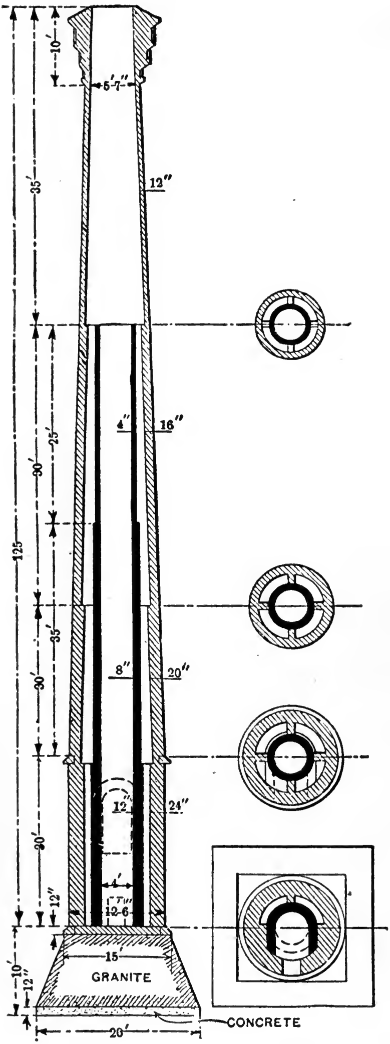


FIG. 4,608.—Heine reinforced concrete chimney in course of construction.

FIG. 4,609.—Heine reinforced concrete chimney finished.



make the diameter at the base equal to one-tenth the height. This refers to the cylindrical portion of the chimney. If octagonal, the diameter of the inscribed or inter circle of the octagon is taken as the diameter of the chimney.

The taper of the outside of a round chimney is $\frac{1}{8}$ or $\frac{3}{16}$ inch to the foot, on each side for special brick and $\frac{1}{4}$ inch for common brick. The brick work of chimneys less than 5 feet in diameter may be one brick (8 or 9 inches) in thickness for the first 25 feet from the top, increasing one-half brick (4 inches) in thickness for each 25 feet from the top downward.

If the diameter be greater than 5 feet, the top section of 25 feet should be $1\frac{1}{2}$ bricks thick, increasing as before.

For chimneys 3 feet in diameter and smaller the top section may be one-half brick in thickness.

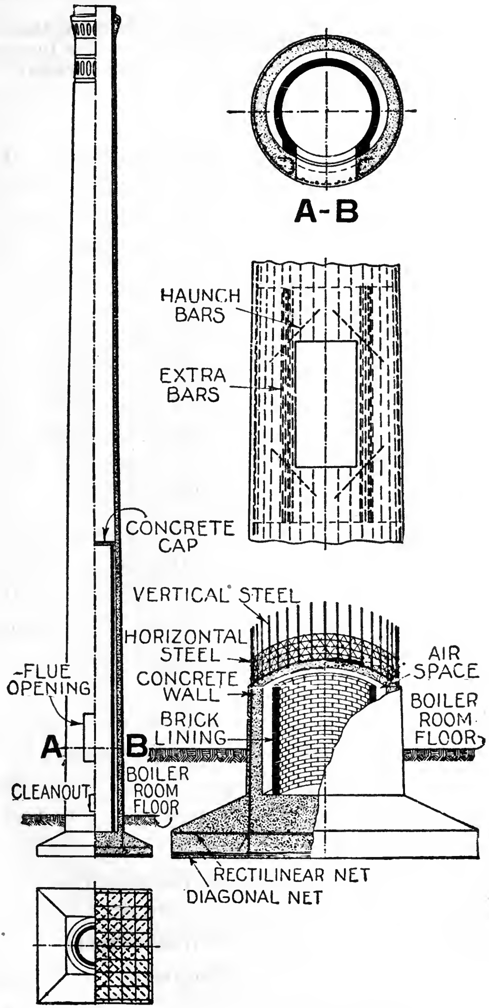
For a chimney 100 feet high the least thickness of outer shell is 16 inches at the base and for 20 feet in height, then 12 inches thick for 30 feet in height, and 8 inches thick for the remaining 50 feet.

FIGS. 4,610 to 4,614.—Proportions for 125 foot chimney (not drawn to scale.)

Chimney Lining.—The cone or lining is built separate from the shell or outer wall. It is constructed in steps each of which may be one-third the height of the chimney. For a 100 foot chimney the thickness may be 12 inches at the base, the second section 8 inches and the upper section 4 inches thick. The core usually is lined with fire brick for from 25 to 50 feet above the entrance of the smoke flue.

As a rule, for ordinary boiler work, when the temperature does not exceed 800° Fahr., the lining need not be more than $1/5$ of the chimney height.

For temperature between 800° and 1,200° the lining should be ½ of the chimney height. Some engineers prefer to extend the lining the



FIGS. 4,615 to 4,619.—Details of reinforced concrete chimney as given by General Concrete Construction Co.

full height in all cases where boilers are likely to be forced. When this is done the lining and outside walls should be independent and not tied together at the top.

Stacks.—The term *stack* means *a sheet metal chimney with, or without fire brick lining*. This construction is being extensively used when great height is required, because it avoids the enormous quantity of brick or concrete necessary for chimney, and on account of the saving in weight, massive foundations are not required and less space is occupied. Moreover a slight settling of the foundation is not followed by masonry cracks as with chimneys.

The weight of metal chimneys when lined is in most cases sufficient to withstand overburning by ordinary wind pressure, but the precaution of bolting securely to a good foundation should be taken.

High Chimneys Not Necessary.—According to Kent, chimneys above 150 feet in height are very costly, and their increased cost is rarely justified by increased efficiency. In recent practice it has become somewhat common to build two or more smaller chimneys instead of one large one, a notable example being

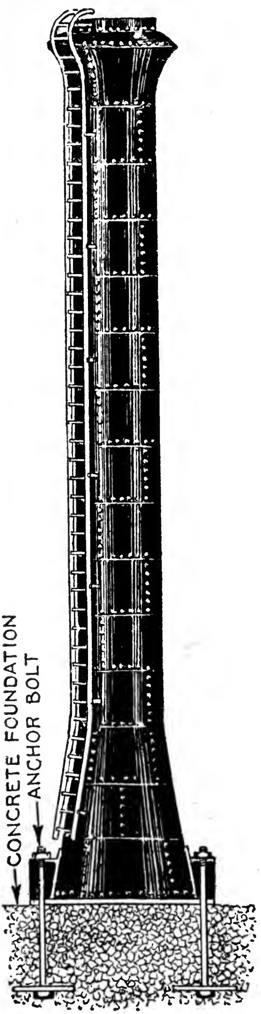
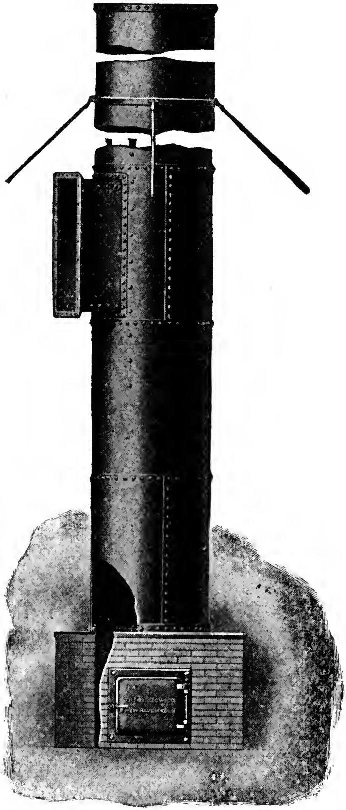


FIG. 4,620.—Typical self-supporting steel stack, showing foundation and anchor bolts.

the Spreckels sugar refinery in Philadelphia, where three separate chimneys are used for one boiler plant of 7,500 horse power the three chimneys are said to have cost several thousand



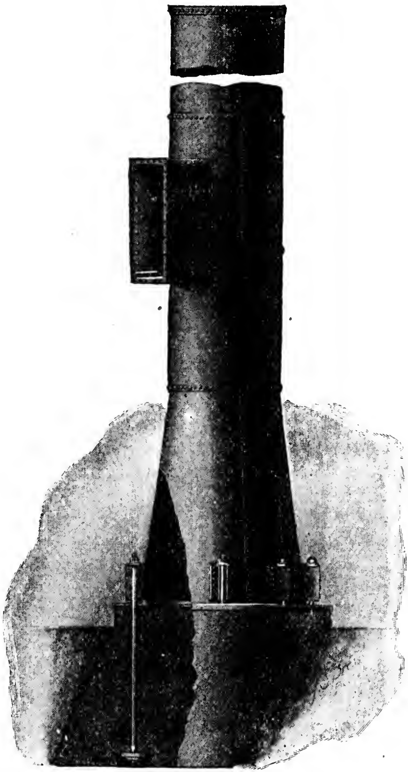


FIG. 4,621.—Bigelow guyed stack with arrangement of base recommended, showing reinforcement of the flue opening cleaning door, etc.

FIG. 4,622.—Bigelow self-sustaining stack, showing arrangement of base and anchor bolts; attachment of the lugs on the cone, also reinforcement of the smoke flue opening.

100-FOOT STACKS

Diam. of Stack	Inside Diam. of Stack at Base Plate	Diam. of Top of Foundation	Diam. of Bottom of Foundation	Depth of Foundation	No. of Foundation Bolts	Diam. of Foundation Bolts	Height of Cone	No. of Cubic Feet in Foundation
Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.		In.	Ft. In.	
4 0	6 0	8 0	12 6	6 0	8	2	8 0	519
4 6	8 0	10 0	15 0	7 0	8	2	9 0	895
5 0	8 0	10 0	15 0	7 0	8	2	10 0	895
5 6	9 0	11 0	16 0	7 0	8	2	11 0	1,040
6 0	9 0	11 0	16 6	8 0	8	2	12 0	1,240
6 6	10 0	12 0	17 6	8 0	8	2	13 0	1,415

125-FOOT STACKS

Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.		In.	Ft. In	
4 0	6 0	8 0	13 0	7 0	8	2¼	8 0	640
4 6	8 0	10 0	15 6	8 0	8	2¼	9 0	1,070
5 0	8 0	10 0	15 6	8 0	8	2¼	10 0	1,070
5 6	9 0	11 0	16 6	8 0	8	2¼	11 0	1,240
6 0	9 0	11 0	17 6	9 0	8	2¼	12 0	1,507
6 6	10 0	12 0	18 6	9 0	8	2¼	13 0	1,719
7 0	12 0	15 0	22 0	9 6	8	2¼	14 0	2,650
8 0	12 0	15 0	22 0	9 6	8	2¼	16 0	2,650
9 0	14 0	17 0	24 0	9 6	8	2¼	18 0	3,210
10 0	15 0	18 0	25 6	10 0	8	2¼	20 0	3,820

150-FOOT STACKS

Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.		In.	Ft. In.	
6 0	9 0	11 0	18 6	10 0	10	2½	12 0	1,820
6 6	10 0	12 0	19 6	10 0	10	2½	13 0	2,060
7 0	12 0	15 0	22 6	10 6	10	2½	14 0	3,000
8 0	12 0	15 0	22 6	10 6	10	2½	16 0	3,000
9 0	14 0	17 0	24 6	10 6	10	2½	18 0	3,660
10 0	15 0	18 0	26 0	11 0	10	2½	20 0	4,300

dollars less than a single chimney of their combined capacity would have cost.

Ques. What may be said of very tall chimneys?

Ans. They have been characterized by one writer as being ***monuments*** *to the folly of their builders.*

The author not only agrees with this opinion, but where the money saved can be invested at 2 per cent. or more, believes chimneys should not be built higher than the roof, utilizing mechanical means to produce draught instead of an enormous mass of brick work or concrete.

Effect of Altitude on Chimney Capacity.—To develop a given horse power requires a constant weight of chimney gas and air for combustion. Hence, as

NOTE.—The table shows sizes of most commonly used self-sustaining stacks constructed as shown in fig. 4,622.

the altitude is increased, the density is decreased and, the velocity through the furnace, the boiler passes, breeching and flues must be correspondingly greater at altitude than at sea level. The mean velocity, therefore, for a given boiler horse power and constant weight of gases will be inversely proportional to the barometric pressure and the velocity head measured in column of external air will be inversely proportional to the square of the barometric pressure.

For chimneys operating at altitude it is necessary not only to increase the height but also the diameter, as there is an added resistance within the stack due to the added friction from the additional height. This frictional loss can be compensated by a suitable increase in the diameter and when so compensated, it is evident that on the assumptions as given, the chimney height would have to be increased at a ratio inversely proportional to the square of the normal barometric pressure.

Ample accuracy is obtained by making the height merely proportional to the barometric readings and increasing the diameter so that the stacks used at high altitudes have the same frictional resistance as those used at low altitudes, although, if desired, the stack may be made somewhat higher at high altitudes than this rule calls for in order to be on the safe side.

The increase of stack diameter necessary to maintain the same friction loss is inversely as the two-fifths power of the barometric pressure.

The table on the next page gives the ratio of barometric readings of various altitudes to sea level, values for the square of this ratio and valves of the two-fifths power of this ratio.

These figures show that the altitude affects the height to a much greater extent than the diameter and that practically no increase in diameter is necessary for altitudes up to 3,000 feet.

For high altitudes the increase in chimney height necessary is, in some cases, such as to make the proportion of height to diameter impracticable. The method to be recommended in overcoming, at least partially, the great increase in height necessary at high altitudes is an increase in the grate surface of the boilers which the chimney serves, in this way reducing the combustion rate necessary to develop a given power and hence the draught required for such combustion rate.

Stacks for Wood Fuel.—The character of this kind of fuel is such that the loss of draught through the bed of the fuel will vary widely. Economy being of little importance, high stack temperatures may be expected, and after unavoidably larger quantities of excess air are supplied due to the method of firing.

Stack Capacities, Correction Factors for Altitudes

Altitude Height in Feet Above Sea Level	Normal Barometer	R Ratio Barometer Reading Sea Level to Altitude	R^2	$R^{\frac{2}{5}}$ Ratio Increase in Stack Diameter
0	30.00	1.000	1.000	1.000
1000	28.88	1.039	1.079	1.015
2000	27.80	1.079	1.064	1.030
3000	26.76	1.121	1.257	1.047
4000	25.76	1.165	1 356	1.063
5000	24.79	1.210	1.464	1.079
6000	23.87	1.257	1.580	1.096
7000	22.97	1.306	1.706	1.113
8000	22.11	1.357	1.841	1.130
9000	21.28	1.410	1.988	1.147
10000	20.49	1.464	2.144	1.165

In general, it may be stated that for this class of fuel the diameter of stacks should be at least as great as for coal fired boilers, while the height may be slightly decreased. It is far the best plan in designing a stack for boilers using wood fuel to consider each individual set of conditions that exist, rather than try to follow any general rule.

One factor not to be overlooked in stacks for wood burning is their location. The fine particles of this fuel are often carried unconsumed through the boiler, and where the stack is not on top of the boiler, these particles may accumulate in the base of the stack below the point at which the flue enters.

Where there is any air leakage through the base of such a stack, this fuel may become ignited and the stack burned. Where there is a possibility of such action taking place, it is well to line the stack with fire brick for a portion of its height.

How to Raise a Stack.—Because of the large call for stacks, the raising and lowering of these stacks has become a special trade. In order to obtain practical information on this subject. the following questions were put to an expert stack erector: What is the quickest and safest way to raise a smoke stack, 60 feet long and 42 inches in diameter, weighing 3,000 pounds. The old stack is to be taken down, the time being limited to ten hours by contract. Stack is to be raised 12 feet to foundation. How heavy should spliced square pine timbers be, of which pole is to be made?

The expert replied as follows:

"Would suggest the following scheme for raising, if the conditions will allow: After erecting and securely guying the pole, place the stack upon the ground with the lower end as near to the pole as the walls of the building will permit; attach the permanent guys at their proper places, and make your sling fast to the stack at a point about one-third of its length from the top end, rig the tackle and run the down haul around the drum of a crab.

"Pine timbers six inches square (the pole not to be over 40 feet long), properly spliced, would safely carry the weight if free from knots or weak spots. A good straight telegraph or telephone pole 40 feet in length and, say, 5 inches through at the top, would be better.

"Take care that the hitch on the pole is made high enough so that the stack can be raised to an upright position without bringing the blocks together.

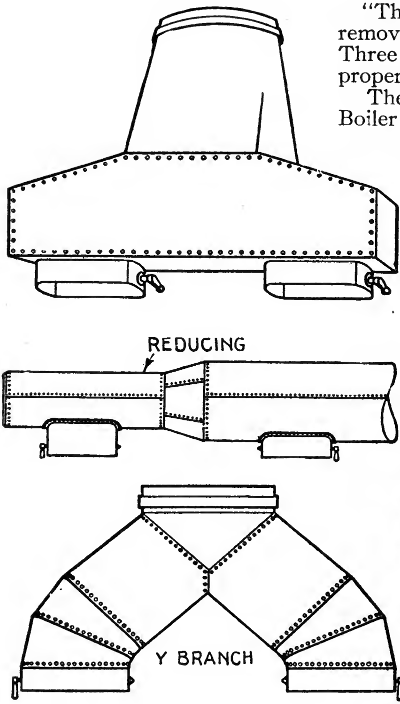
"As the stack is raised, it can be guided and held upright by the guys which may be temporarily secured.

"The stack now stands erect upon the ground at the side of the building. Make another hitch at a lower point upon the stack sufficient to allow the same to be raised to its maximum height, and secure the lower block of the lifting tackle fast to this hitch.

"Place a sling around the bottom of the stack, and make fast a tackle to pull from a point directly in line with stack and pole. Proceed to raise stack, keeping it in a vertical position and just clear of the building by the aid of this last tackle and the guy wires, until the bottom of stack is above the roof, when the lower tackle may be slacked off and the stack moved in toward the pole and lowered to its foundation.

"The stack which is there now may be removed in precisely the reverse manner. Three sheave blocks would be about the proper thing to use."

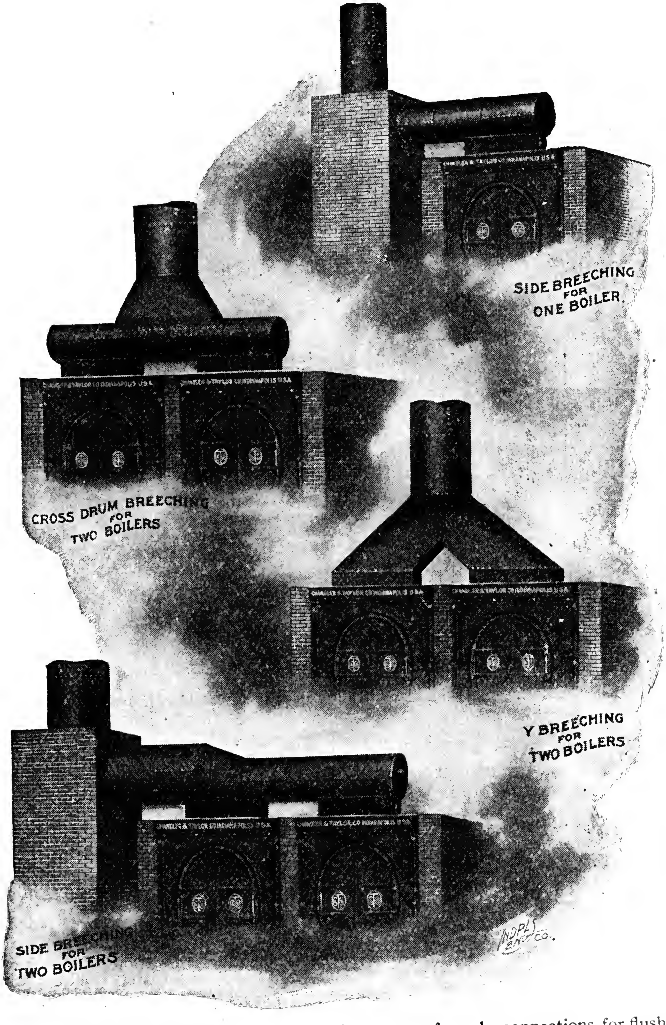
The table on page 2,608 (by Bigelow Boiler Co.) gives sizes of most commonly used guyed and self sustaining stacks.



FIGS. 4,623 to 4,625.—Various forms of two-flue smoke connections.

FIG. 4,626.—Mississippi style of breeching for one boiler.

NOTE.—A leaning chimney at Earnest, Pa., is reported to have been straightened in a novel manner. The stack is 122 feet high, 11 feet square at the base, tapering somewhat at the top and weighs 400 tons. The walls are 36 inches thick. The top was found to be leaning 45 inches from the vertical line. To right the chimney 10½ inches of brick work was removed from the foundations on three sides. As the bricks were removed, square blocks of wood were inserted, one after another, until three sides of the structure rested on the blocks. Between the blocks substantial brick piers 6½ inches high were built, leaving a space 4½ inches between the top of the piers and the bottom of the undermined brick work. The blocks were then set on fire and kept burning evenly. If one burned faster than the others, the fire on that particular block was checked, so that all were made to burn uniformly, and as the blocks were reduced to ashes, the stack slowly righted. As the top gradually swung back through the 45-inch arc, small fissures appeared near the base. In every groove a steel wedge was driven to maintain the weight of the walls. The entire work consumed one day, and the reduction of the wooden blocks to ashes required one hour



FIGS. 4,627 to 4,630.—Chandler and Taylor various types of smoke connections for flush front boilers.

Smoke Connections and Breechings.—Smoke connections for boilers 48 inches in diameter and under should be made of 14 and for larger boilers, of No. 12 U. S. S. steel. Figs. 4,623 to to 4,631, show various designs.

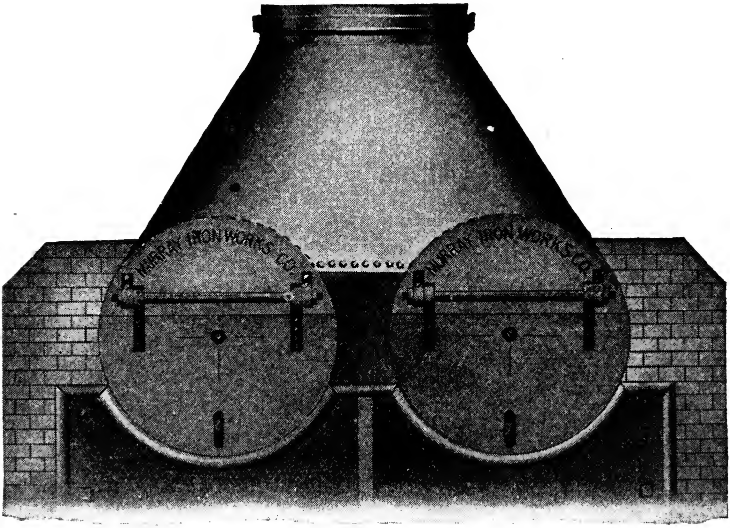


FIG. 4,631.—Breeching for two boiler installation with so-called half-arch front.

The round type of smoke connection is generally used only for small installations, because if built larger than say four feet in diameter it is liable to lose its shape.

A rectangular smoke connection, as shown in fig. 4,623, keeps its shape much better than the round, is easier to assemble and is specially recommended for large installations. With it sufficient area can be obtained by making it of almost any necessary rectangular shape, that is to say, narrow and high or *vice versa*.

NOTE.—When two flues enter a larger one at right angles to it, opposite each other, as is frequently the case where there is a large number of boilers in a battery, and the chimney is placed near the center of the battery, the main flue should always have a division plate in its center between the two entering flues to give direction to the incoming currents of gases and prevent their "butting," as it may be termed. The same thing should always be done where two horizontal flues enter a chimney at the same height at opposite sides.

CHAPTER 78

MECHANICAL DRAUGHT

Formerly the miller relied upon nature to grind his corn by installing a wind mill, but today such method is considered primitive. Similarly and until recently nature has been used exclusively to furnish draught for furnaces, through the medium of a chimney or stack.

A large number of power plant owners think that the expense of creating a draught consists simply in the cost of the chimney, *but such is far from being the case.*

It can be shown that even though the money invested in medium and large size chimneys could not be put out at over 2%, mechanical draught would result in a saving, and accordingly the quotation made in the last chapter may well be repeated here; that is, very tall chimneys have been characterized by one writer as being:

Monuments to the folly of their builders.

When a chimney is used it has to do two things:

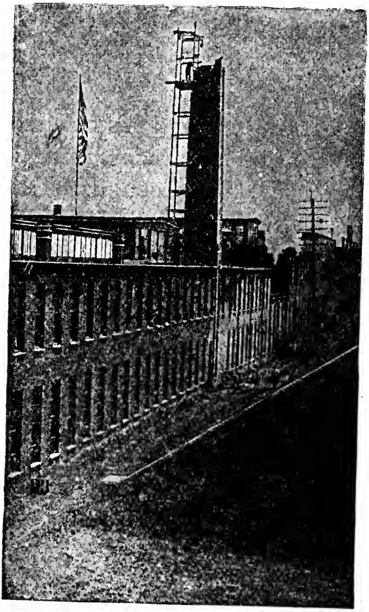
1. Provide sufficient draught to force the air through the bed of fuel.

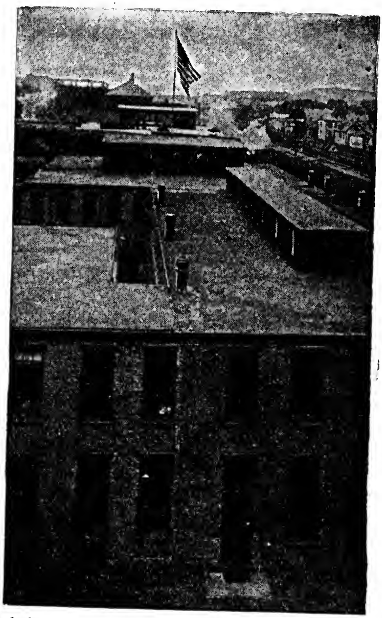
With the heavy fires carried in some furnaces this is considerable.

2. Provide additional draught to "suck" or pull the air and products of conbustion up the chimney.

Where mechanical draught is used the chimney is relieved of the first item, which represents nearly all the duty that otherwise would be performed by the chimney.

Because chimney draught is *natural*, it does not mean as supposed by many, that it disposes of the gases without work or cost.





'IGS. 4,632 and 4,633.—Substituting mechanical draught in place of chimney. The relative proportions of a brick chimney, and of the smoke pipe required when mechanical draught is introduced are forcibly shown in the illustrations, which show the works of the B. F. Sturtevant Co., at Jamaica Plain, Mass. The removal of the boilers to a position too far distant from the existing chimney to permit of its longer fulfilling its office, led to the substitution of an induced draught fan and the subsequent removal of the chimney. The present stack or smoke pipe, barely visible in fig. 4,633, extends only 31 feet above the ground, and no trouble is experienced from smoke.

t takes energy to move the gases, that is, there must be a difference of pressure between the inside of the chimney and the tmosphere outside (as explained in the previous chapter) and

This difference of temperature is ordinarily from 500 to 6,000 F., and as a result, according to Walter B. Snow, from 20 to 40% of the heat of the fuel is dissipated in the atmosphere without any useful effect further than producing a draught. In this connection, Snow says:

"Any attempt to utilize a portion of the waste necessarily reduces the temperature and lessens the draught which, in the case of a chimney, can only be made good by increasing its height. A chimney 100 feet high with external air at 60° and internal gases at 500° will produce an unbalanced pressure of about .65 inch. If the temperature of the gases be lowered to 300°, a chimney about 150 feet in height will be required to produce the same intensity, while for a temperature as low as 200° the chimney will have to be about 240 feet high."

"With the low chimney effective utilization of the heat of the waste gases is therefore impossible, for in order to maintain the draught they must of necessity pass away at relatively high temperature. A high chimney on the other hand entails considerable expense and even then continues to wastefully employ the heat."

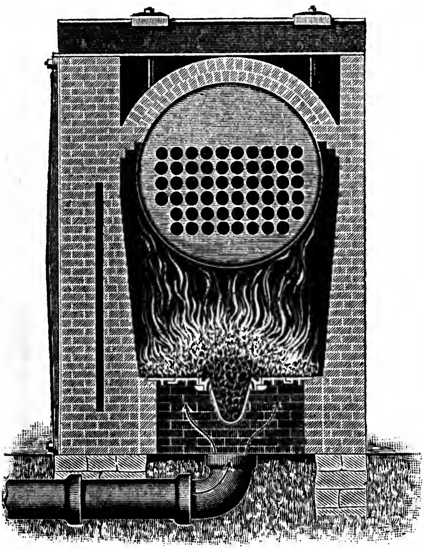
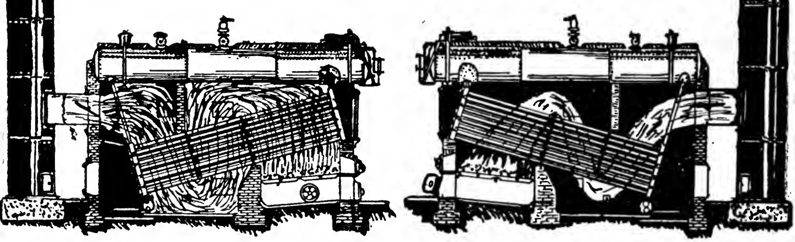


FIG. 4,634.—Section of Jones underfeed stoker in operation showing application of mechanical draught. ***In operation,*** coal being in the hopper, and the ram plunger at its forward stroke, when more coal is needed, the ram plunger is shifted by moving the lever. Coal then falls in front of the plunger and upon the return movement is forced into the retort, this movement being repeated until sufficient fuel is in the retort. Air at low pressure being admitted into the air chamber and through the tuyere blocks, over the top of the green fuel in the retort, but under and through the burning fuel, the result is that the heat from the burning fuel over the retort slowly liberates the gas from the green fuel in the retort. This gas being thoroughly mixed with the incoming air before it passes through the burning fuel above, results in a bright, clear fire, free from smoke, and the complete combustion of all the heat-producing elements in the fuel. The retort being air tight from below and the fuel being in a compact mass in the retort, the air will find its way in the direction of the least resistance, which is upward, hence combustion takes place only *above* the air slots.

As compared with this wasteful process of air movement a fan calls for an expenditure of only about 1.33% of the heat required by the ordinary chimney to produce the same results. Or in other words practically all of the heat of the waste gases is rendered available for utilization and it only remains to provide the necessary means for abstracting the heat. For effective working the initial temperature of these gases must be approximately 75° above the temperature of the steam within the boiler. Between this point and the atmospheric temperature is marked the range through which the heat abstractor may be effective.

"The fuel economizer is now well established as an effective means of transferring the heat from the gases to the water fed to the boiler. It naturally shows the highest efficiency when the initial temperature of the gases is excessive, that of the water entering the economizer is low and the fuel is high priced. The temperature of the gases necessary to produce the requisit draught with a chimney, evidently marks the limit to which they may be cooled by the economizer. With a fan, however, the intensity of the draught is practically independent of the temperature of the gases, and in point of fact when a fan is applied upon the induced principle, a decrease in the temperature actually increases the intensity of the draught produced at a given speed. It is here therefore that the fan shows its fundamental advantage over the chimney, in that it renders available for utilization practically all of the waste heat."



FIGS. 4,635 and 4,636.—Comparison between a delivery stack for mechanical draught and a so called "natural" draught stack. For want of space the upper portion of the latter is shown on the next page. The comparison may seem unkind by tall chimney cranks, but a thorough investigation of the subject will show that the illustrations are not exaggerated. A mechanical draught delivery stack need not be any higher than is necessary to avoid trouble with the local board of health, or just tall enough to clear the roof. Fig. 4,635 shows a mechanical draught installation with Wing turbine blower located in side wall of ash pit.

Reports of tests made by W. R. Roney in plants equipped with fuel economizers and mechanical draught apparatus in place of a chimney show an average saving of about 15 per cent. resulting from the introduction of this combination.

In comparing chimneys with mechanical draught the principal things to consider are:

1. Draught required at different combustion rates for various kinds of coal.

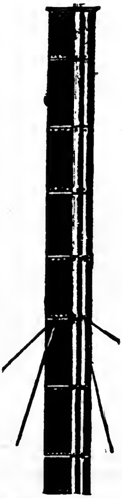


FIG. 4,637.—Upper portion of natural draught stack shown on page 2,618.

2. Chimney temperatures.

3. Height of chimney necessary to produce the required draught.

4. Relative costs and maintenance.

5. Nature of the load.

6. Relative space required.

Draught Required for Different Fuels.—For every kind of fuel and rate of combustion there is a certain draught with which the best general results are obtained. A comparatively light draught is best with the free burning bituminous coals and the amount to use increases as the percentage of volatile matter diminishes and the fixed carbon increases, being highest for the small sizes of anthracites. Numerous other factors such as the thickness of fires, the percentage of ash and the air spaces in the grates bear directly on this question of the draught best suited to a given combustion rate. The effect of these factors can only be found by experiment.

The curves in fig. 4,638 show the draught necessary to burn various kinds of coal at different combustion rates.

The amount of coal which can be burned per square foot of grate per hour is governed by the character of the coal and draught available. When the boiler and the grate are properly proportioned, the efficiency will be practically the same for different combustion rates within reasonable limits.

Chimney Temperatures.—The height of a chimney

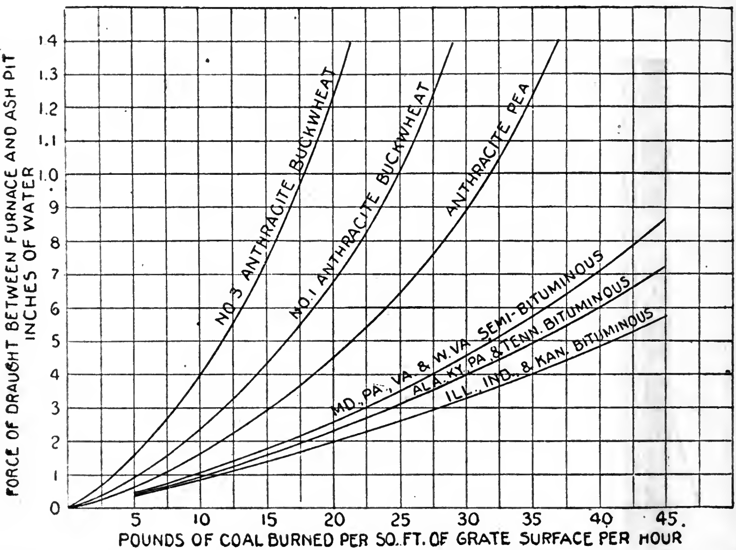


FIG. 4,638.—Babcock and Wilcox curves, showing draught required for various coals. Although the values here given for difference in pressure between the ash pit and space immediately over the fire (with uniform grates) are determined with fair degree of accuracy and may be considered trustworthy, it should be noted that it is impossible to state definitely the ***total*** draught required for efficient combustion of any given fuel because the total draught required for any particular installation depends upon quite a number of items, such as type of boiler, rate of combustion, quality of coal, thickness of fire bed, area and arrangement of breeching, height and cross sectional area of stack, etc., and these factors are variable.

necessary to produce a given draught is influenced greatly by the temperature, because the hotter the column of gases within the chimney, the less the weight and consequently the greater the pressure difference. The effect of temperatures on draught is shown in the following table:

Theoretical Draught Pressure in Inches of Water

(for a chimney 100 ft. high; for other heights, the draught varies as the height)

Temperature in Chimney, Fahr.	TEMP. OF EXTERNAL AIR. (BAROMETER 30 INCHES)										
	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°
200°	.453	.419	.384	.353	.321	.292	.263	.234	.209	.182	.157
220	.488	.453	.419	.388	.355	.326	.298	.269	.244	.217	.192
240	.520	.488	.451	.421	.388	.359	.330	.301	.276	.250	.225
260	.555	.528	.484	.453	.420	.392	.363	.334	.309	.282	.257
280	.584	.549	.515	.482	.451	.422	.394	.365	.340	.313	.288
300	.611	.576	.541	.511	.478	.449	.420	.392	.367	.340	.315
320	.637	.603	.568	.538	.505	.476	.447	.419	.394	.367	.342
340	.662	.638	.593	.563	.530	.501	.472	.443	.419	.392	.367
360	.687	.653	.618	.588	.555	.526	.497	.468	.444	.417	.392
380	.710	.676	.641	.611	.578	.549	.520	.492	.467	.440	.415
400	.732	.697	.662	.632	.598	.570	.541	.513	.488	.461	.436
420	.753	.718	.684	.653	.620	.591	.563	.534	.509	.482	.457
440	.774	.739	.705	.674	.641	.612	.584	.555	.530	.503	.478
460	.793	.758	.724	.694	.660	.632	.603	.574	.549	.522	.497
480	.810	.776	.741	.710	.678	.649	.620	.591	.566	.540	.515
500	.829	.791	.760	.730	.697	.669	.639	.610	.586	.559	.534

This table is only approximate because it is calculated (as has been done by Rankine and others), on the supposition that the temperature is uniform, but in practice this is far from being the case. In one instance a 122-foot chimney showed a temperature at the base of 320° and at the top of only 230°, hence a *less* draught is obtained in practice than indicated by the table.

Now, to burn say 20 pounds of No. 1 anthracite buckwheat per square foot of grate per hour would require (from fig. 4,638), a .68-inch draught. Assuming an external temperature of 50°, the temperature in a 100-foot chimney necessary to produce this draught would from the table be a little

Draught Required in Furnace of Water Tube Boiler

Kind of coal	Pounds of dry coal burned per square foot of grate per hour.						
	15	20	25	30	35	40	45
Eastern bituminous coals	12	.16	.20	.27	.34	.42	.52
Western bituminous coals	.15	.20	.25	.33	.42	.52	.65
Semi-bituminous coals	.15	.20	.28	.37	.48	.60	.80
Anthracite buckwheat No. 1 and larger	.45	.70	1.00				
Anthracite buckwheat No. 2 and No 3	.75	1.30					

over 500°. Since this temperature represents considerable waste, the efficiency could be improved by installing an *economizer*, but this would reduce the chimney temperature about 200°, which would (according to the table), reduce the draught to .292 inch, and the combustion rate (as given in fig. 4,638), to 11½ pounds. Hence, the chimney would be inadequate to serve the boiler with economizer, necessitating mechanical draught. If this had been considered before erecting the chimney considerable money could have been saved, as with mechanical draught it is only necessary to carry the gases out of the building by a very short stack.

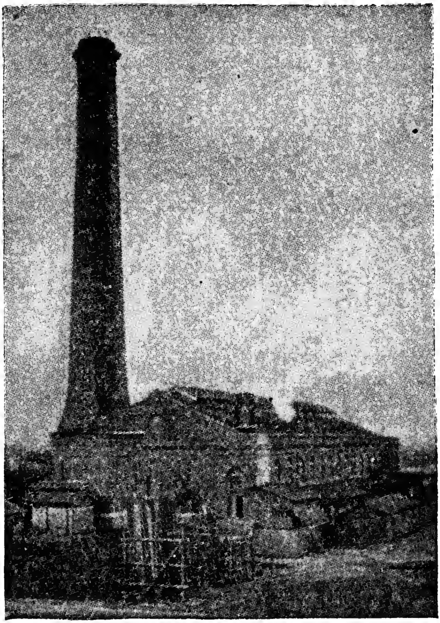


FIG. 4,639.—Osaka Japan water works, showing a mechanical draught stack at the right which superseded the chimney at the left. This picture is worthy of serious thought and consideration, especially by those partly responsible for the present high cost of brick.

Height of Chimney.—It has been shown in the pressure section that chimney height necessary to produce the required draught is greatly influenced by the temperature of the gases, the draught required entirely depending on the kind of fuel as well as the rate of combustion.

In deciding whether to employ chimney draught or mechanical draught all these items should be considered, thus figuring on a chimney of adequate size to serve the plant under the most severe conditions as a basis for comparison with mechanical draught.

Fig. 4,639 gives a good idea of the relative sizes of a chimney and the equivalent mechanical draught stack.

Nature of the Load.—There are no two plants in which the character of the load is exactly the same, and in order to intelligently design a power house, the nature of the load must be the first consideration. In some pumping plants for instance, the load is practically constant, whereas, in most other plants, especially electric light and traction plants, it varies widely. Hence, arises the problem whether to install sufficient boiler capacity to handle the maximum load under natural chimney draught, or a lesser number, using mechanical draught for the overload or *peak* load periods.

Handling Peak Loads.—Where heavy peak loads are common, it will usually be found more economical, both from the standpoint of first cost and also of operation, to install boilers of sufficient capacity to handle the normal output, of the station at close to the rated capacity of the boilers, and with these boilers, to install forced draught fans of sufficient capacity to force the boilers to overload to meet the temporary peaks.

It is not at all unusual, with a properly designed forced draught equipment, to develop from 125 per cent. to 225 per cent. of the rated output of the boilers. If underfeed stokers be also used, much higher overloads can be carried. This forced draught method of handling the peak loads is usually found more desirable than the method of installing sufficient rated boiler capacity to take care of the maximum peak loads, and it has found special favor in those plants which are forced to take care of high peaks during short periods of the year, such as on cold winter days when the light, heat, and power loads overlap for short periods of the day.

Ques. What important points should be considered with respect to peak loads?

Ans. Their extent, frequency and duration, and the ratio of heating surface to grate area necessary to secure maximum overall efficiency.

The ratio of heating surface to grate in stationary boilers is commonly about 35:1. With this ratio, the increase in furnace efficiency at moderate capacities is usually at a greater rate than in the decrease in boiler efficiency at first with an increase in capacity. This makes the ordinary point of maximum combined efficiency somewhat above the boiler's rated capacity, and in many instances the combined efficiency is approximately the same for a considerable range of ratings.

According to Professor Marks, the usual variation of efficiency with capacity in modern boilers and furnaces is as follows:

Per cent. of boilers rated capacity developed

80–100	120	140	160	180	200	220	240	260	280

Corresponding combined efficiency of boiler and furnaces in per cent.:

75	74.9	74.8	74.5	73.9	73.2	72.2	70.8	69.1	66.9

These values are derived from a number of tests, the results of which have, as far as possible, been modified so as to place them on a comparable basis.

Knowing the extent and duration of the overloads the loss due to decrease in efficiency can be computed, and the result will indicate whether it be advisable to increase the ratio of heating surface to grate area.

Saving by Use of Cheap Fuels.—By means of mechanical draught, inferior fuels such as culm and screenings may be substituted for higher grade coals. The cheap fuels like the fine anthracites require for their combustion an intensity and concentration of draught which the chimney, unless of great height, is incapable of producing.

By the use of lower grade fuels a saving of from 25 cents to $2 a ton can be made, and although more of the cheaper coal is necessary, the decrease in its cost usually far exceeds the decrease in efficiency.

The possible savings are shown by the table below which gives the annual saving resulting from the substitution of a cheaper coal for say Cumberland, costing about $5 a ton. The basis of calculation is 312 days of 10 hours each.

If the assumption be made that a coal costing $2.50 and evaporating only 9 pounds of water is substituted for Cumberland the annual saving would be $8,494, as shown by the table.

According to Sturtevant, the fuel cost of operating the fan, even if the exhaust steam were not utilized and it required 2 per cent. of the total coal burned, would be only $179, and if this were charged against the saving, it would still amount to $8,494, a sum sufficient to show a most creditable reduction in operating expense.

A reduction of over $125 per week, equivalent to $6,500 per year, has been made in actual practice in the case of a boiler plant of 1,000 horse power, by the introduction of mechanical draught and the burning of buckwheat and yard screenings with a slight mixture of Cumberland.

Annual Savings Resulting from Burning Cheaper Fuel in 1000 H. P. Boiler Plant

Water evaporation from and at 212° per pound of coal	Cost per Ton								
	$1.00	$1.50	$2.00	$2.50	$3.00	$3.50	$4.00	$4.50	$5.00
11.00					8738	6553	4368	2184	0000
10.50					8112	5824	3536	1248	
10.00				9829	7426	5024	2621		
9.50				9195	6667	4138	1609		
9.00			11,163	8494	5824	3155			
8.50			10,535	7709	4882	2055			
8.00		12,832	9,829	6826	3822				
7.50		12,231	9,028	5824	2121				
7.00	13,105	11,545	8,112	4680					

Maintenance Cost.—This depends to a certain extent upon the method of application. If applied to force air to the ash pits, it will operate at moderate speed, will handle only cool air, and will last as long as the usual boiler fixtures. If employed to exhaust the gases from the boilers, it will be subjected to temperatures ranging up to perhaps 600°.

Overheating of shaft bearings is avoided by passing water through the chambers provided in the boxes. The conditions, so far as they affect the life of the fan are, according to Sturtevant, probably no more severe than in the case of a forced draught installation.

Cost of Operation.—This depends upon the disposition of the exhaust from the fan engine. If this be utilized as it should be in any well planned plant, the cost of draught production becomes very small. If, however, the exhaust must be discharged to the atmosphere the actual expense of operation, as measured

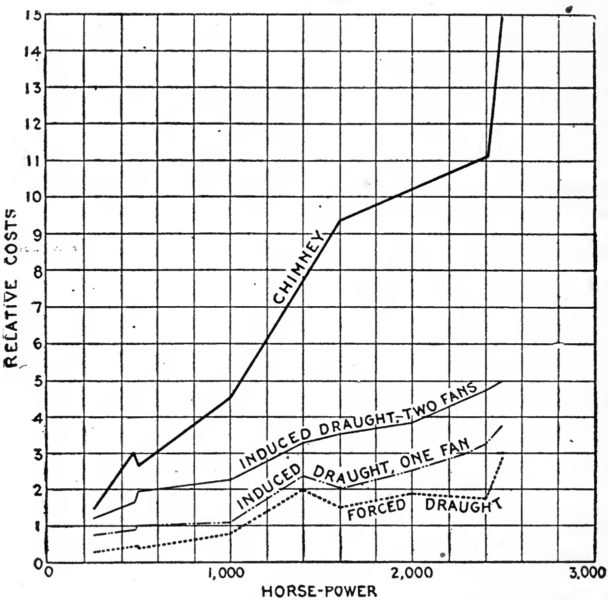
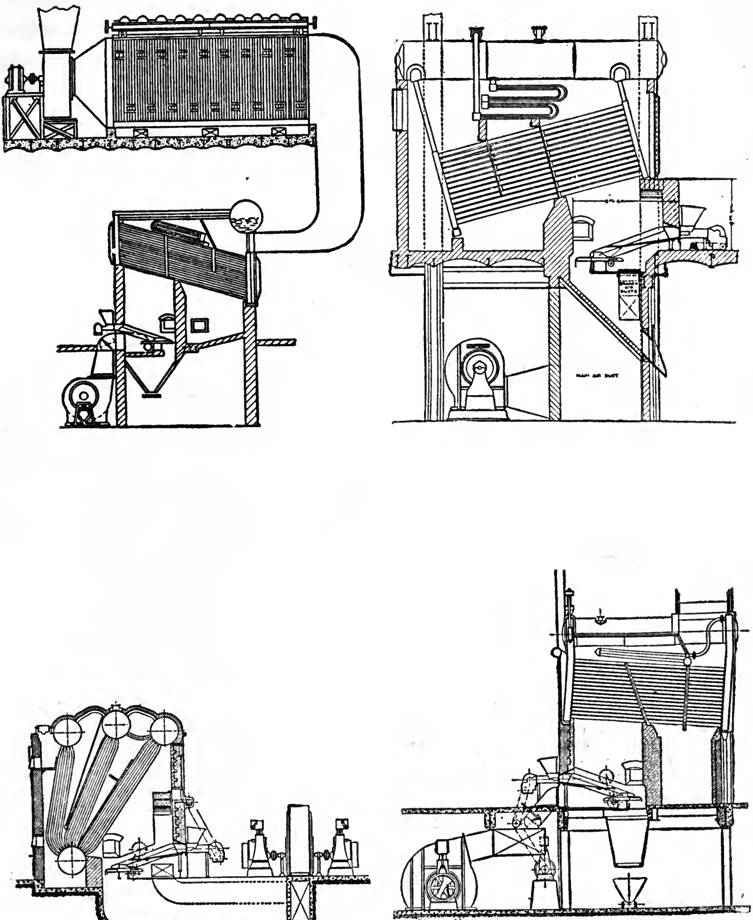


FIG. 4,640.—Comparative cost of chimney and mechanical draught, in a number of boiler plants widely varying according to Snow. In certain of these, the cost of the existing chimney is known, and that of the complete mechanical draught plant is estimated, while in others, the cost of mechanical draught installation is determined from the contract price, and the expense of a chimney to produce equivalent results is calculated. Costs are shown for both single, forced and induced engine driven fans and for duplex engine driven plants, in which either fan may serve as a relay. An apparatus of the latter type is the most expensive, and finds its greatest use where economizers are employed.

by the proportion of the steam used, compared with that generated ranges, according to Sturtevant, from ½ to 2 per cent. in plants of reasonable size up to perhaps 3 to 4 per cent. in small



FIGS. 4,641 to 4,644.—Various arrangements of Sturtevant fans for mechanical draught. Fig. 4,641, arrangement of fan with Riley underfeed stoker, fuel economizer, and induced draught fan; fig. 4,642, forced draught fan with Riley stokers; fig. 4,643, forced draught fan with Sterling boiler; fig. 4,644, fan and engine with Riley stoker.

plants; Professor Marks gives 2 to 4 per cent. for induced draught installations. These figures are evidently based on the wasteful types of engines ordinarily used for fan drive. These are, for small and medium size plants, common slide valve or piston valve single cylinder throttling engines requiring 50 to 60 pounds feed water non-condensing and 40 to 50 pounds condensing, and for

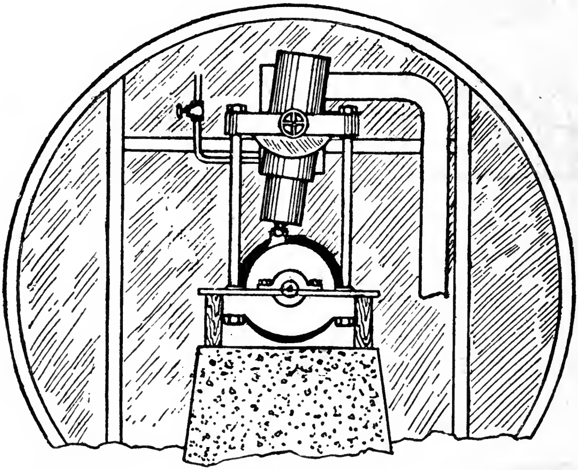


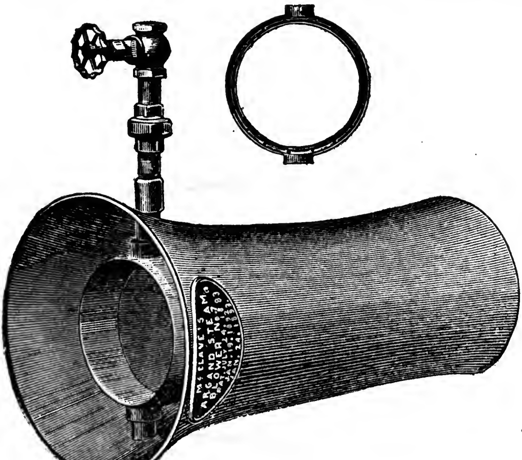
FIG. 4,645.—Graham special trunk piston transfer expansion steam jacketted oscillating engine direct connected to blower. This method of jacketting is such that the steam passing through the cylinder is brought into more intimate contact with the jacketted walls than in any other system, thus permitting a high degree of expansion without condensation. The value of steam jackets and the proper condition under which they should be used are not generally understood. The author's claim that this engine is as economical as the ordinary compound is based on his investigation of steam jackets and test data especially that of Donkin.

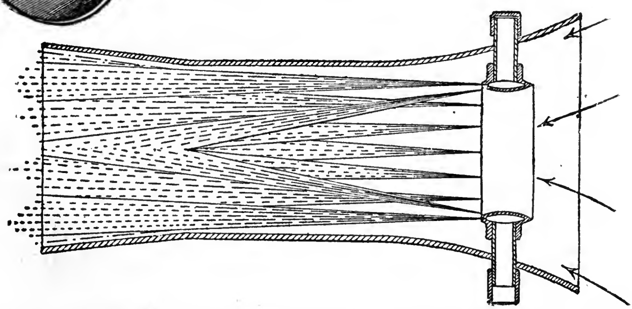
large plants, automatic cut off engines, requiring about 32 pounds feed water non-condensing and 28 pounds condensing. It is a strange fact in engineering that little or no attention is paid to small items in regard to economy.

Although the steam required for fan drive, even with the wasteful engines just mentioned, is only a small percentage of the total steam generated, this is no reason for not providing an efficient engine.

Fig. 4,645 shows the author's transfer expansion oscillating engine direct connected to a blower. This engine is designed especially for economy and will run on about 20 pounds of feed water per horse power per hour, condensing being about as economical as the ordinary compound.

Mechanical Draught Systems.—There are several methods of producing mechanical draught, each





Figs. 4,646 to 4,648.—McClave's Argand jet blower. Fig. 4,646, exterior view, 4,647, jet ring; 4,648, sectional view showing steam jets. ***In construction,*** the outer tube is shaped like two hollow truncated cones with their small ends brought together. The jet ring is placed at one end and concentric with the outer tube. The shape of the outer tube and position of the jet is such as has been found by experiment to give the best results.

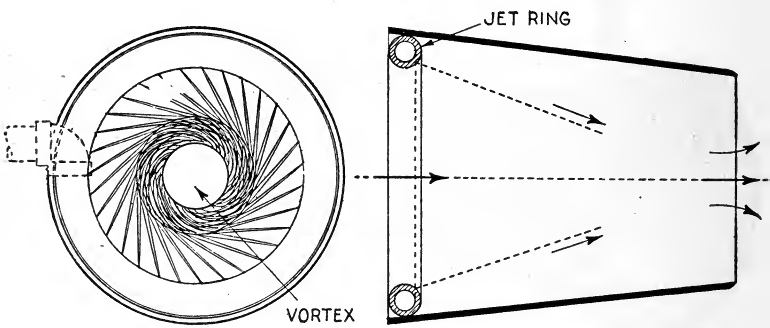
having its individual characteristics, and conditions for which it is suitable. The several ways in which mechanical draught is produced is by means of:

1. Steam jets.

2. Pressure in the ash pit (**forced** *draught*).

3. Suction in the stack (**induced** *draught*).

4. Combined pressure and suction (**balanced** *draught*).



FIGS. 4,649 and 4,650.—Vortex type jet blower. The jet ring is placed at the large end of a cone shaped tube. The jet holes in the jet ring are drilled at angles such that the steam forms a gyratory motion in the tube, thus producing a vacuum.

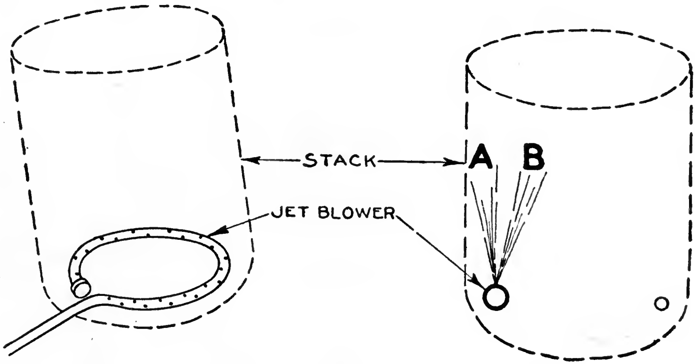
Steam Jets.—Economically, the production of draught by means of steam jets may be regarded as a makeshift because the steam consumption of the jet, either under the grates or in the stack, may run as high as 30 per cent. of the total steam generated, a fair figure according to Professor Marks, being from 5 to 10 per cent.

For some systems of ash pit steam blast the consumption may be as low as 2½ per cent. under test conditions. A good system, under ordinary operating conditions will probably require from 4 to 6 per cent. of the total steam generated.*

The last two items account for the extensive use of jets in marine practice, especially on boats of medium or small size.

Ques. What conditions favor the use of jets?

Ans. They are desirable for intermittent use, as a help to



FIGS. 4,651 and 4,652.—Ordinary steam jet blower made from wrought pipe. The pipe is bent to circular form and the end closed with a cap. ***For maximum efficiency,*** the holes should be drilled at a slight angle with the sides of the stack, so as to project the steam alternately outward and inward, as at **A**, and **B**, fig. 4,652.

carry an occasional peak load, or for the double purpose of producing a draught and aiding combustion with coals that have a tendency to fuse or mat on the grate.

Ques. What are the desirable features of steam jets?

Ans. Very low first cost, extreme simplicity, little space required, minimum weight.

*NOTE.—***Tests*** made on ***steam jets*** at the Brooklyn Navy Yard in 1890 showed that the jet required from 8.3 to 21.2 per cent. of the total steam generated. In the absence of data as to the type and design of the jet as well as full particulars about the test, *conclusions should not be jumped at.* This advice should be applied to all tests. The tendency of forming an opinion without full investigation should be discouraged, especially among engineers.

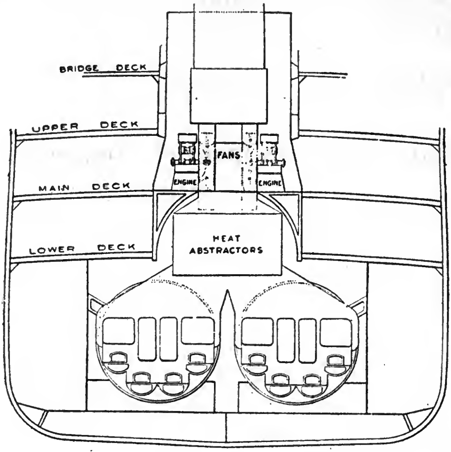


FIG. 4,653.—Arrangement of main boilers, fans and heat abstractors on S. S. Kensington.

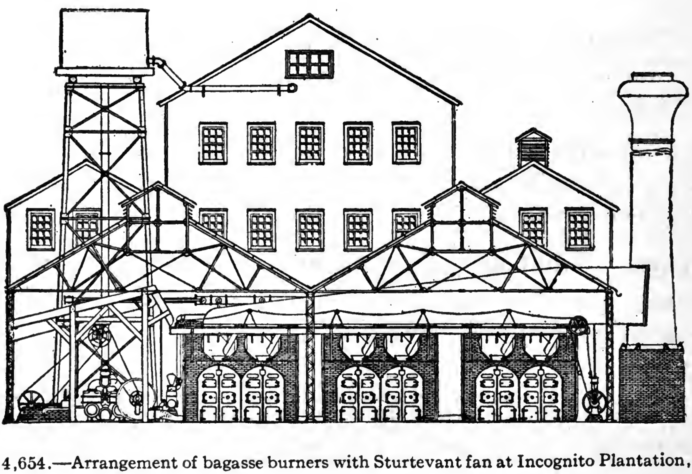


FIG. 4,654.—Arrangement of bagasse burners with Sturtevant fan at Incognito Plantation, La.

Ques. How much draught can be produced with a jet?

Ans. The maximum ash pit blast is about one inch, and when the jet is placed in the stack the draught due to the stack will not be increased over ¾ inch.

Ques. What is the ordinary construction of a jet or jets?

Ans. A pipe of suitable size is bent to circular form about

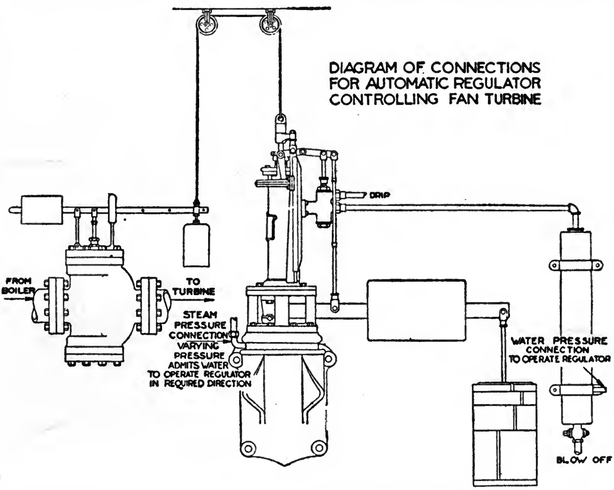
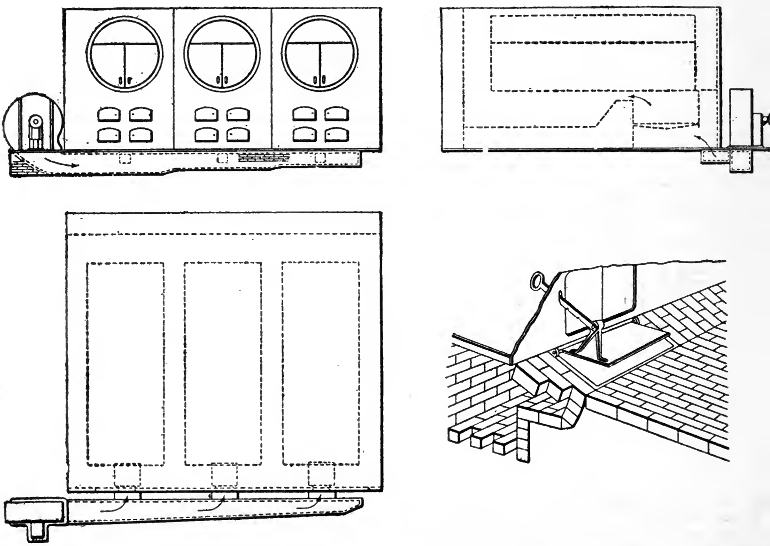


FIG. 4,655.—Sturtevant automatic steam regulator for controlling forced draught fan turbine. ***In operation,*** a very slight rise or fall in the steam pressure actuates the valve and decreases or increases the amount of steam admitted to the driver. The steam pressure can thus be automatically maintained within a pound above or below the normal while the fan promptly responds to changes in conditions and particularly to sudden demands for more capacity. The apparatus is usually supplied with a suitable governor, so that a predetermined maximum speed cannot be exceeded and so that the blower cannot stop dead.

¾ the diameter of stack and a number of very small, evenly spaced holes drilled around the circular portion as shown in fig. 4,651, the end being closed with a cap.

Forced Draught.—This term is used to denote the system in which air under pressure is introduced into an air tight ash pit and *forced* through the bed of fuel on the grate. Sufficient chimney capacity is necessary to draw the gases through the boiler and smoke flue, but the draught is small compared to that required to force the air through the fire, a very short "delivery stack" being sufficient.

The blower or fan is usually placed beside the setting, although it may be



FIGS. 4,656 to 4,659.—Installation of forced draught system to old boiler plant. The figures illustrate the simplest method. The fan which is of steel plate with direct connected double cylinder engine is placed immediately over the end of a brick duct into which the air is discharged. This duct is carried under ground across the front of the boilers, to the ash pits of each of which connection is made through branch ducts. Each branch duct opening is provided with special ash pit damper, operated by notched handle bar, as illustrated in the detail. This method of introduction serves to distribute the air within the ash pit, and to secure even flow through the fuel upon the grate above. Of course, the ash pit doors must remain closed in order to bring about this result. A chimney of sufficient height to merely discharge the gases above objectionable level is all that is absolutely necessary with this arrangement. Although the introduction of a fan in an old plant is usually evidence of the insufficiency of the existing chimney to meet the requirements, such a chimney will, however, usually serve as a discharge pipe for the gases when the fan is employed. The fan thus becomes more than a mere auxiliary to the chimney; it practically supplants it so far as the method of draught production is concerned.

put wherever most convenient and a suitable duct or air passage led from it to the ash pit.

Forced draught has the advantage of being easily applied to old installations for increasing the boiler capacity and costs less than the induced system. Figs. 4,656 to 4,659 show a simple installation of forced draught to an old boiler plant.

Ques. What general conditions call for forced draught?

Ans. Whenever the greater portion of the resistance offered by a boiler system to the flow of air is encountered at the furnace, it is advisable to use forced draught.

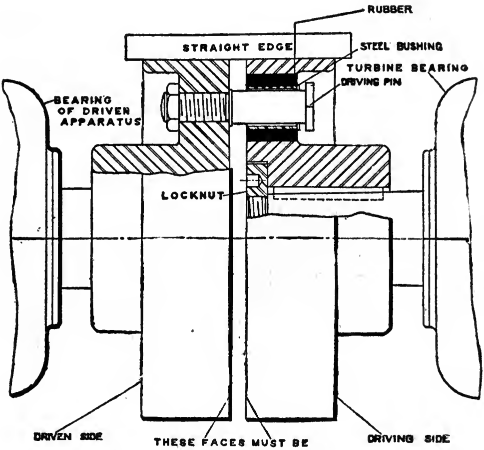


FIG. 4,660.—Sturtevant coupling for direct connected blower set. For successful operation, it is essential that the foundation be level, and that the couplings on driver and driven be in perfect alignment. Special care should be used in installing turbine sets where the alignment may be affected by heat. To cope with such condition the coupling here shown is used. To secure proper alignment set the turbine coupling from eight to twelve thousandths lower than the driven coupling when the machines are cold. The machines should then be run a short time and warmed up thoroughly when a second adjustment is necessary. A third and final alignment should be made after the set has been operating for some time under full load conditions and at full load temperature, at which time the faces of the coupling must run parallel and true. If any trouble be experienced with the apparatus after once set up, it is necessary to check the alignment, as the foundation frequently settles sufficiently to throw the set into serious misalignment. If the set be on a steel plate or cast iron sub-base, it is just as important to align the equipment, since sub-base may warp or warp or spring in shipment. Alignment should be made with reference to the coupling and coupling bolts should be removed. The sub-base should be shimmed up with small metal wedges until the apparatus is level, and should be grouted with concrete.

This is particularly the case when hollow blast grates or underfeed stokers are used, as under these conditions, if an induced draught fan be employed, the high suction which would be necessary throughout the entire system would result in excessive leakage. With forced draught, however, while there would be the same loss of pressure head in forcing the necessary air through the furnace, the pressure throughout the remainder of the boiler system would be very low, in fact just sufficient to cause the gases to flow against the resistance offered by the course traversed. For the same reason forced draught is better suited for burning buckwheat coal, as small anthracite of this class packs on the grates in a dense formation and considerable pressure is required to force air through the fuel bed.

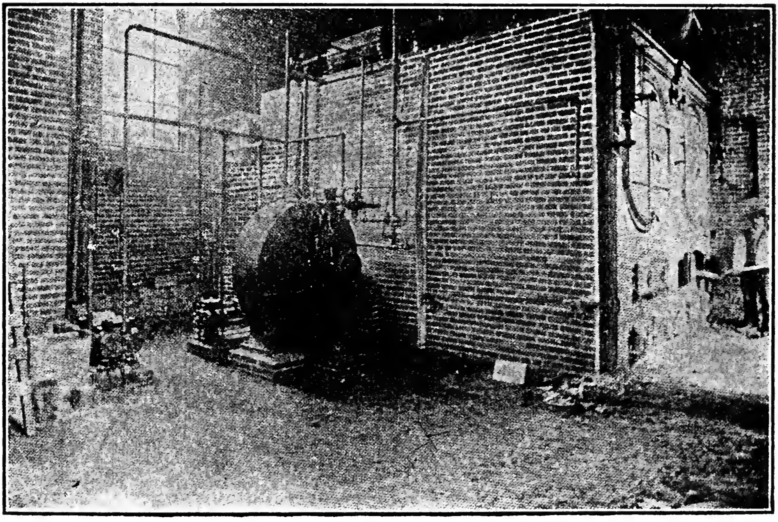


FIG. 4,661.—Forced draught plant with hollow bridge wall at the Crystal Water Co., Buffalo, N. Y. The air is delivered to the ash pit via the hollow bridge wall, being supplied under pressure by the blower seen at the side of the boiler setting. As shown, the blower is operated by a small reciprocating engine; however, compact blowing units with steam turbine drive can be had and which are designed to be placed in the boiler setting, if preferred.

Ques. What are the disadvantages of forced draught?

Ans. It results in a hot, dirty boiler room, there being a tendency for smoke and gases to escape through the crevices in the boiler setting and through leaks in the flues, especially when economizers are used. The draught must be shut off when the ash pit is cleaned. Great care is necessary to prevent holes in the fuel bed.

Ques. Describe the closed stokehold system of forced draught used in marine service.

Ans. In this system the boiler room is entirely enclosed and provided with air locks for the passage of the attendants. The fans discharge into the boiler room and maintain a static pressure

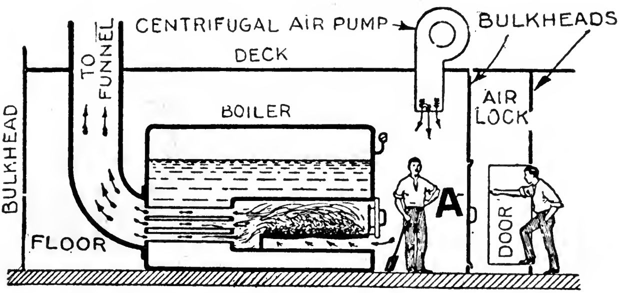


FIG. 4,662.—Closed stokehold method of forced draught as ordinarily used in marine practice. The boilers are placed in an air tight room and air under pressure is supplied by a centrifugal fan. In some cases the ash pan of the boiler is made air tight and connected direct to the outlet of the fan.

of from ¾ to 3 inches of water according to requirements. Fig. 4,662 shows the essential features of the system

Ques. What are the objections to this method?

Ans. Dirtiness, high temperature in stokehold (usually being about 120° Fahr., even in temperate climates) and the fact that the stokehold and ash pits being at a higher pressure than

NOTE.—*The enclosed stokehold system of forced draught* is in general use throughout the various navies of the world, but its suitability for naval work is questionable, as the speed of a warship could be seriously impaired at an extremely inopportune time, on account of the reduction in steaming capacity which would follow any break being made in the plates surrounding the stokehold.

that of the atmosphere, air is caused to flow through the fires and with this system no ducts are required.

Ques. Describe the Howden system of forced draught.

Ans. With this arrangement, the air in the stokehold is at the same pressure as the outside atmosphere but the ash pits are closed and the air handled by the blowers is led through ducts, and after passing over tubes that are heated by the waste gases

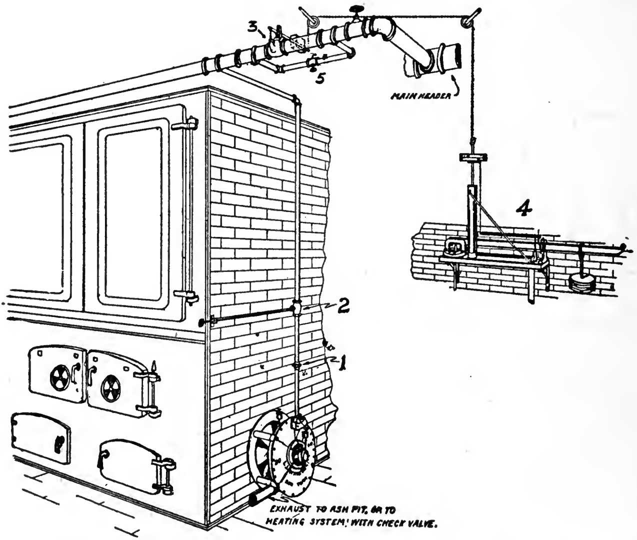


FIG. 4,663.—Wing turbine and fan forced draught system showing side wall installation. The automatic pressure regulator 4, controls the balanced valve 3, controlling all blowers; the by pass 5, make combustion continuous.

from the boiler is delivered to the ash pits under pressure. Some air is also admitted above the fires to prevent smoke being formed and to produce nearer perfect combustion, while the fire doors are usually arranged so as to cut off the draught when they are opened.

Under ordinary conditions the pressure in the ash pits is around one and one-half inches of water, but a blower for this work should be capable of delivering the required amount of air against a resistance of from two and three-quarters inches to three inches of water, this being the static pressure at the fan outlet.

The resistance to the flow of air offered by the ducts leading to the ash pits is a variable quantity dependent upon the air velocity and arrangement

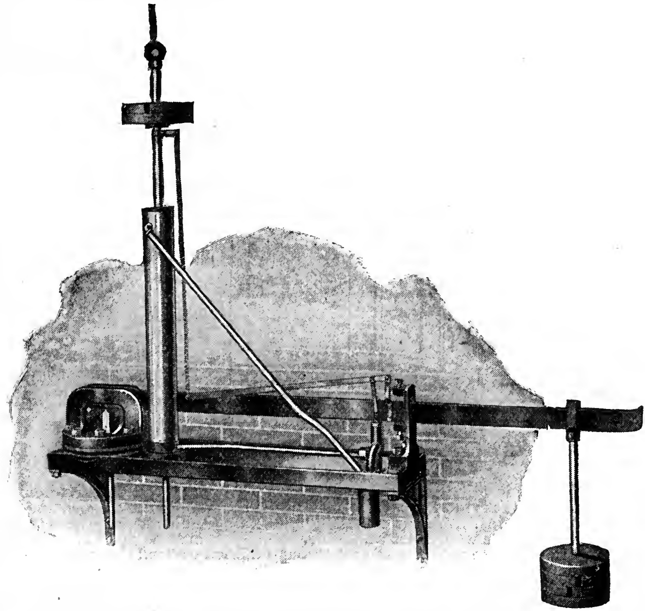


FIG. 4,664.—Wing automatic regulator. It consists of a cylinder with its piston, a diaphragm, and relief valve.

of piping, but if the blower be designed to deliver the needed amount of air against a resistance equivalent to two and three-quarters inches to three inches of water, this easily takes care of the loss of head in the air ducts and enables a pressure in excess of one and one-half inches water gauge to be maintained in the ash pits when desired.

Ques. Why is forced draught employed in marine practice instead of induced draught?

Ans. Because the apparatus is lighter.

A forced draught fan handles the minimum volume of air, although the actual amount or weight is the same whether forced or induced draught be used, and owing to this a smaller and lighter fan can be installed. The question of weight is of great importance on shipboard and as the fan speed is usually higher with draught forced this means that a smaller and lighter engine can be used to develop the necessary power.

Induced Draught.—In this system, a fan is located in the

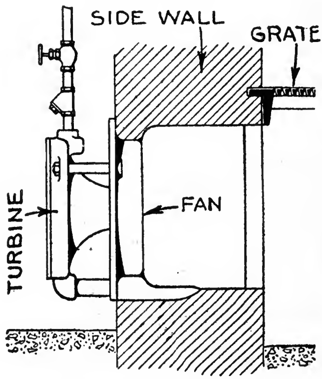


Fig. 4,665.—Standard installation of Coppus turbine blower. The blower forces air into an air tight ash pit. It is most easily installed in the side wall of the ash pit, and generally projects from 5 to 10 ins. from tne wall, according to size, but it may be set flush with the wall. When the side wall is not accessible, the blower may be placed in the rear wall, and made to communicate with the ash pit through a brick covered sheet iron duct leading through the combustion chamber and the bridge wall. Again it may be placed in the front wall or by the ash pit door.

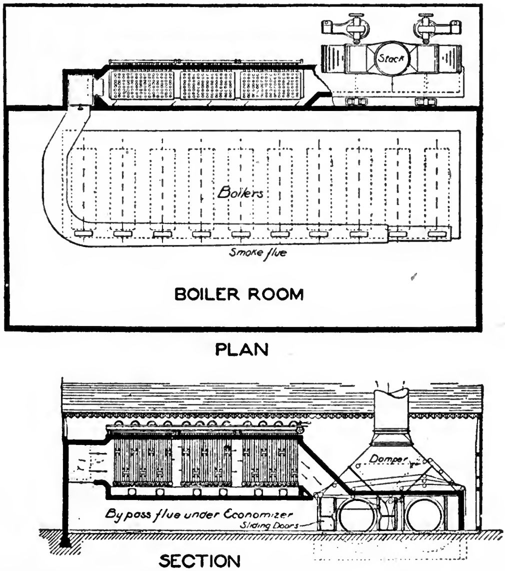
smoke flue, and which in operation draws the gases through tne furnace and discharges them into the delivery stack.

The nature of the service of an induced draught fan is necessarily more severe than that of a forced draught fan.

In the absence of an economizer the temperature of the gases which the fan must handle are usually from 500° to 600° Fahr., and though much less with economizer, in either case are considerably higher than that of the cool air handled by the forced draught fan.

Induced draught is adapted to all kinds of fuel and furnace except those in which underfeed stokers or hollow blast grates are employed.

With this system the fuel will burn evenly all over the grate, there being no trouble from holes or patches burning in certain spots. It is not necessary to shut off the draught when firing as there is no pressure in the combustion chamber to force scorching gases and dust out of the firing doors when opened. The ash pit can be cleaned without shutting off the draught as at all points the flow is toward the place at which the greatest suction or depression in pressure prevails, this, of course, being within the induced draught fan.



FIGS. 4,666 and 4,667.—Typical induced draught plant showing general arrangement of boilers, economizer, fans and fan engines as designed by American Blower Co.

The ventilation of the boiler room is better, as the air drawn into the furnaces from the boiler room is replaced by fresh air from the outside.

It is claimed that the boiler tubes can be kept cleaner as there is less lifting effect at the fire and consequently ashes and dirt are not carried in suspension and deposited in places where the velocity of the gases is lowered, to the same extent as in the case with forced draught.

Ques. What is the most important advantage of induced draught?

Ans. It permits the use of larger economizers.

Since the stack is not required to furnish a suction to carry off the gases as with forced draught, the temperature of the hot gases leaving the boiler may be reduced to as low a point as is commercially desirable, the heat being recovered by a large economizer and returned to the boiler.

Ques. Mention an objection to induced draught.

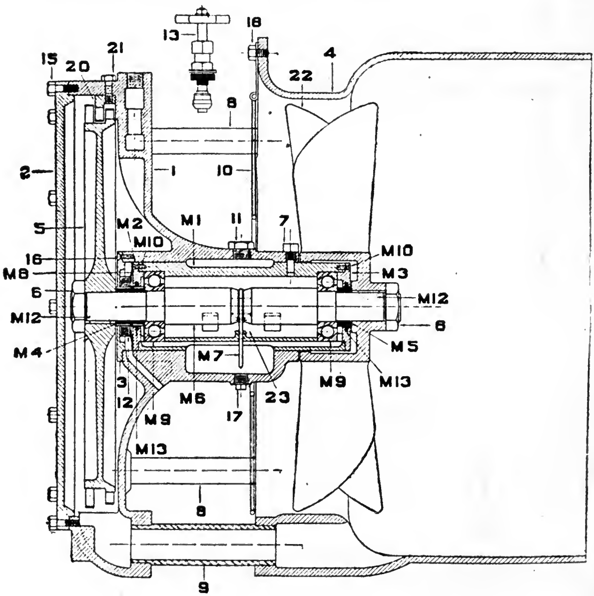
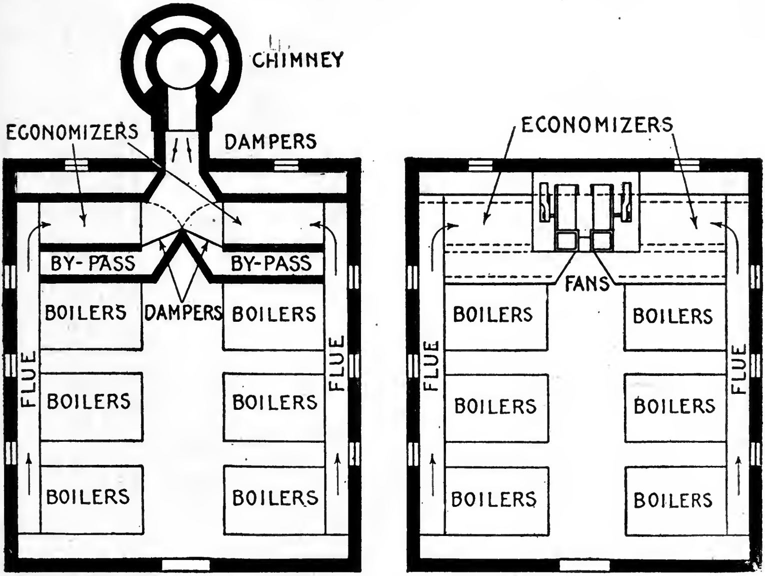


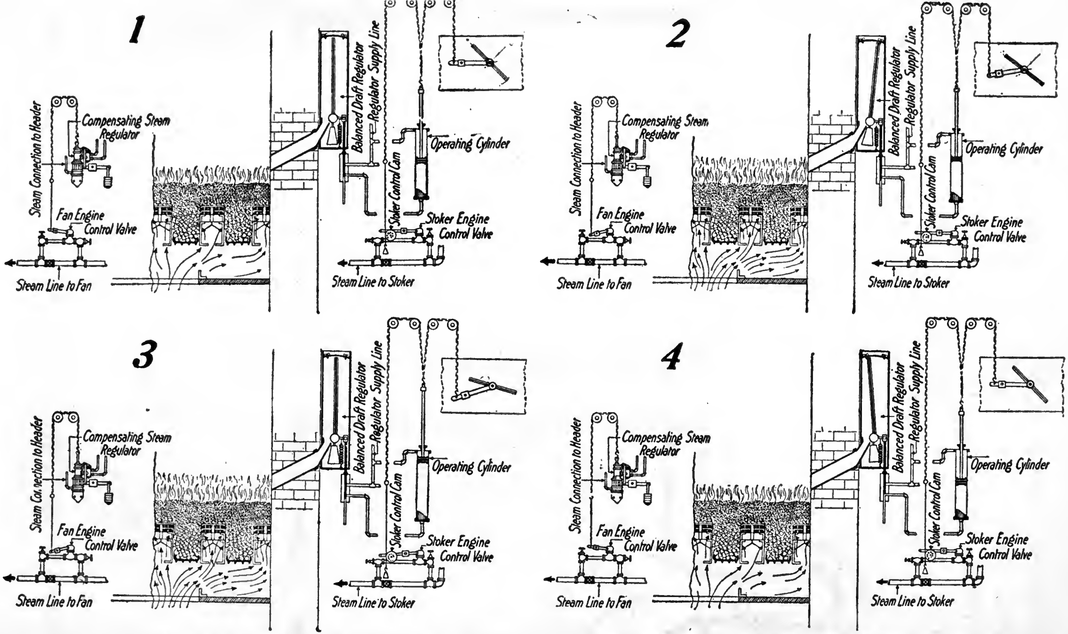
FIG. 4,668.—Coppus turbine blower. ***In construction*** the turbine wheel is of solid bronze with blades cast into the wheel. A shroud ring is put around the buckets which prevents them getting loose or coming out. The wheel is then balanced. Steam from the nozzles strikes the buckets at an angle of 20° to the plane of rotation. ***The parts are:*** 1, turbine. casing; 2, cover; 3, packing enclosure; 4, fan casing; 5, turbine wheel; 6, shaft nuts; 7, lock screw; 8, studs and nuts; 9, exhaust pipe; 10, screen; 11, oil plug; 12, carbon packing ring; 13, valve top; 15, cover bolts; 16, packing enclosure screws; 17, drain plug; 18, screen bolts; 20, reversing sector; 21, reversing sector bolts; 22, fan; M-1, bearing sleeve; M-2, bearing sleeve enclosure, (turbine end); M-3, bearing sleeve enclosure (fan end); M-4, shaft sleeve (turbine end); M-5, shaft sleeve (fan end); M-6, shaft; M-7, oil ring; M-8, enclosure springs; M-9, ballbearings; M-10, enclosure screws; M-12, woodruff keys; M-13, felt ring.

Ans. This system requires a large fan to produce the necessary exhaustion, because the higher temperature of the gases handled enlarges their volume, which moreover is further augmented by air entering the system through leaks in the boiler setting and smoke flue.



FIGS. 4,669 and 4,670.—Comparison of chimney draught and induced draught. The illustrations show a plant of 2,400 horse power of modern water tube boilers, 12 in number, set in pairs and equipped with economizers. Fig. 4,669 indicates the location of a chimney, 9 feet in internal diameter by 180 feet high, designed to furnish the necessary draught; fig. 4,670 represents the same plant with a complete duplex induced draught apparatus substituted for the chimney, and placed above the economizer connections. Each of the two fans is driven by a special engine direct connected to the fan shaft, and each is capable of producing draught for the entire plant. A short steel plate stack unites the two fan outlets and discharges the gases just above the boiler house roof. All of the room necessary for the chimney is saved, and no valuable space is required for the fans.

Ques. Describe the Elles and Eaves induced draught system.



FIGS. 4,671 to 4,674.—Diagrams showing operation of balanced draught. **Position 1.** ***Steam pressure steady;*** steam regulator stationary; fan at fixed speed; combustion steady; regulator blade vertical; pilot valve shut; flue damper open correct amount. **Position 2.** ***Steam pressure falling;*** steam regulator opening steam valve on fan; fan increasing speed, giving more air; combustion increasing, producing more gas and higher furnace pressure; regulator blade moves out; pilot valve open to water pressure; damper opening to provide for greater combustion. **Position 3.** ***Steam pressure again steady;*** steam regulator holds steam valve open; fan still running at higher speed; combustion holds at higher rate with original furnace pressure restored; regulator blade again vertical; pilot valve shut; damper holds in new correct open position. **Position 4.** ***Steam pressure rises;*** steam regulator closing steam valve on fan; fan speed reduced, furnishing less air; combustion reduced, forming less gas and lower furnace pressure; regulator blade in; pilot valve open to drain; damper closing to a new correct position.

Ans. In this arrangement heat is abstracted from the waste gases to raise the temperature of the incoming air.

The fan is situated between the boilers and smoke stack while a suction or reduction in pressure of about one and one-half inches of water is usually allowed at the fan inlet.

Balanced Draught.—This is a combination of forced draught and induced draught, designed to overcome the objectionable

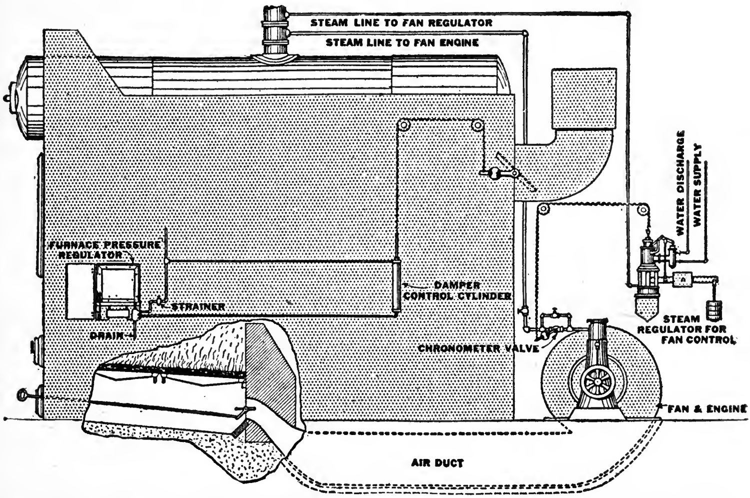


FIG. 4,675.—Diagram of balanced draught furnace pressure regulator showing attachment to furnace and flue damper. ***In construction,*** the regulator contains a swinging plate diaphragm and covers the outer end of a pipe, forming a chamber in which the pressure is the same as in the furnace. The swinging diaphragm is mounted on knife edges and its axis passes through its center of gravity, the broad plate above the center being balanced by a counterweight below, so that the plate swings easily outward and inward in response to the slightest change in pressure on its broad surfaces, and thereby operates a pilot valve. This valve is connected by suitable piping to one or more hydraulic cylinders conveniently located on the boiler setting.

features of each, by maintaining the pressure between the furnace and smoke flue at practically atmospheric pressure, or just enough vacuum to carry off the gases.

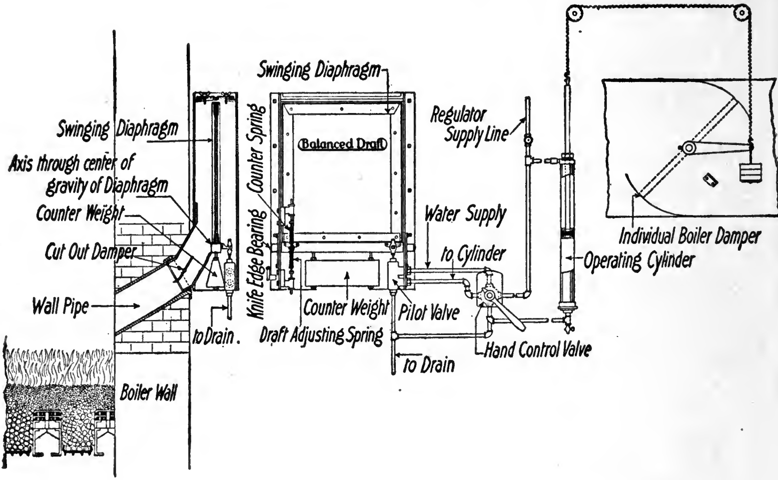


FIG. 4,676.—Diagram of ***single cylinder*** control balanced draught showing steam control of fan and furnace pressure control of flue damper. The essential apparatus used for balanced draught consists of a furnace pressure regulator, a pilot valve, one or more hydraulic cylinders an air pressure regulator and some form of mechanical draught. A cast iron pipe connects the regulator with the furnace, the outer end of the tube ending in the regulator box and damper. The piston of the hydraulic cylinder is connected to the flue damper so that the movement of the piston in one direction closes the damper and the reverse movement opens it. By the action of the pilot valve and the piston, the damper may be opened, closed or held indefinitely in any intermediate position between wide open and entirely closed. ***In operation,*** as the furnace pressure becomes normal in response to the movement of the damper, the swinging diaphragm gradually returns to the vertical and the plunger will be again in neutral position. The compensating feature should be clearly understood. The flue damper does not go from wide open to tight shut and vice versa, but moves only as much as is required to restore the predetermined furnace pressure and is held indefinitely in that position until the furnace conditions require a further change. The air pressure regulator is connected to the main steam line and controls, through a chronometer valve, the steam supply of the blower engine. The operation of this regulator is such that as the boiler steam pressure drops, the chronometer valve is opened, speeding up the fan and increasing the supply of air to the furnace. Conversely, when the boiler steam pressure rises, the fan slows down, decreasing the supply of air to the furnace. The operation of the blower speed regulator is such that a slight drop of the steam pressure is immediately followed by only a slight increase of the blower speed, which automatically is maintained until the steam pressure is restored or until a further slight drop in pressure again increases the speed until the right speed to meet furnace and steam requirements is reached. This prevents the sudden "all on" or "all off" action of the blower so destructive to fuel bed and stokers. ***In adjusting,*** the single cylinder control. the flue damper of each boiler is first closed by hand until the draught over its fire, as shown by a draught gauge, is that found by experience to be productive of the best combustion in that particular furnace. The spring tension is then adjusted to hold the diaphragm vertical with this draught over the fire and thereafter it automatically maintains this draught for all rates of combustion.

Forced draught has the objection that the hot gases escape through the fire doors every time they are opened, and also through any leaks in the setting. With induced draught the reverse conditions obtain, that is, cold air enters through the fire door when open, and also through any leaks in the setting.

Evidently if the difference in pressure inside and outside of the furnace be only sufficient to carry off the gases, these defects will be minimized.

Balanced draught is obtained by the automatic regulation of both the supply of air *to* the furnace and the escape of gases *from* the furnace in such manner as to maintain at all times a constant predetermined draught in the furnace for all rates of combustion.

Its principle is to supply all the air needed for perfect combustion but no more, and at the same time maintain as little suction as possible or just enough to carry off the gases as fast as they are formed.

Forced draught under automatic control supplies the required amount of air, and an automatic damper in the smoke flue maintains a constant predetermined suction or draught.

The action of the automatic control devices for the blower and damper is such that when the blower speed is increased, the damper is opened wide to accommodate the greater amount of gases formed by combustion.

In one arrangement the damper controller changes the position of the boiler damper in unison with the varying speed of the blower, the speed of the blower in turn being controlled by the steam pressure.

A better method is by using steam control for the fan only and furnace pressure control for the damper, as shown in figs. 4,676 and 4,677.

Method of Determining Draught Required.—There are so many points to be taken into consideration in determining the

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NOTE.—***Two cylinder control*** of balanced draught, as shown in fig. 4,677, is specially adapted to stoker work. Without it the increase in air pressure under the fire in response to a falling steam pressure will decrease the suction over the fire and the damper cylinder will open the damper until the limit of the flue is reached. If the pressure then continue to rise or if a large hole form in the fire, or there be a break of some kind at any time allowing the fan to blow right through into the furnace chamber until the flue limit is reached, the pressure in the furnace would, in either case, continue to build up and probably burn out the stoker. The auxiliary cylinder avoids this possibility, for when the damper cylinder has opened the damper wide without being able to restore the predetermined furnace pressure in the furnace, the auxiliary cylinder will start to operate and very gradually close the air gate, reducing the air supply to the stoker until a point is reached where the predetermined pressure is reached and maintained.

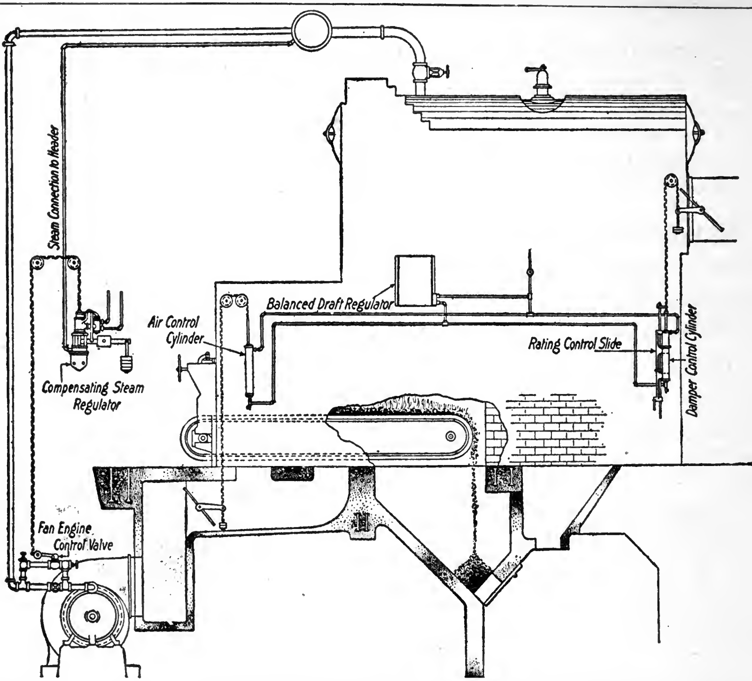


FIG. 4,677.—Diagram of ***two cylinder*** control balanced draught showing steam control of fan, load adjusting panel and furnace pressure control of flue damper ***and air supply***. Many engineers believe that the most economical way to operate their power plant is to run as many boilers as possible at the rating which gives the highest efficiency, taking the load variations with one or two boilers which are used exclusively for this purpose. In modern water tube boilers this point is approximately 170% of rating although the exact point varies with balanced draught, the efficient load can be made temporarily the maximum load for any number of boilers by limiting the maximum opening of their flue dampers. If, however, there be an increase in the steam demand on the plant and all of these steady load boilers are up to their efficient rating, the increase in air pressure which results from the automatic action of the falling steam pressure on the air supply would normally produce a positive pressure in the furnace. To prevent this condition, the balanced draught apparatus is equipped with an additional cylinder, as shown, to control the air supply. ***In operation,*** by means of damper chains leading to the front of the boilers, the dampers of all of the boilers which are to carry the steady load are set to the given maximum rating and the damper cylinder will then, through the operating of the balanced draught regulator, control the exit of the gases and the rate of combustion up to the point at which it is set. After the maximum is reached, further demands for power will cause an increase in the air pressure in the air ducts which will increase the furnace pressure and close the air inlet gate so that only the correct amount of air is supplied for the given rate of combustion. The opening of the flue dampers on the variable load boilers not being limited, the air blast will speed up the combustion in these boilers and they will supply the steam needed to meet the increased demand. If for short periods of peak load it be necessary to operate all boilers above their efficient rating, it is only necessary to remove the limit of the opening of all flue dampers. Again, if the engineer desire to distribute the plant load equally among all the boilers, this also can be accomplished by the use of the two cylinder control.

most suitable draught for any particular installation that the matter should be decided by those whose judgment has been developed by considerable experience.

There are two cases to consider:

1. Draught required **without** *economizer*.
2. Draught required **with** *economizer*.

Draught without Economizer.—For average conditions the total draught required for a well designed boiler plant can be approximately determined from the following simple formula:

$$P=\left(\frac{R}{K}\right)^2$$

Where P = Pressure in inches of water.

R = Rate of combustion in pounds per square foot of grate per hour.

K = Constant for the different varieties of coal.

The equation can, of course, be rearranged to determine values of the other factors as follows:

$$R=K\sqrt{P}$$

$$K=\frac{R}{\sqrt{P}}$$

For a rate of consumption of 20 pounds of coal per square foot of grate per hour the values of K for various fuels are as follows:

For	bituminous	lump	= 34
"	"	run of mine	= 30
"	"	slack	= 26
"	anthracite	nut	= 24
"	"	pea	= 22
"	"	No. 1 buckwheat	= 20
"	"	rice	= 18
"	"	barley	= 16

Draught with Economizer.—In cases where heat is recovered from the waste gases the additional draught required varies with the size and arrangement of the economizer, but as an approximation, the total draught required for the complete installation may be arrived at by adding 60 per cent. to the pressure computed as recommended above, the addition to take care of the frictional loss in the economizer.

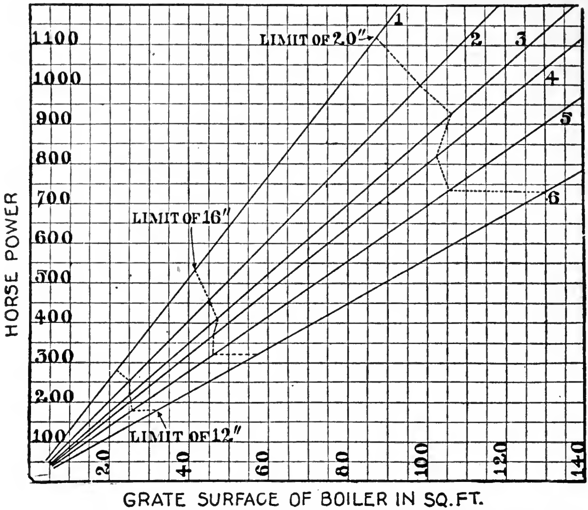


FIG. 4,678.—Horse power curves for 12, 16, and 20-inch Wing blowers. They are based on an efficiency of boiler and grate of 68 per cent. and on rates of combustion and heating values of the coal as given above. For instance, it is desired to know what *h.p.* can be obtained with 36 square feet of grate burning No. 2 Buckwheat anthracite. Moving vertically along the line 36 square feet, it intersects the No. 2 buckwheat line at about the 380 *h.p.* line and that this is within the limits of the 16-inch blower. That is a 16-inch blower will develop 380 *h.p.* with No. 2 buckwheat on 36 square feet of grate. If the buckwheat have 12,500 *B.t.u.* per pound instead of 12,000, the *h.p.* will be increased in the proportion of 12,500/12,000. Again, if only 225 *h.p.* be required, the rate of combustion necessarily will be only 225/380 of 33 pounds, which equals 19½ pounds. The preceding will aid in selecting the proper blower. Note.—Do not use "LIMIT" horse powers except for the highest overload likely to be carried; then you will have a wide margin of blower capacity. ***Line No. 1,*** bituminous coal, 14,000 *B.t.u.* per lb., combustion rate 45 lbs.; ***2,*** bituminous, 12,500 *B.t.u.*, rate 40 lbs.; ***3,*** anthracite No. 1 buckwheat, 12,300 *B.t.u.*, rate 35 lbs.; ***4,*** anthracite No. 2 buckwheat 12,000 *B.t.u.*, rate 33 lbs.; ***5,*** anthracite No. 3 buckwheat, 11,500 *B.t.u.*, rate 30 lbs.; ***6,*** coke breeze, 11,000 *B.t.u.*, rate 25 lbs.

NOTE.—***Anthracite coal requires a stronger blast than bituminous coal,*** because the latter fuel undergoes a coking process during burning, and in the case of slack, the small particles cohere into semi-plastic lumps of varying size while the agitation caused by the escape of gases under the influence of heat results in the fire bed being kept in an open condition, thereby offering little resistance to the passage of air. Anthracite, being geologically the oldest form of coal, has lost the volatile constituents present in bituminous fuels, lies inert on the fire grate, does not coke, and, therefore, requires strong draught to effect the passage of the required amount of air.

NOTE.—***Draught needed to overcome friction.*** Having determined the draught required for the fire bed alone, it is then necessary to ascertain the loss due to the frictional resistance of the boiler, breeching, economizer and stack, and in the case of forced draught the resistance due to the skin friction of the supply duct should also be taken into consideration. Although the resistance due to the fire bed is a variable quantity, the amount of draught needed to overcome the friction throughout the remainder of the system is chiefly dependent on the areas of the various passages, the volume and temperature of the flue gases, and with these last three factors constant, the variation in draught needed to develop the same horse power with different fuels would be solely due to the fire bed resistance.

Points Relating to Draught.—For ordinary forced draught coal burning propositions, the cubic feet of air required per

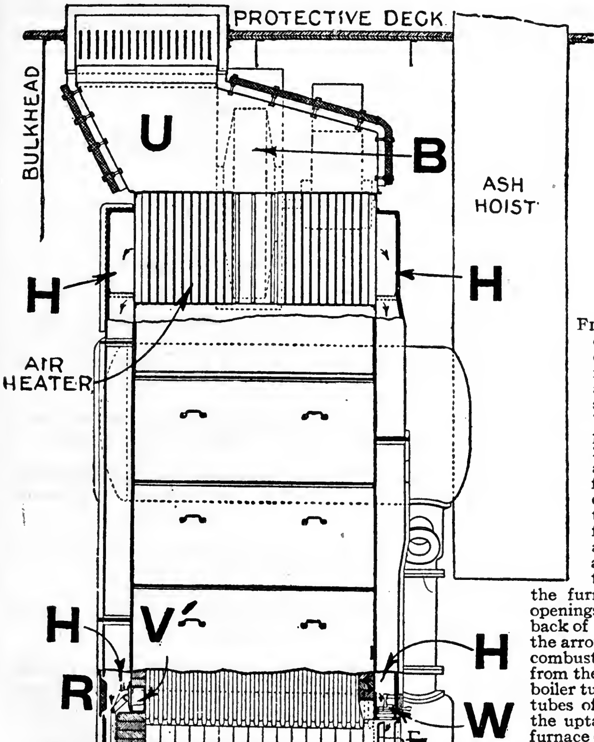


Fig. 4,679.—Howden closed ash pit forced draught system. B is the blower situated at the top and on one side of the boiler. The air heater is composed of 416 tubes, 2½ ins. in diameter, and has a heating surface of 793 square feet or a little over ten times the grate surface. Air ducts H, H are built on the front and back of the boiler to guide the air to the furnace fronts and to openings in the back wall and back of ash pit, as shown by the arrows. The products of combustion pass upwards from the furnace, around the boiler tubes, and through the tubes of the air heater into the uptake U. Above each furnace door F, is an opening covered by a flat valve W, which can be moved by a handle from the outside. The supply of air to the front part of the fire can thus be regulated. In the back wall, some distance above the grate, there is a perforated plate extending almost the whole width of the grate. By means of the damper V′, the supply of hot air from H, to the top of the fire can be regulated. The main supply of air enters the ash pit A, through the large damper V. Both dampers are worked together by the rod L, from the front of the boiler. A hand hole R, is provided in the back of the casing for the easy examination of damper V′.

minute is twenty times the boiler horse power developed allowing about 100 per cent. excess air.

For ordinary induced draught coal burning propositions forty times the boiler horse power developed is the cubic feet of gas per minute that the fan should handle.

Five times the coal burned per hour is the approximate of air in cubic feet the fan should supply per minute for forced draught.

Ten times the coal burned per hour is the approximate amount of gas per minute the fan should handle for induced draught.

The forced draught apparatus of the ordinary proposition requires from 2 to 4 per cent. of the steam developed.

The induced draught apparatus of the ordinary proposition requires 1½—2 per cent. of the steam developed.

The figures given in the two preceding paragraphs, are based on the wasteful types of engines generally installed. Considerably better results could be obtained by the use of an economical engine, as for instance the one shown in fig. 4,645.

The furnace draught required to develop rated capacity under ordinary conditions with run of mine bituminous coal and flat grates is ¼ inch.

The induced draught at the uptake of the boiler required to develop rated capacity under ordinary conditions is ½ inch with run of mine bituminous coal and flat grates.

The ordinary boiler rating is ten square feet of heating surface for each boiler horse power.

Each square foot of grate surface develops 5 horse power when burning 20 pounds of run of mine bituminous coal per hour.

With natural draught the coal burned in a boiler with flat grates is from 15 to 25 pounds per square foot of grate surface per hour. With forced draught this amount usually varies from 40 to 60 pounds.

The draught required in any plant varies directly as the square of the rating developed. For instance, suppose a plant developing 100 per cent rating requires ¼ inch draught. If it be forced to 150 per cent. rating, it will require $(1.5)^2 = 2\frac{1}{4}$ times as much draught. $2\frac{1}{4} \times \frac{1}{4} = \frac{5}{8}$ inch for 200 per cent. rating, four times the draught would be required, or 1 inch.

In a forced draught system it is not desirable to deliver air upward toward the grate, as this will tend to blow holes in the fire. On the other hand air should be distributed evenly throughout the ash pit, so as to cause uniform combustion.

CHAPTER 79

BOILER FITTINGS, FIXTURES AND ATTACHMENTS

There are certain fittings or devices, usually mounted on the boiler and which are essential for its proper operation, as

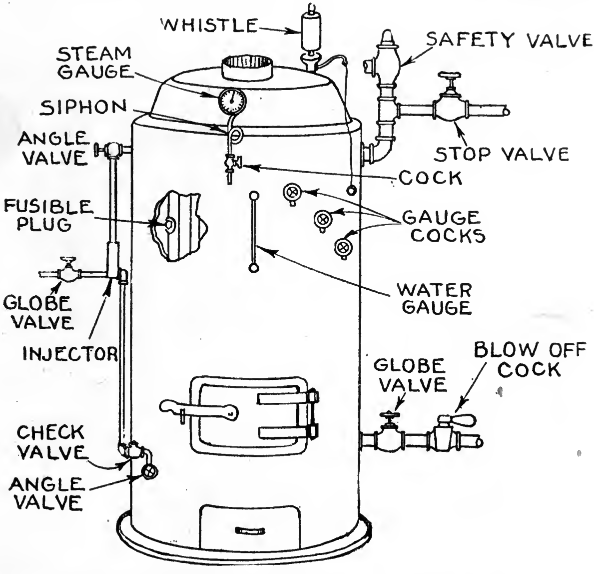
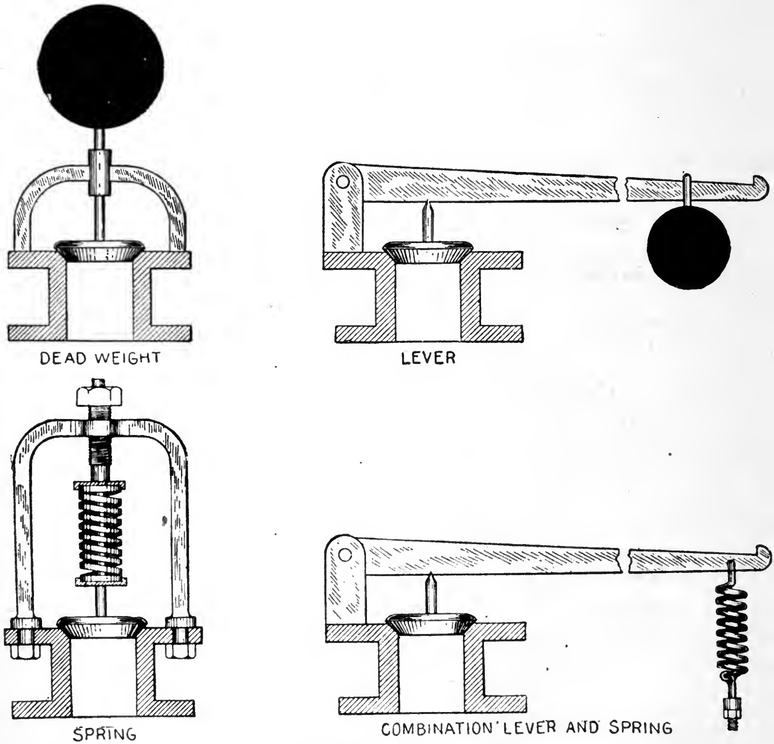


Fig. 4,680.—Vertical boiler showing the boiler fixtures consisting of control and indicating devices essential for safe operation. A portion of the shell is cut away to expose the fusible plug to view.

NOTE.—1, that there must not be any valves between safety valve and boiler; 2, that a stop valve must be placed on main steam line in case of battery of boilers; 3, that the injector must have an individual steam connection with no branches for other use; 4, that a globe valve is placed between check valve and boiler, allowing cleaning or repair of check valve while boiler is under steam; 5, that a globe (or gate) valve must be placed between check valve and boiler as a safeguard to prevent leakage, or in case blow off valve cannot be closed or the valve becoming detached from its seat, and 6, that a drain cock should be put on safety valve connections.

distinguished from the auxiliary apparatus described in the next chapter.

These fittings (sometimes called the boiler attachments) consist of:



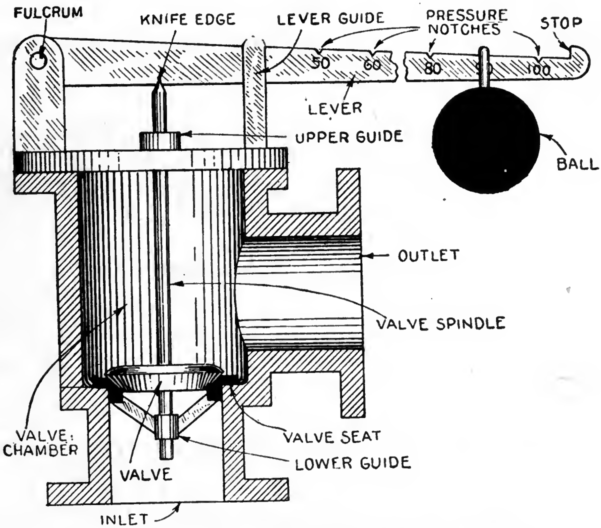
FIGS. 4,681 to 4,684.—Elementary safety valves showing various types. Fig. 4,681, dead weight valve; fig. 4,682, lever valve; fig. 4,683, combination lever and spring valve; fig. 4,684, spring valve.

1. Valves.

a. Safety valve.

b. Stop valve.
c. Check valve.
d. Blow off valve.

2. Water gauge cocks.
3. Water gauge.
4. Steam gauge.



FIG, 4,685.—Sectional view of a lever safety valve showing essentia parts.

5. Injector.
6. Fusible plug.
7. Whistle.

Safety Valve.—This is the most important device fitted to a boiler, as it prevents the steam rising above the safe working pressure, that is, the pressure at which it should be set. Moreover, upon its proper operation depends the safety of those in charge of the boiler.

Ques. What care should a safety valve receive?

Ans. It should be kept clean and should be raised by hand every morning.

Ques. Why should it be raised so often?

Ans. So that it cannot stick in its seat through the accumulation of dirt and scale.

Ques. What types of safety valve are in general use?

Ans. The lever safety valve, and the spring safety valve.

There are two other types: 1, the dead weight valve, used sometimes for very low pressure apparatus as in steam heating; and 2, the combination lever and spring valve in which a spring is used in place of the weight on a lever valve. This type is used principally in England. The four types just mentioned are shown in figs. 4,681 to 4,684.

Ques. For what service is each intended?

Ans. The lever valve is used principally in stationary practice and sometimes on ferry boats, side wheel steamers and other craft navigating quiet waters and carrying moderate or low pressure steam.

Ques. How should a safety valve be attached to the boiler?

Ans. It should be attached to a separate outlet, but if only one outlet be on the boiler, it may be attached to a tee on main steam pipe, as close to the boiler as possible without any kind of valve between it and the boiler.

Ques. What features should a good safety valve possess?

Ans. A good safety valve should be: 1, large enough in diameter, and have sufficient *lift* to allow the steam to escape as fast as it is generated, when the pressure is slightly above that to which it is set; 2, it should close as soon as the pressure has dropped a predetermined amount below the set pressure;

3, it should be enclosed or so protected that it cannot be tampered with or accidentally interfered with by contact with foreign objects; 4, for marine purposes it must be so constructed as not to be affected by the motion of the boat.

Ques. What defects occur in safety valves, and how are they repaired?

Ans. The valve may be broken, which fact will be shown by steam escaping through the escape pipe. In case the valve itself, or the spindle, be broken, sometimes a new valve can be built by fitting a disc of heavy plate into which a stem is riveted in the center.

If the spring give out and no spare one be on hand, it may be possible to fit a long lever, pressing on the spindle of the valve and load it at the end with sufficient weight to hold the normal pressure. Where room permits, lead discs may be cast and placed on the spindle and the valve thus loaded.

In case the valve be jammed and do not blow off with a rapidly rising steam pressure, the valve may be given a sharp blow, which sometimes will start it. If this do not produce the desired relief, all steam outlets to auxiliaries and condenser must be turned on full, to work off the steam. Fire and uptake doors are better opened and the fires deadened with wet ashes, until well within the working pressure.

The steam is better allowed to fall until it is possible to dismount the valve and refit it in efficient condition.

THE LEVER SAFETY VALVE

Construction.—The essential parts of a lever valve consist of: 1, a valve chamber containing the valve seat, inlet and outlet opening; 2, a cover containing the upper spindle and lever guides, also an arm having a pivot hole at its end forming the *fulcrum;* 3, a *valve* and *spindle*, the latter being attached to the valve and the projecting part terminating in a *knife edge;* 4, a *lever*, pivoted at one end to the projecting arm or *fulcrum*, in contact with the knife edge of the spindle at an intermediate point and weighted at the other end with a *ball*.

Why is a lever valve objectionable on vessels navigating rough water?

The inertia of the weight produces a variable pressure on the valve tending to close and open the valve respectively with rise and fall of the boat on the waves. Moreover, when the boat rocks, the horizontal position of the lever is disturbed and the blowing pressure of the valve is lowered.

How is the pressure regulated on the lever safety valve?

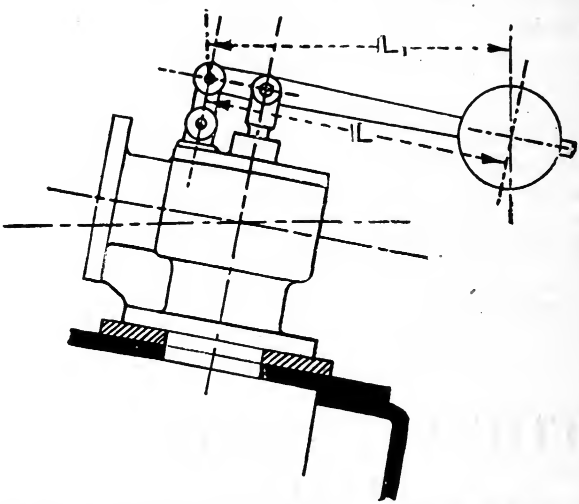


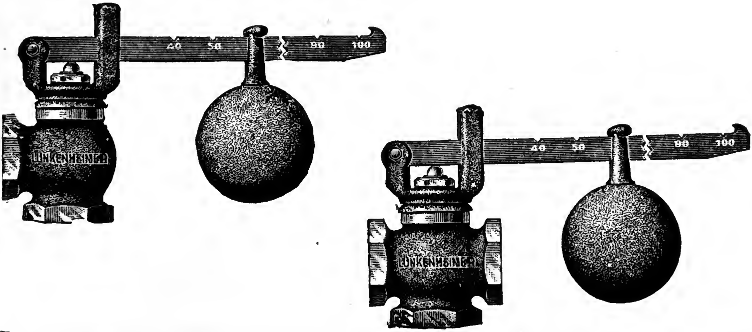
FIG. 4,686. Diagram of a lever safety valve, showing decrease of the weight's effect, as the result of incline in a heavy sea. In the diagram, L, is the length of the lever arm, the full length being effective when horizontal but when inclined the effective length is reduced to L_1

By moving the weight on lever; the farther it is from valve the greater the blowing off pressure.

RULE II, 23.—All common lever safety valves to be hereafter applied to the boilers of steam vessels shall be constructed in material, workmanship, and principle according to the requirements for a safety valve referred to in this section. When this construction of a safety valve is applied to the boilers of steamers navigating rough waters, the link may be connected direct with the spindle of the valve: *Provided, always,* That the fulcrum or points upon which the lever rests are made of steel, knife, or sharp edged, and hardened; in this case the short end of the lever shall be attached directly to the valve casing. In all cases the link requires but a slight movement not exceeding one-eighth of an inch.

What precaution should be taken with a lever valve?

The lever should be raised **frequently** *permitting the valve to blow to guard against the valve sticking to the seat.*



FIGS. 4,687 and 4,688.—Lunkenheimer lever safety valves with screw ends. Fig. 4,687 angle valve; fig. 4,688 cross valve. The cross type valve may be used with the bottom and one side as inlets, and the remaining side as outlet.

U.S. MARINE REQUIREMENTS IN CONSTRUCTION OF LEVER SAFETY VALVES

All the points of bearing on lever shall be in the same plane.

The distance of the fulcrum shall in no case be less than the diameter of the valve opening.

The length of the lever shall not exceed the distance of the fulcrum multiplied by ten.

The width of the bearings of the fulcrum shall be not less than three-fourths of 1 inch.

The length of the fulcrum link shall be not less than 4 inches.

The lever and fulcrum link shall be made of wrought iron or steel and the knife edged fulcrum points and bearings for the points shall be made of steel and hardened. But the chambers and saddle flanges of this and all other types of safety valves attached to boilers may be made of cast iron or other suitable material.

The valve, valve seat, and bushing for the stem or spindle shall be made of composition (gun metal) when the valve is intended to be attached to a boiler using salt water; but when the valve is to be attached to a boiler using fresh water and generating steam of a high pressure the parts named, with the exception of the bushings for the spindle, may be made of cast iron. On safety valves constructed after June 30, 1905, neither the valve nor the valve seats shall be of cast iron.

The valve shall be guided by its spindle, both above and below the ground seat and above the lever, through supports either made of composition (gun metal) or bushed with it.

The spindle shall fit loosely in the bearings or supports.

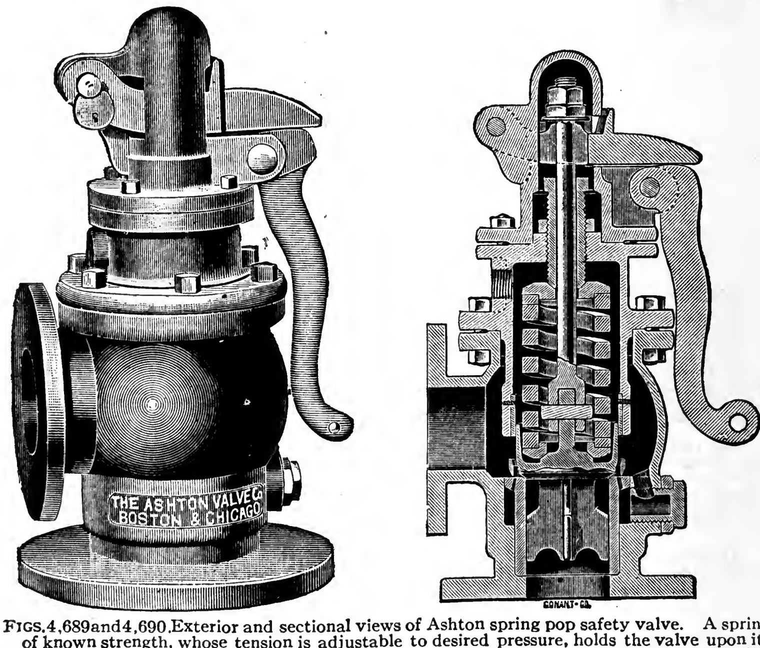
When the valve is intended to be applied to the boilers of steamers navigating rough waters, the fulcrum link may be connected directly with the spindle of the valve; *providing always* that the knife edged fulcrum points are made of steel and hardened, and that the vertical movement of the valve is unobstructed by any lateral movement.

In all cases the weight shall be adjusted on the lever to the pressure of steam allowed in each case by a correct steam gauge attached to the boiler. The weight shall then be securely fastened in its position and the lever marked for the purpose of facilitating the replacing of the weight should it be necessary to remove the same, and in no case shall a line or any other device be attached to the lever or weight except in such a manner as will enable the engineer to raise the valve from its seat. (Sec. 4418, R. S.)

THE SPRING SAFETY VALVE

Construction.—In this type of valve, the force due to the compression of a spring is used to oppose the steam pressure instead of a weighted lever.

The spring, as shown in figs. 4,692 and 4,693 is attached to the lower part of the valve spindle and may be placed inside or outside of the valve chamber.



FIGS. 4,689 and 4,690. Exterior and sectional views of Ashton spring pop safety valve. A spring of known strength, whose tension is adjustable to desired pressure, holds the valve upon its seat. By the lever attached to the valve stem, however, the valve may be raised, allowing the steam to blow off, whenever desired.

The upper end of the spring bears against a cup attached to an adjustable bushing by means of which the pressure on the valve is regulated.

The curved lever arm acting at the top of the spindle is for the purpose of operating the valve occasionally by hand to guard against it "sticking," and thus permitting the pressure to rise above the pre-determined value. The accompanying cuts show actual construction of some modern spring valves.

Why does a pop safety valve "pop"?

In this type of spring valve, the construction is such that as soon as the valve begins to open, an excess area of the disc is presented to the escaping steam, hence it suddenly opens wide.

RULE II, 23.—Any spring loaded safety valve constructed so as to give an increased lift by the operation of steam after being raised from its seat, or any spring loaded safety valve constructed in any other manner, so as to give an effective area equal to that of the aforementioned spring loaded safety valve, may be used in lieu of the common lever weighted valve on all boilers on steam vessels, and each spring loaded valve shall be supplied with a lever that will raise the valve from its seat a distance of not less than that equal to one-eighth of the diameter of the valve opening; but in no case shall any spring loaded safety valve be used in lieu of the lever weighted safety valve without first having been approved by the Board of Supervising Inspectors.

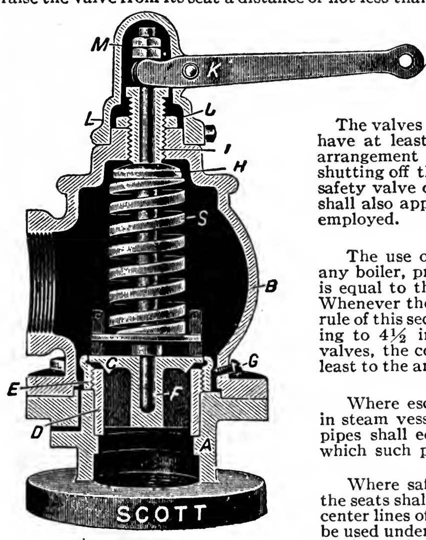


FIG. 4,691. Scott spring pop safety valve. ***The parts are:*** A, base; B, iron case; C, bronze valve or disc; D, bronze bushing or seat; E, adjustable ring; F, steel stem and spindle; G, screw to hold adjustable ring; H, spring plate; I, bronze loading bolt; J, lock nut; K, lever (malleable iron); L, iron cap and screw to hold cap; M, stem or lifting nuts.

The valves shall be so arranged that each boiler shall have at least one separate safety valve, unless the arrangement is such as to preclude the possibility of shutting off the communication of any boiler with the safety valve or valves employed. This arrangement shall also apply to lockup safety valves when they are employed.

The use of two safety valves may be allowed on any boiler, provided the combined area of such valves is equal to that required by rule for one such valve. Whenever the area of a safety valve, as found by the rule of this section, will be greater than that corresponding to 4½ inches in diameter, two or more safety valves, the combined area of which shall be equal at least to the area required, shall be used.

Where escape pipes for safety valves are installed in steam vessels after July 1, 1910, the area of such pipes shall equal the combined area of all valves to which such pipes are connected.

Where safety valves are used with beveled seats, the seats shall have an angle of inclination of 45° to the center lines of their axes. Flat seat safety valves may be used under the formula and table under the heading "Safety valves" in Rule II.

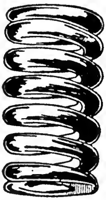
Hereafter no safety valves having a set screw arrangement on top of the valve casing, designed to hold the valve down while the hydrostatic pressure is being applied, shall be allowed. On such valves now in use, inspectors shall require the set screws to be taken out and the hole permanently closed. This does not apply to any safety valve whose form of construction is such that the hole for the set screw or bolt is securely closed when the valve is locked.

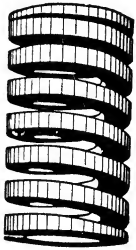
Ques. How is the blowing off pressure regulated on a spring loaded valve?

Ans. By increasing or decreasing the tension of the spring. This style of valve always has an adjustable set screw for this purpose.

Ques. What precaution should be taken with a spring valve?

Ans. *The hand control lever should be raised frequently, permitting the valve to blow to guard against the valve sticking to the seat.*





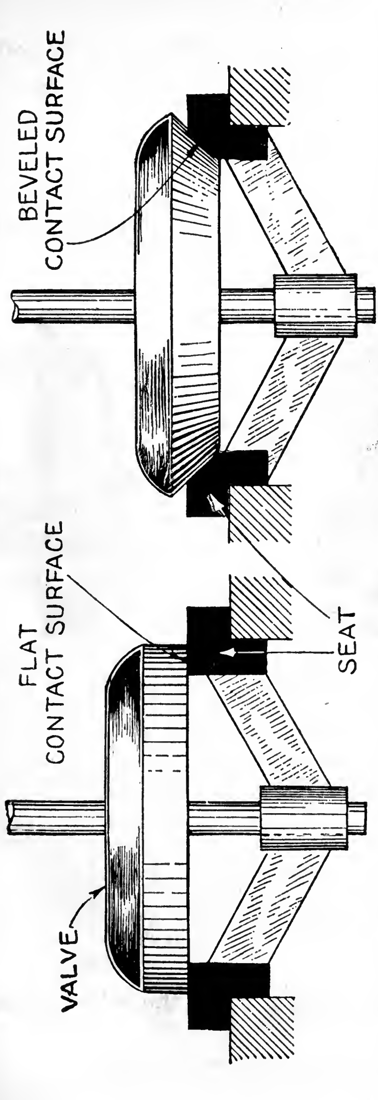
Ques. What kind of a spring valve should be used with superheated steam?

Ans. One with an *outside* spring.

FIGS. 4,692 and 4,693.—American springs for brass and iron pop safety valves. Fig. 4,692, round type for brass valves 2 inches and under; fig. 4,693, rectangular type for brass and iron valves 2½ inches and over.

NOTE.—***Comparison of lever and spring safety valves.*** The lever valve has no definite "pop" point, the valve lifting slowly in opening, and settling gradually in closing. A comparatively long range of blowing is necessary for the valve to effectively open, and a considerable excess pressure is necessary in specifications for such valves. ***Spring valves,*** have a positive opening to practically the full amount. ***At the popping point,*** a properly designed spring valve will lift its maximum, say .15 inch, and this lift will decrease approximately .01 inch per pound that the pressure in the boiler falls below the popping point. Other pressures may force the lift slightly higher with such a valve, but not sufficiently to make these pressures necessary to obtain the full valve efficiency. In specifying spring valves, therefore, an excess pressure should not be allowed, at least not over 1 or 2 pounds.

NOTE.—***Installation and care of safety valves.*** All safety valves should be connected directly to the boiler with a close nipple or a short steam nozzle of the full valve size, or larger. In attaching the flange, the bolts should be drawn up evenly, as distortion of the valve seat may otherwise occur. In making a hydraulic test on a boiler the valve should be properly gagged, and not made to blow at a higher pressure by screwing down the spring. Safety valve springs are designed for a definite pressure, which is usually stamped on a tag fastened to the valve. If a valve is to be set at a pressure differing from the designed pressure by more than 5 or 10 pounds (depending upon the make of the valve) either above or below, a new spring should be furnished. Where safety valves are used with superheated steam, those of the outside spring type should be used in order to protect the metal of the spring from the high temperatures. ***In operation,*** all valves should be made to blow periodically to avoid the danger of sticking.



FIGS. 4,694 and 4,695 Valve and seat with flat and beveled contact surface. ***For marine use*** the beveled type is the standard and the bevel must be inclined at an angle of 45°. Most engineers think that flat seats are not allowed for marine use, but this is not correct, for according to RULE II, 23—Flat seat safety valves may be used under the formula and table under the heading "Safety Valves" in Rule II.

THE VALVE AND SEAT

Classes of Valve and Seat.—There are three types of valve and seat:

1. Plain valve with seat having flat contact surface;

2. Plain valve with seat having beveled contact surface;

3. "Pop" valve with seat having either flat or beveled contact surface.

Of the three types, the latter with beveled contact surface is generally used for marine use.

How do the discharge capacities of flat and beveled valves compare?

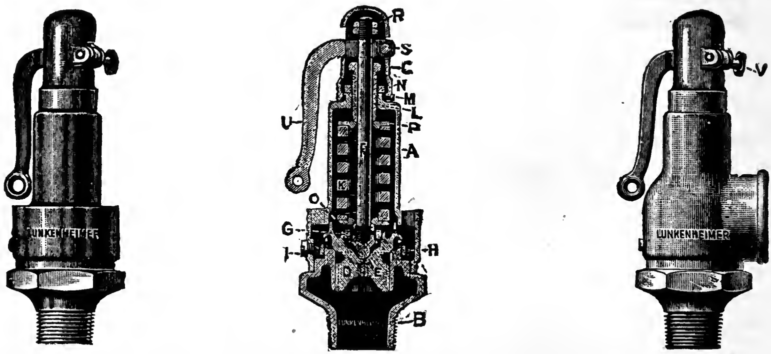
The discharge capacity of a flat valve is 1.41 times that of a 45° beveled valve of same diameter and lift.

What is a pop safety valve?

One so constructed that it opens very suddenly like a cork popping out of a bottle and remains open until the pressure is reduced a pre-determined amount.

What is the advantage of a pop valve?

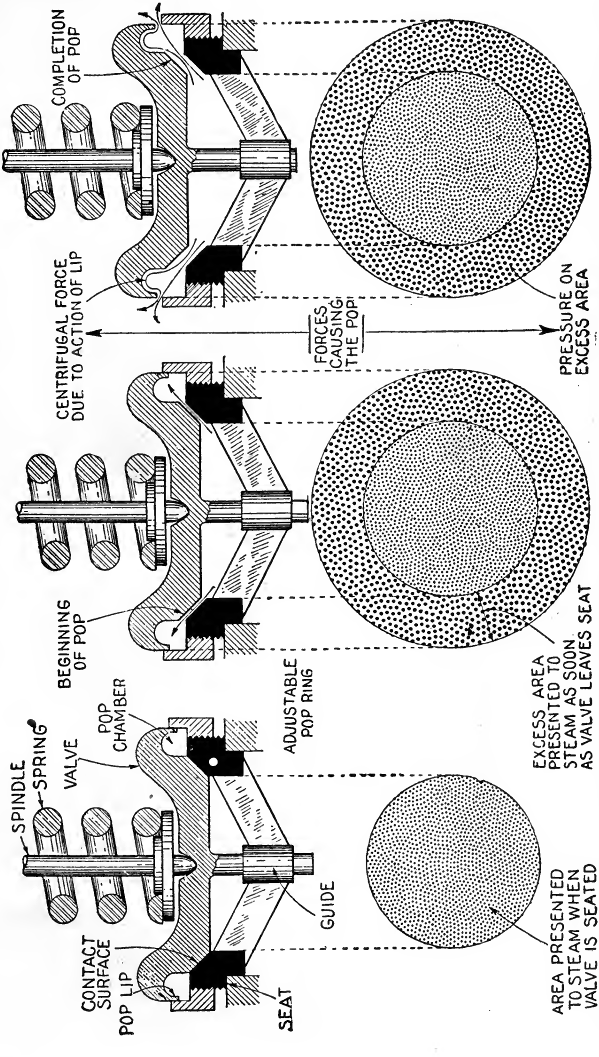
It is very sensitive in that it will blow very close to the set pressure, and also very stable in that it will not chatter but continue blowing until the pressure is appreciably reduced.



FIGS. 4,696 to 4,698.—Lunkenheimer pop safety valves for working pressures up to 250 lbs. Fig. 4,696 top outlet; fig. 4,697 sectional view; fig. 4,698, angle outlet. These valves are made of bronze composition. All valves are provided with lock key attachment to guard against their being tampered with, and adjustment of the amount of pop can be made from the outside of the valve without taking it apart. The springs rest between ball and socket plates, which equally divides the pressure on the disc, and as the spring and disc are encased, the valve cannot be affected by back pressure. Lunkenheimer valves have bevel seats, at an angle of 45 degrees to the vertical axis of the valve, and are provided with suitable levers, by means of which the discs can be raised from their seats. The outlets are made one size larger that the inlets. ***To take the valve apart:*** take out the lock screw and remove the lever U; loosen screw M, and remove bonnet C; relieve the load on the spring by unscrewing the regulating screw L; remove regulating ring screw I; then unscrew bell A. ***To set the valve*** for a higher pressure, turn regulating screw L, down and for a lower pressure turn it up ***The pop*** or amount of escaping steam is regulated by the ring H, in the base of the valve, which is easily accessible without taking the valve apart, and is held securely in place, when set by the regulating ring screw I, on the side of the bell. If the valve do not relieve the pressure enough, remove screw I, and turn the ring H, up, which covers the drill holes and causes the disc to lift higher and remain longer off its seat. If the valve reduces the pressure too much, turn the ring H, down. When the desired adjustment is obtained, secure the ring by means of the screw I.

What names are given to the pressures at which the valve opens, and at which it closes?

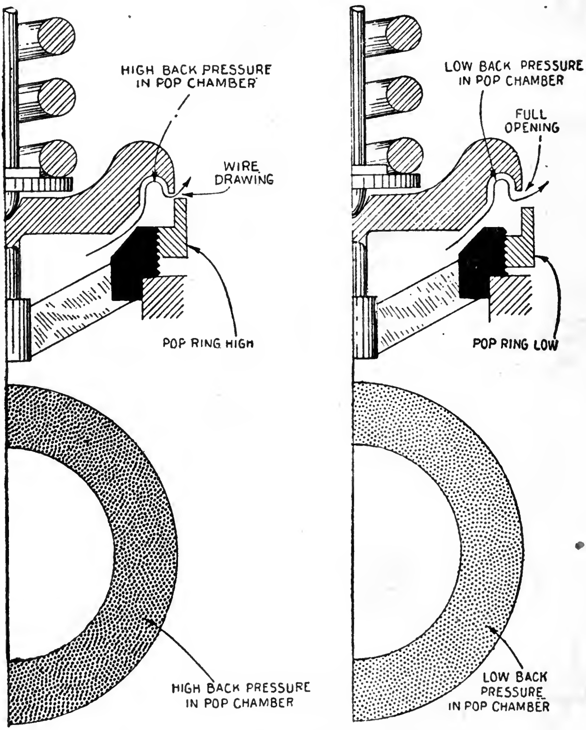
The *blow off* and the *blow down* pressures respectively.



FIGS 4,699 to 4,701.—Construction and operation of a ***pop*** valve. Fig. 4,699 shows the essential parts with their names. ***In operation*** as the valve begins to lift, steam rushes into the pop chamber and being confined (or partially so) therein acts on an excess area as indicated by the shaded ring, fig. 4,700, causing the valve to suddenly lift or "pop" to its full opening as in fig. 4,701, hence the name *pop* valve. The main object of the pop ring is to regulate the blow down or closing pressure. ***To regulate,*** if valve reduce pressure too much, lower pop ring, if not enough, raise pop ring.

Ques. Describe the construction and operation of a pop valve.

Ans. As shown in fig. 4,699 the valve is provided with a projecting *pop lip* and the seat with an adjustable *pop ring* forming the *pop chamber*. *In operation* when the valve begins its opening



FIGS. 4,702 and 4,703.—Pop valve with low and high adjustment of pop ring showing ***why*** the blow down or closing pressure is governed by the postion of this ring. In fig. 4,702, the ring is in high adjustment so that with the valve fully opened as shown, the opening past the ring is restricted resulting in *wire drawing* of the steam with a higher back pressure in the pop chamber than in fig. 4,703 where the ring is in low adjustment giving free passage for the steam to the atmosphere. ***It must be evident*** that with the adjustment of fig. 4,702 giving *high* back pressure in the pop chamber, the valve will remain open longer and reduce the boiler pressure to a lower point than with the adjustment of fig. 4,703, giving *low* back movement, steam rushes into the pop chamber and suddenly acts on an excess area as in fig. 4,700, thus quickly accelerating the movement of the valve which opens wide with great rapidity as in fig. 4,701.

Ques. When the pop chamber opens to the atmosphere what two forces tend to keep the valve open?

Ans. The pressure of the steam on the excess area presented by the pop chamber and the beveled passage way, and the centrifugal force caused by the action of the curved pop lip in changing the direction of the steam.

Ques. How is the intensity of the pop regulated?

Ans. By adjusting the pop ring.

Evidently if the pop ring be screwed down so low that the pop chamber is open to the atmosphere when the valve is closed the valve will not open so suddenly as when it is adjusted to close the pop chamber when the valve is seated as in fig. 4,699.

As usually constructed the pop ring fits loosely and the pop lip so that the pop chamber is a slight opening when ring is in high adjustment.

Ques. What is the main object of the pop ring?

Ans. To regulate the blow down or closing pressure as explained in figs. 4,702 and 4,703.

SAFETY VALVE CALCULATIONS

Introduction. Nearly every one finds more or less trouble in solving safety valve problems, which well may be called the "bridge of sighs," as, indeed, many scores and hundreds of applicants are denied a license, because they cannot correctly answer the questions relating to this requirement, and who otherwise would have passed the examination.

According to the General Rules and Regulations prescribed by the Board of Supervising Inspectors:

Rule IV, 35.—No person shall receive an original license as engineer or assistant engineer of steam vessels (except for license as engineer of saw mill boats and pile drivers propelled by steam, and except for special license as engineer of a steam vessel of any kind of 10 gross tons or under on which a licensed engineer is required) who *is not able to determine the weight necessary to be placed on the lever of a safety valve (the diameter of valve, length of lever, distance from center of valve to fulcrum, weight of lever, and weight of valve and stem being known) to withstand any given pressure of steam in a boiler, or who is not able to figure and determine the strain brought on the braces of a boiler with a given pressure of steam, the position and distance apart of braces being known* * such knowledge to be determined by an examination in writing, and the report of examination filed with the application in the office of the local inspectors, and no engineer or assistant engineer now holding a license shall have the grade of the same raised without possessing the above qualifications. (Sec. 4405 R. S.)

Two Methods.—There are two methods by which the applicant for an engineer's license can prepare to answer questions on the safety valve problem; 1. By learning several rules parrot fashion, or, 2. By *reasoning out the matter* and writing an equation from which the answer to any question the examiner may ask is easily obtained.

The man who adopts the first method, spends considerable time in memorizing the several rules, which have absolutely no meaning to him, and consequently, he does not know any more about the problem than he did at first, although he may be able to recite these rules and pass the examination.

Again, the man who can solve the problem by the second method *understands* what he is talking about; he knows *why* a given weight must be placed at a certain point for the valve to blow at a given pressure. Moreover, he commands *respect* rather than *tolerance* from the examiner.*

Unfortunately, those with very limited knowledge of mathematics are unable to learn how to construct and solve an equation without considerable study, but the author believes, in most cases, that the time spent

*NOTE.—Unfortunately, some of the Government authorities, presumably to facilitate the work of their examiners by having safety valve problems worked out in the same order, insist that the problems be worked according to the so called ***Roper's rules.*** *It should be distinctly understood* that Roper did not originate any "rules" but simply stated safety valve principles in the form of rules, indicating a certain *order* in which the various operations of multiplication, division, etc., are to be performed in solving the problems, just as he might say $3 \times 5 = 15$, while some other writer would express it $5 \times 3 = 15$, the result being the same in either case.

in committing to memory meaningless rules, could be far better utilized in studying the principles of the problem and thus acquire some *real knowledge* rather than *artificial knowledge*.

Safety Valve Rules as stated by Roper

(*Edited and revised*)

1.—To find the weight necessary to put on a safety valve lever, when the area of valve, pressure, etc., are known.

RULE.—A, *Multiply the area of valve by the pressure in pounds per square inch;* **B,** *multiply this product by the distance of the valve from the fulcrum;* **C,** *multiply the weight of the lever by one-half its length (or its center of gravity);* **D,** *multiply the weight of valve and stem by their distance from the fulcrum;* **E,** *add these last two products together;* **F,** *subtract their sum from the second product, and divide the remainder by the length of the lever; the quotient will be the weight required.*

2.—To find the pressure per square inch when the area of valve, weight of ball, etc., are known.

RULE.—A, *Multiply the weight of ball by the length of lever;* **B,** *multiply the weight of lever by one-half its length (or the distance from the fulcrum to its center of gravity);* **C,** *multiply the weight of valve and stem by the distance from fulcrum;* **D,** *add these three products together;* **E,** *this sum divided by the product of the area of the valve, and its distance from the fulcrum, will give the pressure in pounds per square inch.*

3.—To find the distance from the fulcrum at which the weight should be placed for a given blowing off pressure.

RULE.—A, *Multiply the area of the valve in square inches by the steam pressure per square inch;* **B,** *subtract the weight of the valve and stem in pounds;* **C,** *multiply the difference by the distance from the valve to the fulcrum in inches;* **D,** *from this product, subtract the product of the weight of the lever by the distance of its center of gravity from the fulcrum;* **E,** *this difference, divided by the weight of the ball in pounds, will give the required distance in inches.*

4.—To find the distance of the center of gravity of taper levers from the fulcrum.

RULE.—A, *To the width of the small end of the lever add one-third of the difference between the large and the small ends of the lever;* **B,** *multiply the sum by the length of the lever;* **C,** *divide the product by the sum of the large and the small end of the lever, all in inches. The quotient will be the required distance in inches.*

Problem.—RULE 1, fig. 4,704.

Given: Area valve 7.07 sq. ins. Weight of valve and spindle =8 lbs.; weight of lever, 24 lbs.; distance fulcrum to spindle, 4 ins.; distance fulcrum to center of gravity of lever, 16 ins.; distance fulcrum to ball, 2.02 ins. Steam pressure 60 lbs.

Find: *Weight of ball.*

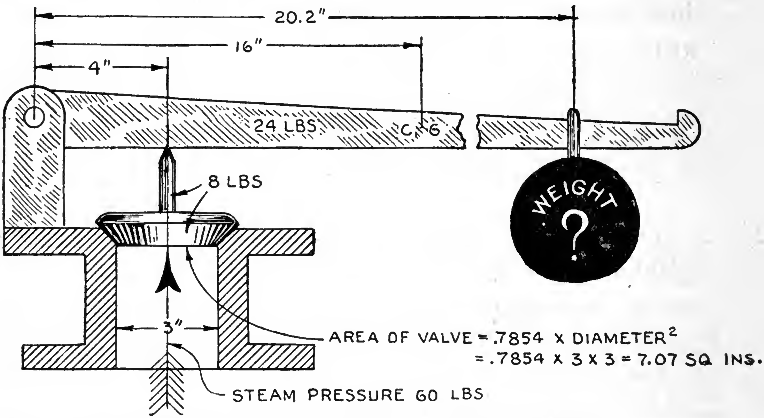


FIG. 4,704. ***Problem Rule 1:*** *To find the **weight** to be placed on a safety valve.*

A. First step

7.07	sq. ins. area of valve
60	lbs. per sq. in., steam pressure
424.20 lbs.	

*This gives the **total pressure** due to the **steam** acting on the valve.*

B. Second step

424.2	lbs. total pressure on valve
4	ins. distance valve to fulcrum
1,696.8	

This is the ***steam moment** tending to **open** the valve.*

C. Third step

24	lbs. weight of lever
16	ins. distance from fulcrum to center of gravity of lever
144	
24	
384	

This is the ***lever moment** tending to **close** the valve.*

D. Fourth step

8	lbs. weight of valve and spindle
4	ins. distance fulcrum to spindle
32	

This is the ***valve and spindle moment** tending to **close** the valve.*

E. Fifth step

384	lever moment from **C**
32	valve and spindle moment from **D**
416	

This is the sum of the ***lever moment*** and the ***valve and spindle moment.***

F. Sixth step

1,696.8	steam moment from **B**
416	lever moment + valve and spindle moment
1,280.8	

```
20.2)1280.8(63.41
     1212
      688
      606
       820
       808
        1200
```

*This is the **required weight** necessary to put on the lever at the **given distance** for the valve to **blow** at 60 lbs.*

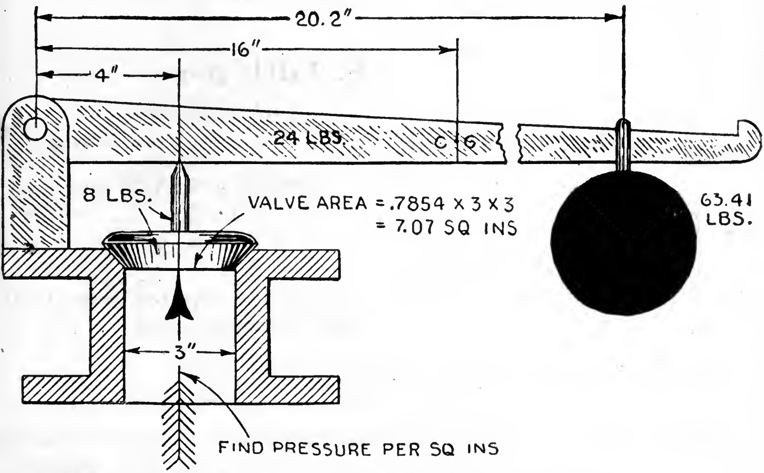


FIG 4,705. ***Problem Rule 2:*** *To find **steam pressure** at which valve will blow.*

Problem.—RULE 2, fig. 4,705.

Given: Area of valve 7.07 sq. ins.; weight of valve and spindle 8 lbs.; weight of lever 24 lbs.; weight of ball 63.41 lbs.; distance fulcrum to spindle 4 ins.; distance fulcrum to center of gravity of the lever 16 ins.; distance fulcrum to ball 20.2 ins.

Find: *Steam pressure at which valve will blow.*

A. First step

63.41 lbs. weight of ball
20.2 ins. distance from fulcrum to ball
12 682
1268 2
1280.882

This is the ***ball moment*** *tending to* ***close*** *the valve.*

B. Second step

24 lbs. weight of lever
16 ins. distance from fulcrum to center of gravity of lever
144
24
384

This is the ***lever moment*** *tending to* ***close*** *the valve.*

C. Third step

8 lbs. weight of valve and spindle
4 ins. distance from fulcrum to spindle
32

This is the ***valve and spindle moment*** *tending to* ***close*** *the valve.*

D. Fourth step

1280.88 ball moment (product A)
384 lever moment (product B)
32 valve and spindle moment (product C)
1696.88

This is the ***sum of the three moments*** *(calculated in* **A, B,** *and* **C)** *tending to* ***close*** *the valve.*

E. Fifth step

7.07 area of valve
4 distance from fulcrum

28.28)1696.88(60 lbs.
1696.8
8

This is the ***required pressure*** *at which the valve will* ***blow.***

Problem.—RULE 3, fig. 4,706.

Given: Area of valve 7.07 sq. ins.; weight of valve and spindle 8 lbs.; weight of lever 24 lbs.; weight of ball 63.41 lbs.; distance fulcrum to center of gravity of the lever 16 ins.; steam pressure 60 lbs.

Find: *Distance of ball from the fulcrum.*

RULE II, 23.—Safety valves when fitted either to the shell of boiler or steam drum may be fitted with internal dry pipes when made of standard steam pipe or of riveted material equal in thickness, and when the combined openings in the dry pipe equal in area at least one and one-half times the opening of the valve.

A. First step

7.07	sq. ins. area of valve
60	lbs. steam pressure per sq. in.
424.20	

*This is the **total pressure** due to the steam acting on the valve.*

B. Second step

424.2	total pressure on valve
8	weight of valve and spindle
416.2	

*This is the **net pressure** acting **upward** on the valve allowing for weight of valve and spindle.*

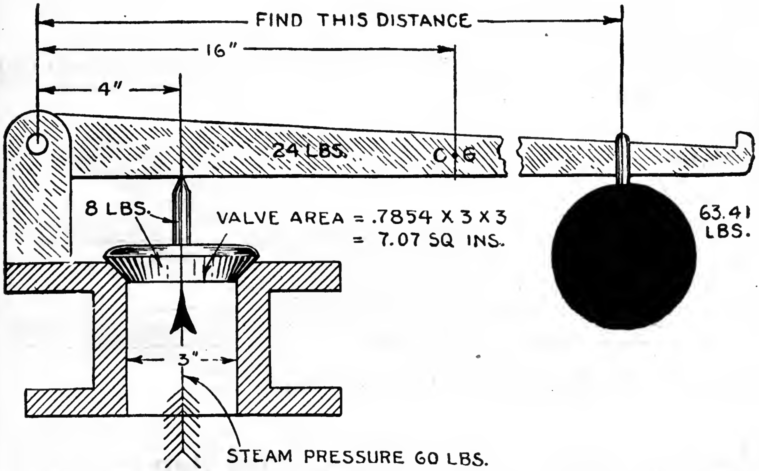


FIG. 4,706. ***Problem Rule 3:*** *To find **distance** from the fulcrum at which the weight must be placed.*

C. Third step

416.2 lbs.	net upward pressure on valve
4 ins.	distance from fulcrum to valve
1664.8	

*This is the **net steam moment** tending to open the valve.*

D. Fourth step

24	lbs. weight of lever
16	ins. dist. from center of gravity to fulcrum
144	
24	
384	

*This is the **lever moment** tending to close the valve.*

1664.8 steam moment (product C)
384 lever moment (product D)
1280.8

This is the difference between the *steam* and *lever* moments.

E. Fifth step

Divide difference between ***steam*** and ***lever*** moments found in **D** by weight of ball, *i.e.*

steam moment − lever moment ÷ weight of ball

63.41)1280.8(20.2 ins.
1268 2
12 600

This is the ***required distance*** *from the fulcrum at which the ball must be placed for the valve to blow at 60 lbs. pressure.*

Problem.—Rule IV, fig. 4,707.

Given: Width of small end of lever 1 in.; width of large end 3 ins.; length of lever 30 ins.

Find: *Center of gravity of lever.*

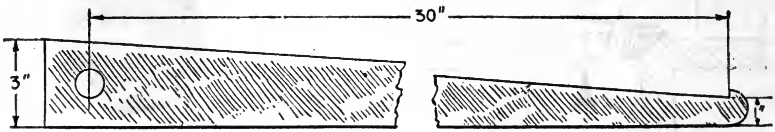


FIG. 4,707. ***Problem Rule 4:*** *To find the* ***center of gravity*** *of the lever.*

A. First step

3 large end
1 small end
3)2 difference
.667 one-third difference
1. small end
1.667 small end + ⅓ difference

B. Second step

1.667 sum from **A**
30 length of lever
50.010

C. Third step

3 large end
1 small end
4 sum of ends
4)50.01 product from **B**
12.5 ins.

This is the required ***distance*** *of the center of gravity from the fulcrum.*

Principle of the Safety Valve.—When a boiler is in operation there are four forces acting on a lever safety valve, of which, one *tends to* **raise** *the valve off its seat* and the other three *tend to keep it* **closed;** when the first force slightly exceeds the sum of the other three forces, the valve will open and allow the steam to escape. The four forces just mentioned may be described as follows:

1. The force due to the steam *which tends to* **open** *the valve;*

It is equal to the area of the valve in square inches multiplied by the steam pressure as indicated by the steam gauge.

2. The force due to the weight of the valve and spindle, *which tends to* **close** *the valve;*

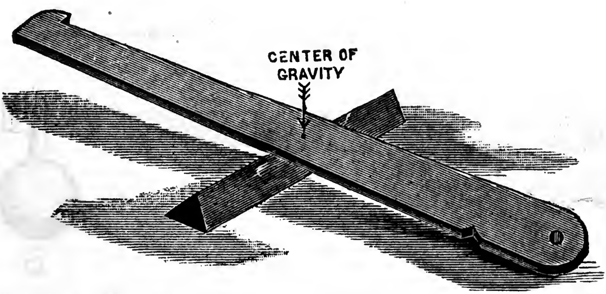


FIG. 4.708. Method of finding the center of gravity of the lever. The center of gravity of the lever is the point where the bar would be in equilibrium if balanced over a knife edge or any other support with a sharp corner placed at right angles to the lever, as shown in the figure.

3. The force due to the weight of the lever, *which tends to* **close** *the valve;*

4. The force due to the weight of the ball, *which tends to* **close** *the valve.*

These forces act at different distances from a point called the *fulcrum*, which corresponds to the point F, in fig. 4,709 about which the lever turns. As indicated in the figure, the four forces are as follows:

S = *total* pressure due to the steam tending to raise the valve;

This is equal to the steam pressure indicated by the steam gauge multiplied by the area of the valve. The area of the valve is equal to its diameter squared, multiplied by .7854.

V = weight of valve and spindle;
G = " " lever;
B = " " ball.

The distances at which these forces act are:

v = distance from fulcrum to center of the valve;
g = " " " " center of gravity of the lever;
b = distance from fulcrum to the ball.

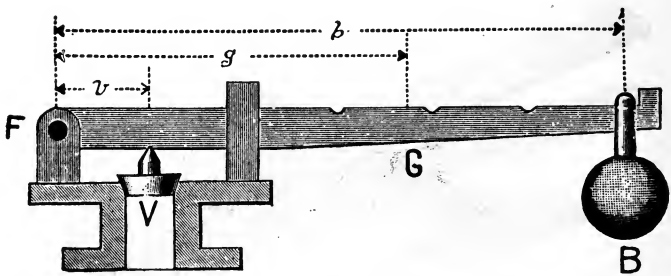


FIG. 4,709. Lever safety valve with dimensions, etc., necessary in making calculations. b, Distance from fulcrum to ball; g, distance fulcrum to center of gravity of lever; v, distance fulcrum to spindle; F. fulcrum; V, weight of valve and spindle; G, weight of lever; B, weight of ball.

The weights are measured in pounds, and the distances in inches.

The weight of the lever is considered as acting at its center of gravity g, distance from the fulcrum.

The center of gravity of the lever is that point where it would be in equilibrium if balanced over a knife edge or any other support with an edge, as in fig. 4,708.

Now, since all of these forces do not act along the axis or central point of the valve (fig. 4,709), it is necessary to determine the *tendency of the several forces to produce rotation of the lever about the fulcrum F.*

In order to determine this, the *moments* of the several forces with respect to the fulcrum F must be determined.

In mechanics the ***moment*** *of a force* is a *measure of its* ***effect*** *in producing* ***rotation*** *about a fixed point.*

The moment of a force, with respect to a point, is the product of the force multiplied by the perpendicular distance from the point to the direction of the force.

The fixed point corresponding to the fulcrum F, fig. 4,709 is called the *center of moments*, and the ***horizontal*** distance, *v, g,* or *b, the lever arm* or *leverage* of the force.

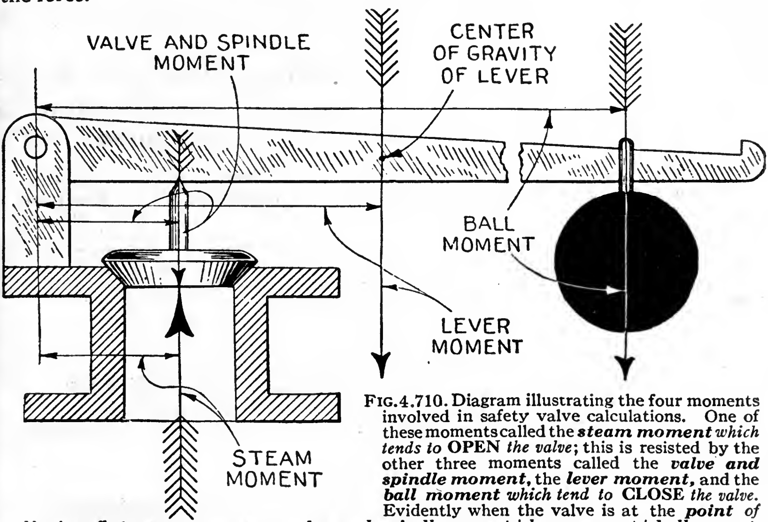


FIG. 4.710. Diagram illustrating the four moments involved in safety valve calculations. One of these moments called the ***steam moment*** *which tends to* **OPEN** *the valve*; this is resisted by the other three moments called the ***valve and spindle moment,*** the ***lever moment,*** and the ***ball moment*** *which tend to* **CLOSE** *the valve.* Evidently when the valve is at the ***point of blowing off,*** the ***steam*** *moment*=***valve and spindle*** *moment*+***lever*** *moment*+***ball*** *moment.* Evidently if the steam pressure increase a very small amount sufficient to cause the steam moment to overcome the ***friction*** *of the mechanism,* the valve will open and blow off.

The moment of the ball B in fig. 4,709 with respect to the fulcrum F, for instance, is equal to the weight of the ball multiplied by its distance from F, that is, moment of the ball = B × *b* or simply B*b*.

The four moments to be considered in solving the safety valve problem are as follows:

1. Moment due to the ***steam;***

It is equal to the *total* pressure of the steam acting on the valve multiplied by the distance from fulcrum to center of valve; that is, in fig.4,709 ***steam moment*** = Sv.

2. Moment due to the *weight* of the ***valve and spindle;***

It is equal to the weight of the valve and spindle multiplied by the distance from fulcrum to center of valve; that is, ***valve and spindle moment*** = Vv.

3. Moment due to the weight of the ***lever;***

It is equal to the weight of the lever multiplied by the distance from the fulcrum to the center of gravity of the lever; that is, ***lever moment*** = Gg.

4. Moment due to the weight of the ***ball.***

It is equal to the weight of the ball multiplied by the distance from the fulcrum to the ball; that is, ***ball moment*** = Bb.

Now, when the valve is at the ***point*** *of blowing off*, the first moment *which tends to* **raise** *the valve* will equal the sum of the other three moments *which tend to keep the valve* **closed;** that is

$$\left\{\begin{matrix}\textbf{\textit{steam}} \\ \textbf{\textit{moment}} \\ S \times v\end{matrix}\right\} = \left\{\begin{matrix}\textbf{\textit{valve and}} \\ \textbf{\textit{spindle moment}} \\ V \times v\end{matrix}\right\} + \left\{\begin{matrix}\textbf{\textit{lever}} \\ \textbf{\textit{moment}} \\ G \times g\end{matrix}\right\} + \left\{\begin{matrix}\textbf{\textit{ball}} \\ \textbf{\textit{moment}} \\ B \times b\end{matrix}\right\}$$

RULE II, 23.—The areas of all safety valves on boilers contracted for or the construction of which commenced on or after June 1, 1904, shall be determined in accordance with the following formula and table:

$$\text{Formula: } a = .2074 \times \frac{W}{P} \ldots\ldots (1)$$

Where a = area of safety valve, in square inches, per square foot of grate surface.
W = pounds of water evaporated per square foot of grate surface per hour.
P = absolute pressure per square inch = working gauge pressure + 15.

When this calculation results in an odd size of safety valve, use next larger standard size.

EXAMPLE.

Boiler pressure = 75 pounds per square inch (gauge).

2 furnaces: Grate surface = 2 (No.) × 5 feet 6 inches (long) × 3 feet (wide) = 33 square feet

Water evaporated per pound of coal = 8 pounds.

Coal burned per square foot grate surface per hour = 12½ pounds.

Evaporation per square foot grate surface per hour or W, = 8 × 12½ = 100 pounds. P = 75 + 15 = 90 lbs. absolute.

From equation (1)

$$a = .2074 \times \frac{100}{90} = .23 \text{ cu. ins.}$$

Therefore area of safety valve = 33 × .23 = 7,59 square inches.

For which the diameter is 3⅛ inches nearly.

or simply:

$$Sv = Vv + Gg + Bb.$$

This is the safety valve equation with which any problem is easily solved. In working out an example, the given values are

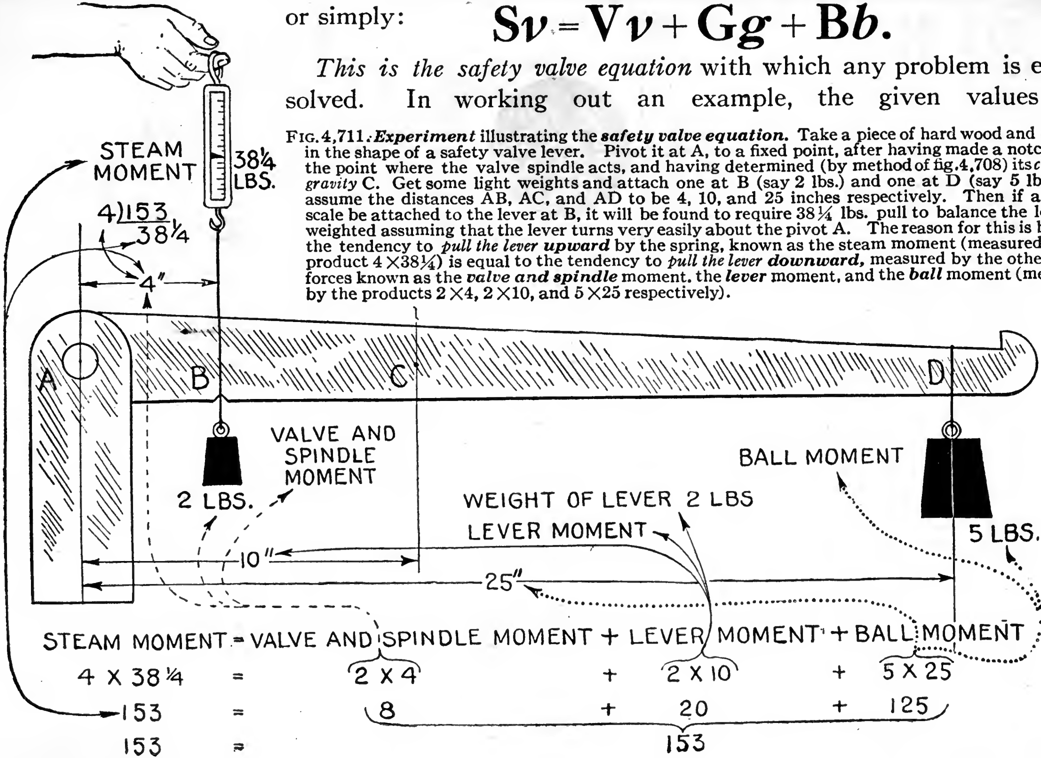


FIG. 4,711. *Experiment* illustrating the ***safety valve equation.*** Take a piece of hard wood and cut out in the shape of a safety valve lever. Pivot it at A, to a fixed point, after having made a notch at B, the point where the valve spindle acts, and having determined (by method of fig. 4,708) its *center of gravity* C. Get some light weights and attach one at B (say 2 lbs.) and one at D (say 5 lbs.) and assume the distances AB, AC, and AD to be 4, 10, and 25 inches respectively. Then if a spring scale be attached to the lever at B, it will be found to require 38¼ lbs. pull to balance the lever as weighted assuming that the lever turns very easily about the pivot A. The reason for this is because the tendency to *pull the lever **upward*** by the spring, known as the steam moment (measured by the product 4 × 38¼) is equal to the tendency to *pull the lever **downward,*** measured by the other three forces known as the ***valve and spindle*** moment, the ***lever*** moment, and the ***ball*** moment (measured by the products 2 × 4, 2 × 10, and 5 × 25 respectively).

substituted for the letters and the equation solved for the unknown letter.

Example:—What weight ball must be put on a 3″ safety valve so that it will blow at 100 lbs., if the weight of valve and spindle be 8 lbs., lever, 24 lbs., distance of valve from fulcrum 4″; distance of center of gravity from fulcrum 16″; distance from fulcrum to ball 38″.

S, the total pressure tending to raise the valve is equal to the steam pressure multipiled by the area of the valve in square inches = 100×diam.×diam.× .7854 = 100×3×3×.7854 = 706.9 lbs., say 707 lbs.

Now write out the equation and substitute the values given in the example and value just found for S, under the proper letters, thus:

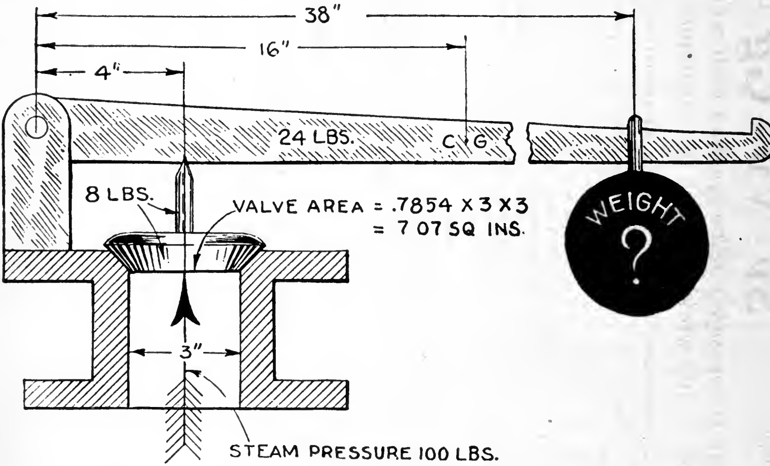


FIG. 4,712. ***Example:*** *To find what* ***weight*** must be put on the safety valve when **the con**ditions are as indicated in the figure.

$$\underbrace{Sv}_{707\times4} = \underbrace{Vv}_{8\times4} + \underbrace{Gg}_{24\times16} + \underbrace{Bb}_{B\times38}$$

multiplying

$$2,828 = 32 + 384 + 38B$$

and adding

$$2,828 = 416 + 38B$$

The equation must be "solved for B," which means that everything must be transferred to the left hand side of the equality sign except the B. The first step then is to get the 416 on the left hand side; to do this, subtract 416 from both sides, thus:

$$\begin{array}{r} 2{,}828 = 416 + 38B \\ 416 \quad 416 \qquad\quad \\ \hline 2{,}412 = \qquad\quad 38B \end{array}$$

As it now stands, 2,412 = 38B, or in other words, 38B = 2,412:

Now, divide both sides by 38, thus:

$$\frac{38B}{38} = \frac{2{,}412}{38}, \text{ hence:}$$

$$B = \frac{2{,}412}{38} = 63.4 \text{ lbs., weight of ball.}$$

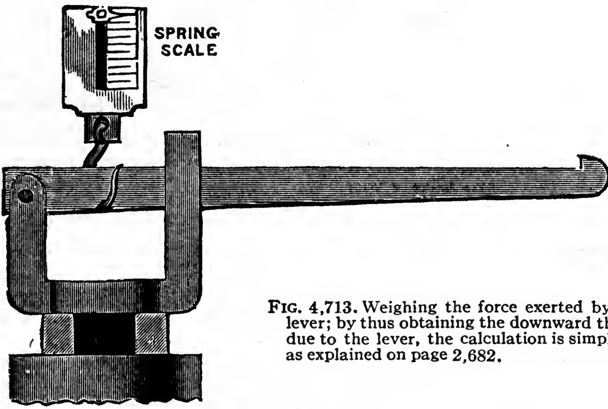


FIG. 4,713. Weighing the force exerted by the lever; by thus obtaining the downward thrust due to the lever, the calculation is simplified as explained on page 2,682.

RULE II, 23.—*Examples continued.*

Boiler pressure=215 pounds.

6 furnaces: Grate surface=6 (No.) ×5 feet 6 inches (long) ×3 feet 4 inches (wide)=110 square feet.

Water evaporated per pound coal=10 pounds.

Coal burned per square foot grate surface per hour=30 pounds.

Evaporation per square foot grate surface per hour=10 ×30=300 pounds.

Hence W=300, P=215 +15=230 lbs. absolute.

$$A = .2074 \times \frac{300}{230} = .27$$

Therefore area of safety valve=110 ×.27=29.7 square inches, which is too large for one valve. Use two.

$\frac{29.7}{2}$ =14.85 square inches. Diameter=4⅜ inches.

When the engineer has to solve a safety valve problem in actual practice, he may do so without finding the center of gravity of the lever, if he use a spring balance as in fig. 4,713.

The balance should be hooked under the point at which the valve spindle acts and then by pulling up on the balance, the actual downward pressure of the lever *at this point* can be determined. To this weight should be added the weight of the valve and spindle.

The forces then will be in as fig. 4,714 from which the equation is:

$$Sv = Mv + Bb$$

here M, is equal to the sum of the pressure of the lever as indicated on the scale and spring fig. 4,713 plus the weight of the valve and spindle; the other letters are as before.

If the weight of the ball, or its distance from the fulcrum be required, the equation can be still further simplified by letting

---

RULE II, 23.—*Examples continued.*

To determine the area of a safety valve for boiler using oil as fuel or for boilers designed for any evaporation per hour:

Divide the total number of pounds of water evaporated per hour by any number of pounds of water evaporated per square foot of grate surface per hour (W) taken within the limits of 100 to 380 lbs. This will give the equivalent number of square feet of grate surface for boiler for estimating the area of valve. Then proceed as before.

EXAMPLE.

Required the area of a safety valve for a boiler using oil as fuel, designed to evaporate 8,000 pounds of water per hour, at 175 pounds gauge pressure.

Make W=200.

$\frac{8,000}{200}=40$, the equivalent grate surface, in square feet

For W=200, and P=175+15=190 lbs.

$$A = .2074 \times \frac{200}{190} = .218$$

and .218 × 40 = 8.72 square inches, the total area of safety valve required for this boiler, for which the diameter is $3^5/_{16}$ inches nearly.

M, in fig. 4,714, represent the *sum* of the pressure of the lever as indicated on the spring scale plus the weight of the valve and spindle, subtracted from the *total* pressure of the steam on the valve. The equation then becomes

$$Mv = Bb$$

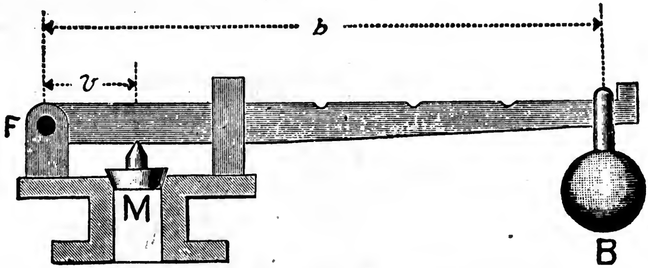


Fig. 4,714.—Lever safety valve with dimensions, etc., necessary in making calculations where the thrust due to the lever is determined by a spring balance as in fig. 4,713. *b*, distance fulcrum to ball; *v*, distance fulcrum to valve, M = S—L, that is, the total pressure due to the steam tending to raise the valve, less the downward thrust due to the lever as measured in fig. 4,713; F, fulcrum; B, weight of ball.

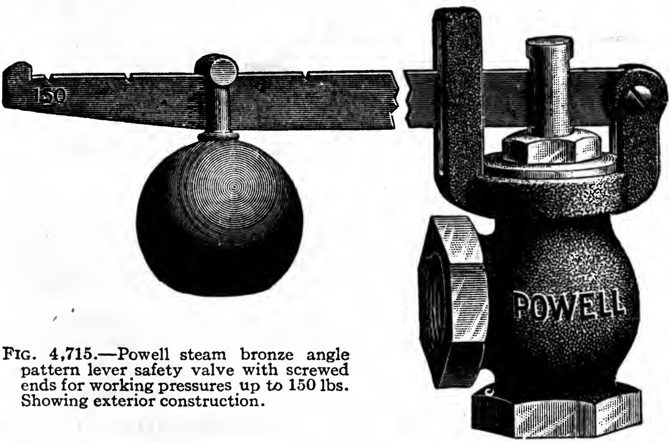


Fig. 4,715.—Powell steam bronze angle pattern lever safety valve with screwed ends for working pressures up to 150 lbs. Showing exterior construction.

RULE II, 23.—Whenever the area of a safety valve, as found by the rule of this section will be greater than that corresponding to 4½ inches in diameter, two or more safety valves, the combined area of which shall be equal at least to the area required, shall be used.

Stop Valve.—The term stop valve is commonly and erroneously applied to all hand control valves, but strictly speaking a stop valve is a *non-return valve*, that is, it is virtually a check valve with a hand wheel and screw stem which acts only to close the valve, as shown in fig. 4,716.

When the hand wheel is turned to open position, the opening of the valve will depend upon the direction of pressure just as in the case of an ordinary check valve.

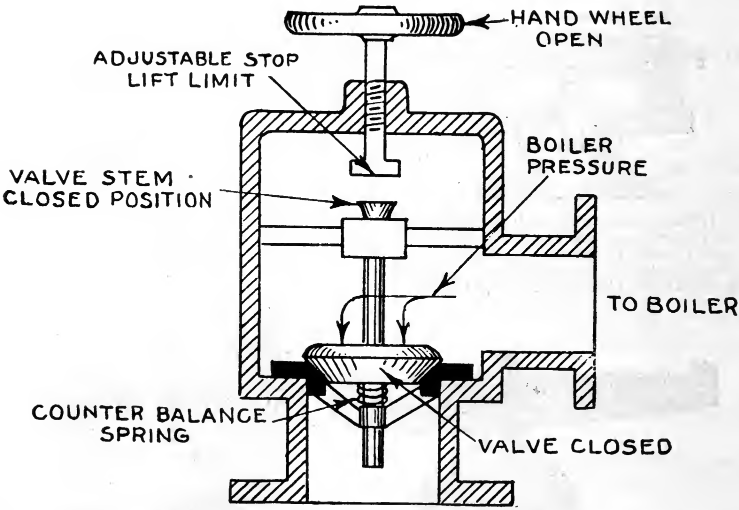


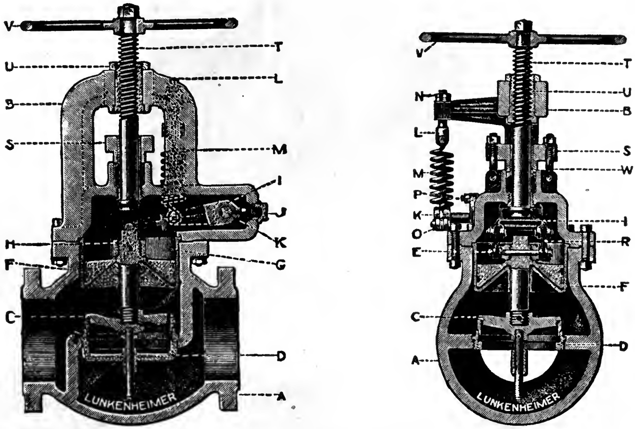
FIG. 4,716.—Stop or non-return valve. A form of check valve which can be opened or closed by hand control when the pressure in the boiler is *greater* than that in the line, but cannot be opened when the pressure *within* the boiler is *less* than that in the line. The counterbalance spring slightly overbalances, the weight of the valve and tends to hold the valve open, thus preventing movement of the valve with every slight fluctuation of pressure.

A non-return or stop valve is an exact mechanical equivalent of the electrical discriminating cut out or reverse current circuit breaker and electrically speaking it may be called a *discriminating stop* or *reverse flow shut off*.

Ques. Where, and for what purpose, are stop valves used?

Ans. A stop valve is placed on the main steam outlet of each boiler of a battery of boilers, to prevent inflow of steam in case of accident or shut down for cleaning or repairs of one or more of the boilers.

The importance of stop valves for use on a battery of boilers is universally acknowledged, and in some countries their installation is compulsory. It is evident that should a tube be blown out or a fitting ruptured in one of the boilers of a battery, the steam from the other boilers would rush into the header and discharge into the disabled one. An ordinary valve would here



FIGS. 4,717 and 4,718.—Lukenheimer non-return stop valve with outside spring and lever mechanism. Fig. 4,717 vertical section parallel to pipe; fig. 4,718 vertical section at right angles to pipe. The outside spring and lever is provided to effect a slight counterbalancing effect to hold the valve open, this being necessary in order to counteract the influences within the valve or line which tend to actuate the disc with every slight fluctuation of pressure. These fluctuations, usually caused by the engine, are frequently met with in steam lines, and unless some means be applied for counteracting these pulsations, the disc will be kept in continual motion. Where the fluctuations of pressure do not exist, and the flow of steam is steady, the use of the exterior spring and lever mechanism is not necessary. ***In adjusting*** the spring, the valve should be connected and tried, without the spring under tension. If, however, when steam is turned on, a pulsating condition develop, which can easily be detected by observing the movement of the spindle L, the regulating nuts N, should then be adjusted, gradually placing the spring under tension, until the rapid movement of the spindle L, is stopped. The adjustment of the nuts tends to lift the disc from its seat as it places the spring under tension, causing it to pull upon the lever O. This lever is keyed to the shaft K, which shaft enters the valve through the stuffing box P. Attached to the shaft O, is the forked arm I, to which are pivoted the links R, which, in turn, are loosely connected to the piston F. When the spring is under tension, the disc is raised from its seat and cannot close until the steam pressure above the disc exceeds that under it. This difference in pressure, which is governed by the tension on the spring, is never more than five pounds. When the valve is properly set to overcome the tendency of pulsation, the disc remains practically in equilibrium until there is a reduction in pressure on the inlet side, when it will instantly close.

be inadequate, as considerable time would necessarily be consumed in reaching and closing the valve, and a certain amount of danger must be anticipated. Where a stop valve is used a slight reduction of pressure in the damaged boiler will cause the valve to act and isolate it from the others in the battery, preventing damage and possible injury or loss of life.

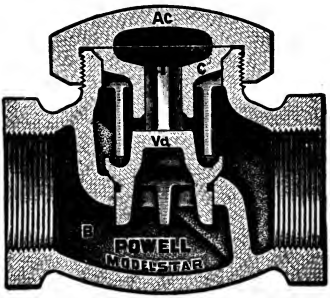
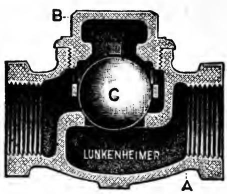


FIG. 4,719.—Powell disc check valve. The check disc V*d* has integrally cast wing guides, which snugly engage within the guide C, auxiliary guides being provided below the disc. ***To regrind,*** remove bonnet A*c*, lift out guide C, place a little fine sand or ground glass and water on the disc face, replace same in the body B and apply a screwdriver to slot in disc stem. Rotate back and forth until a good bearing is obtained, then carefully wipe off the ground glass or sand and replace valve guide C, and screw on bonnet.



FIGS. 4,720 to 4,722.—Lukenheimer ball check valves. Fig. 4,720, anglé pattern; fig. 4,721; horizontal pattern; fig. 4,722, vertical pattern. This form of check consists of three parts, A, seat casting; C, ball; B, bonnet. It meets the requirements for users of this type of check valve, but is not desirable for sizes above 3 inches because of the high cost and weight of the ball.

A stop valve will prevent steam being turned into a boiler which has been cut out for cleaning or repairs, as it can not be opened by hand when pressure is on the header side. It can, however, be closed when desired.

The valve can be connected in either a horizontal or vertical position.

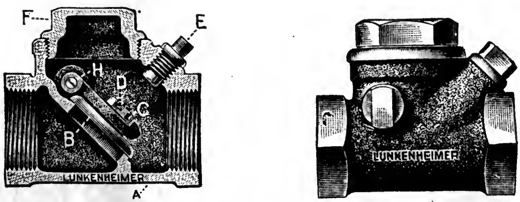
Check Valve.—This is a form of stop or non-return valve used to control the admission of feed water into the boiler.

The pressure within the boiler keeps the valve upon its seat unless overcome by superior pressure caused by the pump or injector, thus permitting feed water to enter while preventing its escape from the boiler.

Check valves on marine and other boilers sometimes have adjustable lifts, controlled by a wheel and spindle, but those designed for use on locomotives are generally non-adjustable, as only one boiler has to be considered.

There are several kinds of check valve, as:

1. Disc check.



FIGS. 4,723 and 4,724.—Lukenheimer swinging check valve. The design gives a valve opening area equal to that of the connecting pipes. The valve disc B, is attached by the nut D, to the carrier C, which is pivoted at H. The two side plugs (fig. 4,723) serve as bearings for the pivot pin H. Should the movement of the pin cause the plugs to wear, they can be easily renewed at small expense. To prevent the disc lock nut jarring loose, a hole is drilled through both the lock nut and threaded end of disc, through which a wire is inserted. To regrind, unscrew bonnet F, and place some powdered glass or sand, and soap or oil on the seat; also unscrew plug E, opposite disc, which permits inserting a screw driver in the slot of the disc.

2. Ball check.
3. Swinging check.
4. Adjustable check.

Fig. 4,719 shows a disc check valve which is the form generally used. It has but three parts: the main casting, valve, and bonnet.

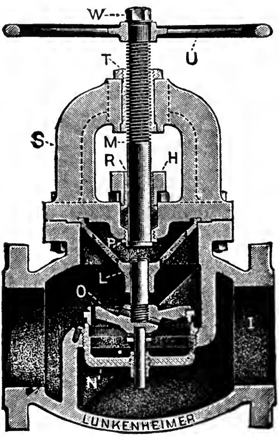
According to Hutton the valve should be sufficiently large in diameter to deliver the water with a lift not exceeding ⅛-inch, higher lifts resulting in rapid destruction of the valve seat from the hammering action of the valve, especially when used with engine driven pumps. Of course with an injector when the feed is continuous, the valve remains off its seat while the injector is in operation, and accordingly a higher lift is not objectionable.

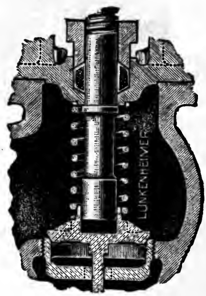
The author believes that in determining the size of a check valve its *area of valve opening*, for a satisfactory lift, should be such that the rate of flow will not exceed 200 feet per minute. A method of figuring the area required is given in the following example:

Example.—A certain boiler requires 1,000 lbs. of feed water per hour. Determine feed check valve opening and diameter for ⅛-inch lift, 45° beveled seat and a flow of 200 feet per minute.

1 cubic foot of water at 212° (from table) weighs 59.76 pounds, hence

volume of 1,000 pounds water $= 1{,}000 \div 59.76 = 16.74$ cu. ft. per hour, or





FIGS. 4,725 and 4,726.—Lukenheimer adjustable lift check valve. Fig. 4,725, valve without spring bearing on disc; fig. 4,726, detail showing valve with spring bearing on disc.

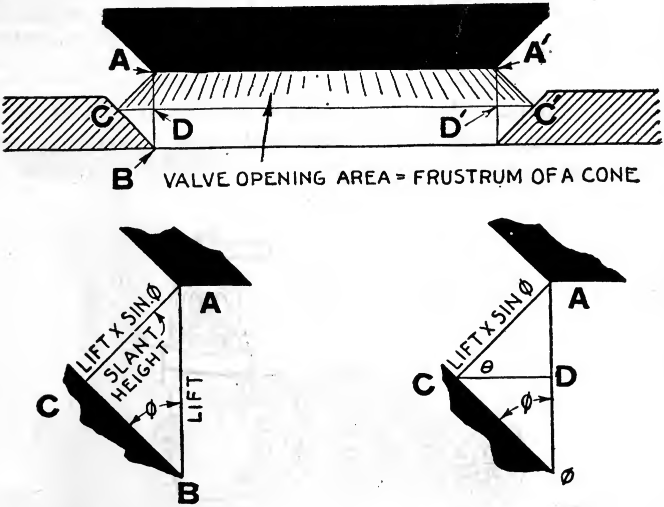
For a flow of 200 feet per minute

$$\text{valve opening area} = \frac{16.74 \text{ cu. ft.} \times 144 \text{ sq. ins.}}{60 \text{ minutes} \times 200 \text{ ft.}} = .2 \text{ sq. in.}$$

NOTE.—According to Hutton the cross sectional area of a feed valve in square inches = the evaporative capacity of the boiler in pounds × .00082. For instance, for a boiler evaporating 6,000 pounds of water per hour, area = 6,000 × .00082 = 4.92 square inches and

$$\text{diameter corresponding} = \sqrt{\frac{4.92}{.7854}} = 2\tfrac{1}{2} \text{ inches}$$

Now for a beveled seat, the effective valve opening area as shown in fig. 4,727, is equal to the slant surface of the frustion of a cone whose upper base diameter AA′ is equal to the diameter of seat opening.*



FIGS. 4,727 to 4,729.—Beveled valve and seat with diagrams, illustrating method of calculating valve opening area as explained in the accompanying *note*.

* NOTE.—The slant surface is, obviously, perpendicular to the seat, and since the height of the slant surface is less than the lift, the capacity of a beveled valve is less than that of a flat valve. In fig. 4,728, AC, is the slant height, θ is the angle ABC, between the direction of lift and the valve seat, hence in triangle ABC,

$$\sin \phi = AB \div AC = \text{lift} \div \text{slant height}$$

for which

$$\text{slant height} = \text{lift} \times \sin \phi \quad \ldots\ldots (1)$$

Now, the area of the valve opening or frustion of a cone = slant height × average base circumference .... (2)

In fig. 4,727, the diameter of the lower base CC′ is larger than diameter AA′ of the top base by the distances CD+C′D′ or 2CD.
Now in fig. 4,729,

$$CD \div CA = \cos \theta$$

from which

$$CD = CA \cos \theta = \text{lift} \times \sin\phi \cos\theta$$

but since by construction $\phi = \theta = 45°$, and lift $= \frac{1}{8}$ inch

$$2CD = 2 \times \tfrac{1}{8} \times \sqrt{\tfrac{1}{2}} \times \sqrt{\tfrac{1}{2}} = \tfrac{1}{4} \times \sqrt{\tfrac{1}{2}} = .125$$

and calling the upper base diameter AA′, uniting, in fig. 0,006,

$$CC' = 1 + .125 = 1.125$$

hence average base diameter $= \frac{1}{2}(1 + 1.125) = 1.063$ .... (3)
substituting given values in (1)

$$\text{slant height} = \tfrac{1}{8} \times \sqrt{2} = .177 \text{ inches}$$

Figs. 4,723 and 4,724 show ball, and swinging check valves. In many places where check valves are used it is desirable to control the lift of the disc to prevent chattering.

In marine practice, the fast running pumps attached to the engine, bring severe duty on the check valves, and for such conditions, a means for adjusting the lift as in figs. 4,725 and 4,726 is desirable.

Blow Off Valve.—The object of a blow off valve is to provide means for discharging mud, scale, and other impurities which enter the boiler in the feed water.

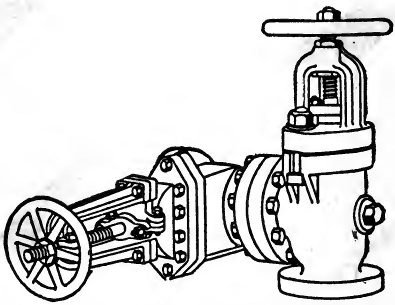


Fig. 4,730.—Lunkenheimer "Duro" blow off valve and "Victor" gate valve bolted together. Blow off valves have probably given more trouble than any other boiler fitting. Many kinds have been offered upon the market, which are claimed to possess the chief requisite in valves of this kind, that is, durability, but in practice they all appear to lack this essential feature. The combination of a blow off and gate valve as above is extensively used. This combination has many advantages that can not be obtained by the use of a blow off valve alone. The gate valve is used as an emergency valve, should accident happen to the blow off valve, in which event the former can be closed until repairs are made. It not only serves as an emergency valve, but also insures a perfectly tight blow off arrangement. The gate valve should be opened and closed but once a day, being closed after the last blow off and opened early in the morning. ***It is essential,*** however, that the gate valve be operated at least once in twenty-four hours in order to prevent it becoming inoperative.

The chief difficulty encountered with the blow off valve is leakage which is greatly aggravated by the presence of boiler scale.

When scale is removed by the use of kerosene and other agents, it comes off in small pieces, as well as large ones, and these accumulate in the blow off pipe.

When the valve is open, these (in the ordinary valve) are hurled against the seat with great force and grind the surface of the seat and valve away, rendering it difficult to maintain a tight valve for more than a few months without repairs. In order to guard against this grinding action, a blow off valve should be so constructed that the valve and seat, when open, are out of the path of the escaping water and impurities. An example of such construction is the *plug cock*, and this has been found more serviceable than either a gate valve or some special forms of blow off valve. Some of the latter provide a self-cleaning feature, while closing, while in others, the valve and valve seat are protected while open. The most desirable valve contains a combination of these features.

If angle valves be used they should be provided with a removable plug to permit running a rod into the pipe when cleaning the boiler in order to clean the pipe.

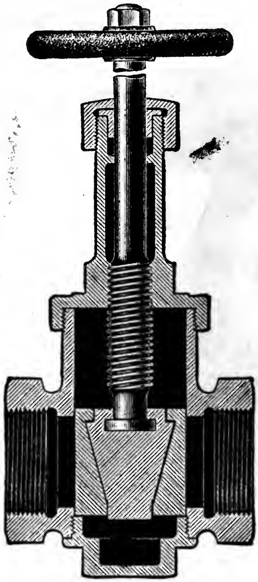


FIG. 4,731.—Star wedge adjustment blow-off valve. ***In operation**, when closing*, the wedge expands the split piston, which is accurately fitted to the cylindrical chamber; in *opening*, the first movement of valve spindle releases pressure of wedge on the piston, and then wedge raises piston to full opening of the valve.

Ques. How should a blow off valve be connected to a boiler?

Ans. A gate valve should be placed between the blow off valve and boiler.

Ques. Why?

Ans. To insure a tight outlet and to provide additional means of shutting off the connection in case anything happen to the blow off valve.

Ques. How should a blow off connection be made on a horizontal return tubular boiler?

Ans. The boiler shell is tapped at the rear end for the blow off pipe. The latter should preferably be run straight down to below the floor level of the combustion chamber and then out, the pipes in the combustion chamber being protected from the heat by some insulating material as tile, brick, etc.

Water Gauge Cocks.—It is of first importance that those in

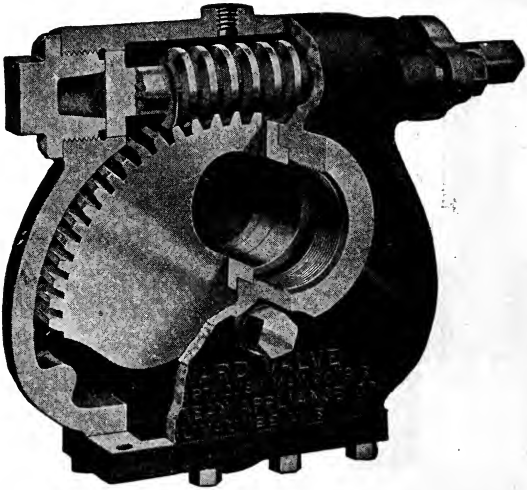


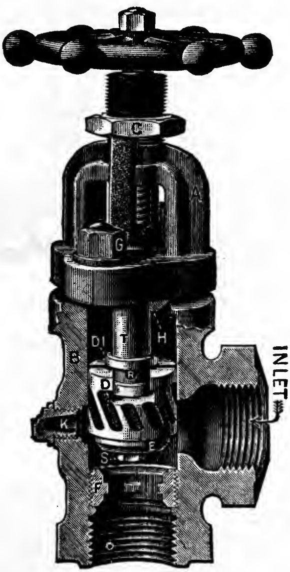
FIG. 4,732.—Ward worm gear blow-off valve. ***In construction,*** the body of the valve is made of semi-steel and the working parts of admiralty bronze.

charge of a boiler shall know with certainty the height of the water level within the boiler, and the principal means for ascertaining this are the water gauge cocks.

NOTE.—***Blow off cocks*** are preferably of gun metal, but they are sometimes of cast iron with or without gun metal linings for the plugs to work in, and with gun metal plugs. The gun metal may be composed of 88 parts of copper, 10 of tin, and 2 of zinc. The taper of the plug may be 1 in 6 for steam pressures up to 90 pounds per square inch; 1 in 8 up to 180 pounds per square inch; for higher pressures the taper should be 1 in 10. The cock should have a solid bottom and a stuffing box top. Metallic packing is the best for blow off cocks for boilers producing steam of very high pressure. A screw should be fitted to the bottom of the cock to ease the plug when it sticks fast.—*Hutton.*

Usually three cocks are provided (except on very small boilers which sometimes have only two), the upper and lower cock being placed at the safe high and low water levels respectively, and the third cock midway between.

To ascertain the water level each cock is opened *slightly* and the presence of water, or steam in the escaping steam tested by its appearance, sound, and feel to the hand. With a little experience there can be no mistake made in determining the water level by means of the gauge cocks.



The reason the valve is only opened slightly is because a full opening tends to raise the water level, thus indicating a false level, as in figs. 4,734 and 4,735.

Gauge cocks may be classed:

1. With respect to the means employed for closing, as:

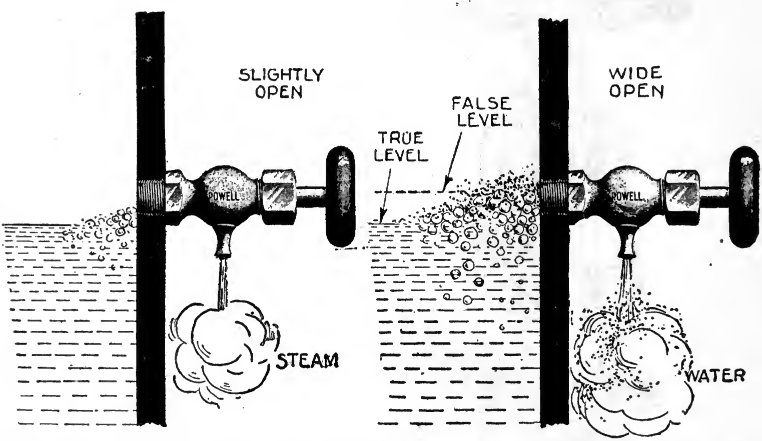
a. Compression.
b. Pressure.

FIG. 4,733.—Powell-regrinding blow-off valve. ***In construction,*** the yoke top A, is secured to the body by studs G. The packing is adjusted by pusher gland P, which is operated by the outside screw nut C, above the bridge of yoke A. The faces D1 and H, fitting tight, permit repacking under pressure. The brass plunger D is milled to receive the collar on stem T. Spiral grooves are cast on the outer face, which, receiving the pressure from the steam as the valve is opened, cause it to revolve as it nears the seat when closing. This gives the disc a grinding motion and keeps both disc and seat clear of scale and sediment. The seat ring F is extended downward to protect it from the cutting effect of the rushing water and steam as the valve is opened. To this plunger is attached disc E, secured by nut S. By removing plug K, the inlet pipe from boiler can be cleared of sediment or scale. ***To regrind,*** insert a plug or nail through the hole R; this locks the disc, then rotate back and forth with fine brickdust or sand on the bearing.

2. With respect to mechanical features, as:

a. Screw.
b. Regrinding.
c. Weighted.
d. Spring.
e. Combined spring and diaphragm.
f. Self-grinding (rotating).
g. Double seat.

Compression cocks are those in which the force employed to close them is opposite in direction to the steam pressure.



FIGS. 4,734 and 4,735.—Right and wrong way of testing water with gauge cocks. When the cock is only slightly opened, as in fig. 4,734, the water level is not materially raised by the outrushing stream, but if opened wide, as in fig. 4,735, the reduction of pressure inside and consequent violent ebulition to restore equilibrium causes a considerable disturbance of the water level near the cock, resulting in a false level as shown. *This precaution should be remembered*, especially when using the lower cock, because if opened wide, the water is lifted surprisingly high, hence, unless the lowest cock be at a liberal height above the crown sheet, it may when opened wide indicate water though the true level may be dangerously low.

Fig. 4,736 shows an ordinary screw compression cock with a flat seat, and fig. 4,737, one with a taper screw. The screw forms a positive and satisfactory method of closing the valve and is well adapted to high steam pressure.

An improved form of screw compression cock is shown in fig. 4,738, in which the stem projects through the hand wheel and is arranged with communication with the boiler, the water level in the glass will be *approximately** the same as that in the boiler.

The glass is protected by two or more guard rods running parallel to it. In order to clean, repack or renew the glass the valves may be closed, shutting off communication with the boiler. A cock is provided on the

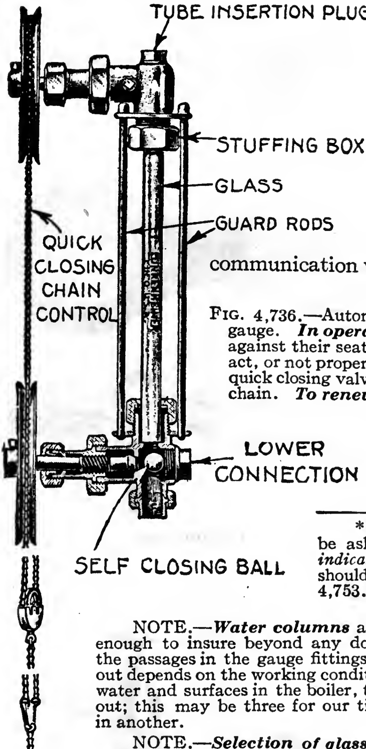


FIG. 4,736.—Automatic and chain control offset cylindrical water gauge. ***In operation,*** should the glass break, the balls are blown against their seats, thus closing the outlets. Should the balls not act, or not properly seat, the escape may be quickly shut off by the quick closing valves, both of which are operated in unison by the chain. ***To renew a tube,*** the tube insertion plug is removed and the old tube withdrawn and a new one inserted. To test whether the connection be clear and the gauge working properly, open and close drain cock. Most or all of the water will leave the glass and if connections be clear, will quickly rise to its former level.

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* NOTE.—If an applicant for an engineer's license be asked the "catch" question: *Does the water gauge indicate the* ***true*** *level of the water in the boiler?* he should answer *no*. The reason is explained in fig. 4,753.

NOTE.—***Water columns*** and ***glass water gauges*** should be blown often enough to insure beyond any doubt that the pipes leading to the column and the passages in the gauge fittings are perfectly clean. The frequency of blowing out depends on the working conditions of the plant. Thus the more foul the feed water and surfaces in the boiler, the oftener must the column and glass be blown out; this may be three for our times a day in one plant and only once a day in another.

NOTE.—***Selection of glass water gauge.*** The principal consideration in selecting a glass water gauge is to avoid those containing torturous, inaccessible passages, and to select one that will permit the insertion of a new glass without cramping it sidewise and running the risk of breakage. The size of the glass and the length between fittings depend upon the height above the floor. Where water columns are comparatively low, ½ or ⅝ inch glass are commonly used, but for vertical water tube boilers where the water glass is from 12 to 18 feet above the floor ¾ and ⅞ inch glasses are preferable. The distance between fittings is governed to a considerable extent ty the type of boiler, since the latter usually determines the limits of rise and fall of water level. In horizontal tubular and water tube boilers the permissible variation of water level is rather small.

NOTE.—In locating the water column in a locomotive boiler, put an end of a stick against the crown sheet and mark the top of the fire door on the stick, which should be held vertically, and at the middle of the door, especially if the door be oval. Withdraw the stick and transfer the distance between the top of the door and crown sheet to the end of the boiler. From this point measure vertically upward at least 2 ins. *plus* the thickness of the crown sheet. Place a carpenter's level at this point and draw a horizontal line on the end of the boiler. This line locates the level of the hole for the lowest gauge cock.

NOTE.—***Water columns*** should be connected up with pipes having tees and crosses at the bends instead of elbows so that by removing plugs from the tees and crosses, the entire pipe line between column and boiler may be cleared of any foreign matter by inserting a stiff wire.

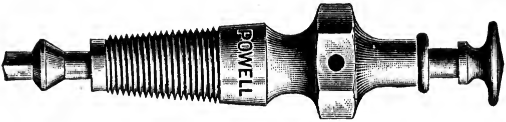


FIG. 4,737.—*Spring* cock; long shank push button or "Mississippi" pattern.

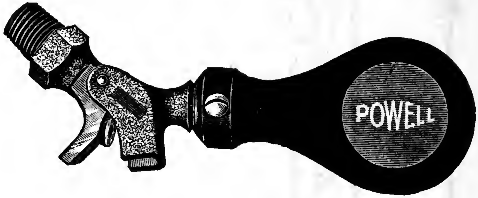
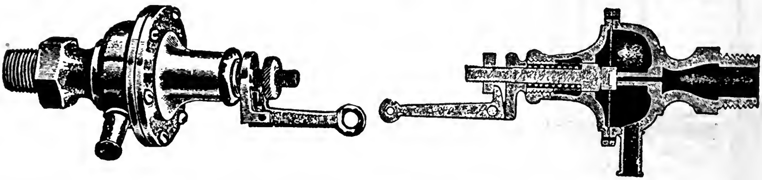
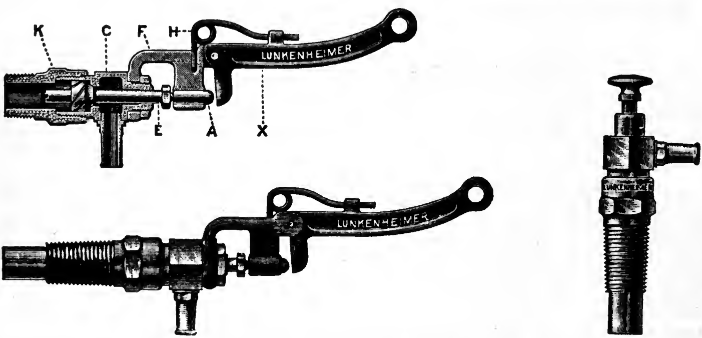


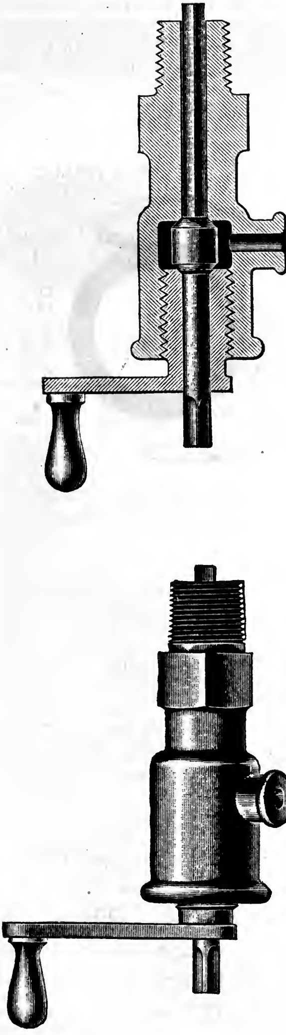
FIG. 4,738. — *Compression* cock; short shank, weighted lever or "ball" pattern.



FIGS. 4,739 and 4,740. —*Combined spring and diaphragm compression* cock.



FIGS. 4,741 to 4,743 —Lukenheimer self-grinding gauge cocks. Fig. 4.741 short shank with lever; fig. 4,742, long shank with lever; fig. 4,743, long shank without lever. ***In operation,*** when the lever is moved to open position, the projection X (fig. 4,741) presses against the loose piece A, which forces back the stem E, and unseats the disc, allowing steam or water to pass out of the nozzle. The guide next the disc is provided with spiral grooves, so that the water or steam in passing through these spirals will impart a rotary motion to the stem E. When the pressure on the loose piece A, is released the boiler pressure forces the valve to its seat, while the stem is rotating, thus grinding in the seat bearing a little every time the cock is opened. The piece A, being independent precludes the possibility of wedging between stem and body.



FIGS. 4,744 and 4,745.—Star *crank handle screw compression* **double seat** *re-grinding cock*, as used in U. S. Navy. The spindle is made extra long and triangular in shape, extending through cock and acting as a cleaner when opened.

provided in the improved form fig. 4,741. The latter is provided with an arm to which is attached a chain enabling the attendant to operate the cock by pulling the chain.

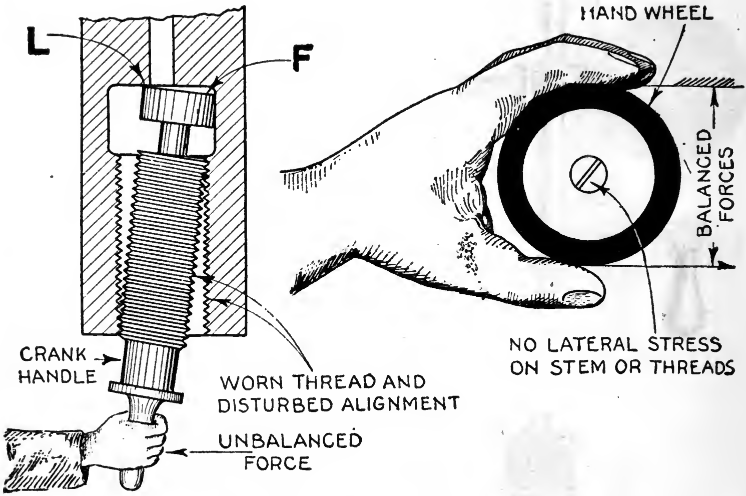
Figs. 4,737 and 4,738 show two forms of pressure cocks with spring.

The main force acting to keep the cock closed is the steam pressure, the spring seen in the sectional view being simply to counteract the opening force due to the weight of the lever and chain. Both cocks are known as Mississippi cocks because they are largely used in Western river practice, and are virtually the same except that one has a push button and the other a lever.

An unusual type is shown in figs. 4,739 and 4,740 in which a diaphragm is employed to prevent leakage about the stem. However, the author regards this as a useless complication.

Three self-grinding cocks are shown in figs. 4,741 to 4,743. The spiral slots cut into the valve discs, cause the valve to revolve when open and, as claimed, grind the seat a little in closing. It is doubtful if the momentum thus generated can have much grinding effect, but even the reseating of the valve in a different position each time would prove beneficial in maintaining a tight joint.

The screw compression cock shown in figs. 4,748 and 4,749 has a double seat, one of which seats against the pressure when cock is closed, and the other against the screw when cock is opened to prevent leakage of steam around spindle. This is an admirable feature, but the author objects to the crank handle in place of a hand wheel, regardless of Naval or foreign practice for the reason illustrated in figs. 4,750 and 4,751.



FIGS. 4,750 and 4,751.—Why the author objects to crank handles on cocks or any other screw-fittings. The illustrations require no explanation; however, it might be mentioned that cocks like nuts are usually screwed without judgement, that is closed with entirely too much force, hence a considerable turning force is sometimes required to open them. When this force is applied to a crank as in fig. 4,750, since it is unbalanced, the lateral thrust must be resisted by the threads at diagonally opposite points. Moreover, when the threads become worn from this abuse, as soon as the crank begins to turn the alignment is destroyed and the valve tends to dig into the seat at **L**, and to leave it at **F**, here shown exaggerated for clearness. The unequal grinding effect tends to cause a leak at **F**.

Water Gauge.—This should be regarded as a secondary means of ascertaining the water level, although most engineers acquire the bad habit of relying on it almost entirely. The water gauge consists of a strong glass tube, long enough to cover the safe range of water level, and having the ends connected to the boiler interior by fittings. As both ends of the tube are in

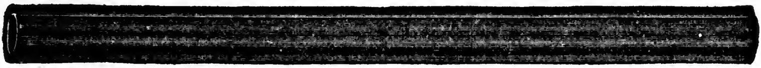
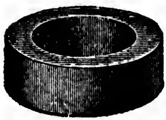


FIG. 4,748.—Scotch water gauge glass. Usually carried in stock in sizes from ½ to ¾ ins. diameter and from 10 to 24 ins. in length.



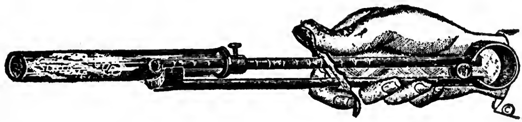
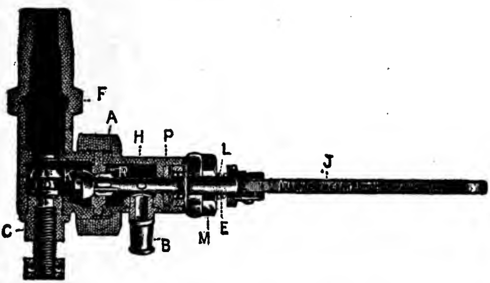


FIG. 4,749.—Gauge glass washer or *grommet*, which forms the stuffing box packing to make tight joints at each end of the glass.

FIG. 4,750.—Patent gauge glass cutter.



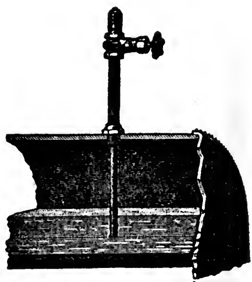
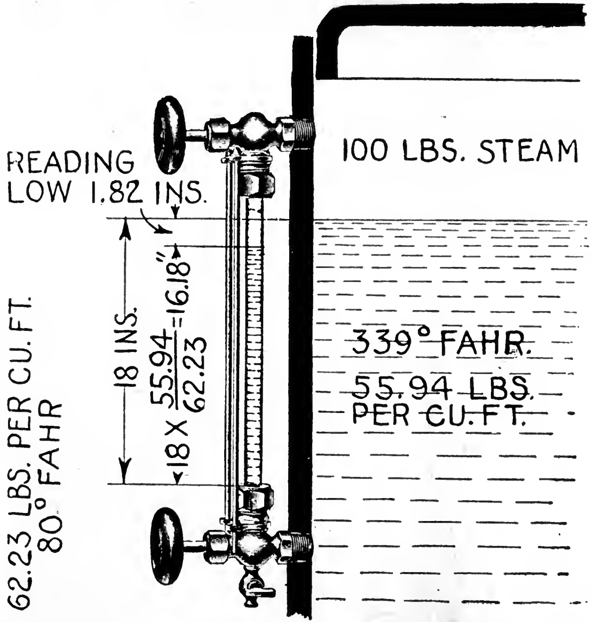
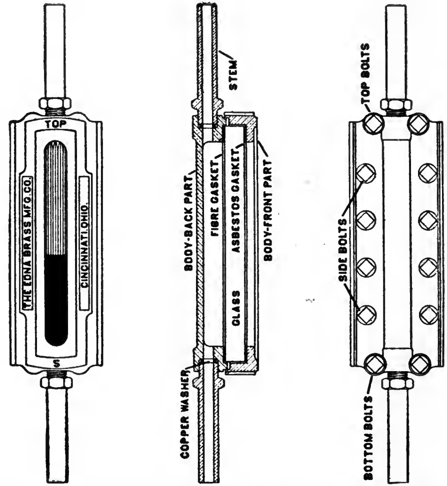


FIG. 4,751.—Lunkenheimer "Excelsoir" gauge cock. ***It is provided with*** an auxiliary valve D, which may be closed at any time and the main valve and trimmings removed for examination or repairs. Ordinarily, valve D, is screwed back to a joint against plug C, thus dispensing with a stuffing-box. Plug C, is placed directly opposite the boiler connection to permit the insertion of a rod to clean out the passageway. The seat R, can be reground, reversed or renewed with but very little trouble, and is held between the hub and body by the union ring A. By means of this construction, the nozzle B, can be conveniently set and locked at any angle desired. The opening in the nozzle B, is sufficiently large to take care of the discharge through the valve, so there is very little pressure in the hub to cause leakage around the stem, and the packing washer P, reduces to a minimum whatever leakage there may be.

FIG. 4,752.—Lunkenheimer fusible plug low water alarm. ***It consists of*** a tube, one end of which reaches down to the low water line, while the other has a valve and fusible plug attached. ***In operation,*** when the water in the boiler drops down below the end of the tube, it drains the water out of the same, and permits steam to enter, which melts the fusible metal, and, with a loud report, the steam hisses through the pipe, and thus gives notice of the approaching danger. The valve is then shut off, a new fusible disc attached, the valve opened, and the alarm is again ready. Each alarm is supplied with several fusible discs, and extra ones can be furnished at small cost. This alarm is threaded for ¾-inch pipe for connection to the boiler.





FIGS. 4,754 to 4,756.—Edna ***reflex*** water gauge. The effect of the corrugated surface of the glass in contact with the water is such that the water can be plainly seen even in dim light as the water shows as a black liquid the space not occupied by water appears as silver white, a well-marked water line. The gauges are suitable for pressure up to 300 pounds.

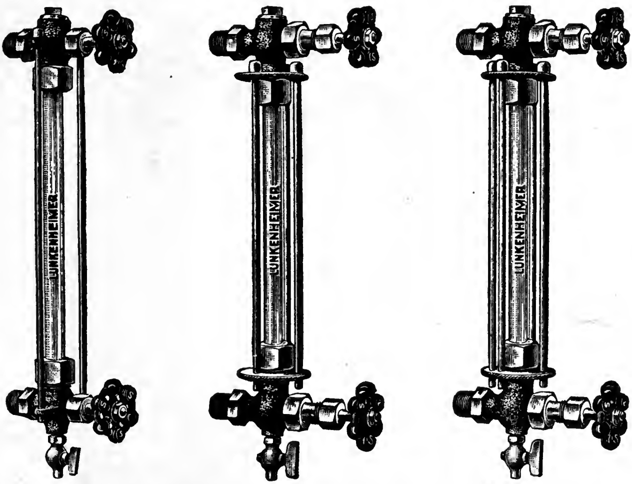
FIG. 4,753.—When a water gauge does not register the correct water level. Since the water in the tube is not in circulation it is quickly cooled, especially on exposed boilers, thus there is a considerable difference in temperature between the water in the boiler and that in the tube. Suppose the boiler be under 100 pounds steam pressure, the corresponding temperature of the water is 338.7° and the weight of a cubic foot of water at this temperature is 55.94 pounds; also if the water in the tube be cooled down to, say 80°, the corresponding weight per cubic foot is 62.23 pounds. Now, if the height of the water in the boiler be 18 inches above the bottom of the gauge, as shown, the height of the water in the gauge will be $18 \times 55.94 \div 62.23 = 16.18$ inches, or $18 - 16.18 = 1.82$ inches lower than that in the boiler. Although the gauge always indicates less than the true level, *this should **not** be considered in the emergency of low water with disabled feed pumps.*

bottom angle valve to empty or blow out the glass in order to respectively test the water level or clean the glass. The cock is used also to drain the lower valve in freezing weather.

Water gauges may be classed:

1. With respect to operation, as:

a. Plain.
b. Automatic (self closing).
c. Chain control (quick closing).



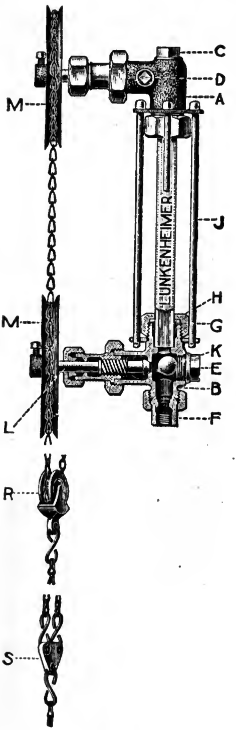
Figs. 4,757 to 4,759.—Lukenheimer, two, three, and four rod plain cylindrical water gauges. The plug in the top fitting prevents replacing the glass tube.

2. With respect to the glass, as:

a. Cylindrical { plain / offset }

Fig. 4,752 shows the general construction of a gauge containing all the improvements.

The author objects to automatic or self-closing gauges except possibly



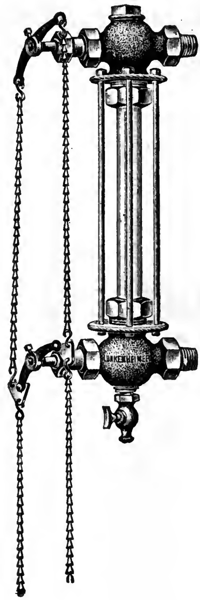
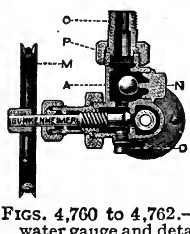
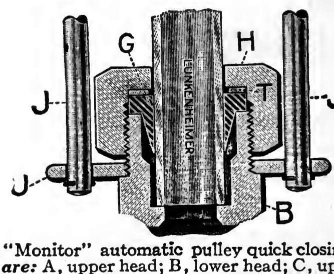


FIG. 4,763. — Lunkenheimer lever quick closing cylindrical water gauge. The chain control adapts the gauge for tall vertical boiler where it is far removed from the floor, and in case the glass break it can be shut off from the flow by pulling down on the chain, thus avoiding the difficult operation of closing a gauge when standing on a ladder.

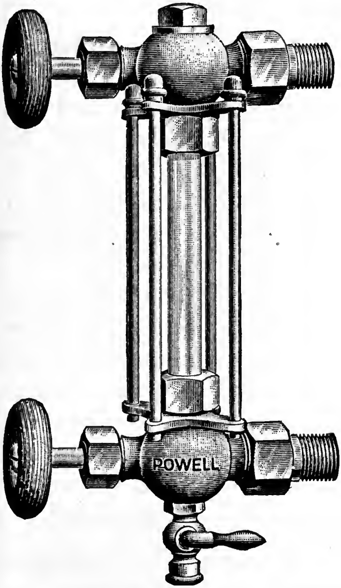


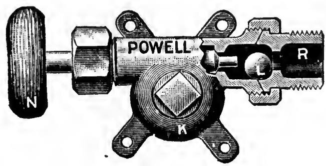


FIGS. 4,760 to 4,762.—Lunkenheimer "Monitor" automatic pulley quick closing cylindrical water gauge and details. ***The parts are:*** A, upper head; B, lower head; C, upper clean out plug; D, side plug; E, lower head plug; F, drain connection; G, packing; H, supply box cap; J, guard; K, shut off ball; L, lower valve stem; M, control pulleys; O, glass; P, stuffing box; R, and S, chain gear; T, gasket.

in very small boiler rooms, as on small steam vessels, where the breakage of a glass might cause personal injury, because the balls might stick and interfere with the proper operation of the gauge resulting in a "dead" glass. Shutting off a plain gauge with broken glass is not nearly as hazardous a task as some suppose, especially if the valves be opened only enough to permit free movement of the water column instead of opened wide *as is usually and erroneously done.*

Water Column.—Frequently the gauge cocks and water





FIGS. 4,764 and 4,765.—Powell automatic offset cylindrical water gauge, and top sectional view of upper fitting. The automatic cut off balls in shanks close in case the glass break. In fig. 4,765, after gauge is in position on boiler, close valve N, and the small pin on the end of the stem in passing through the seat will push ball L back in the recess, equalizing the pressure and the valve N, must then be opened wide. Should the glass break, the sudden rush of steam causes the ball to seat, thus shutting off further escape.

gauge are connected to a central column, the assembly being known as a water column. On a well designed column there are nine openings as shown in fig. 4,766.

An improved form of water column is the so called safety or alarm column, as shown in figs. 4,767 and 4,768, having an automatic whistle, which blows in case of low water and awakens the firemen and other attendants supposed to be on duty.*

Sometimes water columns are made up of wrought pipe and fittings, as is used on some marine water tube boilers. This construction forms a light, yet substantial column.

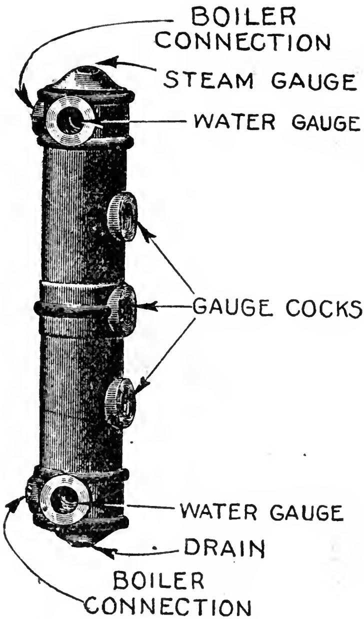


FIG. 4,766.—Water column without fixtures showing the various openings and what they are for.

Steam Gauge.—This is a very important fixture and one which should be tested from time to time to ascertain if it correctly indicate the steam pressure.

A steam gauge indicates the difference of pressure inside and outside the boiler, that is, it indicates the *gauge* pressure as distinguished from the *absolute* pressure.

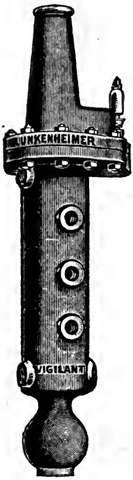
For instance, if the hand of the gauge point to 80 pounds it indicates that the pressure inside the boiler is 80 pounds higher than that outside, that is the actual or absolute pressure within the boiler is 94.7, and since the pressure outside or atmospheric pressure is 14.7, then the pressure difference or gauge pressure is 94.7—14.7=80 pounds. If the boiler

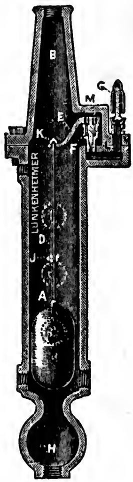
* NOTE.—The author objects to the alarm feature, because the firemen naturally become less attentive in watching the water gauge, and if the mechanism become inoperative, serious results might follow.

were suddenly placed on top of a mountain where the atmospheric pressure were say, only 12 pounds, then the gauge reading would be 94.7—12=82.7 pounds, although the pressure within the boiler did not change.

Ques. How does a steam gauge work?

Ans. A steam gauge works on one of two principles: 1, the expansion of a corrugated diaphragm when pressure is applied,

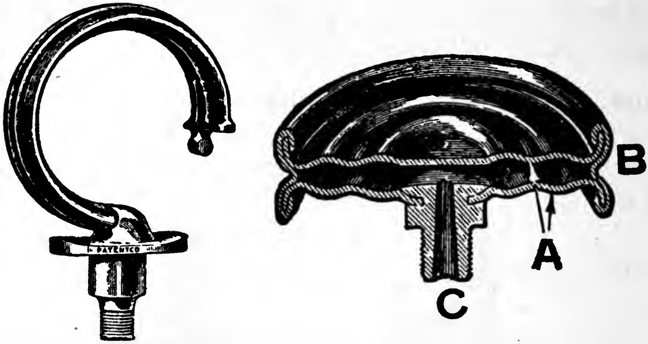




FIGS. 4,767 and 4,768.—Lunkenheimer "Vigilant" safety water column and detail of whistle valve. The column contains a float C, attached to the rod D, which operates through a hole in the valve lever E. The slip J, which can be placed in any desired position in the rod D, strikes the valve lever E, when the water in the boiler reaches the high limit. In fig. 4,768 as the valve lever E, is raised it lifts the valve L, from its seat, allowing steam to blow the whistle. The same result is accomplished when the water reaches the low limit. As the float falls, the knob K, on the rod D, forces lever E, down, which opens the valve allowing steam to blow the whistle. As shown, E, is not directly connected to valve L. The valve casing M, by means of two lugs at the top thereof, is pivotally connected to the lever. Within this casing is fitted valve L, the arrangement insuring proper contact of valve with its seat. In fig. 4,768, H, is a sediment chamber with the lower end tapped to received pipe to blow out sediment.

and 2, the tendency of a curved tube to assume a straight position when under pressure.

Figs. 4,769 and 4,770 show the mechanical details. Fig. 4,769 represents



FIGS. 4,769 and 4,770.—Diaphragm and bent tube as used in the two classes of steam gauge.

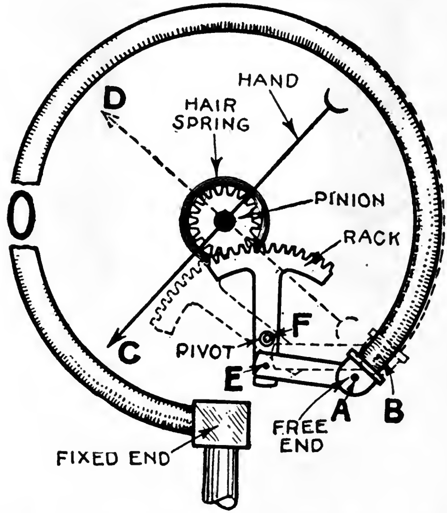
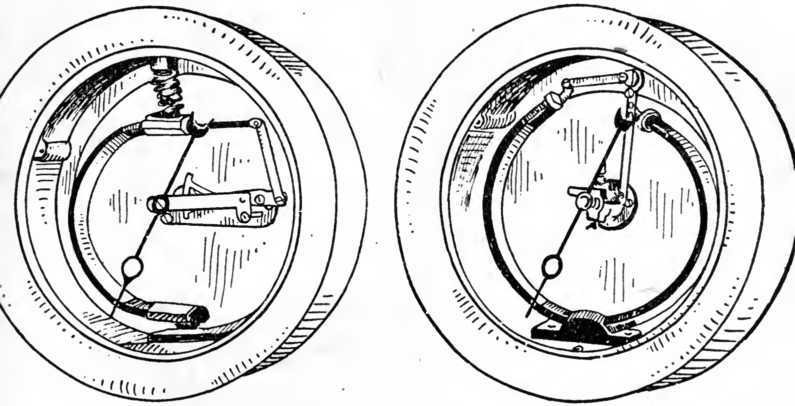


FIG. 4,771.—Multiplying mechanism of a bent tube steam gauge, showing zero position in full lines, and one position under pressure in dotted lines. The free end, **A**, of the tube is connected by a link to the rack arm at **E**, the latter being pivoted at **F**, as shown. Evidently when the free end of the tube moves a short distance, as from **A** to **B**, the motion of the pointer or indicating hand will move a much greater distance as from **C** to **D**. ***In construction,*** by making **EF** of suitable length, any degree of sensitiveness may be obtained, thus adapting the gauge for a low or high range of pressure. The hair spring which is connected with the pointer shaft, offers a slight resistance which takes up the lost motion in the mechanism and renders it "taut" at all times.

a section of a pair of metal plates or diaphragms, *A A*. These are made with circular corrugations, as shown in section and also by the shading. The steam enters by the pipe, *c*, and fills the chamber between the metal plates or diaphragms. The corrugations of the latter give them sufficient elasticity, so that when the pressure is exerted between them they will be pressed apart by the steam. If they were flat, it is evident that they would not yield, or only to a very slight degree, to the pressure of the steam.

Fig. 4,770 shows the bent tube construction.

The tube is of flattened or elliptical section to render it more sensitive to the pressure. This is due to the fact that the pressure tends to force the



FIGS. 4,772 and 4,773.—***Single*** and ***double*** tube steam gauges; interior views showing mechanism. The double tube movement has an auxiliary spring at the free end of the tube.

flattened sides apart which in turn increases the tendency of the tube to straighten itself.

The bent tube principle is now almost universally used in steam gauge construction. Since the movement of the free end of the tube is very small, its motion is *multiplied* by means of a segmental rack which actuates a small pinion on a pointer shaft as shown in fig. 4,771.

Ques. How can the accuracy of a steam gauge be tested?

Ans. When the gauge is in good working order, the index or pointer moves easily with every change of pressure in the boiler, and if the steam be shut off from the gauge, the index should always go back to 0. In order to determine the accuracy of its indications, however, it should be compared with a test gauge, or if a greater degree of accuracy be desired, it should be tested with a dead weight gauge tester such as shown in fig. 4,775.

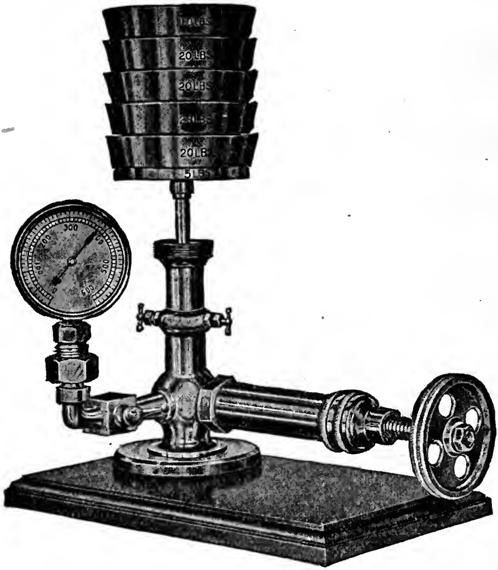


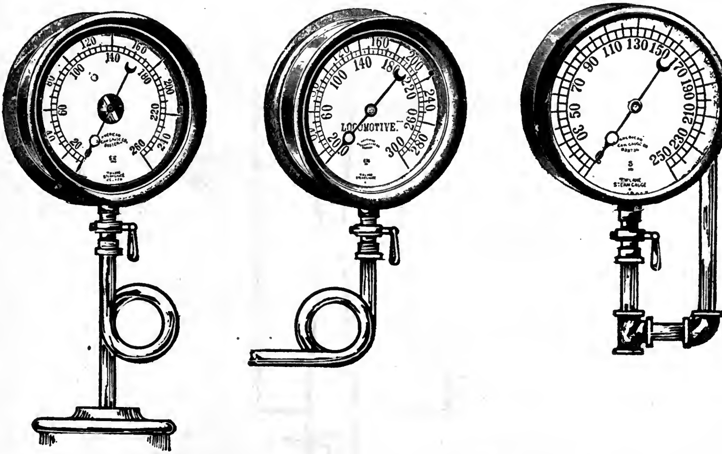
FIG. 4,774.—Ashton *dead weight* pressure gauge tester for pressures up to 500 pounds per square inch. The interior of the apparatus is filled with oil and by turning up the screw the plunger rod which supports the dead weights is forced upward, thus transmitting the pressure to the gauge to be tested.

Ques. Describe an ordinary method of testing a steam gauge.

Ans. When steam is at some point not over half the working pressure, place the ball on the safety valve at the point where it commences to blow off and mark this point. Move the ball twice as far from the fulcrum as this mark, and it should blow off at twice the pressure as first indicated by the gauge.

Ques. What precaution is taken to prevent the steam taking the temper out of the discs or tubes of steam gauges?

Ans. They are put on with a turn or two of pipe between the boiler and the gauge, as shown in figs. 4,775 to 4,777; the



FIGS. 4,775 to 4,777.—Various forms of connection for steam gauge. The pocket formed by the connection becomes filled with water of condensation which protects the spring from the heat of the steam.

bend of the pipe gradually filling with condensed steam, which prevents the live steam touching the elastic discs or tubes.

Ques. Describe a method of quickly ruining a steam gauge, as is usually done by those in charge of contractors' outfits and other makeshift rigs.

Ans. Any gauge will be ruined by disregarding the precaution given in the preceding question, especially if superheated steam be used.

Ques. How should a gauge be installed?

Ans. A gauge should be located in a cool place and secured to some substantial object where it will be free from vibration or jar. Before connecting a gauge *the goose neck should be filled with water to protect the bent tube from the hot steam.*

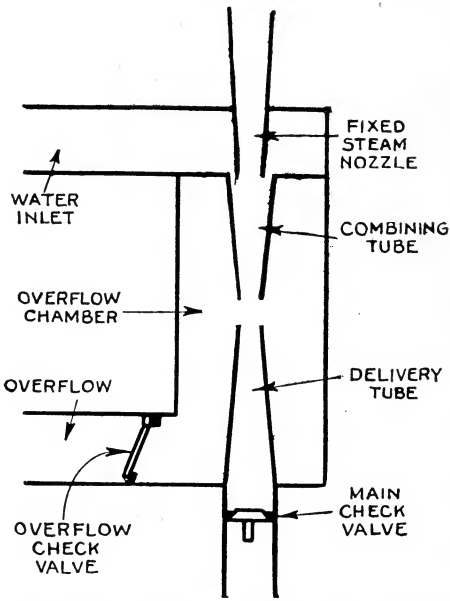
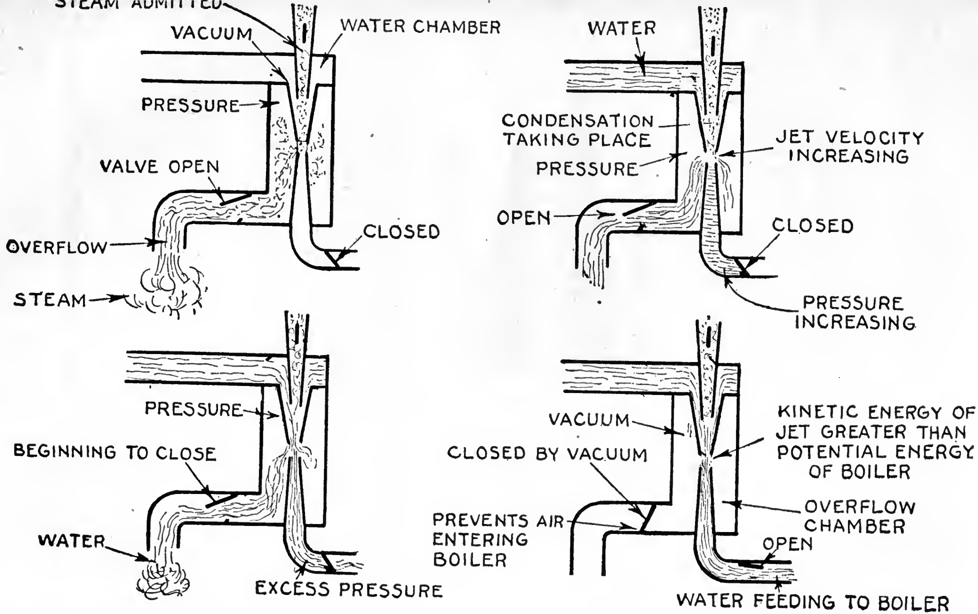


FIG. 4,778.—Rudimentary fixed nozzle, ***single tube,*** injector. The assembly of a steam nozzle, combining and delivery tubes is called a *single tube* injector, as distinguished from a double injector which has two sets of nozzles and tubes, one for lifting, and one for forcing.

Injectors.—An injector is an instrument for forcing water into a boiler against the boiler pressure by means of a steam jet.

Principle of the Injector.—An injector forces water into the boiler because *the kinetic energy of a jet of steam in much greater than that of a jet of water escaping under the same conditions.*

The simplest form of injector is shown in fig. 4,778, in which the details of construction are omitted. It consists of: 1, a steam nozzle, 2, combining



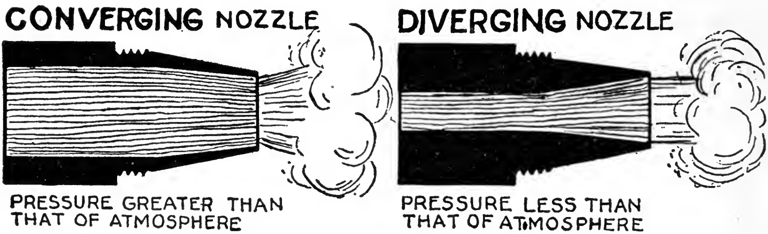
FIGS. 4,779 to 4,782.—Starting cycle of the injector. Fig. 4,779, steam admitted; flows through the overflow check valve and passes out through overflow outlet; the action of the steam jet creates a vacuum in the water chamber; fig. 4,780, vacuum created in water chamber draws in the water, which meeting the steam in combining tube, condenses and the jet of steam issuing from overflow (fig. 4,779), becomes a jet of water rapidly increasing in velocity, which builds up pressure against the boiler check; fig. 4,781, the continued increase in velocity of jet causes pressure against boiler check to exceed boiler pressure and the latter begins to open, part of the jet water entering boiler and part flowing out through overflow; fig. 4,782, velocity of jet has become so great tha all resistance is overcome, the check valve being forced wide open, all the water entering boiler. The action of the jet now creates a vacuum in the overflow chamber, which causes overflow valve to close, thus shutting out the air which would otherwise be forced into the boiler.

tube, 3, delivery nozzle with check valve, 4, inlet for water, and 5, overflow.*ƒ

In operation, steam from the boiler, entering the steam nozzle, passes through it, through the space between steam nozzle and combining tube, and then out through the overflow. This produces a vacuum which draws in the water through the water inlet.

The incoming *cold* water condenses the steam in traversing the combining tube and the water jet thus formed is driven at first out through the overflow, but as the velocity of the water jet increases, sufficient momentum is obtained to overcome the boiler pressure, with the result that the water enters the delivery tube, and passes by the *main* check valve into the boiler.

When the jet of water begins to flow into the boiler, it produces a vacuum in the overflow chamber as it passes the space between the combining and



FIGS. 4,783 and 4,784.—Lifting and non-lifting nozzles. In fig. 4,783, the pressure of the steam as it leaves the nozzle, being greater than that of the atmosphere, there is no tendency to produce a vacuum to lift the water. When expansion of the steam takes place within the nozzle as in fig. 4,784, the pressure is reduced below that of the atmosphere, thus producing a vacuum and drawing in the water. It will be noted that in double tube injectors (see fig. 4,785), the lifting nozzle is made *diverging*, and the forcing nozzle *converging*.

delivery tubes which causes the overflow check valve to close, this prevents air entering the delivery tube.

Injectors may be classed as:

1. Non-lifting.
2. Lifting. { diverging nozzle / double tube }

*NOTE.—The arrangement shown in fig. 4,778 is called a ***single tube*** injector as distinguished from the ***double tube*** type.

ƒNOTE.—In the accompanying elementary diagrams, *converging* or ***non-lifting*** nozzles are shown. It should be understood that ***in construction,*** the nozzle is made *converging* or *diverging* according as its function is to lift, or force respectively as explained in figs. 4,783 and 4,784.

3. Positive.
4. Automatic.
5. Adjustable nozzle.
6. Exhaust.

Ques. What is the difference in construction between non-lifting and lifting injectors?

Ans. In order that an injector be able to lift its water supply, the pressure at the end of the steam nozzle must be less than that

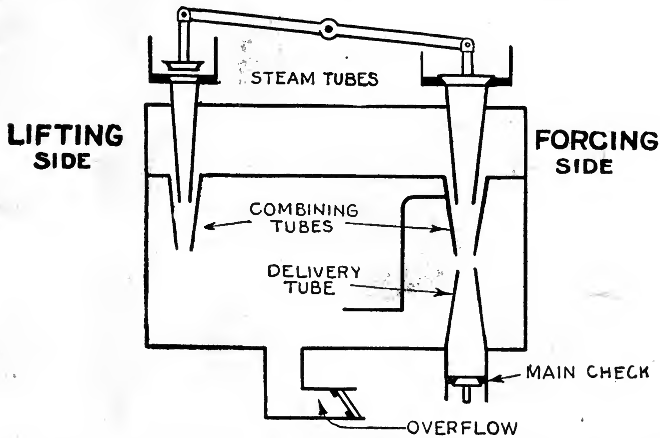


FIG. 4,785.—Rudimentary fixed nozzle, ***double tube*** injector. In this type the lifting tube lifts the water to the injector, and the forcing tube forces the water into the boiler. This type is adapted to high lifts.

of the atmosphere. This result is secured by using a diverging nozzle.

The non-lifting injector has almost become obsolete. Figs. 4,783 and 4,784 show non-lifting (converging) and lifting (diverging) nozzles.

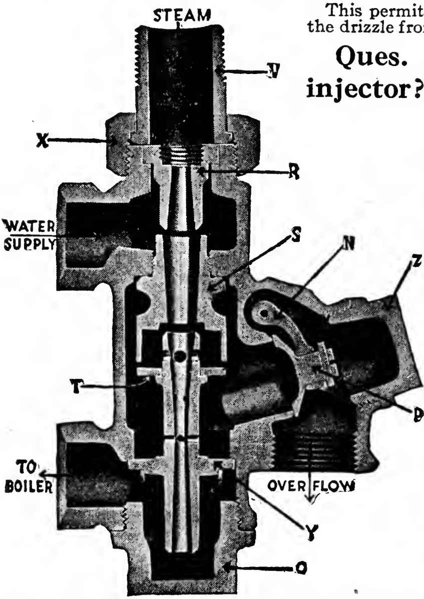
Ques. What other method is used to lift the water supply and adapt the injector to high lifts?

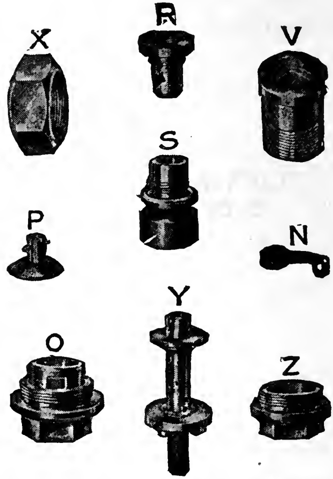
Ans. By providing two sets of nozzles and tubes as in the so called double tube as shown in fig. 4,785, one set being employed to lift the water and the other to force it into the boiler.

Ques. What is a positive injector?

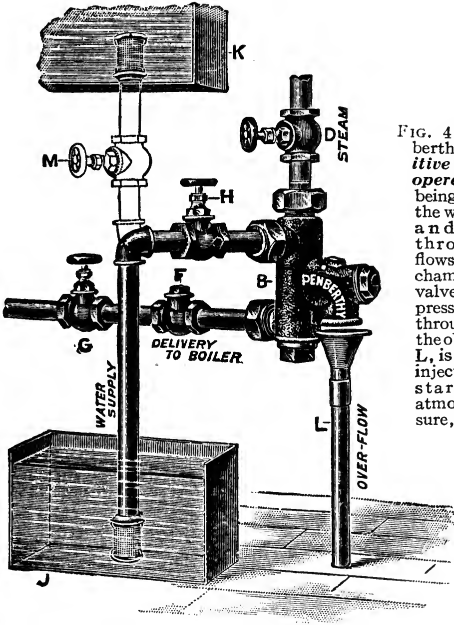
Ans. One with a hand operated overflow valve, as in fig. 4,799. This permits operation at high pressure by stopping the drizzle from the overflow.

Ques. What is an automatic injector?





Figs. 4,786 to 4,795.—Pemberthy single tube fixed nozzle lifting automatic injector. ***The parts are:*** R, steam jet; S, suction jet; T, ring valve; Y, delivery jet; O, plug; V, tail pipe; X, coupling nut; N, overflow hinges; P, overflow valve; Z, overflow cap. ***In operation,*** momentary period elapses between the opening of injector steam valve and the establishment of the jet of water to boiler. During this interval the steam and water must not be allowed to back up in suction line, hence a series of exhaust openings are provided at intervals along the jet passages. At first the steam and water exhaust from all these openings or "spills," then the establishment of the jet of water begins at the top and proceeds downward. It is therefore possible for the exhaust from lower spills to be drawn in again into the upper spills. Under such conditions the upper zone of injector may be established and have ceased to "spill," thus inducing an inward suction at upper spills. Now this upper zone has established because the steam and water quantities were rightly proportioned for that instant and that zone. But if the lower zone (which is not yet established) be allowed to throw its surplus back up and into the upper zone, the upper zone will again be disturbed and unbalanced. Therefore the ring valve is used to prevent such an occurrence. Just as soon as suction is developed at upper spills, the ring T, is drawn upward to its seat on jet S, forming an auxiliary chamber around upper zone for its protection. This ring valve T, is to the upper zone just what the outer overflow valve P, is to the injector as a whole. Without the ring T the injector could not be operated on the lower steam pressures. When water is taken from pressure source a special large steam jet is employed. Hot water is not favorable for low starting. Standard temperature for local tests is 74° Fahr



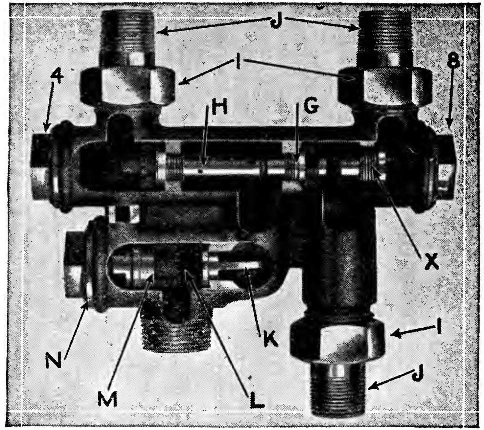


FIG. 4,796.—Penberthy ***auto-positive*** injector. ***In operation,*** steam being admitted, the water is raised and forced through overflows from vacum chamber through valve K, and from pressure chamber through valve L, the object of valve L, is to allow the injector to be started against atmospheric pressure, no matter what the steam pressure within its range, and when started, the boiler pressure holds valve L, to its seat and that in turn holds valve K, near its seat, thus accomplishing the closing of the overflow automatically which in positive double tube injectors requires a positive hand closed valve. The advantages claimed are: 1, very hot water is handled as high as 135° fahr., and a range of 25 to 200 lbs., working steam pressure is secured; 2, automatic action; 3, if injector "break," the steam and water escape at overflow instead of going down the suction pipe, as with a positively closed overflow. ***The parts are,*** 8, steam plug; X, steam jet; G, suction jet; H, delivery jet; 4, delivery plug; N, overflow plug; L, pressure valve; M, pressure valve collar; K, vacuum valve; I, coupling nut; J, tail pipe.

FIG. 4,797.—Penberthy single tube fixed nozzle lifting ***automatic*** injector with connections. B, injector; D, globe valve in steam pipe; F, check valve in delivery pipe; G, globe valve in delivery pipe; H, globe valve in suction pipe; J, water supply taken from below injector; K, water supply taken from overhead tank; L, waste pipe from overflow; M, second globe valve in water supply pipe where an overhead tank is used or supply is taken from water works pressure.

Ans. One that is self-starting after its operation has been stopped by an interruption of its water supply.

Ques. Describe the automatic feature.

Ans. It comprises two check valves, which when seated close progressively the combining and the overflow chambers to the atmosphere.*

Ques. What is a double tube injector?

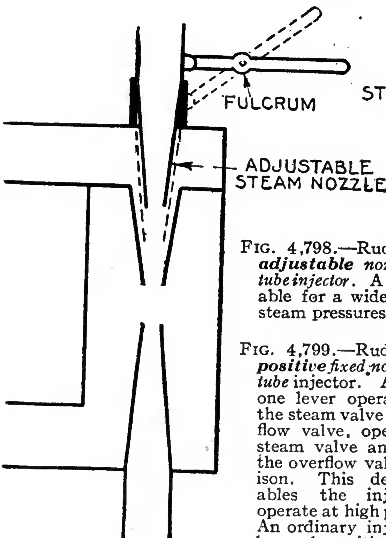


FIG. 4,798.—Rudimentary ***adjustable*** *nozzle single tube injector*. A type suitable for a wide range of steam pressures.

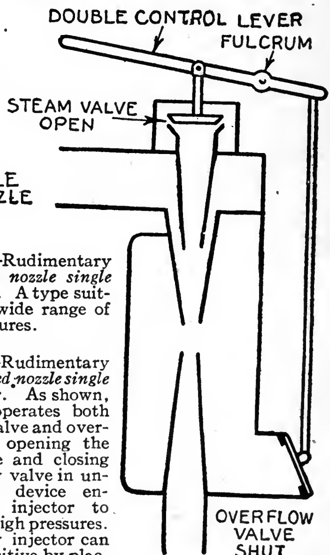


FIG. 4,799.—Rudimentary ***positive*** *fixed nozzle single tube* injector. As shown, one lever operates both the steam valve and overflow valve, opening the steam valve and closing the overflow valve in unison. This device enables the injector to operate at high pressures. An ordinary injector can be made positive by placing a stop cock in a short piece of pipe screwing into the overflow, and closing the cock after injector is started. It should be noted that such stop cock arrangement renders injector non-automatic while the stop cock is closed.

Ans. It is virtually two injectors combined into one, the first acting to lift the water, and the second to force it into the boiler.

Ques. What is the advantage of a double tube injector?

*NOTE.—***In restarting,** steam blowing through combining tube ejects the air causing combining chamber check to close and establishes a vacuum which draws up the water. The jet of water escapes through overflow until sufficient pressure is obtained to lift boiler check. At this instant the vacuum created in overflow chamber causes overflow check to close, thus preventing air being carried by the jet into the boiler.

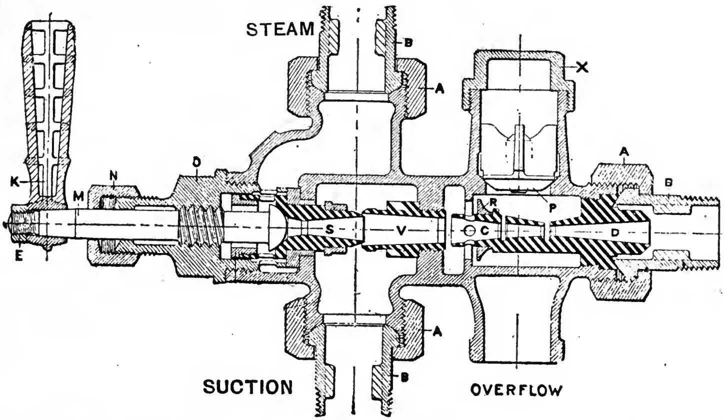


FIG. 4,800.—Metropolitan single tube sliding nozzle lifting automatic injector. ***The parts are:*** S, sliding steam nozzle; V, lifting tube; C and D, combining and delivery tubes; R, auxiliary check valve; P, overflow valve; O, steam plug; M, steam valve and stem; N, packing nut; K, steam valve handle; A, coupling nut; B, tail pipe; X, overflow cap; E, nut for stem M. ***In construction*** a *sliding* steam nozzle is provided. ***In operation*** when this nozzle is in the forward position enough water will flow in to work from 25 to 90 lbs. For pressures above 90 lbs., turn handle K, until the nozzle is drawn to its extreme backward position which will admit sufficient water for pressures up to 150 lbs.

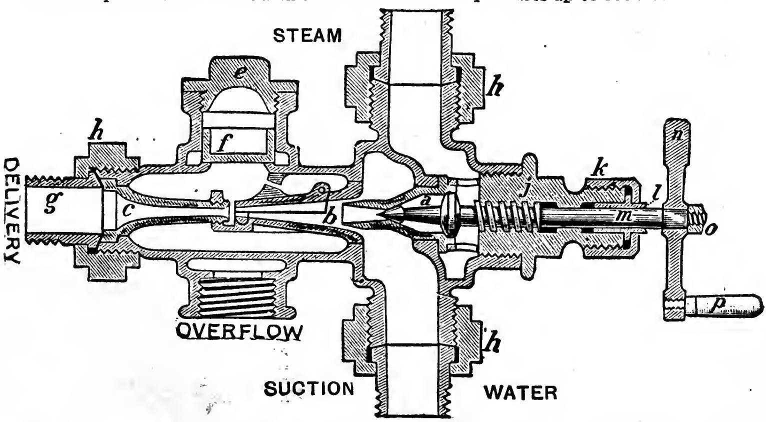
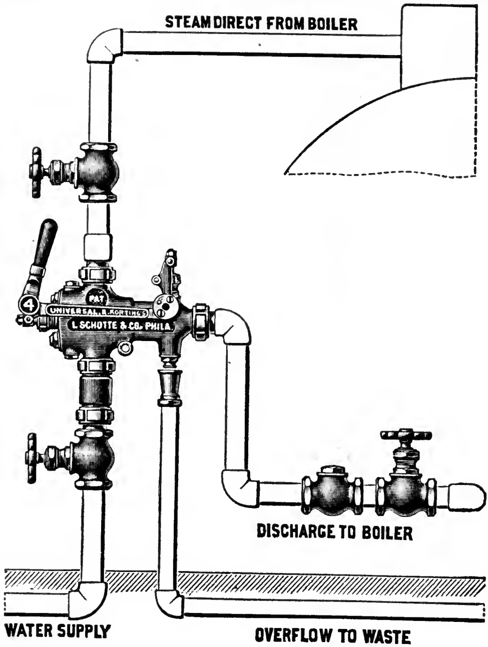


FIG. 4,801.—Schaeffer & Budenberg single tube fixed nozzle, lifting automatic injector with ***flap combining tube. The parts are:*** *a*, steam nozzle; *b*, combining tube ***with flap; c***, delivery tube; *e*, cap screw for overflow; *f*, overflow valve; *g*, tail pipe; *h*, tail pipe nut; *j*, screw plug with stuffing box; *k*, follower nut on plug *j*; *l*, packing sleeve to *j*; *m*, steam spindle; *n*, crank to spindle *m*; *o*, screw nut to spindle *m*; *p*, handle to crank *n*.



Ans. It is desirable for installation where the injector must lift the water a considerable distance.

FIG. 4,802.—Koerting ***double tube*** fixed nozzle lifting positive injector and connections. The lower tube is for lifting the water to the injector, and the upper tube for forcing the water in the boiler. Injector is shown in closed position of the operating handle. ***To start,*** the left handle is moved slowly; the quantity of feed is regulated by valve on water supply line. A strainer should always be attached to the water supply line when water is not clear.

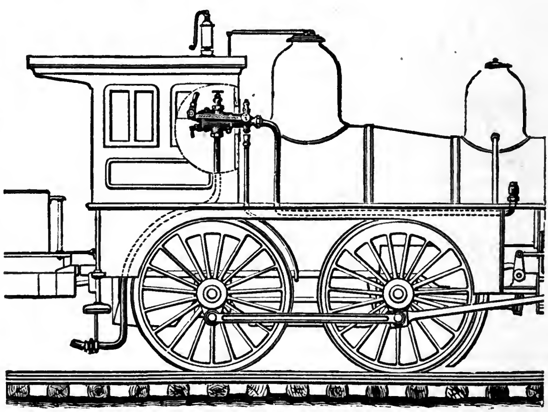
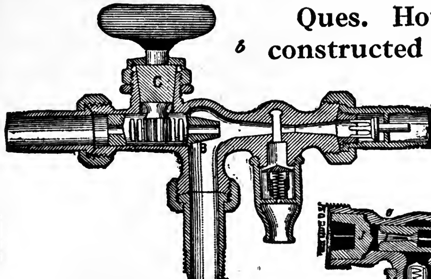
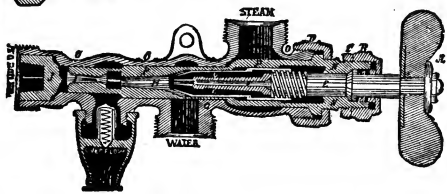


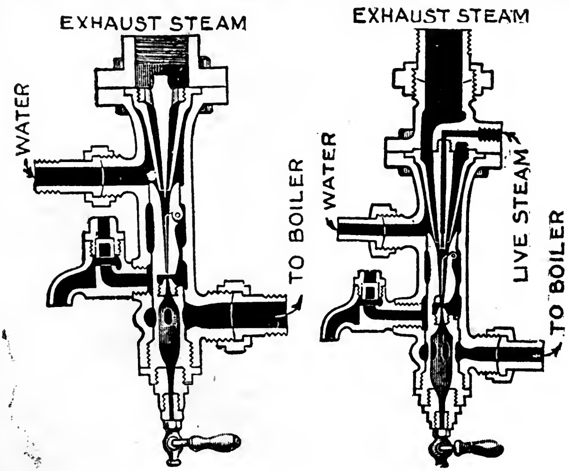
FIG. 4,803. — Koerting double tube fixed nozzle lifting positive, ***adjustable capacity*** injector as connected to a locomotive. ***To start,*** open with handle; to stop, close with handle. To use injector as a heater, open quickly with handle, when steam will flow back into water tank.



Ques. How should an injector be constructed to adapt it to work satisfactory with a wide range of steam pressures?



FIGS. 4,804 and 4,805.—Griffith's single tube ***adjustable nozzle*** injectors. Fig. 4,804 class B, non-lifting injector; fig. 4,805, "Eclipse" injector for feeding locomotive, stationary portable and marine boilers. To start the non-lifting injector (fig. 4,804) open water valve, then steam valve, and move plug B slowly forward with the handle *b* until water ceases run at the overflow. To stop injector, close steam valve, then water valve. ***Directions*** to ***for Eclipse injector*** (fig. 4,805): When the water must be lifted: 1, close the regulator by turning it to the right as far as possible; 2, turn on the steam, slowly at first, until the water, being taken up, shows at the overflow; 3, open the regulator slowly until the discharge from the overflow ceases. The injector is then at work. When the water reaches the proper line 1, turn off steam; 2, close the regulator always. Otherwise the injector will not "lift" properly when started. Where the water runs to the injector after once regulating for the pressure, it is only necessary to turn on the water, and then the steam. To remove the injector from its shell, screw the jam nut C, up against the main nut D, then, keeping the jam nut tight against D; unscrew the latter, which will loosen the injector in its shell so that it can easily be drawn out. Should it become necessary to repack the injector at M be careful to put the packing in front of the follower T, and compress with the latter.



FIGS. 4,806 and 4,807. —Schaeffer & Budenberg low and high pressure ***exhaust steam*** injector. It is worked by exhaust steam only up to 75 pounds pressure (fig. 4,806), and a little live steam is introduced at the top of the injector in order to force against pressures higher than 75 pounds (fig. 4,807). The boiler steam does not come in contact with the water until after the exhaust steam has been condensed.

Ans. It should be provided with an adjustable nozzle so that the water passage between the steam nozzle and the combining tube can be varied in size automatically, or by hand as shown in fig. 4,798.

Fusible Plug.—This is a safety device which acts in case of dangerously low water. It consists of a core of an alloy of tin, lead and bismuth, and a covering of brass or cast iron.

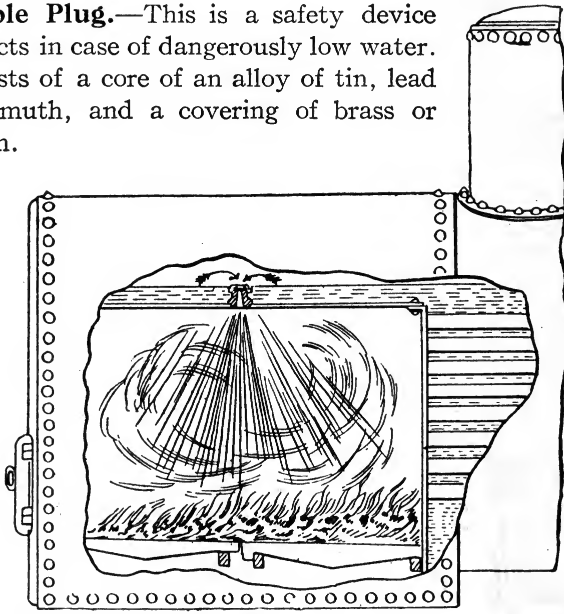


FIG. 4,808.—End of fire box boiler showing fusible plug in crown sheet in the act of blowing.

Although the alloy be kept at a comparatively low temperature by the water on one side, the fire on the other will not melt it. But when the water level becomes low enough to leave the plug uncovered, the core of alloy, having a low melting point, is *expected* to fuse, thus relieving the pressure in the boiler and extinguishing the fire.

Fusible plugs are unreliable; blowing out when there is no apparent cause, and sometimes remaining intact when the plates become overheated.

The fusible plug should be made of such shape that when screwed into

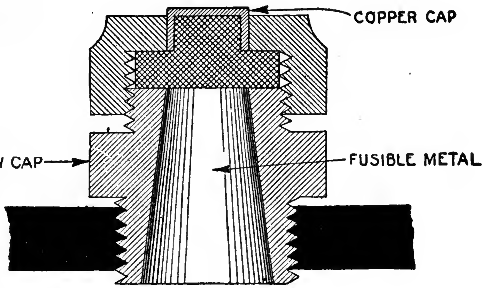


FIG. 4,809. Bailey fusible plug. The body of the plug is permanently fixed. A screw cup holds the fusible disc in place. The upper part of the disc is protected by a copper cap which is intended to prevent the water coming in contact with the soft metal, thus maintaining its normal point of fusion. Plain or ordinary plugs do not have the copper cap to protect the fusible disc.

U.S. Marine Rules—Fusible Plugs

RULE II, 20.—Fusible plugs for use in boilers of steam vessels under the jurisdiction of the Steamboat-Inspection Service shall be made of a bronze casing with the bore tapering continuously and evenly from end to end, and filled from end to end with tin not less than 99.7 per cent pure and to contain not more than .1 per cent of lead and not more than .1 per cent of zinc. The small end of the bore may be countersunk not more than one thirty-second of an inch in depth and width. but no recess. thread. or cavity other than this countersink shall be allowed.

Fusible plugs, except those which are hereafter provided for, shall have an external diameter of not less than three-fourths of an inch pipe tap, and the filling shall be at least one-half of an inch in diameter at the smaller end and shall have a larger diameter at the opposite end of the plug: *Provided, however,* That all fusible plugs fitted in boilers carrying a steam pressure exceeding 150 pounds to the square inch may be reduced at the smaller end of the filling to five-sixteenths of an inch in diameter.

Every boiler other than boilers of the water-tube type shall be fitted with at least two fusible plugs as described above and located as follows:

Upright boilers shall be fitted with two fusible plugs of an external diameter of not less than three-eighths of an inch pipe tap, the filling to be at least one-fourth of an inch in diameter at the smaller end and shall have a greater diameter at the opposite end. The fusible plugs shall be located in separate tubes not more than 2 inches below the lowest gauge cock.

Externally heated cylindrical boilers, with flues, shall have one plug in the top of the upper flue, not more than 4 feet from the back end of the flue, and shall also have a plug fitted to the shell of the boiler immediately below the fire line and not less than 4 feet from the front end: *Provided, however,* That when the flues are not more than 6 inches in diameter fusible plugs of not less diameter than three-eighths of an inch pipe tap may be used in such flues.

Fire-box, Scotch, and other types of shell boilers not specially provided for, having a combustion chamber common to all furnaces, shall have two plugs fitted to the crown sheet of the combustion chamber at or near the center of the crown sheet and not more than 12 inches apart. Boilers fitted with separate combustion chambers shall be fitted with a fusible plug in the center of the crown sheet of each chamber.

Boilers of types not herein provided for shall be fitted with at least two fusible plugs of such dimensions and located in such parts of the boiler as will, in the judgment of the local inspectors, best meet the purposes for which they are intended.

Fusible plugs shall be renewed after six months of service, and the inspector of boilers shall assure himself at each annual inspection by personal examination and by testing the ends of the filling by filing to determine its condition that the plugs are in good and serviceable condition.

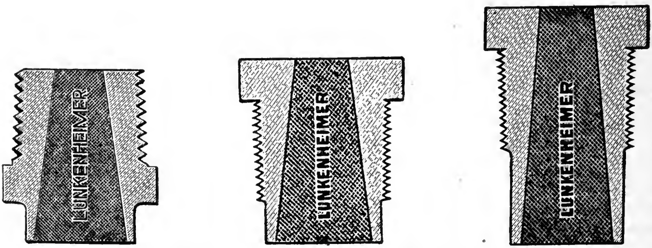
Fusible plugs shall be so fitted that the smaller end of the filling is exposed to the fire and shall be at least 1 inch higher on the water side than the plate or flue in which they are fitted.

Notwithstanding anything which may be contained in this rule, fusible plugs shall be so fitted that the end of the filling on the water end of the plug is not less than 1 inch above the dangerous low-water level.

the crown sheet it projects one and a half or two inches *above* the plates, so that when the alloy melts there will still be sufficient depth of water over the exposed plates to prevent injury from heat. The core is often made annular with a copper center. This gives a very large opening. Sometimes the core is covered with a thin copper cap, shown in fig. 4,809, which protects the alloy from contact with the water, thus preventing chemical change and the formation of scale.

Ques. Where are fusible plugs placed?

Ans. In the parts exposed to great heat, as: in the crown sheet of a locomotive fire box; in the lower tube sheet, or a little above the crown sheet, in one of the tubes of a vertical boiler; in the backhead of a cylindrical tubular boiler, about three inches above the top row of tubes; in the lower portion of the upper drum of a water tube boiler.



FIGS. 4,810 to 4,812.—Lunkenheimer fusible plugs. Fig. 4,810, inside type; fig. 4,811, outside type; fig. 4,812, extra long pattern outside type. The plugs are made of bronze and are filled with pure Banca tin in accordance with the requirements of the Board of supervising inspectors.

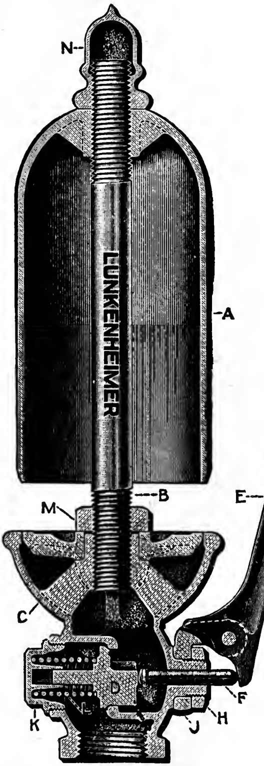
Whistle.—All marine, locomotive and a large proportion of stationary boilers are fitted with whistles, which form a most effective means of signalling.

Whistles may be classed as:

1. Single tone.
2. Multi-tone (chime).
3. Variable tone.

   a. Siren.
   b. Mocking bird.

Fig. 4,813 shows a single tone whistle, consisting of a metallic cylindrical bell closed at the top and open at the bottom, the lower edge being made thin to facilitate vibration. The bell should be of sufficient length to prevent breaking up the notes of vibration. The pitch of the tone depends on the ratio of diameter to length. When this ratio is large, the sound is of low pitch. Low pitch whistles are generally used on tug boats.



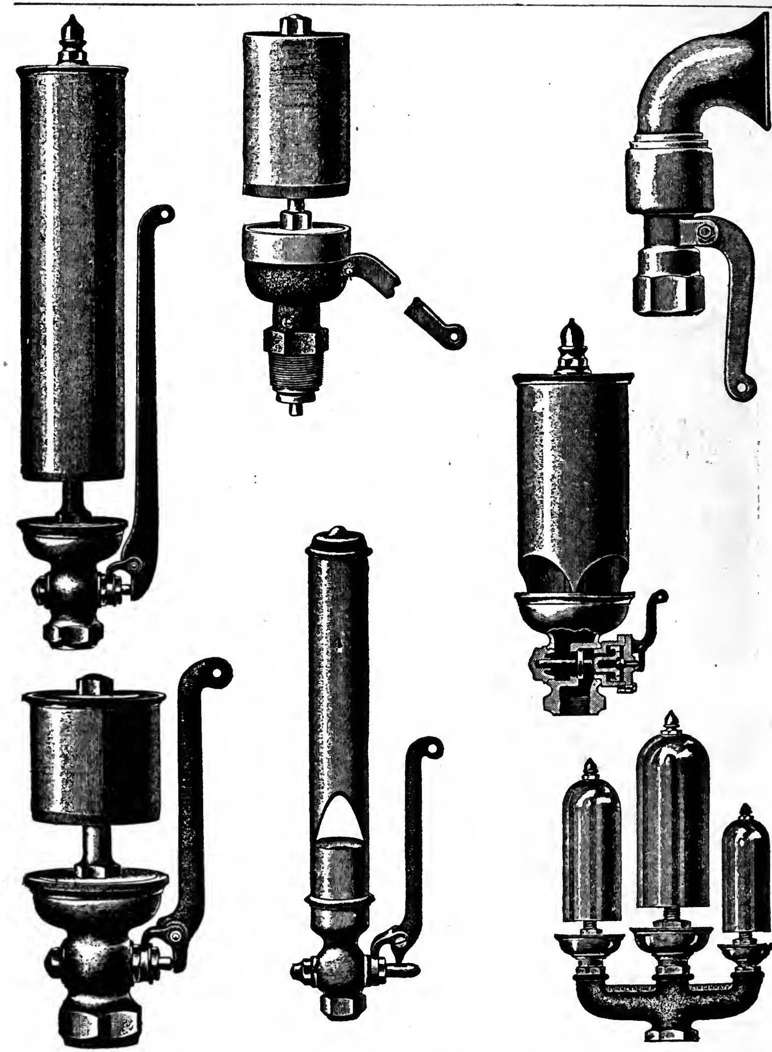
A single bell chime whistle has the inner volume of the bell throughout its length divided into two or more segments of unequal arc, but the arc length being made so that while each produces a different note, the notes form a musical chord, either major, minor, or any musical combination that pleases the designer.

Instead of a single bell, a chime whistle may be made up of several whistles of different sizes, the two types being shown in figs. 4,819 and 4,820.

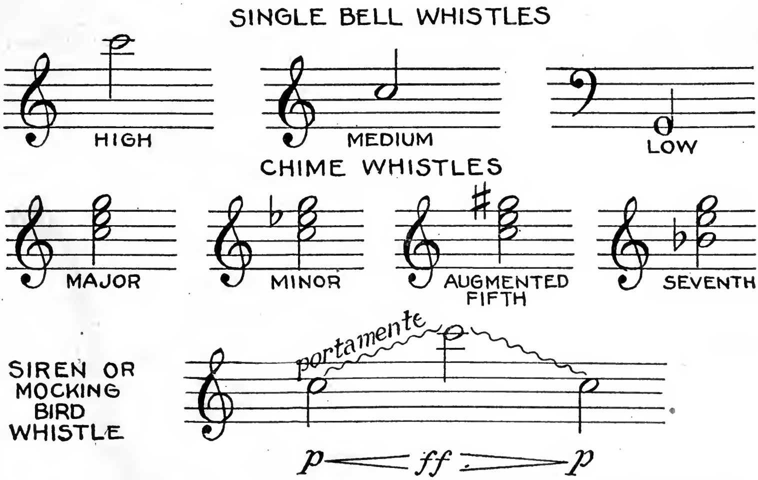
For emergency signalling the steam siren is used which gives a very piercing and disagreeable sound that can be heard at great distance. The construction employs a stationary and revolving disc. If the stationary disc be pierced with small holes at an angle to its faces and is placed directly in front of a similar disc, free to rotate, but having the holes at the same radial distance from the disc center piercing its surface at an opposite angle, then if steam be blown through the stationary disc, the reaction of the gas on the walls of the holes in the revolving disc will cause the disc to revolve.

As the speed of revolution increases, the rapid interruption of the flow

FIG. 4,813.—***Single tone*** whistle. The supply of steam is regulated by the valve D, which opens against a weak spring L, and the steam pressure, the opening force being applied to the stem F, through lever E, by means of a chain or wire attached to the lever at its upper end. The sound is produced by the rush of steam in a thin cylindrical sheet through opening M, directly against the edge of the whistle bell A, in which the vibrations necessary to produce the sound are produced. The bell is held in place by the threaded rod B, and jamb nut N. The lever pivot J, is secured by nut H. By removing cap K, the valve may be removed for examination or repair.



FIGS. 4,814 to 4,820.—Various whistles. Fig. 4,814, medium bell; fig. 4,815, short bell; fig. 4,816, siren; fig. 4,817, extra short bell; fig. 4,818, organ; fig. 4,819, single bell chime; fig. 4,820, multi-bell chime.



FIGS. 4,821 to 4,828.—Musical effect of various whistles. ***I, single bell whistles,*** fig. 4,821, short bell; fig. 4,822, medium bell; fig. 4,823, large bell. ***II, Chime whistles,*** fig. 4,824 to 4,827. ***III,*** fig. 4,828, ***Siren or Mocking-bird whistle.***

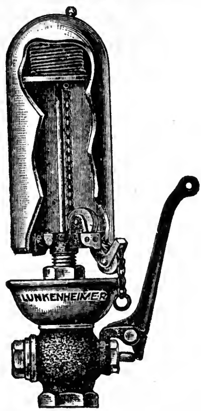


FIG. 4,829.—Lunkenheimer single bell variable pitch or sliding piston "mocking-bird" whistle. The bell is attached to the steam nozzle by a central rod and jamb nut. The piston slides along the central rod under control of the chain which is guided by pulleys, being brought back to its normal position when chain is released by the spring in the upper part of the bell.

By locating the two discs at the base of a trumpet, the volume of the sound becomes very much increased, as in the case of the ordinary megaphone.

In place of a rotating disc, a siren effect may be produced in an ordinary whistle whose bell is fitted with a movable piston, as in fig. 4,829.

An important part of a whistle is the valve. Only a balanced valve should be used, *especially with high pressure steam.* Fig. 4,830 shows one construction of balanced valve.

Steam or Air Required for Whistles.—The great amount of steam or air required to blow large size whistles is not fully realized by most people.

In quite a number of cases, manufacturers are asked to accept returned whistles of large size, simply because of the fact that the boiler or air compressor was not of large enough capacity to supply the necessary volume. Particularly is this true when the whistles are to be blown by air. By referring to the table below, the amount of free or compressed air necessary for various size whistles can be ascertained.

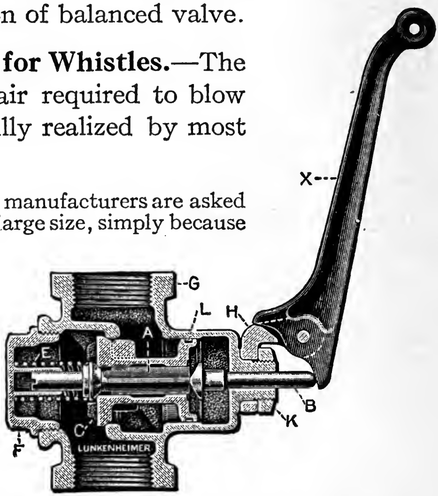


FIG. 4,830.—Lunkenheimer balanced whistle valve. ***In operation,*** steam pressure on the disc C, normally holds it to its seat. A slight pull on lever X, suffices to open the small auxiliary valve A. This admits steam through the opening in the center of the stem of valve C, to expansion chamber where it acts upon the piston, the area of which, being equal to that of valve C, practically balances it, and with only a slight additional pressure, the valve opens wide. When lever is released, the spring E, closes auxiliary valve A, and the main valve C, closes easily without jar, as the steam entrapped in the balancing expansion chamber tends to cushion and retard its movement.

Air Required to Blow Whistle

Diameter of whistle bell.........inches		1	1¼	1½	2	2½	3	3½	4	5	6
Size of pipe connection..........inches		¼	¼	⅜	½	¾	¾	1	1¼	1½	1½
Cubic ft. of air required, per second at pressures given below	Compressed	.11	.12	.13	.24	.41	.62	1.1	1.3	1.7	2.1
	Free	.41	.43	.45	.91	1.8	2.7	5.1	6.8	8.6	12
Air pressure.................. .....lbs.		40	40	40	40	50	50	50	60	60	70

CHAPTER 80

AUXILIARY APPARATUS

In addition to the apparatus described in the last chapter, there are numerous other devices in the boiler room necessary to the proper and economical operation of the boiler. These may be divided into three groups, as:

1. ***Combustion*** apparatus.

   a. Draught gauges.
   b. Damper regulations.
   c. Pyrometers.
   d. Tube cleaners.

2. ***Feed water*** apparatus.

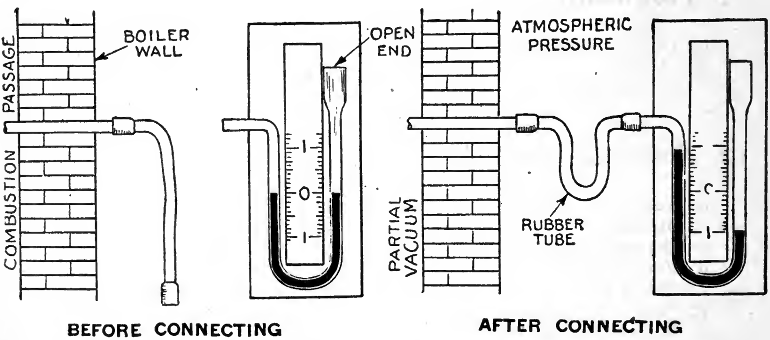
   a. Tanks.
   b. Strainers.
   c. Oil separators.
   d. Feed pumps.
   f. Pump governor.
   g. Feed water regulators.
   h. Water flow meters.
   i. Feed water heaters.
   j. Economizers.
   k. Evaporators
   l. Distillers.

3. ***Steam*** apparatus.

   a. Dry pipes.
   b. Separators.
   c. Steam loops.
   d. Steam traps.
   e. Super-heaters.
   f. Steam flow meters

1. COMBUSTION APPARATUS

Draught Gauges.—The draught or reduction of pressure in the combustion passages of a boiler is measured by the height of a column of water (or equivalent), which this difference of pressure will support.



Figs. 4,831 and 4,832.—U type draught gauge, at zero before connecting and indicating 2 inches draught after connecting. ***In reading,*** since the columns in the two tubes fall and rise equal distances, take the reading of one leg only and double it to obtain the draught in inches.

Fig. 4,831 shows a simple form of draught gauge called the U-gauge from its shape. It consists of a bent glass tube with adjustable scale and filled to the zero point with water.

One leg is open to the atmosphere and the other connected by rubber tubing and an iron pipe to the inside of the combustion passage at a point where it is desired to determine the draught. When thus connected, as in fig. 4,832, the greater pressure of the atmosphere pushes the water down in the open leg and up in the other until the difference in the heights of the columns in the glass tube corresponds to the pressure difference between the atmosphere and hot gases in the combustion passage.

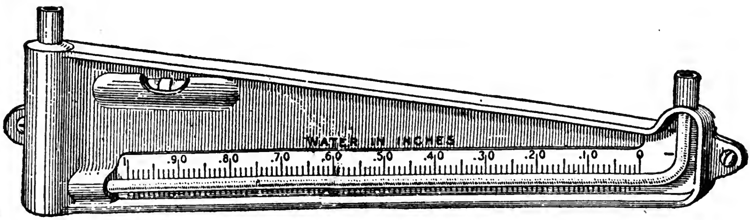


FIG. 4,833.—Inclined tube differential draught gauge. ***The fluid*** used is a special non-drying, non-evaporating, oil of known specific gravity. The incline and diameter of the tube are so proportioned that the draught may be read direct to one hundredth of an inch in term of distilled water. The indications are taken on one leg of the instrument only, and the movement of the fluid is ten to one.

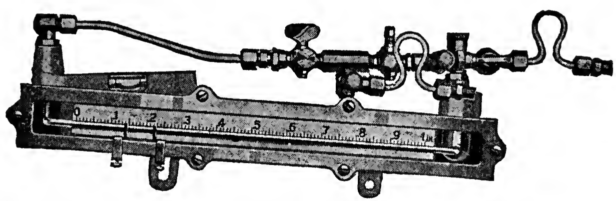
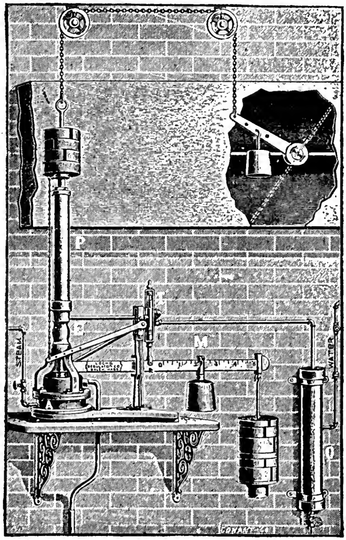


FIG. 4,834.—Ellison inclined tube combination differential draught gauge. With the style of cocks and cross piping, the furnace draught, flue draught, or differential between furnace and flue is independently indicated with the single tube. The furnace pointers are the first part and the differential pointer the second, all black except the high differential which is red. The differential ordinarily giving a wider liquid movement than the furnace draught, the gauge is so operated except momentarily on the furnace as a check or in case of excess soot in passages, indicated by too high readings. On the furnace, excess air through holes in the fire or thin bed causes the liquid to recede. whereas excess air by opening damper or increase in stack draught causes the liquid to advance. On the differential, excess air from any cause moves liquid forward only. Chamber connection is piped to the flue or over last pass, other connection to furnace. For differential readings, right and left cocks are open and middle cock is closed as shown. For furnace readings, right and left cocks are closed and middle cock is open, vent in left cock, slanting upward, open to atmosphere when closed. For flue readings, only the flue cock is open. Portable attachments are used for momentary pass readings or differential readings with furnace, connected with tee in chamber by removing plug. Where the low differential drop is only slightly over the high furnace pointer, second and third pointers can be brought close together by sliding them under from the other side of the clips or by holding both with one clip, taking one clip off. For lower drop, one or both furnace pointers are taken off. For high furnace draught and low drop, read drop between first hair, transposing second and fourth pointer, making second pointer red.

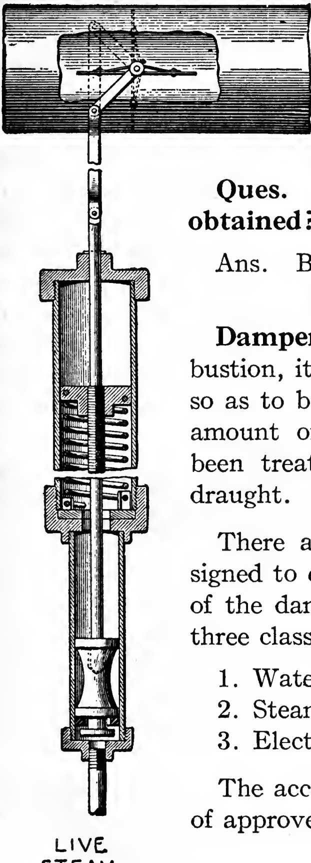
The instrument just described answers the purpose for occasional readings, but as a permanent fixture as for use in properly watching the draught a more reliable gauge is necessary.

Ques. What are the objections to the U gauge?

Ans. Since the gauge must be open to the atmosphere, the



Fgi. 4,835.—Locke ***hydraulic*** damper regulator. ***In construction and operation,*** **A,** is the steam piston chamber connected by a ⅜ inch pipe with any steam pipe carrying full boiler pressure by which the regulator is governed, and should be placed where it will not feel the pulsation of the engine or pump. **P,** the water motor is utilized in controlling the damper, mechanical stoker, or forced draught, separately or combined as may be required. The water valve **I,** regulates the supply of water used in motor **P.** The stem of this valve is connected with, and actuated by, the scale beam **M.** Any attempt of the steam to rise above the pressure set for will raise this beam, admitting water to the motor, lifting the weights, partially closing the damper. Any attempt of the steam to fall is followed by a corresponding fall of the scale beam, closing the inlet valve to motor **P,** and opening the outlet, lowering the weights and opening or partially opening the damper, etc. **E,** is a lever which by means of a chain attached to motor **P,** operates a cam by which valve **I,** is moved, closing the same and checking the movement of motor **P** and damper **H,** thereby preventing it going fully open or closed, and yet keeping it in just the place to maintain even steam pressure. The receiver or mud drive **D,** is used to permit any sediment which may be in the water to settle. The water supplied to motor **P,** should never be of a high temperature, and the cooler the better, and may be taken from any pipe convenient, carrying not less than 15 lbs. pressure. Motor **P** is proportioned to suit the water pressure. Condensed water may be taken from the bottom of a steam pipe; a coil should e used for this purpose. A graduated scale bean **M,** by which the machine can be set quickly and accurately to any desired pressure, will be found a reliable and positive test for the gauges. Piston of motor **P** control damper **H** through chain and pulley transmission, when acted upon by water. Chamber **A** contains no diaphragm, a rubber piston packing being used.



evaporation of the water renders the readings unreliable, moreover, the vertical column gives a scale too short for accurate readings.

Ques. How is a more extended scale obtained?

Ans. By inclining the tube as in fig. 4,833.

Damper Regulation.—For efficient combustion, it is necessary to regulate the draught so as to burn just enough fuel to generate the amount of steam required. The subject has been treated at some length under forced draught.

There are numerous forms of apparatus designed to effect automatic opening and closing of the dampers and they may be divided into three classes, according as they are operated by:

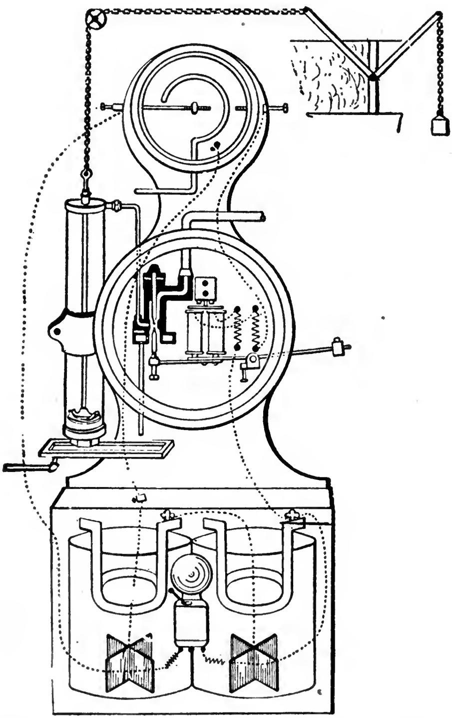
1. Water pressure.
2. Steam pressure.
3. Electricity.

The accompanying illustrations give examples of approved forms of the three classes.

FIG. 4,836.—Tilden ***steam*** damper regulator. ***It consists of*** a brass cylinder in which is a piston connected to a spring, which balances the steam pressure. Condensed steam from the boiler is admitted under the piston, and being pure water, contains nothing that will corrode the parts and no grit or impurities to cause the piston to stick. Since the spring is in a separate chamber, no steam or water can come in contact with it, and there is no condition present that will change its strength or alter its movement. Steam is admitted to the pipe, seen at the bottom of the figure, and any variation in pressure results in a movement of the piston and rod so that the damper is opened or closed in proportion to the change in pressure. Connection is made direct, as shown in the illustration where this is possible, but if not, a rocker shaft made of ¾-inch piping may be used to transmit the motion.

Pyrometers.—For taking temperatures above the range of the ordinary mercury thermometer, as for instance, high temperatures of the furnace, a special form of thermometer called the pyrometer is used, of which there are many types.

A common method of determining temperatures higher than 1,000 degrees is by employing a number of fusible alloys placed in crucibles which are enclosed in a porcelain oven and subjected to the heat of the furnace whose temperature is desired.



All alloys whose melting point is below the temperature of the furnace become liquids and by this means, with the proper selection of metals, it is possible to determine, within reasonable limits, the temperature maintained in the furnace, as metals or alloys can be secured whose melting points are not far apart.

The water pyrometer is another apparatus for determining high temperatures.

FIG. 4,837.—McDonough ***electric*** damper regulator. ***In construction,*** there are two pieces in the casing of the steam gauge (seen at the top of the cut), which are screwed in so that they touch the expanding pipe coil when the pressure rises or falls to the point for which it is desired the apparatus shall operate. When the spring touches one of these pins, an electric circuit is closed and the electro-magnets in the case at the bottom of the apparatus are energized so that they lift the armature and open the valve, thus admitting water to the cylinder and forcing the piston down, so as to close the damper. When the steam pressure falls, the spring coils up and, in so doing, touches the other pin, thus making a second electric circuit and operating other electromagnets to ring an alarm bell.

This consists of a block of iron or other metal of known weight which is subjected to the heat of the furnace for a sufficient time to be raised to the temperature of the gases, and is then dropped into a vessel containing a known quantity of water, the temperature of which is determined before and after the heated metal has been dropped into it.

Air pyrometers are of two classes; *one maintains a* ***constant volume*** *with a* ***varying pressure,*** *and the other a* ***constant pressure*** *with a* ***varying volume.***

These pyrometers are arranged with tubes and graduated scales which read directly the temperature to which the bulb is subjected.

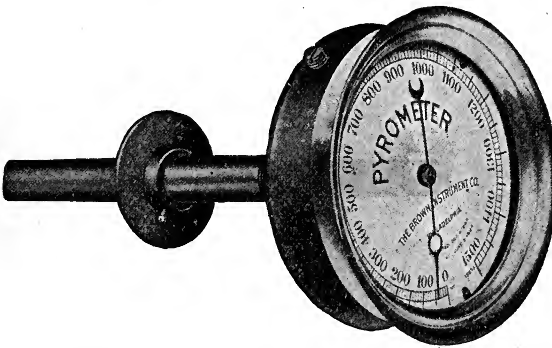
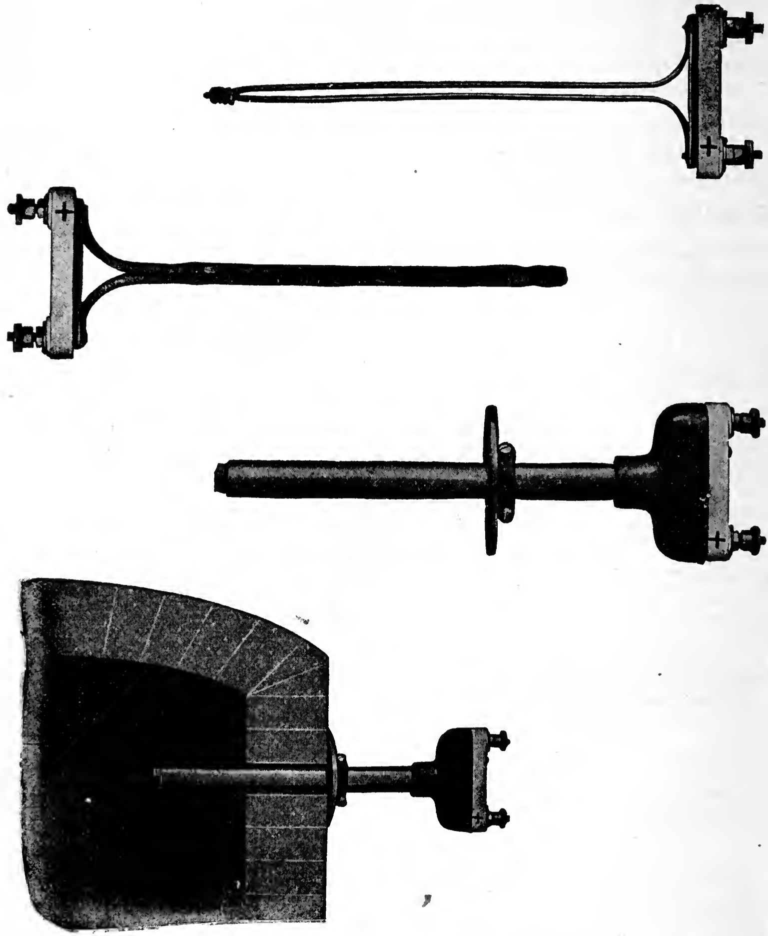


FIG. 4,838.—Brown expansion pyrometer. ***In principle,*** it operates through the difference in expansion of graphite rods and a steel stem, the temperature being indicated on the dial. By means of a compensating device, the exact temperature is indicated no matter how much of the stem above 12 in. rod is inserted in the heat.

The air is contained in a porcelain bulb of known volume, and the connecting tubes to the indicating scales are made of very small diameter and convenient length.

Electrical pyrometers are either of the thermo-couple type or depend upon change in conductivity of some metal wire.

NOTE.—To determine the temperature of the furnace, subtract the original temperature of the water from the highest temperature it attains, multiply this difference by the weight of the water plus the water equivalent of the cup; divide this product by the weight of the iron block times its specific heat; to the quotient is added the highest temperature reached by the water; the result will be the temperature of the furnace. The water equivalent of the cup is obtained by multiplying its weight by the specific heat of the metal of which it is made.



FIGS. 4,839 to 4,842.—Hays thermo-couple pyrometer and method of installation. Fig. 4,389 bare coupled; fig. 4,840, couple in asbestos lining; fig. 4,841 complete thermo-couple; fig. 4,842, couple inserted in furnace. ***The principle*** upon which this instrument works is that of *producing a current of electricity by heating two dissimilar metals*. ***In construction,*** the rods are welded at one end, being suitably insulated by lava or asbestos insulation. Lava is used for temperatures above 1,000° F.

The indicating devices used with electrical pyrometers are in fact milivoltmeters which are calibrated to read the degree of heat instead of the voltage of the couple.

Tube Blowers.—No matter how much care be exercised to secure perfect combustion, there is always more or less soot deposited on the tube surface, and since soot is a very excellent insulator, the efficiency of the boiler decreases as the soot accumulates. Moreover, a fine ash will also gradually collect on the tube surface. The tubes are cleaned by means of tube blower, classified as:

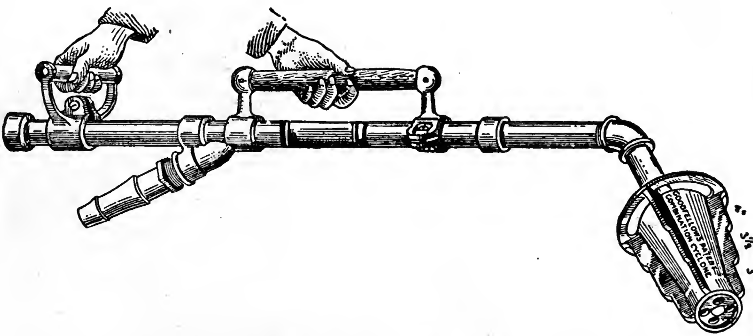


FIG. 4,843.—Goodfellow tube blower. The adjustable head fits and holds itself in different sizes of boiler tubes. Its adjustable steam nozzle delivers steam in lines oblique to the line of travel, drawing in hot air between the flanges, creating a whirling of steam air and grit, through and out of the tube. The adjustable handle enables the highest boiler tube to be reached from the floor, being so arranged that the steam hose may be attached at the middle or end of the handle.

1. Portable, single jet.

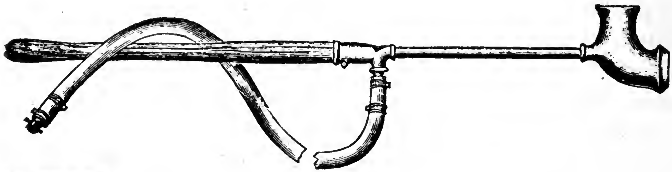
   a. Blower.
   b. Ejector.

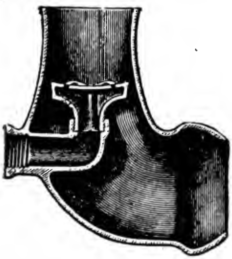
2. Fixed.

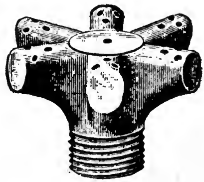
   a. Single jet.
   b. Multi-jet.

Figs. 4,843 to 4,846 show two types operated by hand, the first being a blower and the second working on the suction principle.

The term *fixed blowers* means those in which all the tubes may be reached without moving the apparatus, either by 1, an adjustable nozzle that may be pointed at any tube by turning a control wheel, or 2, by multi-jets,







FIGS. 4,844 to 4,846.—Thompson soot ejector. Steam issuing from the jet forms a vacuum in the tube, drives out the soot and ejecting it up the chimuey as shown in fig. 4,847. Fig. 4,845, section of head and top; fig. 4,846, enlarged view of central top.

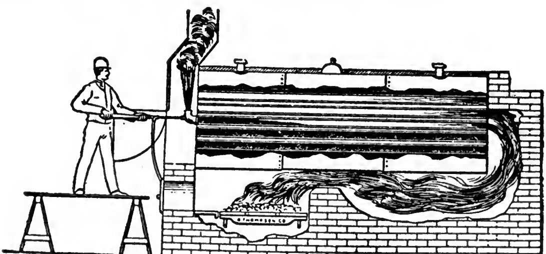


FIG. 4,847.—Thompson soot ejector in operation showing soot being discharged up the chimney. ***In using***, after connection is made to steam pipe turn on the steam and thoroughly warm the ejector, then partially close off the steam and introduce the ejector into the smoke head with the discharge pointing into the chimney flue. As soon as the soot in the smoke head is sufficiently removed to allow the steam to be turned on full, place the ejector in the upper tubes first; as each tube is cleaned change to the next, allowing the steam to blow continuously, thereby maintaining the forced draught in the stack. By slightly lowering the handle when changing from one tube to another the operation of entering the tube is greatly facilitated. It is advisable to slightly open the furnace door which insures the escape of the soot up the chimney. Use dry steam. After using, put the ejector in a pail of water, turn on the steam and wash it out. Steam hose will keep much longer if hung up perpendicularly.

whose combined action reaches all the tubes. Fig. 4,848 and 4,849 show the two types.

Tanks.—A supply of feed water must be carried on traction

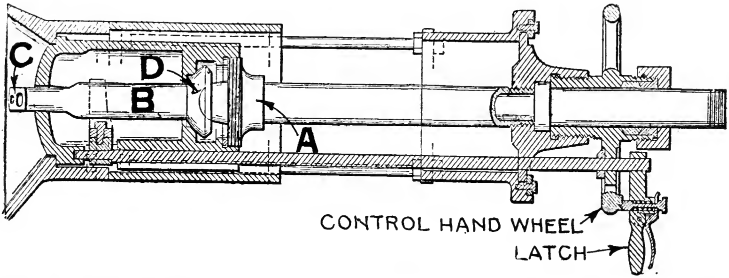


FIG. 4,848.—Monarch tube blower. By means of the control hand wheel, all the tubes may be reached by turning the wheel.

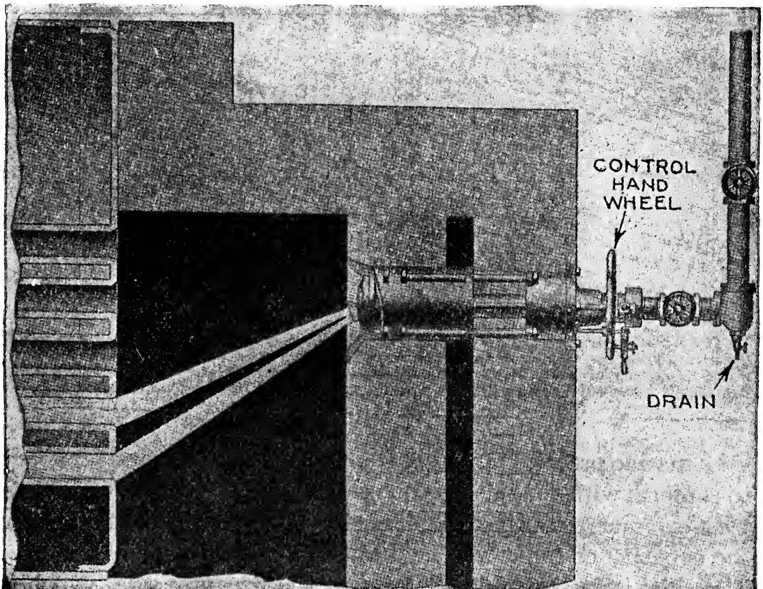


FIG. 4,849.—Monarch tube blower in position in rear wall of combustion chamber. The fireman should operate the blower several times a day.

engines, locomotives, steam boats, etc., where permanent connection cannot be made with some source of water supply. In such cases the construction and size of the tank required for the feed water are items of importance.

The construction varies greatly according to conditions of service and may be of boiler plate, light sheet iron galvanized, sheet copper, or wood.

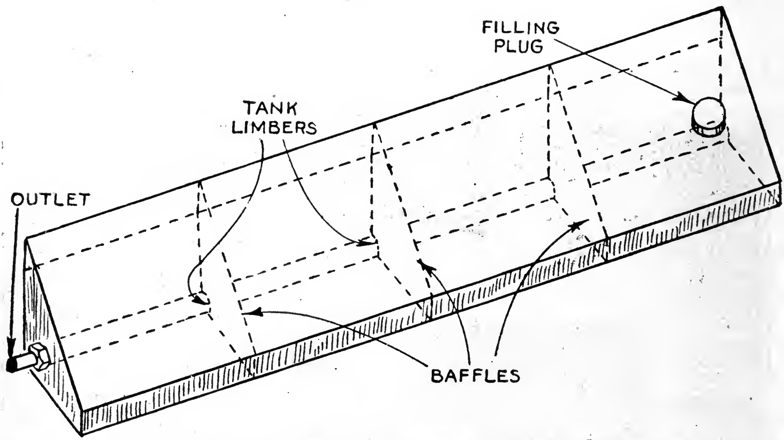
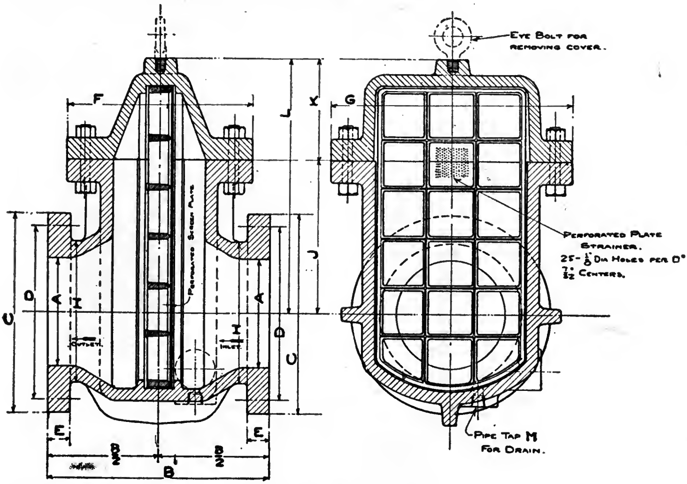


FIG. 4,850.—Copper water tank of steamer ***Stornoway***, shaped to fit in space under boiler and between keelsons. Made of sheet copper with baffles to prevent disturbance of water due to motion of boat. ***Approximate capacity*** =8 cubic feet =**7.48** ×8 =59.8 gallons; weight of water =**8⅓** ×59.8 =498 lbs. Approximate size of top of tank 8 ft. × 2 ft.

In marine practice tanks are frequently made of irregular shape to conform with the sides of the vessel and it is a favorite problem with examiners to ask candidates for engineer's license to figure the capacity of tanks and coal bunkers of such irregular shape. The chief item is to find the area of the irregular side, which is then multiplied by the length to obtain the volume. The area of the irregular side is (when a planimeter is not available), usually found by Simpson's rule.*

In marine practice for small wooden boats an excellent place for the feed water tank is between the keelsons under the boiler, as this gives a low center of gravity and the water is heated from the hot ashes in the ash pan directly above. In such installations if the tank be of such length that it cannot be removed for repairs without moving the boiler, it should be built in sections with suitable connections.



FIGS. 4,851 and 4,852.—Schutte & Koerting steam strainer. It is placed in the steam main in front of the throttle valve for the purpose of catching scale and other foreign matter. ***In construction,*** for saturated steam, it is made up of cast iron body, and of open hearth steel body and cover for superheated steam. Designed for a working pressure of 250 pounds.

Copper of course is the best material for such tanks, and several baffle plates should be provided in the tank to prevent undue disturbance of the water by the motion of the boat.

Example.—A steam lighter has a 200 horse power engine. What size feed water tank should be provided to furnish water for a three-hour

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*NOTE.—***Simpson's Rule.—1.*** Divide the length of the figure into any sufficient number of equal parts; ***2,*** add half the sum of the two end ordinates to the sum of all the other ordinates; ***3,*** divide by the number of spaces (that is, one less than the number of ordinates), to obtain the mean ordinate, and multiply this by the length to obtain the area.

non-condensing run if the engine require 40 pounds of steam per horse power per hour, allowing 10 per cent. for auxiliaries?

Total water required by engine in three hours:

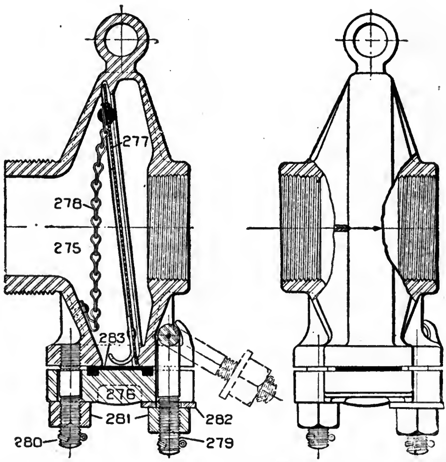
$3\times40\times200=$ ....24,000 pounds

Water for auxiliaries:

10 per cent. of 24,000 = ... 2,400 pounds

Total water consumed in three hours.........26,400 pounds

Capacity of tank $=26,400\div8\frac{1}{3}=3,208$ gallons
Volume " " $=26,400\div62.4=$ 423 cubic feet



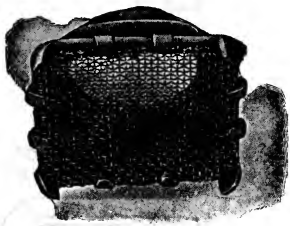
FIGS. 4,853 and 4,854.—Sellers locomotive feed water strainer. *It has* standard pipe or coupling nut connections, and is attached to the end of the injector suction pipe. In place of the usual wire netting, a perforated strainer plate is provided, the holes being small enough to give adequate protection. The dust trap is large enough to admit considerable accumulation before cleaning is required. The strainer can be cleaned in a few minutes without breaking the pipe or hose joint. When the nuts are slackened, the T head bolt swings upward and the cap rotates on the fixed stud clear of the opening, so that the straining plate can be partially removed. The ends of the bolts are provided with split pins to prevent complete removal of the attaching nuts and washers, and their possible loss.

Strainers.—There are numerous uses for strainers in nearly all power plants. Where the feed water is dirty they are quite necessary to prevent trouble with the feed pump and especially with injectors. They are also desirable for bilge water ejectors, circulation pumps of marine condensers, and various other devices, to protect the mechanism from dirt or other foreign matter in the water.

Wire netting of fine mesh is generally used to catch these substances, and to prevent choking, it is important that the amount of wire netting surface provided be considerably greater than the cross section of the pipe, otherwise the accumulation of dirt etc., around the wire netting will soon interfere with the free flow of the water.

Figs. 4,853 and 4,854 show a locomotive feed water strainer, which illustrates the excess area of netting.

Oil Separators.—The condensate from condensers and returns



FIGS. 4,855 and 4,856.—Hayden & Derby strainers, for injectors or ejectors. Fig. 4,855, union strainer, this form screws on to the injector or ejector, and by removing the cap and screen can be withdrawn for cleaning. Fig. 4,8_6, flat strainer, a type suitable for vertical connections, as for instance, where an injector receives its water supply for a barrel or other vessel. Note the short legs at the corners which insure clearance between the strainer and surface on which it rests.

from steam heating and drying systems, which are most economically used for boiler feed, contain an accumulation of oil and grease from the main engines and auxiliaries.

This oil and grease, if carried into the boiler is most injurious, affecting the efficiency and the safety. For oil in a boiler tends to form a film over the entire inner surface and is the most effective heat insulating medium known. Accordingly its presence in the boiler tends to cause overheating of the metal, with attendant danger of bulging and bagging of tubes, leaky joints, etc.

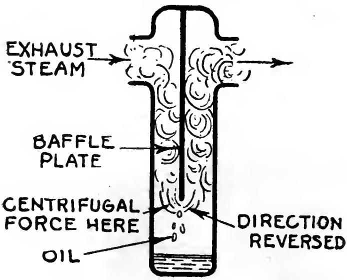
It is necessary therefore in condensing plants where the condensate is used for feed water, to provide an oil separator to remove the oil before the water enters the boiler. There are numerous devices for accomplishing this, and according to the principle of operation employed, the separation may take place:

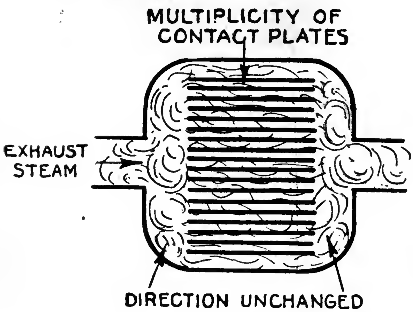
1. Before condensation, by:
   a. Centrifugal force
   b. Contact

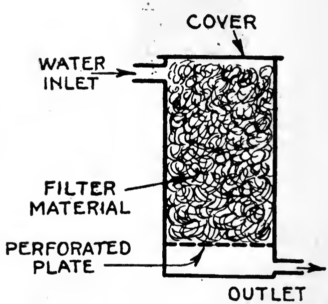
2. After condensation, by:
   a. Filtration {pressure filter / hot well}

Figs. 4,857 and 4,858 show the two types of separators which remove the oil before condensation, and which are fully explained under the cuts.

Fig. 4,859 shows the simplest form of pressure filter. The construction







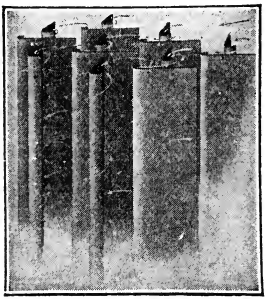
Figs. 4,857 to 4,859.—Various oil separators, sometimes called grease extractors. 1. ***Before condensation types:*** fig. 4,857, centrifugal force form; fig. 4,858, ***surface contact type.*** 2. ***After condensation type:*** fig. 4,859, pressure filter. In fig. 4,857, the exhaust steam from the engine laden with oil, enters the separator, and by means of the baffle plate its direction is suddenly reversed as shown, causing the centrifugal face thus created to hurl the particles of oil to the bottom of the chamber. In fig. 4,858, the direction of steam flow is not changed,but by interposing a number of plates with narrow passages the steam is divided up into a number of thin films and rubbing against the plate surface a wiping action takes place which separates the oil from the steam. This action is intensified by the staggered formation utilized in commercial separators employing the contact principle. Fig. 4,859 shows a simple form of filter consisting of a closed vessel filled with excelsior or other filtering material. and having a perforated plate at the bottom, to prevent the excelsior being carried out of the filter.

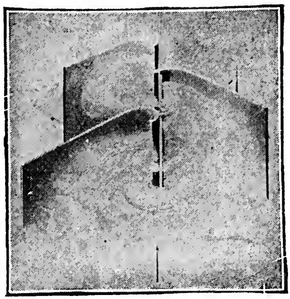
is such that the condensate passes through the filter under pressure, hence filter material may be packed in firmly to more effectually prevent any short circuiting of the water. This is permissible because the water being under pressure, can force its way through the compact filter material, and is one of the distinguishing features between a filter and a hot well.

Ques. What kinds of filtering materials are used?

Ans. Animal charcoal, sand gravel, broken pumice stone, and fibrous materials, such as sponges, bagging, toweling, etc.

Of the first mentioned, animal charcoal is the best, though somewhat expensive. It may, however, be removed from time to time, washed in lye water and replaced, but fibrous materials, as sponges or bagging, soon





FIGS. 4,860 and 4,861.—Webster ***centrifugal force, before condensation,*** oil separator; fig. 4.860, arrangement of baffles; fig. 4,861, passage of steam through baffles.

become clogged also with oil and impurities, requiring either replacement or frequent cleaning and washing.

Hot Wells.—Briefly, a hot well may be defined as a ***combined*** *after condensation, non-pressure multi-compartment* ***filter*** *and* ***receptacle*** *for the condensate*, en route from the air pump to the feed pump.

By non-pressure is meant that there is no perceptible pressure drop during the process of filtration, the hot well, in fact, being open to the atmosphere, as distinguished from a closed pressure filter.

Since pressure is not employed in the filtration process, the filtering material must not be compressed, but placed loosely in the hot well so that the water can pass freely through it.

In order to obtain efficient separation of the oil, a long travel must be provided for the water. This is done by dividing the hot well into numerous compartments arranged so that the water flows alternately upward and downward in passing progressively from compartment to compartment, as shown in fig. 4,864.

In marine practice, where the feed pump is frequently operated by the main engine (as it should be), the capacity of the pump is a little

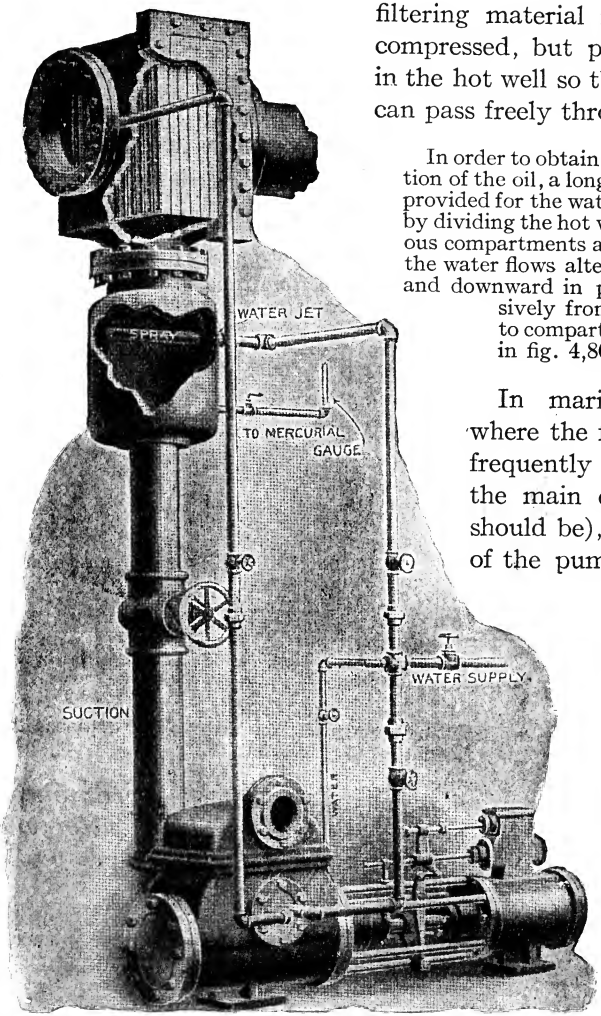


FIG. 4,862.—Bundy ***contact before condensation,*** oil separator, and connections. In this arrangement is created at the bottom of the receiver a pressure below atmosphere equal to in excess of the combined demand of engine and auxiliaries, otherwise a receding water level in the boiler would not respond to the pump when worked full capacity with "make up" open and "by pass." closed.

The object of the by pass connection between pump and hot well is to prevent air being pumped into the boiler. By a close adjustment of the by pass valve the excess water taken from the hot well is returned, which prevents the pump emptying the last compartment of water.

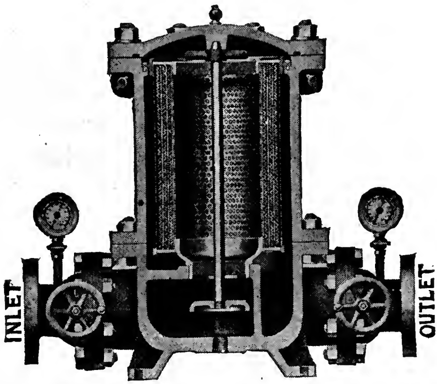


FIG. 4,863.—Lagonda ***pressure filter*** oil separator; sectional view showing perforated spool case layers of terry linen and spacer, valve for closing up filter spool when raised and lifting handle. ***In operation,*** the feed water enters the inlet side of the filter and passes up through the bottom of the filtering spool, through the perforated core and layers of terry linen, traveling to the outlet from all points of the spool, all the water passing through each layer of the cloth. ***In design,*** the total effective filtering area of the cloth is over 200 times the area of the inlet, giving positive or pressure filtration without undue pressure drop. ***In construction,*** there are two chambers so that one may be cleaned while the other is working thus permitting continuous operation.

When all the stuffing boxes are tight the plant will run on condensate alone for a surprisingly long time, but because of various leaks which exist

FIG. 4,862.—*Text continued.*

that in the exhaust pipe between the separator and condenser. To accomplish this result, a water spray is provided in the receiver, which produces a constant discharge of water under a low static pressure directly into the receiver. This spray water passes with the oil into the air pump, from which it is discharged into waste pipe or sewer. The volume of water thus used is comparatively small. The suction tapping n the bottom of the receiver is necessarily large in order to provide an unrestricted area for the discharge of water and oil. In this way possibility of flooding the separator is avoided.

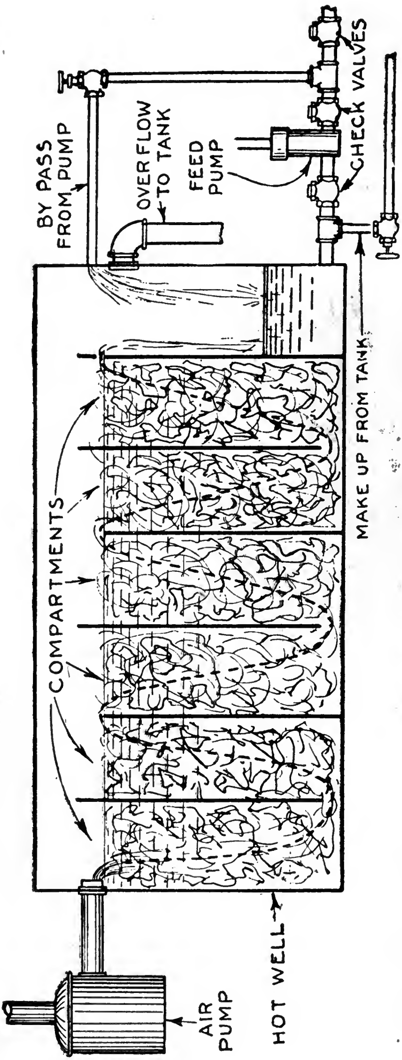


FIG. 4.864.—Hot well and connections. ***In construction,*** there are numerous compartments which are filled with filtering material. The compartments are arranged alternately open and closed at the bottom, causing the water to pass through all the compartments and come into instant contact with the filter material, as explained in the text.

more or less even in the best managed plant, it is necessary to supply additional water to bring back the water level in the boiler to normal and this is done by opening the "make up" connection from tank or other supply and closing the "by pass."

Ques. What trouble is frequently experienced with hot wells?

Ans. Flooding.

If anything happen to stop the action of the feed pump, the condensate from the air pump quickly floods the hot well and for this reason it is desirable, especially in marine practice, to provide an overflow connection to tank to avoid loss of condensate.

Evidently then, the condition of the last compartment is an index of the feed pump's performance, and this compartment should preferably be of proper size to give quick warning of failure of the feed pump, especially when water tube boilers are used.

Example.—A 25 horse power marine engine requires 20 pounds of steam per horse power per hour. What should be the size of the last compartment of the hot well to require 5 minutes to fill? *

Total steam or feed water used by the engine in five minutes is:

$$25\times20\times\frac{5}{60}=42 \text{ lbs.}$$

$$\text{Capacity}=42\div8\tfrac{1}{3}= \quad 5 \text{ gallons}$$

$$\text{Volume} = 5\times231=1{,}155 \text{ cubic inches}$$

Feed Pumps.—The subject of direct connected boiler feed pumps (both single and duplex), has been treated at considerable length in Vol. I and need not be further considered here except in a general way. All pumps, used for supplying boilers with feed water may be divided into two general classes.

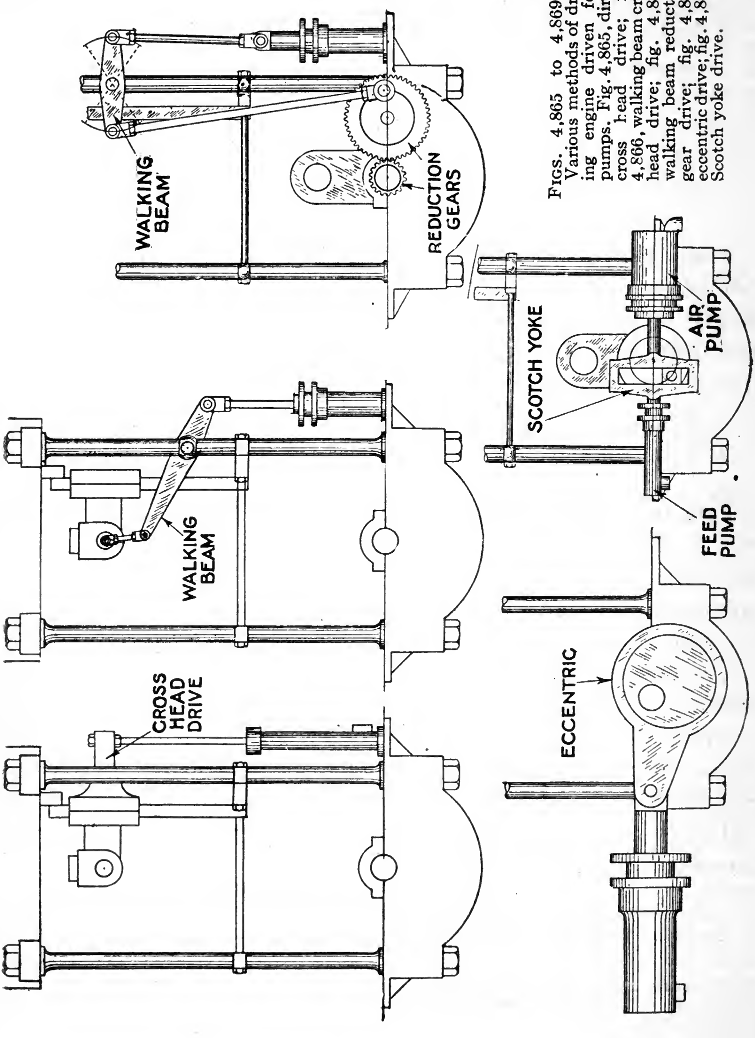
1. Engine driven.
2. Independent.

Engine Driven Pumps.—The term "engine driven" here means that the pump is driven direct by the main engine, and accordingly has the advantage of the superior economy of the engine, as distinguished from an independent pump which has its own power unit attached.

In considering the fact that it requires about ten times as much coal to drive an independent pump as one driven by an economical engine, there is no room for argument as to which is the more desirable, especially in marine practice, notwithstanding the fact that a large portion of the heat supplied to the independent pump may be recovered through a primary or secondary heater, exhausting into receiver, etc.

A reason that engine driven pumps are not more extensively used is because the high speed of the engine and necessarily low speed of the pump

* NOTE.—The calculation does not take into account the change in density of the water, because of its temperature, but such precision is not necessary, and would accordingly be a waste of time.



FIGS. 4,865 to 4,869.—Various methods of driving engine driven feed pumps. Fig. 4,865, direct cross head drive; fig. 4,866, walking beam cross head drive; fig. 4,867, walking beam reduction gear drive; fig. 4,868, eccentric drive; fig. 4,869, Scotch yoke drive.

require some form of reduction gear, the numerous parts of which are subject to wear. Also, if the pump become disabled, the main engine must be shut down during repairs.

There are various forms of transmission between the engine and pump, as:

1. Direct connection to cross head.
2. Walking beam.
3. Reduction gears.
4. Eccentric.
5. Scotch yoke.

These various drives are shown in figs. 4,865 to 4,869. Sometimes so called "power" pumps are used, being driven by belt from the line shaft. This is an excellent method, as by selecting pulleys of suitable size, the pump may be driven at any speed desired. This form of transmission is so extensively used and generally understood that little need be said.

Belts should be run at from 3,000 to 5,000 feet per minute.

The proper size belt is obtained from the following simple rule:

A single belt one inch wide, traveling 1,000 *feet per minute, will transmit one horse power; a double belt twice this amount.*

Example.—What diameter of plunger is required for a single acting pump of the type shown in fig. 4,865, to deliver 600 pounds of feed water per hour to the boiler when operated by a 10 inch stroke engine making 200 *r.p.m.*

600 lbs. of water per hour $= 600 \div 60 = 10$ lbs. per minute.

10 lbs. of water $= 231 \times (10 \div 8\frac{1}{3}) = 277$ cu. ins.*

The pump being **single** *acting*, makes one delivery stroke per revolution of the engine, hence,

displacement per delivery stroke $= 277 \div 200 = 1.385$ cu. ins.

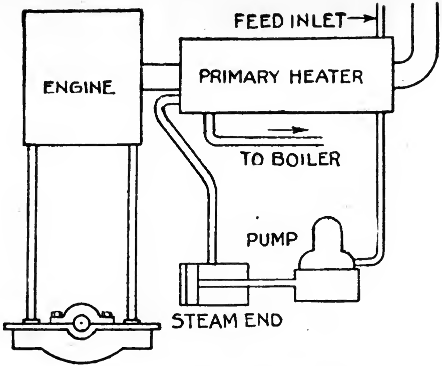
For 10-inch stroke, cross sectional area of plunger

$$= 1.385 \div 10 = .1385 \text{ sq. ins.}$$

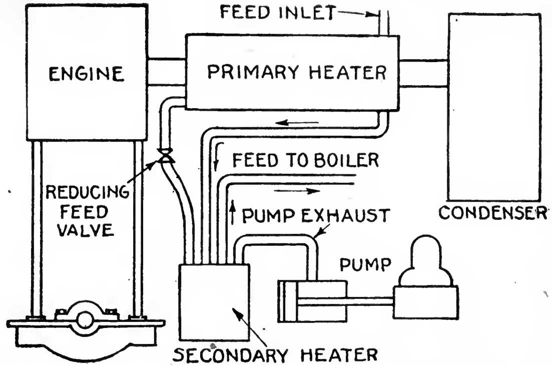
$$\dagger\text{Diameter corresponding} = \sqrt{\frac{.1385}{.7854}} = .42, \text{ say } \tfrac{7}{16}$$

*NOTE.—One gallon of water weighs $8\frac{1}{3}$ pounds, and occupies 231 cubic inches at 62° Fahr.

†NOTE.—Area of circle $= .7854 \times \text{diam.}^2$, $\text{diam.} = \sqrt{\frac{\text{area}}{.7854}}$



NON-CONDENSING



CONDENSING

FIGS. 4,870 and 4,871.—Feed water heater method of improving the efficiency of a direct connected pump. Fig. 4,870, non-condensing connections; fig. 4,870, condensing connection. In fig. 4,871, the exhaust for the pump is piped to the main or *primary* heater and a large part of its heat is recovered in heating the feed water. When a condenser is used as in fig. 4,871, a small or secondary heater should be provided, into which the pump exhausts. Any steam that is not condensed in the secondary heater passes to the primary heater, a reducing valve being placed between the two heaters so as to maintain a predetermined pressure in the secondary heater. ***In operation,*** the feed water in passing through the primary heater is heated to temperatures ranging from 110° to 130°, more or less depending upon the vacuum maintained in the condenser. The water thus heated now passes through the secondary heater where additional heat is imparted to it from the exhaust of the pump and other auxiliaries, its final temperature being within a few degrees of that of the exhaust. By means of the adjustable reducing valve, evidently any pressure desired may be maintained in the secondary heater, thus varying the back pressure on the pump and its working temperature range to some value as may be found by test to give the best economic effect. Of course increasing the back pressure involves increasing the size of the pump cylinder to do the work.

NOTE.—***Selection of boiler feed pumps.*** Either two small pumps may be installed, using one at high speed and using the other as a spare, or one large pump may be installed and run at slow speed, using an injector in case the pump break down. Evidently in the first instance if the growth of the plant require increased boiler capacity both pumps must be run at the same time, hence there is no reserve pumping capacity in case of break down to one. With the large pump and injector, there will be considerable margin to meet the increasing load without using both pump and injector at the same time. If a line shaft be available, a power pump with gear or belt transmission is desirable, using an injector for emergency feed and while the main engine is idle, there should always be two devices (as two pumps or a pump and an injector) for feeding the boiler to guard against interruption in case of break down of one.

Independent Pumps.—The term "independent" means that the pump has its own driving power attached, forming a unit *independent* of the main engine.

There are numerous kinds of independent pump used as boiler feeders, and which may be classed:

1. With respect to the water end, as:

   a. Reciprocating.
   b. Rotating.

2. With respect to the steam end, as:

   a. Direct connected.
   b. Fly wheel {direct drive. / geared.}
   c. Turbine.

Reciprocating Pumps.—The first and worst type of reciprocating pump is the *direct connected*, although it is the one almost universally used in small and medium size plants. These pumps are said to require about 120 pounds of steam per horse power per hour, but considering the average condition as to leakage, 200 pounds would be a safer figure.

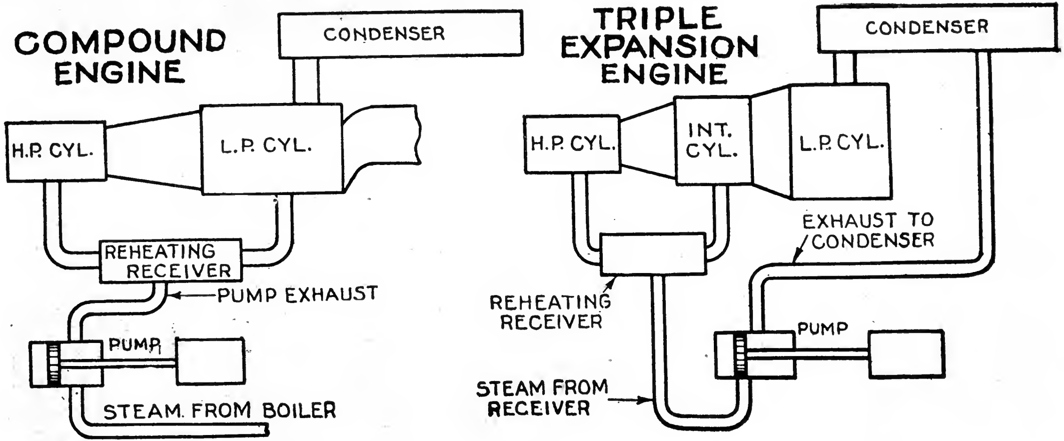
When these pumps are used, their wastefulness should be reduced as much as possible 1, by employing the exhaust to heat the feed water, or 2, by running compound in combination with the main engine that is exhausting into the engine receiver when the latter is a two or more stage expansion engine.

Figs. 4,870 and 4,871 show application of the first method to condensing and non-condensing plants, and figs. 4,872 and 4,873 the second method, with receiver and condenser exhaust, being virtually compounding arrangements.

One prominent writer says: "As the power required for pumping the feed water is only a small portion of the entire amount, an extremely uneconomical pump does not represent a great percentage of the entire fuel." *This tendency among engineers to disregard small losses cannot be too strongly condemned.*

Why use "an extremely uneconomical" pump, even if relative power required be small?

Example.—What horse power is required to pump the feed water for 1,000 horse power plant operating at full load, with 100 pounds steam pressure, and how much coal is required per hour to drive the pump, assuming the pump uses 200 pounds of steam per hour, the actual steam chargeable to the pump being say, 10 per cent. of its rate. Mechanical efficiency of pump 50 per cent., and evaporation 7½ to 1.



FIGS. 4,872 and 4,873.—***Compounding*** method of improving the efficiency of a direct connected pump. Fig. 4,872, arrangement with compound engine; fig. 4,873, arrangement with triple expansion engine. In fig. 4,872 the pump receives its steam from the boiler, and exhausts into a reheating receiver where more or less of the condensate it contains is re-evaporated. The exhaust then does useful work in the *l.p. cyl*. In fig. 4,873, steam is taken from the receiver and exhausted into the condenser. If the pump be suitable for high pressures, a more economical arrangement would be to take steam from the boiler and exhaust into the receiver, thus obtaining the advantage of expansion in the *int.* and *l.p. cyls.*

Approximate amount of water evaporated by boiler per hour:

$$1,000 \times 30 = 30,000 \text{ pounds}$$

To force water into a boiler under 100 pounds pressure is equivalent to raising the water

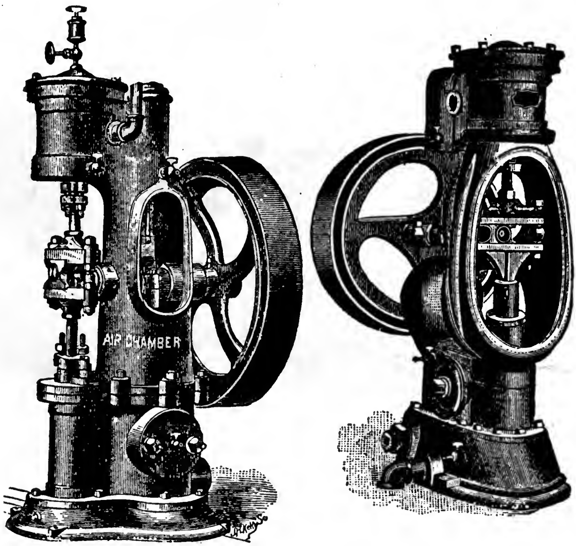
$$100 \times 2.3 = 230 \text{ feet}$$

Foot pounds of work to pump the water:

$$=30{,}000 \times 230 = 6{,}900{,}000 \text{ ft. lbs. per hour.}$$

$$=6{,}900{,}000 \div 60 = 115{,}000 \text{ ft. lbs. per minute}$$

$$\text{Horse power}\begin{cases}\text{at water end} = 115{,}000 \div 33{,}000 = 3.46\\ \text{at steam end} = 3.46 \div 50 \text{ per cent.} = 6.92\end{cases}$$



Figs. 4,874 and 4,875.—Vertical fly wheel feed pumps. The familiar Scotch yoke is employed for transmitting motion from the piston rod to the fly wheel.

Charging 10 per cent. of the steam consumption to the pump (the rest being recovered by feed water heaters), then

net steam used by pump = 10 per cent. of 200 = 20 pounds per *i.h.p.* per hour

or

$$20 \times 6.92 = 138 \text{ pounds per hour (total)}$$

NOTE.—One boiler horse power = 30 pounds of water at 100° Fahr., evaporated per hour into steam at 70 pounds gauge pressure.

If one pound of coal evaporate 7½ pounds of water, then
coal required to run pump—$138 \div 7\frac{1}{2} = 18.4$ pounds per hour

A seemingly negligible quantity, however, for a working day of 10 hours, and 300 days operation in one year.

$$\text{Coal per year required by pump} = \frac{18.4 \times 10 \times 300}{2{,}000} = 27\frac{1}{2} \text{ tons}$$

which with coal at say $5 per ton amounts to:

$$27\frac{1}{2} \times 5 = \$137.5$$

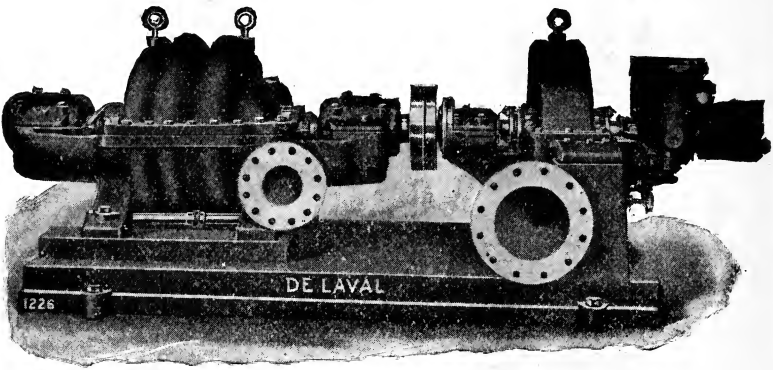


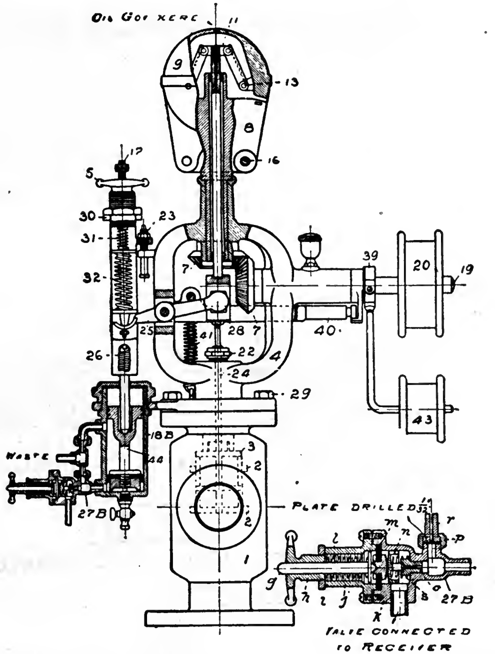
FIG. 4,876.—De Laval 8-inch three-stage centrifugal boiler feed pump, directly connected to class C, three stage turbine. Suitable for feeding boilers of 25,000 horse power.

Assuming the same 10 per cent. basis of steam chargeable to the pump, a fly wheel pump of the type shown in fig. 4,875, expanding the steam during the latter half of its stroke would require only one-quarter of the coal, or still better, economy could be obtained by employing a fly wheel pump with a riding cut off valve, which would require only one-tenth the coal used by the direct connected pump, resulting in a saving of:

$$137.50 - 13.75 = \$123.75 \text{ per year}$$

a sum which would not ordinarily be considered in selecting the type of pump to install, but which even the president of the plant would stop to pick up if he saw it lying in the yard.

In the planning of a power plant such sums virtually lie in every corner, yet most of us do not see them because we are slaves to the *power of suggestion*, that is, we follow blindly the practice of others without using our reasoning powers and common sense.



FIGS. 4,877 and 4,878.—Jarecki "Erie" discharge pressure fly wheel pump governor and detail of regulating valve. Connect receiver water pressure from a point where the water will be clean to union valve on regulator 27B. ***In starting pump,*** regulate the governor by screwing up or down speeder screw 5 so that the pump will run the desired maximum speed and lock screw with lock nut. Screw up regulating screw *h* (fig. 4,878), for the desired maximum pressure. ***In operation,*** the pressure acts on diaphragm *m* and is counter balanced by spring *l*. When maximum pressure is reached, the pressure on diaphragm overcomes counter pressure spring *l*, and needle valve *n* opens, letting water pressure under plunger 44 in cylinder 18B. A plate drilled with 1/32 inch hole connects the bottom of cylinder 18B with the waste. A variation of three or four pounds in receiver pressure will bring the needle valve *n* from its closed position to full opening, which will bring the pressure under piston 44 from atmospheric pressure to 50 above, and carry piston 44 from its lowest position to its highest, and bring the pump from its highest speed to its slowest speed. Any fraction of variation of the three or four pounds will make a like variation in the position of needle valve—the pressure under, and position of plunger 44, which in turn changes the speed of the pump, so that the pump is maintained at the slowest constant speed which will furnish the required supply. While the pressure device is in operation there will be a waste of water through the 1/32 inch hole in plate—the amount depending on the pressure under piston 44. On single pumps, stop screw 23 is set so that the pump will just turn over when maximum pressure is reached. On duplex pumps where it is desired to bring the pump to a stop with maximum pressure, stop screw 23 may be screwed down so that it will not strike or may be dispensed with. To set the automatic stop on class "A," loosen the binding screw on the rider lever socket 39, then set the roller on safety lever 40 in center of projection on throw-off 39 and lay rider pulley on top of the belt and tighten binding screw.

Rotating Pumps.—Turbine driven centrifugal feed pumps are very extensively used, especially in large plants, because they are continuous in action, put no severe strains on the piping, if the feed valves were all shut off by some chance, no dangerous pressure would result, less attention required, and saving in maintenance. The pump is from two to five stage, depending on the boiler pressure.

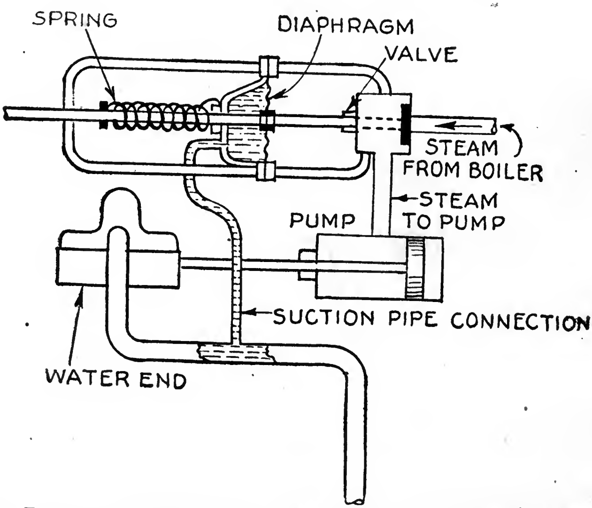


FIG. 4,879.—Elementary ***suction pipe*** *pressure governor*, or ***automatic stop.*** ***In construction*** the parts are so arranged that the spring opposes the vacuum acting on the diaphragm; that is, *the spring acts to* ***close*** *the throttle valve, and the diaphragm (under vacuum) to* ***open*** *the valve.* ***In operation,*** as long as a vacuum due to the lift is maintained in the suction pipe, atmospheric pressure acting on the diaphragm will overcome the force due to the spring and the valve will be opened to some point at which the two forces are in equilibrium. Evidently the higher the vacuum, the further will the valve be opened. Accordingly such arrangement *tends to maintain a* ***constant speed*** ***with variable lift,*** but not for variable pressure in the discharge pipe. Should the water supply fail and the vacuum be broken, the pressures on both sides of the diaphragm will be equalized and the spring will close the valve thus stopping the pump, which otherwise would race and perhaps result in injury.

The steam consumption of the turbine driven pump is about the same as that of the ordinary slide valve engine. Fig. 4,876 shows an approved form of turbine-driven centrifugal feed pump.

Pump Governors.—When no automatic control devices are provided, the speed at which a feed pump runs varies with the boiler pressure, sometimes feeding too much water, and at other times, not enough. To correct this governors are provided. They may be divided into two general classes:

1. Speed regulators.
2. Pressure regulators.

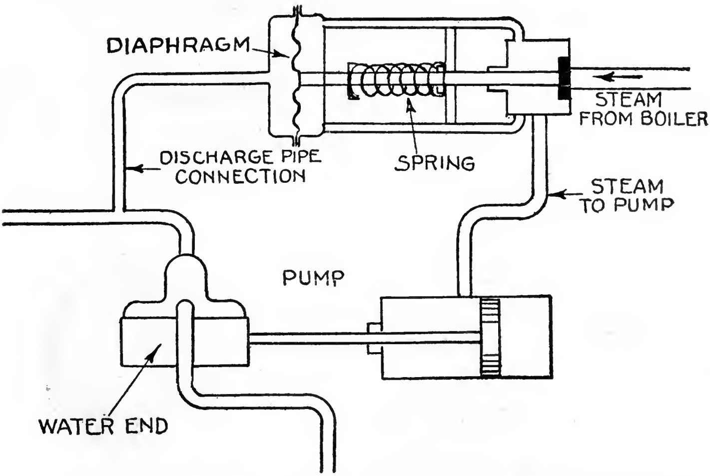


FIG. 4,880.—Elementary ***discharge pipe*** *pressure governor*. ***In construction***, the parts are so arranged that the spring opposes the discharge pressure acting on the diaphragm; that is, *the spring acts to* ***open*** *the valve, and the diaphragm (under discharge pressure), to* ***close*** *the valve*. ***In operation***, when the pump is started and before pressure is produced in the discharge pipe, the governor valve is held wide open by the spring, until the discharge pressure becomes strong enough to overcome the spring, when the valve throttles the steam supply to some point where the two opposing forces are in equilibrium. Evidently the *amount of throttle opening varies inversely with the pressure*, and hence such arrangement *tends to maintain a* ***constant pressure*** *by* ***variable speed*** *of the pump*.

One type of speed regulator suitable for a direct connected reciprocating pump employs a small oil pump to actuate the mechanism connected to the throttle valve. A regulating screw serves to change the speed of the pump, and after it is once adjusted, the throttle valve is automatically opened and closed to preserve constant speed.

Fig. 4,881 shows the connections, and fig. 4,882, detail of the governor.

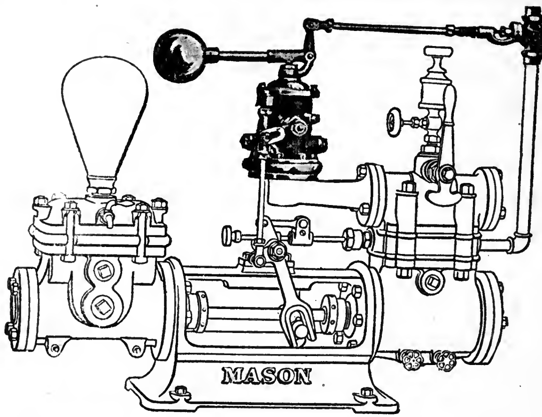


FIG. 4,881.—*Speed* regulating governor connected to pump.

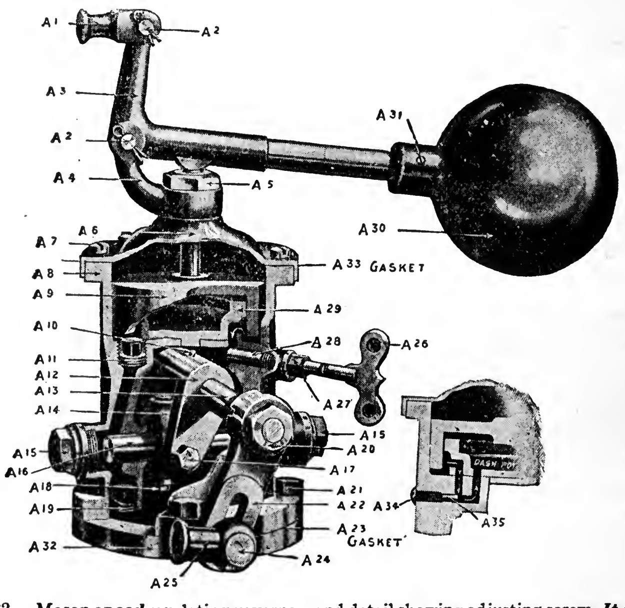


FIG. 4,882.—Mason ***speed*** regulating governor, and detail showing adjusting screw. ***It consists of*** a reservoir filled with a good, clean grade of machinery oil, in which plunger A-16 works

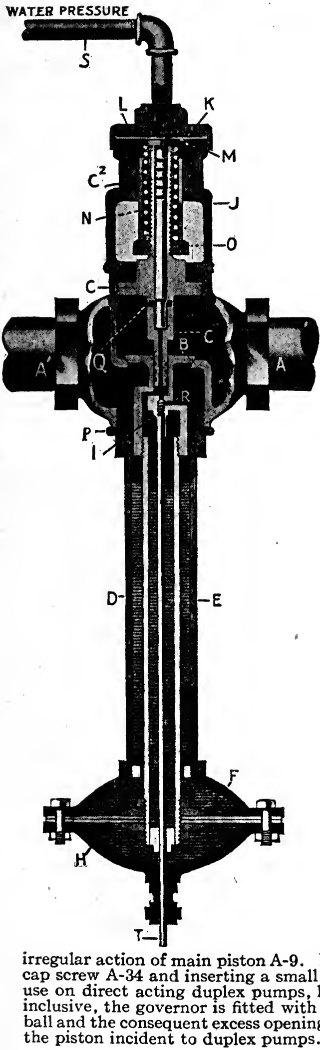


FIG. 4,883.—Locke "beats all" pump governor adapted for general use. ***In operation,*** steam under pressure fills chamber B, at all times, and enters openings at Q, passing around valve spindle C′, and down the central passage, creating a pressure in chamber G, and under diaphragm H; this raises the valve from its seat and allows steam to pass to the pump, which, when it has created a pressure (acting through pipe S, upon diaphragm L,) sufficient to compress spring N, forces valve C, to its seat, cutting off the flow of steam to chamber G. As the pressure in this chamber is soon reduced by the escape of steam through exhaust valve R, to the low pressure side, the pressure of steam in chamber B, acting upon the main valve closes it tightly and stops the pump. Now should the pressure fall slightly, the spring N, will raise and open valve C, and the operation is repeated. It will be seen that the pump will start whenever the water pressure is not sufficient to balance spring N, and overcome the pressure which is set at any point desired by wheel O. The exhaust may be changed by turning valve spindle T, to the right or left.

FIG. 4,882.—*Text continued.*

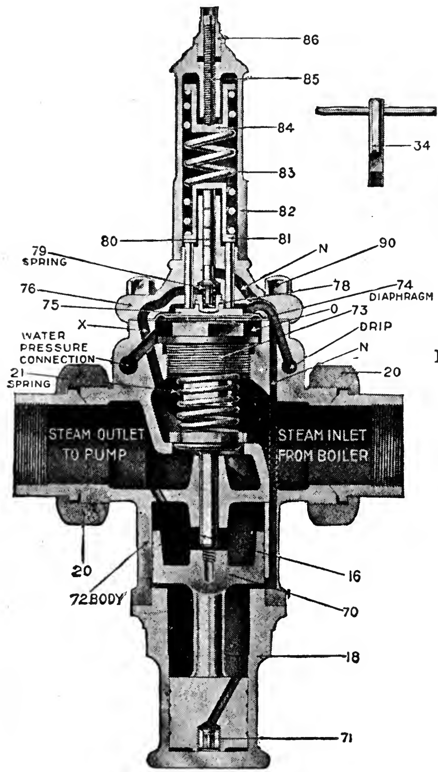
horizontally in unison with the strokes of the pump, being connected through yoke A-14, rocker A-12, and the shaft A-13, which extends through the shell to motion Arm A-22, which is connected by a rod to some reciprocating part of the pump. Oil flows through check valves A-19 into the plunger chamber, whence it is forced up the passage through valve A-11 under piston A-9. Oil then returns by valve A-28 (which is controlled by key A-26) into the lower chamber to be re-pumped as before. In case the pump or engine run more rapidly than is intended, oil is pumped under piston A-9 faster than it can pass through the outlet, as adjusted by A-28, which forces piston A-9 upward, raising lever A-3 with its weight A-30, and by means of a rod connected from jaw A-1 to a balanced valve, located in the steam supply pipe to the pump, the steam supply is throttled, maintaining the speed of the pump at the number of strokes for which the governor is adjusted. In case the pump run slower than is intended, oil runs out of chamber under A-9 faster than it is pumped in, which allows weight A-30 on lever A-3 to force the piston down, thereby opening the balanced valve admitting sufficient steam to maintain the required speed. As outlet at A-28 can be increased or diminished by means of a key, the operator is able to vary the speed of the pump at will. Dashpot A-29 also fills with oil and acts as a check, preventing irregular action of main piston A-9. Dashpot A-29 is adjustable by screw A-35 by removing cap screw A-34 and inserting a small screw driver to open or close the adjusting screw. For use on direct acting duplex pumps, having steam supply pipe, from ½ inch to 2 inches inclusive, the governor is fitted with a special valve, which prevents the fall of the governor ball and the consequent excess opening of the balanced valve during the momentary pause of the piston incident to duplex pumps.

For fly wheel pumps an ordinary throttling governor may be used, or for better economy a variable cut off shaft governor.

Pressure governors may be divided into two classes, according as their operation depends on the pressure:

1. In the suction pipe, or
2. In the discharge pipe.

Fig. 4,879 illustrates the principle of a *suction* pipe pressure governor, which is in fact strictly speaking an automatic stop to prevent racing, rather than a governor.. Similarly fig. 4,880 illustrates the principle of a *discharge pipe* pressure governor, the operation being clearly explained under the cut.



FIGS. 4,884 and 4,885.—Mason ***intermittent*** discharge pipe pressure governor. ***In operation,*** steam from boiler enters at point marked, "steam inlet from boiler," and thence through passage X, through the port, which is kept open by tension of the spring 83 upon auxiliary valve 80. It continues down through passage N to under side of differential piston 70 and raises valve 16 so that boiler pressure is admitted to the pump through passage marked "steam outlet to pump." This starts the pump, which continues in motion until the required water pressure is obtained in the system and acts on diaphragm 74, through connection marked "water pressure connection." This diaphragm is raised by excess of water pressure, and carries with it auxiliary valve 80, which closes the port for steam pressure. By the closing of this valve, the boiler pressure is shut off through passage N, from differential piston 70, and steam pressure from the boiler immediately closes main valve 16, so that no more steam is admitted to the pump. The pump remains inactive until the water pressure in the system drops below the normal point and relieves the water pressure in the chamber which causes auxiliary valve 80 to open again and start the pump as before described. Check valve 71, which is placed in bottom of the piston 70, allows the piston to drop freely, so that the main valve can close promptly when the desired pressure is reached. When the valve 16 is opening, the check is closed, which prevents valve 16, opening too suddenly, and allowing the pump to race. By changing the tension of spring 83, through key stem 85, the amount of water pressure which it is desired to carry in the system can at any time be changed or regulated.

Feed Water Regulators.—An ideal condition in the production of steam is that water be fed into the boiler continuously at the same rate as it is converted into steam so that the water level will remain at a fixed point.

The output of a boiler is affected inversely by the rate at which the feed water is supplied.

When the feed is intermittent, the generation of steam decreases quickly when the feed valve is open and increases rapidly when the valve is closed.*

Evidently, then, if water be fed into the boiler at the same rate as it is being evaporated, the best relation will exist between output and demand, except in some special cases such as mentioned in the foot note.

By the use of feed water regulators, an *approximately* continuous feed is obtained.

There are numerous types of regulator, and they may be classed, according to principle of operation, as:

1. Displacement.

   a. Buoyancy body or float.
   b. Specific gravity body.

2. Evaporation.
3. Expansion.

Displacement Regulator.—The simplest form consists of a hollow metal buoyancy float placed in the water column which moves up and down with changes in the water level and operates the feed supply valve, either:

1. Direct by lever connection, or
2. Through auxiliary valve and diaphragm.

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* NOTE.—In some cases an intermittent feed can be used to advantage, as for instance, on locomotives, where in going down grade the feed is turned on, which prevents the safety valve blowing and fills the boiler to high level, so that on up grade where maximum power is required, the feed may be shut off, while the excess water is evaporated.

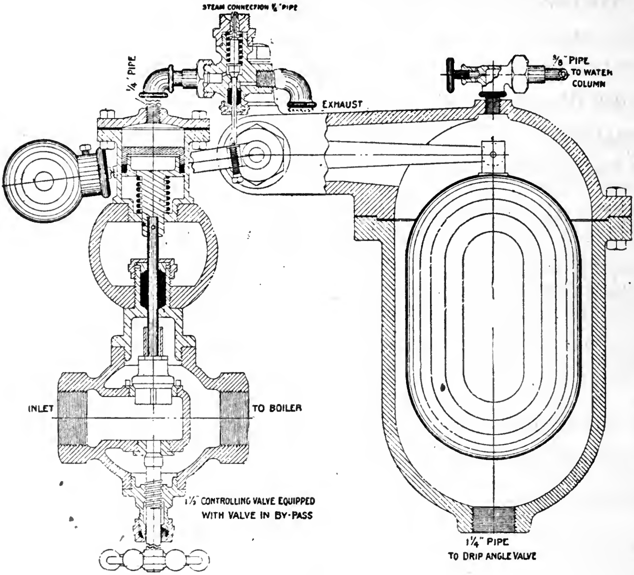


FIG. 4,886.—Chaplin-Fulton "Vigilant" ***specific gravity body,*** *auxiliary valve control* ***displacement*** feed water regulator. ***It consists essentially of,*** 1, a special combination union angle valve nipple, which is screwed into the water column at the middle gauge cock opening. From the union of this valve a three-eighths inch pipe connection is made to the top of the chamber of regulator; 2, a hooded chamber in which, and to which is attached the operating mechanism of the regulator. The chamber is placed as close to the column as possible, with its bottom not less than eight inches above the point at which it is desired to carry the water level. A connection is made from the bottom of the chamber to the boiler or to the bottom connection to the water column; 3, a specific gravity body is hung, inside the chamber, from the end of a lever, whose fulcrum is a shaft, one end of which extends through a stuffing box, while the other rests on a step inside; 4, a counterweight arm is keyed to the protruding end of the fulcrum shaft; 5, on the counterweight shaft near the fulcrum is an adjustable connection with the auxiliary valve. This valve is attached to the top of the hood, and a steam connection made to the gauge pipe or other pipe where dry steam may be obtained. The valve has an upper and lower seat so arranged that when against the upper seat the steam connection is shut and the bottom one is open to the atmosphere. When seated on the bottom seat the connection to the air is shut and the steam pressure is admitted to the controlling valve. The controlling valve is the third part of the regulator and is placed in feed line to boiler. ***In construction,*** it is similar to a check valve, and the entering water tends to lift the valve. A stem extends from the valve to a chamber located above the cast iron loop, and is connected to a piston moving in the chamber. The upper cover of the chamber forms a reservoir for water which prevents the live steam reaching the piston cups. ***In operation,*** when the water level in the column is below the opening of the special nipple, steam will enter the chamber of regulator, and the water in it will be displaced, falling through the pipe at its bottom to the level of the water in the water column. The weight or displacement body in the chamber will then fall by gravity to the bottom of the chamber, the counterweight and lever will rise, holding the auxiliary valve against its top seat, and the exhaust valve will be open to the air. There will then be no pressure on the piston of feed valve and the latter

In distinction from a float, the term specific gravity body means a hollow cylindrical body of such substantial construction that it is too heavy to float, but of course, weighs less when submerged in water than when in the steam space.

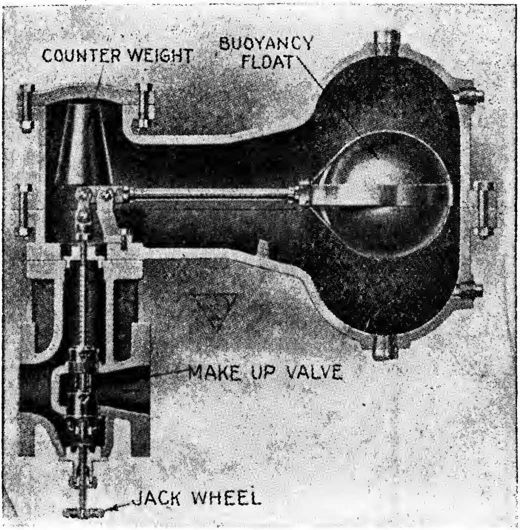
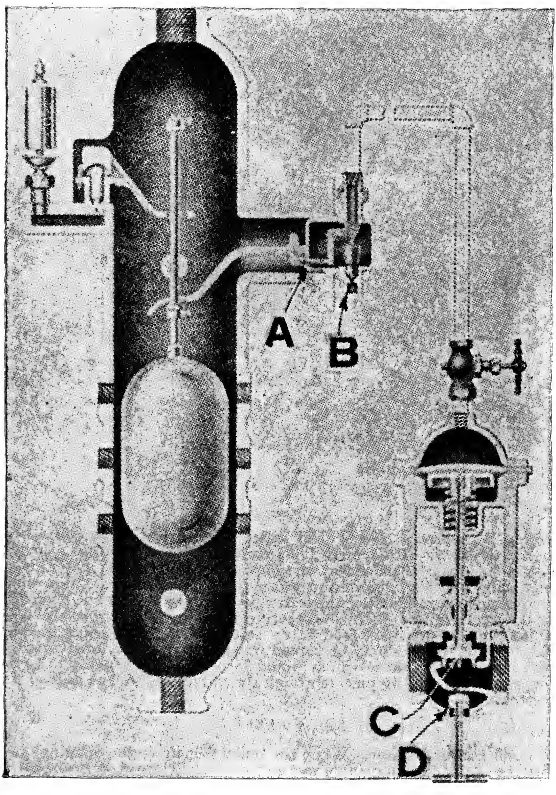


FIG. 4,887.—Stets ***buoyancy float direct control*** feed water regulator. ***It consists of*** an enclosed make-up valve, actuated by a buoyancy float connected at the end of a lever as shown. ***In installing,*** the regulator is placed at the elevation of the mean water level in the boiler and connected to the boiler by steam and water pipe the same as for an ordinary water column. ***In operation,*** the movement of the feed valve is controlled by the level of the water which carries the float to rise or fall thus respectively closing or opening the valve. A jack wheel is provided at the bottom of the feed valve, so that in case the boiler has to be filled for hydrostatic test, the valve stem may be forced upward in order to uncover the V-ports and admit water at levels above those which would be within the range of the float movement. This jack wheel serves as a by pass (through the valve), as well as a downward limit stop for the valve stem.

FIG. 4,886.—*Text continued.*

will be wide open and the boiler taking water. When the boiler fills up to the opening of the special nipple the same will be sealed by the rising water and steam will be cut off from entering the chamber, and that which was in it will be condensed, slightly reducing the pressure therein, so that the water from the boiler fills it to the top. The inside weight or displacement body, now weighs less than it did when the chamber contained steam only, by the weight of water which it displaces. The counterweight or outside weight is now heavy enough to overbalance the inside weight and goes down, while the inside weight goes up. As the outside lever goes down, the actuating valve goes down, opening the steam connection and shutting the exhaust. This admits the steam pressure to the piston chamber of controlling valve and forces the piston and valve down, and shuts off the feed water. No more water can enter the boiler until the water level falls to the opening of the special nipple, when steam is admitted to the top of the chamber, the water in it falls to the old level, all the operations are reversed and the controlling valve opens again.

A counter weight is used to offset the excess weight, so that the cor bination of the two is equivalent to a light or buoyancy float. The reaso for such construction is to prevent the possibility of leakage or collap under steam pressure.



Figs. 4,887 ar 4,888 show th essential featur of these type Fig. 4,886 show what the auth calls for want a better name, specific gravit body displac ment regulato

Evaporatio Regulators.-

The operation this type of reg ulator depend upon the evapor ative effect of metal tube con taining wate and steam, whe enclosed by vessel containin

FIG. 4,888.—Willian *buoyancy float au iliary valve contr* ***displacement*** fee water regulator. comprises in additio to the regulator, water column wit high and low wat alarm. The automatic valve C, is shown open, admitting water to the boiler. ***In operatio*** as the float, rises, the collar on the float rod lifts the lever and opens A, admitting boiler pre sure to the operating chamber by allowing the exhaust valve B, to close. The pressure communicated through the connecting pipe to the top of the diaphragm, overcomes th spring and closes the automatic feed valve C. As the water line falls, the reverse operatic takes place. ***A continuous feed*** is secured with the valve D. When the boiler is in regul service this valve is opened to admit water at a slightly lower rate than that at which it being evaporated. The automatic valve C, opens slightly at distant intervals, admittin only enough water to make up the difference between that evaporated and the amou passing through the continuous feed valve D. When the boiler is not in service this valv should be closed. The stop and waste valve above the diaphragm is used for testing th operation of valve C.

water, the enclosing vessel having an outlet which communicates with the diaphragm chamber of the feed valve

The amount of evaporation of the water in the enclosing vessel will depend on the proportion of the inner tube filled with steam, which depends upon the water level in the boiler.

In operation steam in the inner tube evaporates more or less of the water in the enclosing vessel, which brings pressure on the feed diaphragm opening the valve, to some point corresponding to the amount of water evaporated.

Figs. 4,890 to 4,892 is an example of a regulator operating on this principle.

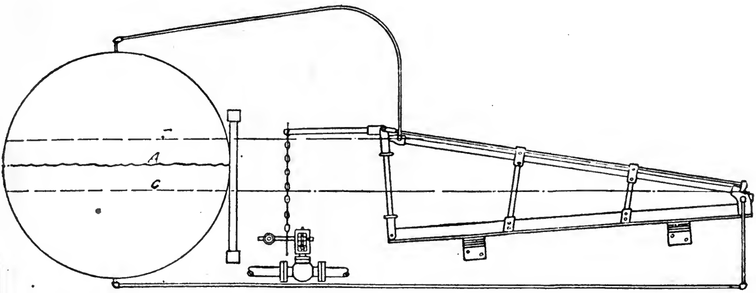
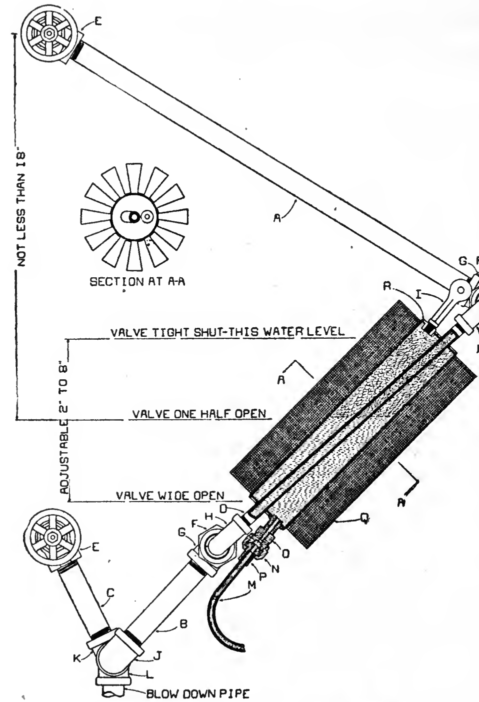
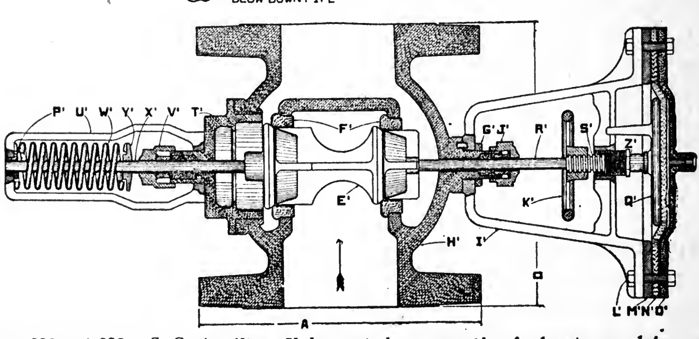


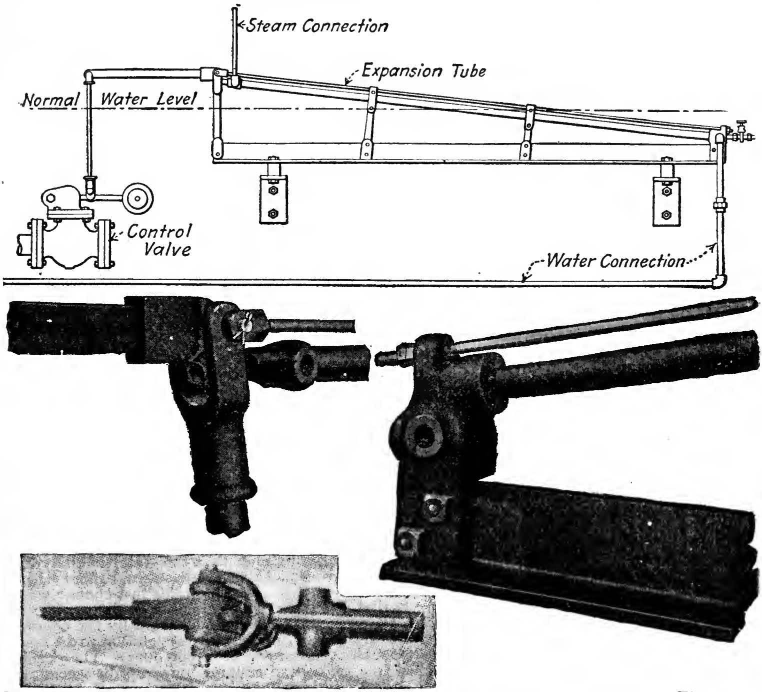
FIG. 4,889.—Copes, *direct control* **expansion** feed water regulator. The expansion tube is placed at any convenient, accessible point along the side, back, or front of the boiler, so that the top end of the expansion tube is on a level with the highest desired water level in the boiler (no load level), while the bottom end is on a level with the lowest desired water level (peak load level). Suitable connections are made directly to the steam and water space of the boiler, so that the water will rise and fall in the expansion tube exactly the same as in the boiler. Proper connection is made between the expansion tube lever and the control valve lever. ***In operation,*** the expansion tube is partially filled with water, depending upon the water level in the boiler, and the load. Now the part of the expansion tube filled with steam is maintained at the temperature of the steam, since as fast as it radiates heat, it causes condensation and the liberation of the latent heat at steam temperature. On the other hand, the lower part of the thermostat is at a temperature considerably below steam temperature, since the radiation of heat for this part of the tube can take place only at the expense of the sensible heat of the water. When the water is at its minimum level and the expansion tube is filled with steam, expansion is maximum, also when filled with water the contraction is maximum, the length and feed valve opening operated thereby runs with the height of the water in the expansion tube.

Expansion Regulators.—The principle upon which this class regulates the water is *the expansion and contraction of a metal tube subjected to variable temperature*, the movement thus produced being multiplied by a system of levers which operates the feed





FIGS. 4,890 to 4,892.—S. C. ***Auxiliary Valve control, evaporation*** feed water regulator. A ⅛ inch pipe size tube D, extending through the generator R. is connected to the water column or



FIGS. 4,893 to 4,896.—Copes feed water regulator and details of construction. Fig. 4,893 assembly; figs. 4,894 and 4,895, detail showing how lineal expansion of the expansion tube is transmitted to the bell crank lever, which in turn operates the feed control valve; fig. 4,896, lower end of expansion tube, rigidly bolted to base. Adjustment of lever, and valve opening can be made by adjusting nuts on tension rod.

FIGS. 4,890 to 4,892.—*Text continued.*

boiler drum by extra heavy ⅜-inch fittings and nipples so arranged that the generator's position can be raised or lowered to meet operating conditions in the pla nt. This tube D, contains boiler pressure, the lower part being filled with water to the corresponding level of the water in the boiler; the portion above the water must be filled with steam at boiler pressure, the same as a gauge glass. Surrounding the tube D, is a casing or generator R, with heads at each end and brazed to shell R, and tube D. This in turn is connected to a ¼ inch O.D. seamless flexible tubing M, the other end of which connects to diaphragm O^1 and P^1. The whole system including O^1 and P^1 also tubing M, and generator R, is filled with water and sealed with plug I. The water within the tube R, is exposed to radiation through the fittings and is below boiling point at one atmosphere while the steam is hot, hence, any portion of the tube D. containing steam will be heated and will boil the water surrounding it forming steam pressure in the generator R, and this will force a proportionate amount of water in generator down through the tubing M, into diaphragm O^1 and P^1, moving the valve disc E^1, in proportion to the amount of tube D, exposed to steam from boiler. The generator R, is installed on the same level as normal water level inboiler. ***In actual operation,*** after the regulator is cut into service, the water will drop in the boiler and a corresponding distance control valve, being so arranged that expansion of the tube opens the valve, and contraction closes it.

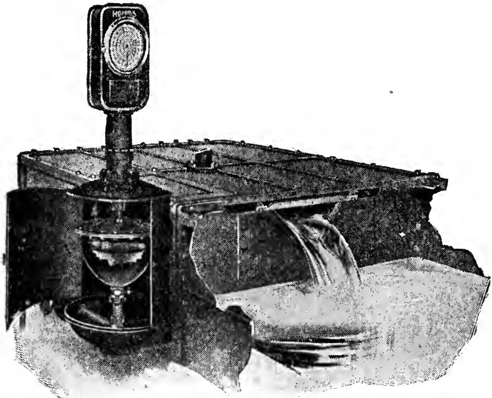


Fig. 4,889 shows the essential features of a regulator operating on the expansion principle, and figs. 4,893 to 4,896, details of construction.

FIG. 4,897.—Hoppes V notch feed water meter recorder and integrator. ***It consists o*** a tank with a V notch and a cabinet attached to the tank by a bracket. Inside of the cabinet is a vessel, called the weighing vessel, suspended by a coil spring, the vessel being connected to the tank by a flexible bronze hose in such a manner that the water in the vesse will be in equilibrium with the water behind the weir. As the water rises behind the V notch it also rises inside the weighing vessel and as this vessel contains just enough wate at each unit of height to draw down the spring in exact ratio to the rate of flow. The recording and integrating device is located in the head on a column supported by the cabinet A clock movement operates a circular chart on one side, making one revolution in 24 hour and on the other side is an aluminum disc making one revolution per hour. The pen fo making the record on the chart is attached to a cross head running vertically between antifriction bearings and directly connected to the weighing vessel. An arm is carried to th other side which supports a small planimeter wheel on a vertical axis and is revolved by th aluminum disc. The planimeter wheel moves a tram of gears operating the integrato which indicates the amount of water in pounds that has passed the weir. When the wate is just starting over the V notch the planimeter wheel rests at the center of the disc. A the head increases the wheel is drawn toward the lower periphery of the disc, and as th disc has a constant motion a correct record is made of the water passing the notch in an given time.

FIGS. 4,890 to 4,892.—*Text concluded.*

in tube D, thereby heating the water in generator and creating a pressure and thus forcin a proportionate amount of water down through tube into diaphragm O^1 and P^1, until the valv disc E^1, is off the seats F^1, a sufficient distance to allow enough water to flow through int the boiler to take care of the amount evaporated. If the load and fire conditions remai constant at this time, the disc E^1 will remain stationary. ***In actual practice,*** however, th load changes more or less, making a smaller or larger demand for water and the valve dis E^1, will move from .001 to .03 at a time to accommodate the load changes. It is therefor claimed that the regulator gives a continuous graduated feed in exact proportion to the load On light load and uniform fire it will give a constant feed and water level. On increasin load it will always feed at a lower rate than boiler out-put until peak load level is reached and on decreasing load it will feed above the boiler out-put until light load level is reached with variation in water level depending on the position of the generator. The only time tha regulating valve will close tight shut is when there is no load such as being in the bank, etc

Ques. What is essential for the proper operation of feed water regulators?

Ans. The feed pump must be provided with a governor giving such control as to maintain an excess pressure in the feed line so as to meet any demand of the feed water regulator control valve.

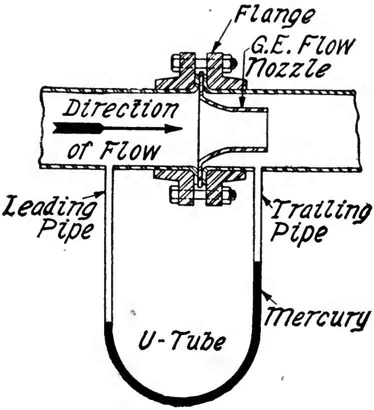


FIG. 4,898.—Elementary flow nozzle meter. A U tube is connected as shown and partly filled with mercury. ***It is evident*** that the flow of a gas or fluid produces a temporary reduction of pressure in and near the throat of the flow nozzle. The pressure under the flow nozzle and in the trailing pipe will therefore be the static pressure minus a pressure proportional to the velocity, while the pressure in the leading pipe equals the static pressure. Due to this differential pressure, the mercury in the U tube is deflected until the unbalanced column exactly balances the differential pressure. The difference in height of the mercury in the U tube is a measure of the rate of flow, and by suitable mechanism this rate of flow may be *indicated or recorded* on a properly calibrated scale.

Meters.—These are used to measure feed water, circulating water, steam, etc. There are three general classes of meter, according as the velocity head necessary to obtain a pressure difference (which is the measure of the rate of flow), is obtained, by means of a

1. Flow nozzle,

2. Orifice tube.

3. Pitot tube.

In the manufacture of these devices

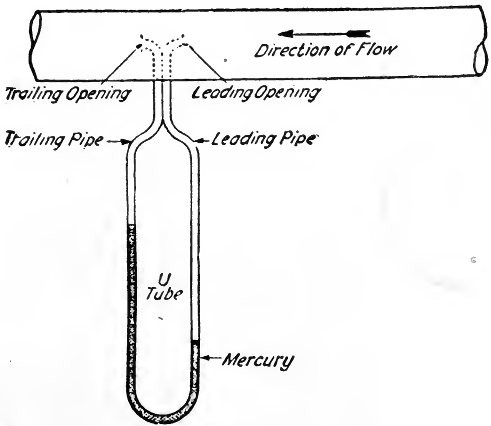


FIG. 4,899.—Elementary pitot tube meter as described in the accompanying text.

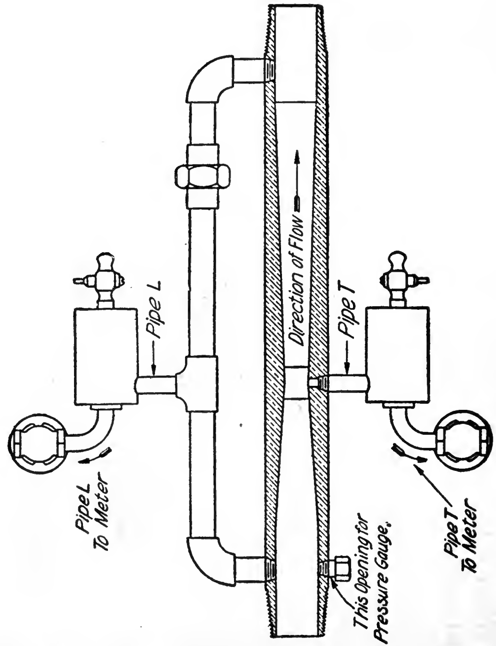
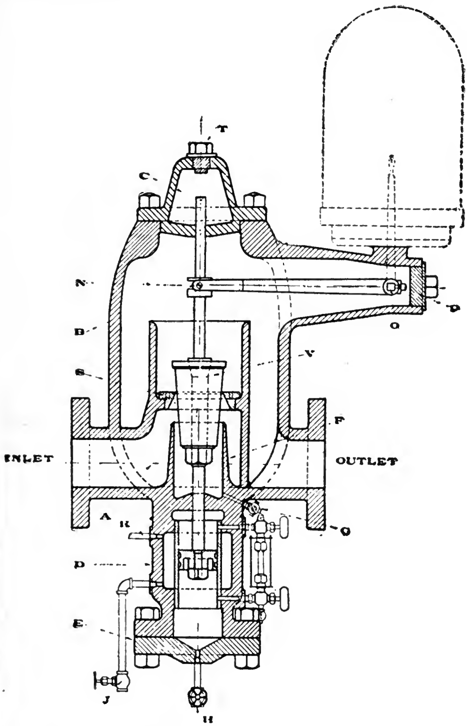


FIG. 4,900.—Orifice tube as used on flow meters for pipe sizes less than two inches in diameter. The orifice tube consists of a pipe tapered internally at both ends to form an orifice near the center of the tube. When water or steam flows through the tube there is a temporary reduction of pressure in the orifice. The pressure in the pipe T, will, therefore, be the static pressure minus a pressure proportional to the velocity, while the pressure in the pipe L, is the static pressure. The orifice tube is installed by removing a section of pipe and inserting it in the place of the section removed.

they must be carefully tested to determine the law governing them and also the effect of elbows, valves, tees, etc., upon the accuracy.



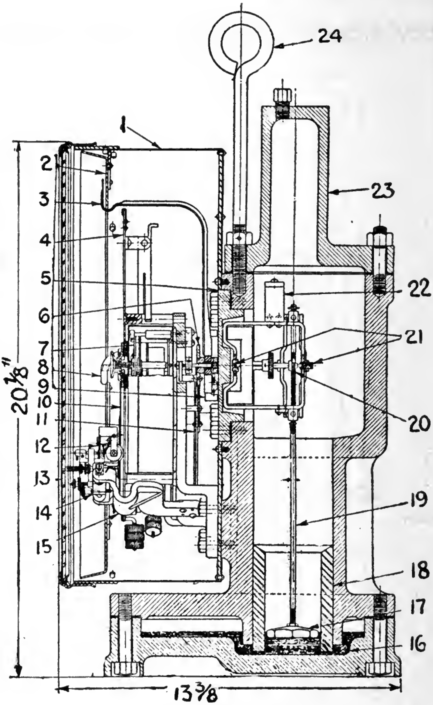
Flow Nozzle Meters.—In meters of this type there is a metal funnel or nozzle inserted between and held in place by the two flanges of a pipe.

The nozzle is of steel for measuring steam, and of either steel or bronze for measuring water.

No appreciable drop in pressure is produced by the use of flow nozzles and the same nozzle may be used for measuring either water, oil, air, steam or other gas. Fig. 4,898 illustrates the operation of meters employing the flow nozzle to obtain the velocity head.

FIG. 4,901.—American "St. John" ***orifice,*** steam meter. ***In operation,*** steam enters the body of the meter A, on the underside of the valve V, thus raising the valve—the height of which is governed by the quantity of steam flowing—and passes to the outlet chamber B. S, is a monel metal seat screwed into the portion of the casing which separates the spaces A and B. V, is a special bronze valve, having a nickel steel spindle. This valve, when at its lowest position, fits closely in and on the monel metal seat, thus shutting off entirely the flow of steam. As the tapered valve rises, the space between it and the monel metal seat is the annular orifice through which the steam flows and increases to the maximum when the valve is at the highest position, the rate of increase being regulated by the taper of the valve. This spindle, and when the meter valve is at its lowest position, the pencil tracks on a base line printed near the edge of the chart or paper ribbon, while the brass pointer will be over the zero mark on the indicating plate. ***The chart,*** with its horizontal divisions, one-half inch apart, representing hours, is drawn under the pencil point with a uniform vertical movement, while the pencil traces a line which remains as a record of the rise and fall of the meter valve, and hence of the rate of flow of the steam at all times throughout the day. This line drawn by the moving pencil is call the "steam line."

FIG. 4,902.—General Electric indicating recording flow meter equipped with integrating attachment. 1, case containing external mechanism; 2, indicating scale plate; 3, indicating pointer; 4, plate on which recording chart revolves; 5, copper plug; 6, pinion; 7, clock; 8, recording pen; 9, external mechanism; U, magnet; 10, recording pen arm; 11, sector; 12, integrating attachment; 13, glass in door; 14, locking device for integrating attachment; 15, bracket supporting integrating attachment; 16, mercury well; 17, internal mechanism float; 18, internal mechanism sleeve; 19, internal mechanism rack; 20, internal mechanism pinion; 21, internal mechanism bearings; 22, internal mechanism frame; 23, dome for rack when float is raised; 24, eye bolt for lifting meter.



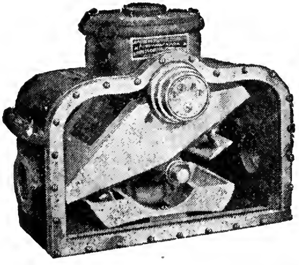


FIG. 4,903.—American "Simplex" condensation meter for measuring amount of steam delivered for heating purposes. View shows exhibition meter with glass front. ***In operation,*** when sufficient water has run into one side of the bucket to over-balance it, the bucket tilts, discharging the water into the meter case, and thence through the outlet pipe or pipes into the sewer, or return system, and the other side of the bucke. is brought into position to be filled. This action continues as long as water flows into the meter. The shaft on which the bucket is mounted, is supported on roller or ball bearings on the outside of the meter case, thus excluding any corrosion which might retard the operation of the meter. In the bottom of the meter are dash pots, which remain filled with water, serving as cushions thus making the operation of the meter practically noiseless. The recording dial indicates at all times the number of pounds of water that have passed through the meter.

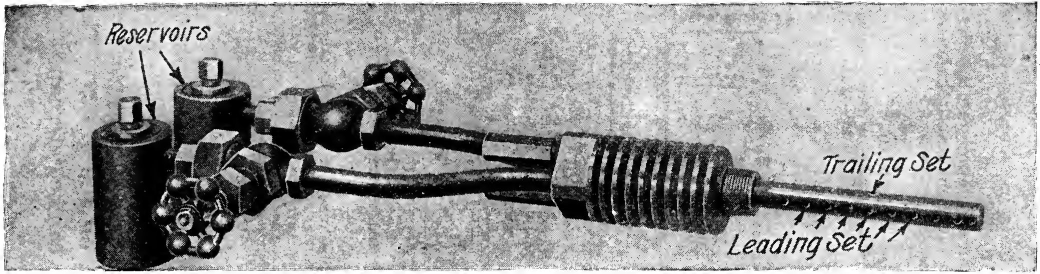


FIG. 4,904.—General Electric nozzle plug as used in ***pitot tube*** meter. It will satisfactorily measure the flow of clean gases and fluids at normal velocities. It is not recommended for the measurement of steam carrying boiler compound or other foreign matter, or for water or other liquids except when free of solid matter. The nozzle plug is composed of a double conduit tube extending across the pipe diameter, each conduit having a separate set of openings. The leading set of openings extends the length of the tube across the pipe diameter and faces against the direction of flow. The trailing set of openings is located midway between the ends of the tube and at the center of the pipe diameter and faces in the direction of flow. The leading and trailing sets of openings in the nozzle plug correspond to the leading and trailing single openings respectively in the elementary Pitot tube. The gas or fluid when flowing impinges against the leading set of openings in the nozzle plug and sets up a pressure in the leading conduit, which equals the static pressure plus a pressure due to the velocity head. The drag of the gas or fluid over the trailing set of openings lowers the pressure in the trailing conduit. The differential pressure, due to the flow, is transmitted to the mercury in the U-tube of the meter. Since the leading set of openings in the nozzle plug extends approximately across the diameter of the pipe, the velocity pressure transmitted to the meter is the mean velocity pressure due to the flow, rather than the velocity at a single point in the pipe as is the case of the elementary form of pitot tube. The introduction of the nozzle plug in the main causes no appreciable drop in the pressure even at a very high rate of flow.

Orifice Tube Meters.—As a means of producing velocity head, orifice tubes are desirable in small size meters to measure flow in pipes of less than two inches diameter. Fig. 4,900 shows an orifice tube as used for this purpose. Due to the difference in pressure produced in operation, the mercury in the U tube of the meter is deflected until the unbalanced column exactly balances the differential pressure.

Pitot Tube Meters.—Consider two small pipes inserted in the main pipe, as in fig. 4,899, in such a manner that one opening, called the leading opening, faces against the direction of flow, and the other opening, called the trailing opening, faces in the direction of flow of the gas or fluid being measured.

These two pipes are connected to the two glass legs of a vertical U-tube containing mercury.

It is evident that the gas or fluid when flowing, impinges against the leading pipe, which equals the static pressure plus a pressure due to the velocity head. The drag of the gas or fluid over the trailing opening lowers the pressure in the trailing pipe. Due to the differential pressure the mercury in the U-tube is deflected until the unbalanced column exactly balances the differential pressure.

Fig. 4,904 is an example of meter working on the pitot tube principle. The perforated tube is virtually the equivalent of a number of pitot tubes arranged side by side.

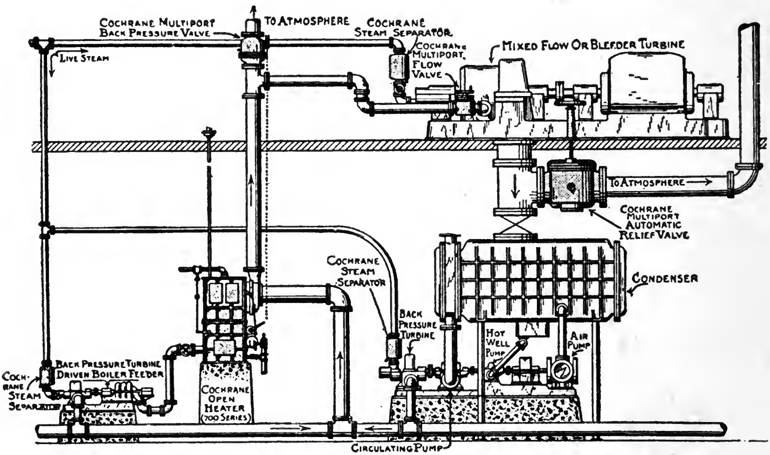


FIG. 4,905.—Cochrane open feed water heater in steam turbine plant, in which the exhaust steam from the back pressure auxiliary turbines, non-condensing engines, etc., is used first to heat boiler feed water in a Cochrane heater, the surplus steam passing to the heating system or to the intermediate stage of the main turbine. Where the amount of steam required by the heating system is more than the auxiliaries can supply, the main turbine can be of the "bleeder" type.

Feed Water Heaters.—Heating boiler feed water by means of exhaust steam effects a considerable saving in fuel. The heat imparted to the water in a feed water heater takes the place of an equivalent amount of heat from fuel on the grates. The amount of saving for any given condition can be determined by a simple calculation.

Example.—If the temperature of the feed water be 60° Fahr., before entering the feed water heater, and the heater raise its temperature to 210°, what is the saving with boiler pressure at 100 pounds?

Total heat in one pound of steam at 100 pounds pressure = 1,150.4 *B.t.u.*

Heat in 1 pound of feed water before entering heater, 60 − 32 = 28 *B.t.u.*

Heat required to form 1 pound of steam = 1.122.4 *B.t.u.*

Heat saved by feed water heater, 210 − 60 = 150 *B.t.u.*

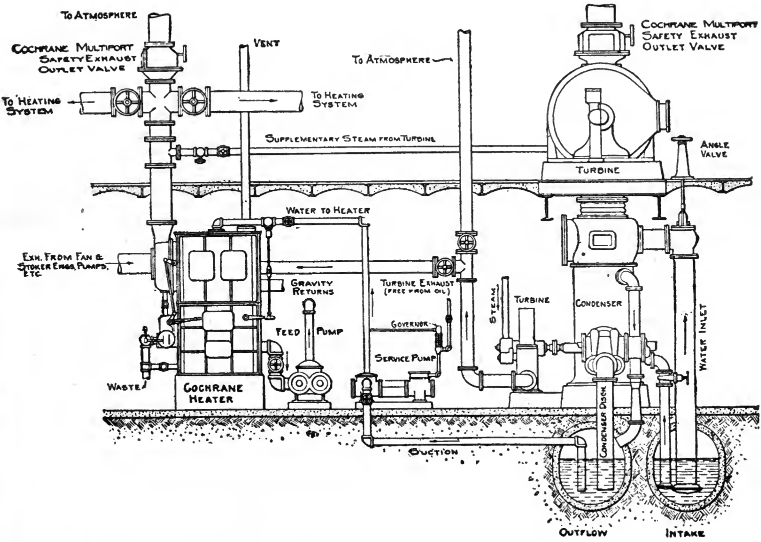


Fig. 4,906.—Cochrane open feed water heater in jet condensing plant.

Percentage of saving = 150 ÷ 1,122.4 = .13, that is, 13 per cent., which is equal to 1 per cent. for each 150 ÷ 13 = 11½ degrees that the temperature of the feed water is raised by the heater. No saving of fuel is realized where the water is heated by an injector or by a live steam purifier, since both devices first draw from the boiler the heat which is to be imparted to the water, whereas in the exhaust steam a waste product is utilized.

Heaters may be classed as:

1. Open.
2. Closed.

    a. Water tube.
    b. Steam tube.

Open heaters.—This type of heater consists essentially of an open chamber in which the exhaust steam and water to be

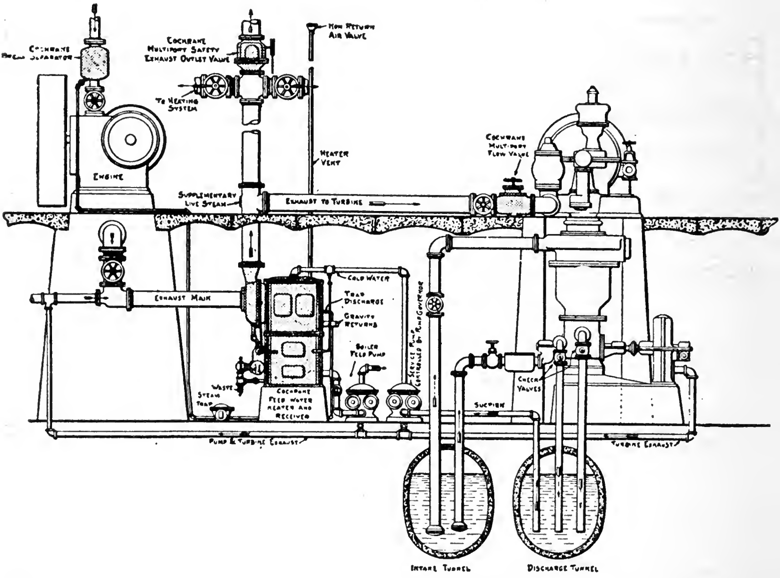


FIG. 4,907.—Cochrane steam stack and cut out valve heater and receiver and Cochrane multiport flow and relief valves in connection with mixed flow turbine and condenser.

heated are brought into intimate contact by spraying the water through the steam, both the water and the condensate going to the boiler.

The operation of an open heater is analogous to that of a jet condenser. Because of the intimate and direct contact of the steam with the water, the open heater is more efficient than the closed heater, or as stated by one maker of open heaters, it is 1 per cent. to 2 per cent. more efficient than the closed. It would accordingly be safe to say that the saving is not over ½ to 1 per cent., varying with the condition of the tubes. Whereas, an open heater is a little more efficient than the closed type, it has the disadvantage of contaminating the feed water with oil in the exhaust steam, and hence some form of grease extractor should be used.

An important advantage of the open heater is that by means of a series of pans, scale forming substances can be precipitated before the water enters the boiler, such arrangement being called a purifier.

Fig. 4,909 shows an open feed water heater, with purifier and oil separator combined.

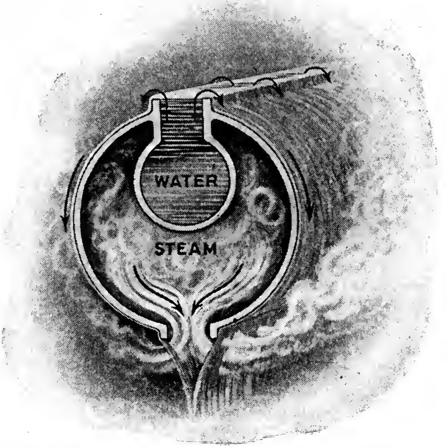


FIG. 4,908.—Water distribution or contact pipe of National open feed water heater. Extending from one end of the heater to the other are contact pipes, so called because they are designed to heat the water by surface contact. Each of these pipes is really a double cast iron pipe, the larger containing steam, while the smaller, which is not concentric, is filled with the cool feed water. The smaller or water pipe is closed at the back end so that the feed water entering the front end completely fills it, and the water is warmed by the steam which surrounds it. More water entering the pipe causes some to overflow the port at the top, and as it overflows it follows around the larger pipe as a thin film which is warmed, not only by the hot walls of the steam pipe, but also by actual contact with the exhaust steam which fills the heater. When this film or curtain of water, which closely hugs the outside of the larger pipe, reaches the ribs projecting from the bottom, it breaks up into two sheets of fine spray and while in this form mingles with the exhaust steam which passes through it. The larger pipe is filled with steam which can escape only through the port at the bottom. This port extends the full length of the pipe. The escaping steam must pass through the fine water spray, and this intimate and thorough mingling heats the water to nearly the temperature of the steam.

Closed Heaters.—In this type of heater the steam does not come in contact with the feed water, but is separated by a metal surface through which the heat must pass.

Evidently in such arrangement no oil can enter the boiler, and because of the metal surface, the heater is somewhat less efficient in transmitting heat than the open heater, varying with the condition of the surface of the metal being subject to deposit of oil on the steam side, and scale on the water side. Accordingly, a closed heater should not be used unless the feed water be reasonably free from scale forming substances.

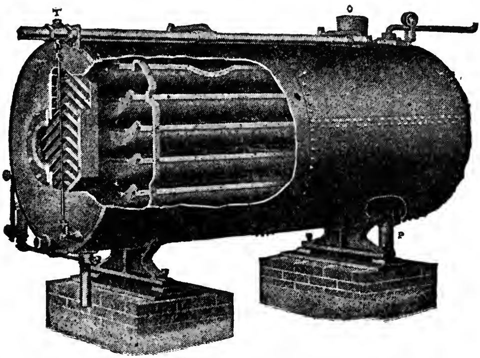


FIG. 4,909.—Hoppes *open* feed water heater, purifier and oil separator. ***It consists*** of a cylindrical chamber containing a series of pans as shown, and a corrugated plate at the end to catch the oil. The exhaust steam enters at the back end and its direction is suddenly changed by the corrugated plate, the corrugations of which catch the oil. Passing into the heater proper it performs its work of heating and the portion not condensed escapes by the outlet, near the front end. The water is admitted to the heater through a balanced regulating valve, and is evenly distributed to the top pans by the inside feed pipes. Overflowing the edges of the pans, it follows the under sides to the lowest point before dropping to the next pan below. In like manner it flows progressively from pan to pan till it reaches the chamber at the bottom, whence it passes through the hooded suction opening to the pump. The troughs of the pans afford most efficient settling chambers for solids in suspension in the water and eliminate the necessity of a filter, while solids precipitated from solution are deposited and retained on the under sides of the pans; and in this connection it may be noticed that no matter how great the deposit of lime on the pans, the water is always in direct contact with the steam and the heating and purifying action is in no way retarded, but is maintained constantly at 210° F. under atmospheric conditions when there is ample supply of exhaust steam.

In construction the water tube form of closed heater consists of one or more brass or copper coils through which the water flows, being surrounded by a cylindrical casing to guide the steam over the coil heating surface.

Fig. 4,911 shows a heater of this kind. The steam tube form of closed heater is shown in fig. 4,910.

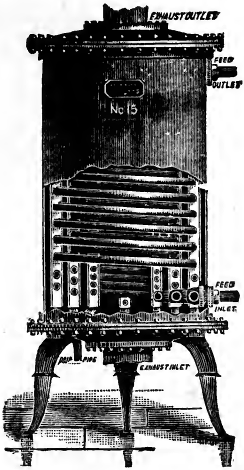


FIG. 4,911.—National *closed* **water tube** heater. ***In construction,*** two or more coils (depending on size) are connected *in parallel* and placed within a casing which is provided with inlet and outlet for the exhaust. The ends of the coils are brazed into gun metal manifolds. The coils are spaced so that ample area is provided for the flange of the exhaust without undue back pressure.

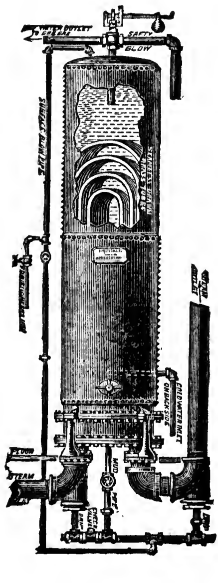


FIG. 4,910.—Berryman *closed* **steam tube** *heater and purifier.* This is the original type of Berryman feed water heater in which the exhaust steam passes through the tubes which are surrounded by a large volume of water. It is used to a considerable extent in plants where the inequalities of service compel an irregular feeding of the boilers, or where the exhaust steam supply is intermittent as from hydraulic elevator pumps, trip hammers, cotton compressors, etc. In such cases, a large volume of water held in storage is very essential in order to absorb the heat from the exhaust steam as received and store the water for use as required as in dye houses and bleacheries in which case the heater becomes virtually a hot water reservoir. ***In construction,*** the shell is of heavy steel plate and the tubes of cold drawn seamless copper. Each tube is separate and may be removed independently of any other tube. Expansion and contraction are properly provided for and, due to the large water volume, all impurities settle in the bottom where they may be drawn off through a drip connection. Both ends of each tube are expanded into a heavy, steel tube head bolted to the lower part of the steel shell and all pipe openings are of ample area to prevent back pressure or impeded circulation. This heater is made either vertical or horizontal. The illustration shows the various necessary connections.

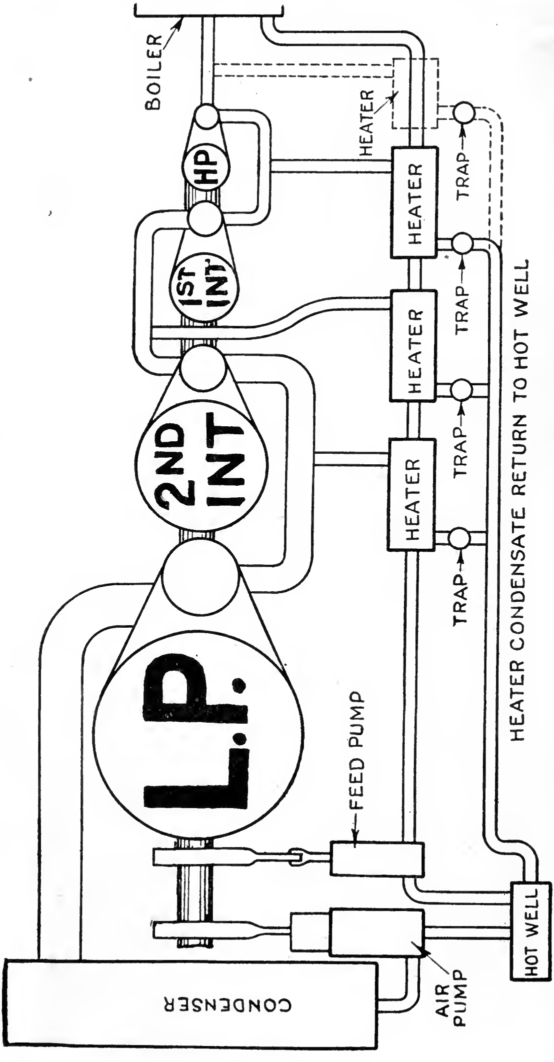


FIG. 4,912.—Series heaters as used with quadruple expansion engine. ***As described*** by Professor Durand, the heater system "may consist of say three chambers or heaters (as shown) through which the feed passes in series. In the first it is heated by steam drawn from the *l.p.* receiver. It then passes on to the second chamber, where it is heated by steam drawn from the second *i.p.* receiver, and then goes on to the third chamber, where it meets with steam drawn from the first *i.p.* receiver. As the feed water thus becomes hotter and hotter it meets with steam of higher and higher temperature drawn from the successive higher receivers in the engine, and it is thus brought nearly to the temperature of the water in the boiler. The exhaust from pumps may also be turned into the first chamber, thus making it a means of taking heat from their exhaust and of returning it with the feed to the boiler. In some cases also live steam of full boiler pressure has been used in a last chamber to still further raise the temperature of the feed. Various modifications may be worked out in the details of the operation of such feed heaters, but in all cases their significance lies in the fact that the cycle of operations as a whole may in this way be brought a step nearer to the ideal cycle than would otherwise be the case. All such changes, if made in accordance with the proper principles, may therefore result in a saving of heat and in a gain in the economy of the engine, and in this fact lies the chief significance of the feed water heater as a feature of modern engineering practice."

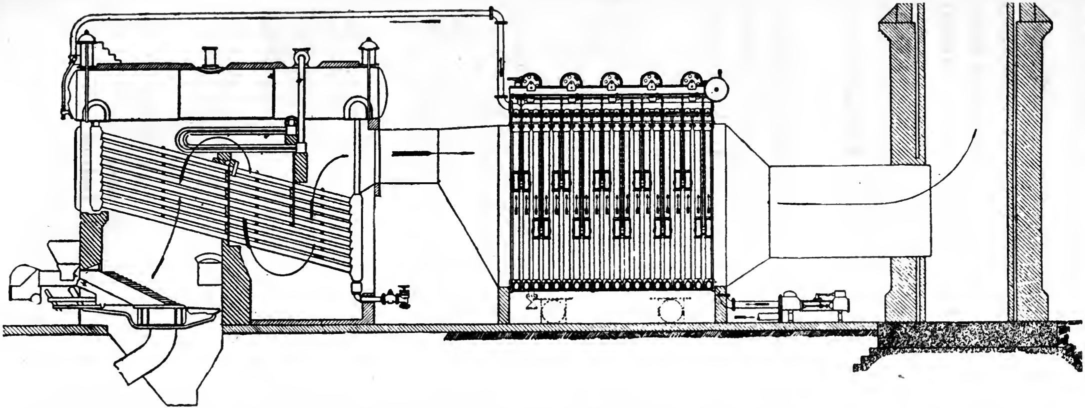


FIG. 4,913.—Green economizer installation showing counter current principle of the gases and water traveling in opposite directions. By using an economizer, the temperature of the feed water may be raised from the water supply, hot well or exhaust steam feed water heater temperature to a temperature approaching that of the water in the boiler. The higher feed water temperature thus obtained results in a proportional saving in fuel as the transmission of less heat by the boiler surface combined with that recovered by the economizer will produce the same amount of steam as would be produced if the economizer were not used. Assuming a feed water temperature entering the economizer of 180 degrees F., a temperature rise in the economizer of 130 degrees F., giving a final temperature of 310 degrees F. and a steam pressure of 150 pounds gauge, under these conditions the saving would be: $100(316-180) \div 1,225.5-180=12.44\%$.

Results under varying conditions of feed water temperature and boiler pressure may be approximated by estimating 1 per cent saving of fuel for each 10 degrees to 11 degrees F. added to the temperatures of the feed water.

NOTE.—An economizer precipitates many of the impurities found in water that must of necessity be used for boiler feeding and, because of the slow motion of the water in the tubes, these precipitates fall to the bottom. They can then be blown off or washed out as sludge, but if they had been allowed to form in the boiler they would have become baked onto the tubes as hard scale, which is dangerous and also difficult to remove. The most common scale forming substances are the bicarbonates of lime and magnesia. These, however, are easily precipitated if the water be heated to about 200 to 210 degrees F., because the bicarbonate is reduced to monocarbonate, part of the carbon dioxide being set free and the monocarbonate is insoluble. The sulphates of lime, which form the hardest scale, are not thrown down in this manner, but become insoluble in part above 270 degrees F., so that if this temperature be reached in the economizer, they will be precipitated. Some of the salts of magnesia are decomposed at high temperatures and will also be precipitated in the economizer.

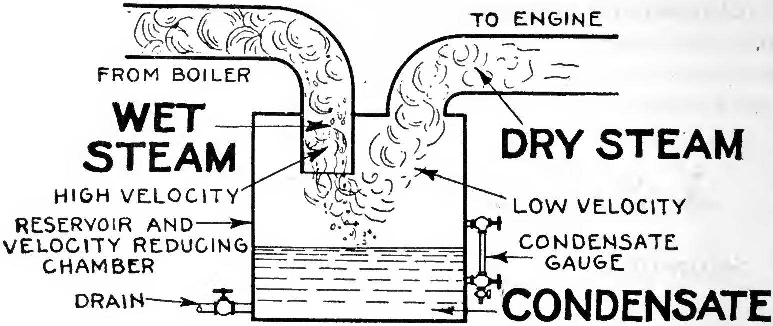


FIG. 4,915.—Elementary steam separator, illustrating principles of operation. Steam from the boiler is led into chamber of larger section than the pipe, and out again after: 1, having its *direction* **suddenly** *changed* (usually through 180°), and 2, having its *velocity* **reduced** while passing through the chamber. *Change in direction of the steam flowing at 6,000 to 8,000 feet per minute creates considerable* **centrifugal force** *which acting on the heavy globules,* **hurls** *them out of the path of the steam.* The velocity of the steam in changing its direction is reduced because of the large size of the chamber which diminishes the disturbance due to the steam passing through the chamber, thus increasing the efficiency of the device.

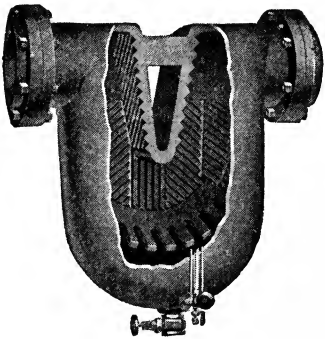
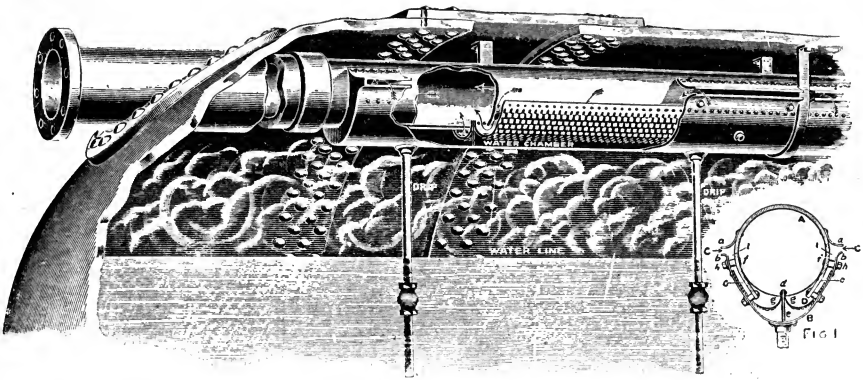


FIG. 4,916.—Austin separator. The baffle plate which serves to change the direction of the steam flow is not set at right angles to the entering steam current, but is set at an angle so that when the steam is impinged against it, the particles of water rebound at an opposite angle. This sets up a rotating motion in the steam, bringing the latter in contact with the inside walls of the separator. These walls are heavily corrugated, as is also the surface of the baffle plate, and all corrugations are designed so as to carry the drainage out of and away from the course of the steam. Any moisture not caught by the upper baffle plate and by the inner walls, is subject to further separation process by means of additional baffle plates located in the well or receiver portion of the separator, one of these plates being shown in the illustration. The separator is adapted for steam flow in either direction.



FIGS. 4,917 and 4,918.—Sweet dry pipe or internal separator. ***In operation,*** the steam after rising, enters the separator through two narrow slots C (fig. 4,918), and in passing down through the thin passages *c*, is brought in contact with the perforated plates or lining D, through which moisture is separated to chamber *e*. Steam from passages *c*, then enters the main pipe A, from which it is taken from the boiler. Water for chamber *e*, is conducted to the water in the boiler by pipes E, which are provided with check valves as shown.

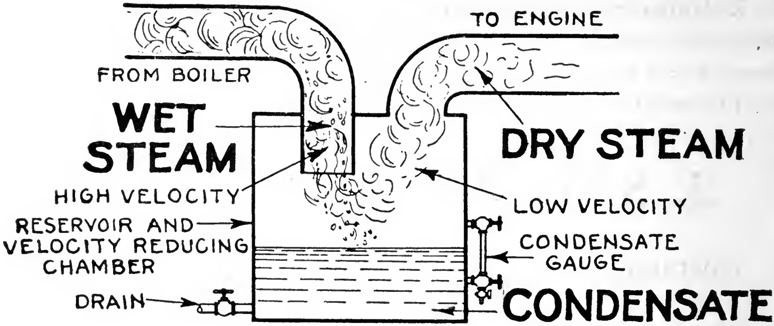
remove moisture, by arranging the device so as to suddenly change the direction of flow of the steam.

The water globules being much heavier than the steam, continue in the same direction because of their momentum, and are accordingly hurled out of the steam and by suitable provision are led into a receiver and drawn off from time to time, as shown in fig. 4,915.

Steam Loop.—This is an arrangement of piping wherein water condensation is returned to the boiler. It consists of four essential parts:

1. Riser; 2. Goose neck; 3. Condenser; 4. Drop leg.

Fig. 4,919 shows these essential parts, each of which has its special and well defined duty to perform, and their proportions and immediate relations determine the capacity and strength of the system.



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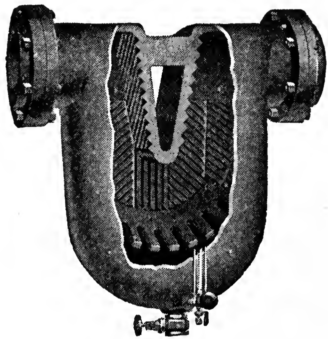

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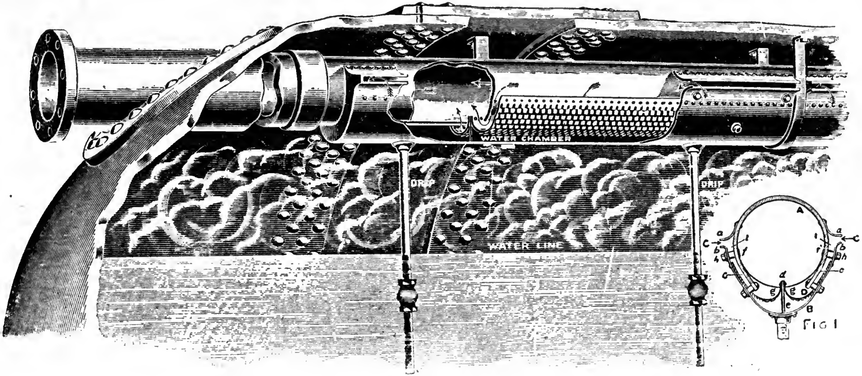

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Steam Loop.—This is an arrangement of piping wherein water condensation is returned to the boiler. It consists of four essential parts:

1. Riser; 2. Goose neck; 3. Condenser; 4. Drop leg.

Fig. 4,919 shows these essential parts, each of which has its special and well defined duty to perform, and their proportions and immediate relations determine the capacity and strength of the system.

The *riser* does not contain a solid body of water, but a mixture of water and steam.

The steam part of this mixture is readily condensed by means of the *condenser* at the top, usually and erroneously called the *horizontal pipe*. This condensation reduces the pressure in the system which causes an upward flow of the mixture in the riser, that is, the riser is constantly supplying steam, conveying large quantities of water in the form of a fine spray to take the place of the steam condensed in the condenser.

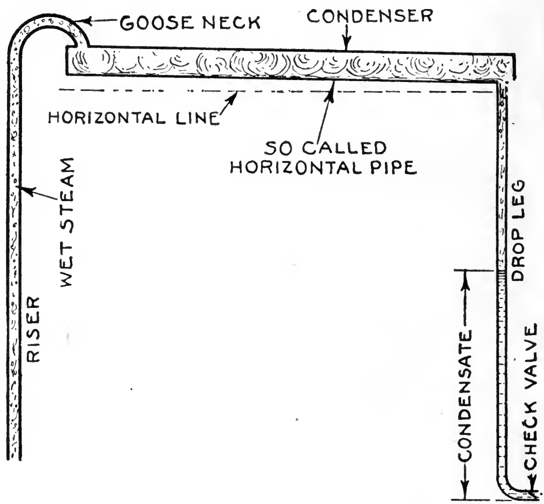
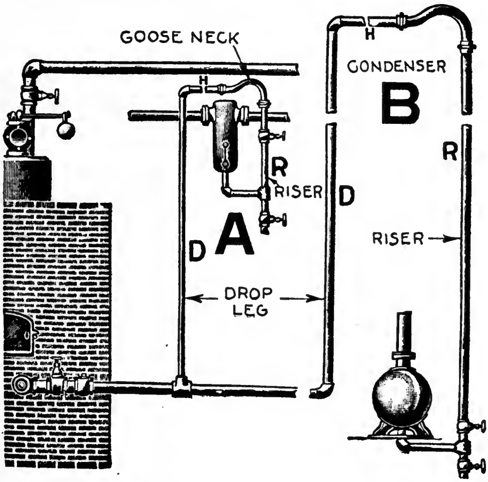


FIG. 4,919.—Essential parts of a steam loop: 1, riser; 2, goose neck, or non return device; 3, condenser, commonly and erroneously called the horizontal pipe; 4, drop leg, or balancing pipe. A check valve is placed at the end of the drop leg to prevent surging or fluctuating of the water level, thus rendering the operation stable. There are two conditions necessary for proper operation of a loop: 1, sufficient length of drop leg to balance the pressure reduction due to ***weight and friction*** of the mixture in the riser; 2, sufficient cooling surface of condenser to condense at a rate which will give the proper flow in the riser.

As soon as the water mixed with the steam passes the *goose neck*, it cannot return to the riser; hence the contents of the pipes constantly work from the separator toward the boiler, the condenser being slightly inclined toward the drop leg so as to readily draw the condensate into the drop leg.

The condensate will accumulate in the drop leg to a height such that its weight will balance the weight of the mixture in the riser.

In order to proportion a steam loop properly by calculation, the specific gravity of the mixture in the riser should be ascertained, the difference of pressure between the boiler and the separator, and the pressure under which the system is to work, the latter quantity being used to determine the weight of water at the existing pressure and temperature.



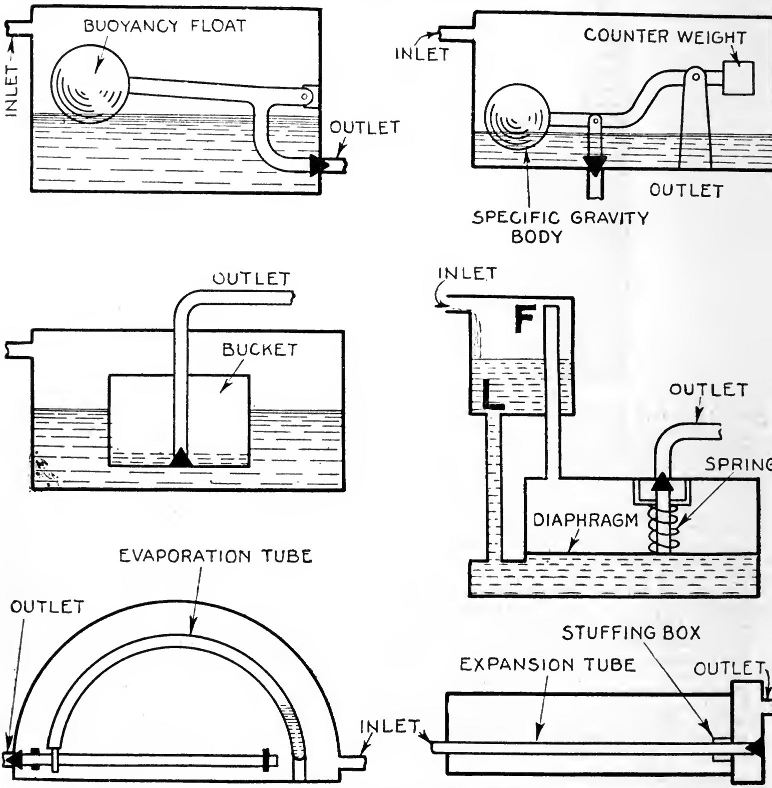
Figs. 4,920 and 4,921.—Steam loop installation **A**, from separator; **B**, from drain reservoir located below the water level in the boiler. ***Example:*** If the difference of pressure between the separator and the pipe be, say, 2 lbs., then it will sustain a column of water at a temperature of 297° Fahr., equal to $2.509 \times 2 = 5.018$ ft. high. The riser, R, however, does not contain water alone, but a mixture of steam and water, the specific gravity of which varies, but may be taken as one-fourth that of water, about three-fourths of the volume being assumed to be steam. In that case the column sustained will equal $5.018 \times 4 = 20.072$ feet. Deducting 10 per cent. for friction, the net height of the riser pipe may be 18 feet. This applies to installation **A**. The calculation of installation **B** (fig. 4,921), is not so simple. Assuming in this case that there is a difference of 5 lbs. pressure between the top and bottom of the riser pipe, and that the lower point in the return system is 12 feet below the water level in the boiler; the same pressures and temperatures as before. If the loop be full of steam only, the water will rise in the drop leg, D, $5 \times 2.509 = 12.545$ feet to balance the difference in pressure. Adding this height to the required lift, it will be found that the top of the water column should stand $12.545 + 12 = 24.545$ feet above the bottom of the riser when the system is in equilibrium. Now, as the mingled water and steam in the riser pipe weigh more than the steam, the pipe must be lengthened still more; assuming the previous specific gravity of one-fourth that of water, this additional height will naturally be 24.545 feet $\div 3$ or 8.182 feet, one-fourth of the extra height being above the present level, and three-fourths below. Adding together 24.545 and 8.182 feet, the result gives 32.727 feet for total height of riser pipe, or subtracting the 12 feet lift, gives 20.727 feet as the height of the drop leg above the water level in the boiler

NOTE.—A drip should be connected with the separator so as to drain the latter and the riser when they become filled with water, as will generally be the case after steam has been shut off for some time and the main piping has become partly filled with accumulated water.

Steam Traps.—By definition a steam trap is an *automatic device which allows the passage of water but prevents the passage of steam.*

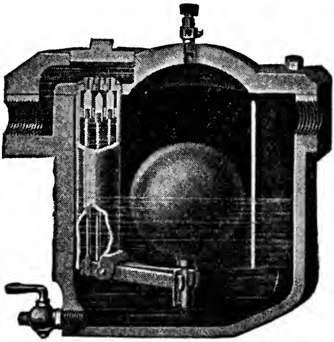
It is used in steam plants to automatically drain the pipes of condensate. According to Crane "a trap is a trap, and it is unfortunate that it is impossible to get along without them."

There is an undue multiplicity of traps on the market (each



FIGS. 4,922 to 4,927.—Elementary steam traps. Fig. 4,922, buoyancy float trap; fig. 4,923 counterweighted specific gravity body trap; fig. 4,924, bucket trap; fig, 4,925, differential trap; fig. 4,926, evaporation trap; fig. 4,927, expansion trap.

one better than the other, according to the makers), and they may be classed:

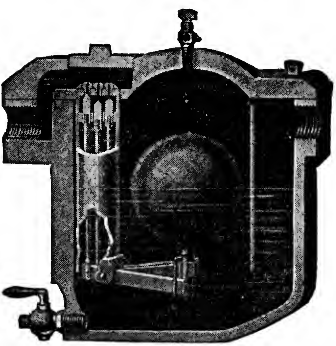


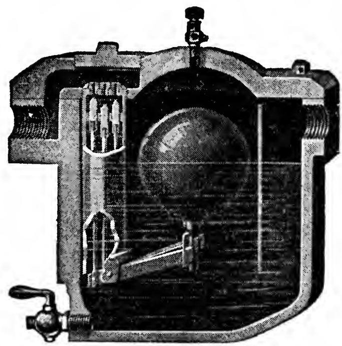
1. With respect to the *disposition* of the condensate, as:

   a. Non-return.
   b. Return.

2. With respect to *nature* of operation, as:

   a. Intermittent.
   b. Continuous.





FIGS. 4,928 to 4,930.—Wright "emergency" ***buoyancy float*** steam trap. Fig. 4,928, service discharge; fig. 4,929, semi-emergency discharge; fig. 4,930, emergency discharge. ***In operation,*** condensation enters the trap, filling it to about the center and forming a seal of from four to six inches of water at both inlet and outlet, which prevents escape of steam. When thus filled, the float rises and opens the center valve (fig. 4,928), *slightly*, if there be but little water coming in, but *widely* in case of a sudden inflow. For greater flow, the water rises in the trap, further raising the float and opening valve No. 2 sufficiently to discharge the surplus water, or wide open if necessary. Valve No. 3 is opened in the same manner providing for full capacity of the inlet pipe. The trap is provided with a water gauge and blow off valve for removing sediment.

Traps are said to be **non-return** when they do not return the condensate to the boiler, and **return,** when they do return the condensate to the boiler.

The terms *intermittent* and *continuous* are self-defining; they relate to the nature of the discharge from the trap. Most traps are intermittent, about the only working principle that will give approximately continuous discharge is that of *evaporation.*

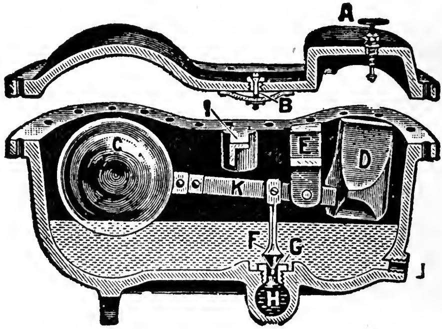


Fig. 4,931.—McDaniel ***counter-weighted specific gravity body*** steam trap. A, hand discharge; B, air vent; C, specific gravity body; D, counter-weight; E, fulcrum support; F, valve; G, valve seat; H, outlet; I, cross tie; J, tap for blow off valve; K, lever.

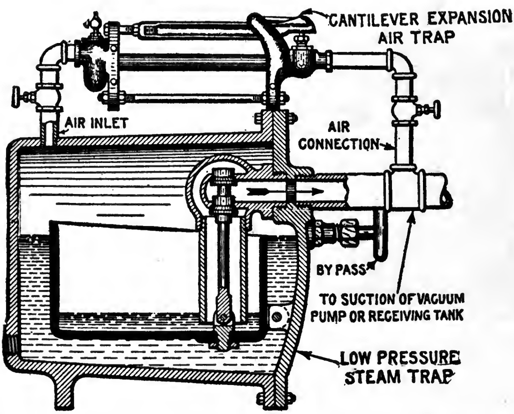


Fig. 4,932.—Kieley combination low pressure ***bucket*** trap with cantilever expansion air trap attached. The object in using a combination of this kind is to remove the air from the trap and heating system through the expansion air trap into the discharge. It is adapted to discharge water into the returns of a vacuum system.

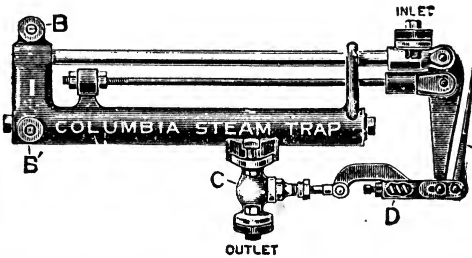


FIG. 4,934.—Watson and McDaniel "Columbia" ***expansion*** steam trap. Its action depends on the greater expansion of brass than of iron. ***In operation,*** the condensation enters at inlet and passes through the brass tube at the top into the cast iron part I, and on to the outlet valve C. As the brass tube becomes heated from the steam, it expands and forces the outlet valve to close. When there is water coming to the tube, the temperature is decreased and the tube contracts, opening the valve so that the trap is open to pass the condensed water out and closed to save the steam. The brass tube is screwed to the body at one end and moveable at the other. This movement is multiplied by the lever to give the valve a larger opening. The iron rod below the brass tube is adjustable to suit the required conditions of operation. The outlet valve has the same area as the pipe connections. There is a spring provided at D, to allow for any excess movement from too much expansion of the brass tube which might bend the tube or crush the outlet valve. The lever A, is made on a cam shape at the lower part and can be moved to a horizontal position which opens the valve to blow steam through if any sediment or dirt lodge on the seat. The connections B and B′, are for connecting a water gauge to show the water level, but these are rarely used and are not necessary.

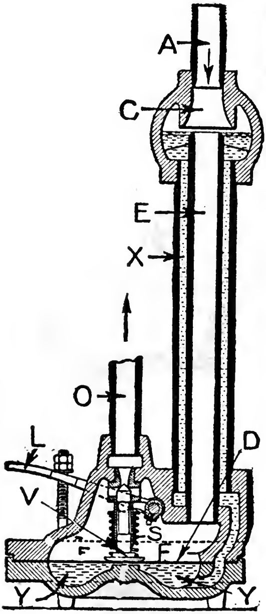


FIG. 4,933.—Flinn ***differential*** steam trap. ***Briefly,*** the column of water X, acting on the diaphragm closes the valve. The water entering pipe E, together with the action of the spring, equalizes column X, and opens the valve. That's all there is to it. Describing the action in further detail—the water of condensation enters at A, fills lower chamber Y, pipe X, and receiving chamber C, up to the level of the top of pipe E. This column of water, acting on the under side of the diaphragm D, forces the valve to its seat against the counter pressure of the spring S. Any additional water that enters the trap overflows through pipe E, filling chamber F and pipe E, to a point about midway of its height, where the effect of the column of water in pipe X is balanced. The pressure on each side of the diaphragm is then equal—the shorter column in pipe E, aided by the spring, balancing the pressure of the longer column in pipe X. Any further increase in the height of the water in pipe E, causes a depression of the valve V, which allows water to escape until the column has fallen to a level a little below the middle of pipe E, when this valve closes again. This action is repeated at intervals according to the quantity of water entering the trap. So long as the water keeps coming in in sufficiently large quantities the valve remains wide open. The valve acts every time the water rises above the water seal line and every time it falls below it. The diaphragm is not affected by the working pressure, whether one or three hundred pounds, as there is the same steam pressure on both sides, top and bottom. There are but three working or moving parts, the spring, the diaphragm, and the valve itself. The adjustment of the spring is accomplished by the outside lever L, which lever also serves to open the valve for blowing out the trap. This is sometimes necessary when grit and dirt pass into the trap from the steam pipes and get under the valve. By depressing the outside lever L, the valve V, is thrown wide open and the trap can be blown out.

Figs. 4,922 to 4,927, illustrate various principles employed in constructing steam traps.

In fig. 4,922 a light or buoyancy float at the end of a lever operates a valve controlling the discharge by the rise and fall of the condensate.

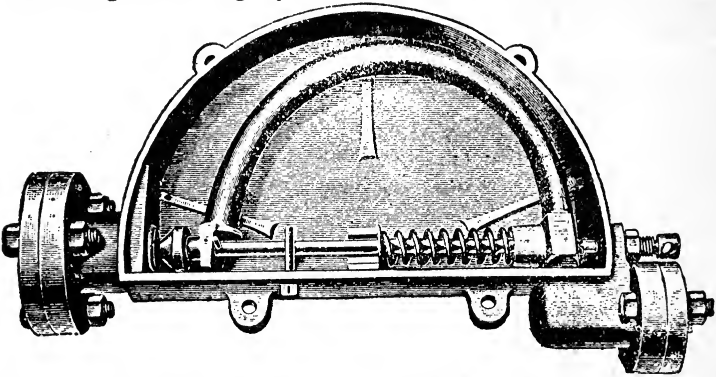


FIG. 4,935.—Heintz *evaporation* steam trap. ***It consists of*** an outer casing with removable cover, a curved evaporation tube of elliptical cross section, a plug valve, and a spiral spring. The evaporation tube is partially filled with a liquid. The action is similar to that of a steam gauge. ***In operation,*** when steam forces out the condensate and enters the trap chamber, the excess heat of the steam carries evaporation of the liquid within the evaporation tube, the pressure thus produced tending to straighten the tube and thus close the valve. It is claimed that the trap is very sensitive to changes of temperature so that in operation the discharge is practically continuous.

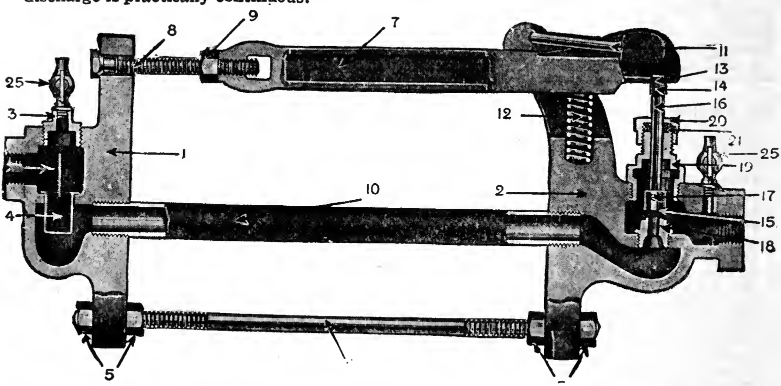
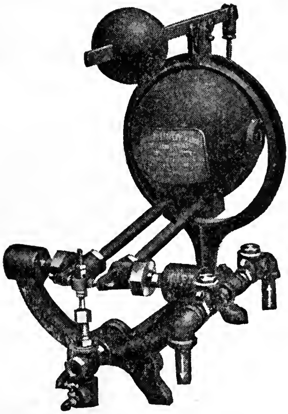


FIG. 4,936.—Kieley cantilever ***expansion*** steam and air trap. ***The parts are:*** 1, inlet head; 2, outlet head; 3, plug; 4, strainer basket; 5, nuts; 6, lower rod; 7, lever; 8, lever bolt; 9, locknut; 10, expansion tube; 11, lever pin; 12, spring; 13, clamp; 14, cotter pin; 15, disc; 16, disc stem; 17, rivet; 18, seat; 19, bonnet; 20, packing nut; 21, packing; 22, plate; 23, gasket; 24, cap screws; 25, air cocks.



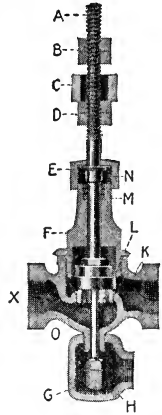


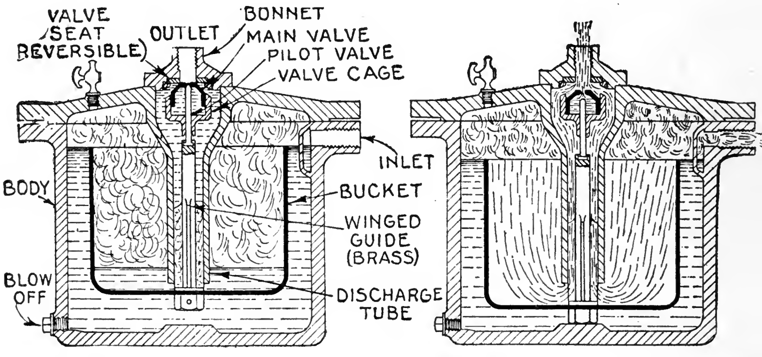
FIG. 4,937.—Bundy ***return*** trap. ***In operation*** when the bowl fills, it tilts and opens the valve admitting steam at boiler pressure, thus equalizing pressure in trap and boiler, and since the trap is placed above the water line, the water will pass by gravity from the trap into the boiler. ***To re-adjust.*** Place the counterbalance ball at a point on the lever where it will easily raise the empty bowl. See that the lower lock nuts which are touched by the sleeve are set just high enough on the valve stem to effectually close the steam valve without injuring disc or seat. Also that the upper set of locknuts are adjusted so that the bowl will have some headway on its downward stroke before engaging the ring to open the valve. Some lost motion must be maintained between the two sets of lock nuts, so the bowl may gain headway either up or down before the sleeve touches the lock nuts, thus opening and closing the valve with a quick movement.

FIG. 4,938.—Bundy return trap valve. The parts are: A, valve stem; B, upper lock nuts; C, valve stem sleeve; D, lower lock nuts; E, stuffing box nut; F, valve bonnet; G, air valve disc lock nut; H, air valve ell; I, air valve disc; K, valve body; L, valve disc; M, packing; N, valve gland follower; O, renewable seat. In order to remove valve from the trap for purpose of adjustment, cleaning or repairs, proceed as follows: Loosen the set screws that hold the valve stem sleeve C, which will release the valve stem. Remove the air valve ell H, unscrew the air valve disc lock nut G, and take off the air valve disc I, unscrew the valve bonnet F, and the entire valve stem can be lifted out, and the valve body unscrewed from the trap. When replacing the valve, reverse the order of the above operation. ***In installing the valve,*** make sure of the following: 1. That the trap side X, is made on to the nipple sufficiently far that the stem A, will be located centrally in the sleeve C. 2. That the adjustment, by the nuts B, and D, is such that when the disc L, is down on the seat, the top of bowl will be 1/8″ clear of the ring, and when the air valve disc I, is up to its seat, the under side of bowl will be 1/16″ clear of the ring. 3. This is very important for the reason that if the top of bowl rests against the ring, the steam disc cannot close, and if the under side of bowl rests on the ring the air valve disc cannot close. 4. A clearance of 1/8″ between top of bowl and ring, and 1/16″ between bottom of bowl and ring is all that is required, but this must be maintained for proper performance of the valve—and incidentally, the trap. 5. This leaves about 1/4″ space—or lost motion—between the top of sleeve C, and under side of nuts B, as shown in illustration, and this space must be maintained. The outlet of the air valve ell H, which should never be closed, should be open only sufficient to permit the trap to fill and discharge freely. 6. Be sure that the adjusting nuts on the valve stem are securely locked. 7. Do not use Stillson or tooth jawed wrenches. They are not necessary; a machinist's monkey wrench will answer all purposes, and will not deface or destroy the parts.

The heavy specific gravity body in fig. 4,923, lightened by the counterweight is virtually the same thing as a buoyancy float.

In fig. 4,924 the condensate rises until it overflows into the bucket which then sinks and opens the valve for discharge.

The spring in fig. 4,925 acts to hold the valve open. In operation the condensate entering the upper chamber flows down in tube L, and the pressure of water then acting on the diaphragm overcomes the spring and closes the valve, holding it shut until the water in upper chamber overflows into pipe F, thus bringing water pressure on the upper side of the diaphragm equal to that on the underside, leave thef ull force of the spring to open the valve, to discharge condensate in pipe F.



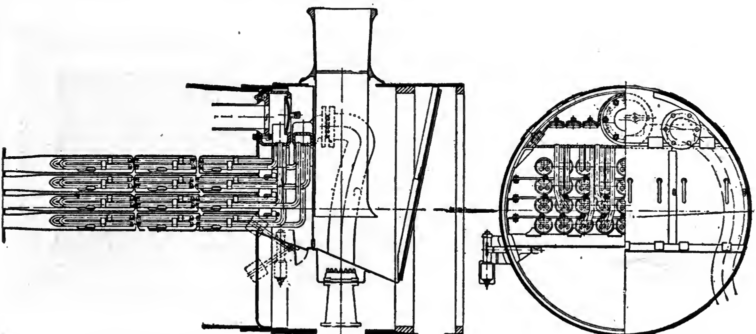
FIGS. 4,939 and 4,940.—Vance bucket ***pilot valve*** steam trap. Fig. 4,939 before discharge; fig. 4,940 during discharge. ***In operation,*** condensation enters the trap at inlet against baffle plate, and overflows into the bucket, which when full, drops and opens the pilot valve. This relieves the pressure under the main valve and the pressure on top of this valve, ***under the seat,*** then forces it to bottom of cage. The condensation is then discharged from bucket down to low water line which keeps end of discharge tube always water sealed. The bucket then rises and valves close.

In fig. 4,926, one end of the expansion tube is secured to the discharge chamber, and the other end working through a stuffing box closes or opens communication with the discharge chamber, as it respectively expands or contracts with changes of temperature due to the presence of hot steam or relatively cold condensate within the tube. The evaporation trap employs a principle commonly used for steam gauges, namely: a curved tube under pressure tends to assume a straight form. The curved sealed tube of the trap contains a small quantity of a liquid.

In operation when the trap chamber is full of condensate no vapor is formed by the tube, which under this condition holds the valve open.

When the condensate is discharged, the chamber fills with steam and heats the liquid in the curved tube, causing evaporation therein with rise of pressure. This tends to straighten the tube which in turn closes the valve. The accompanying cuts illustrate the construction of various traps embodying the principles just described.

Superheaters.—The economic value of superheating is too well known to require any discussion here. The degree of superheat ordinarily used in this country with engines is 25 to 100°



FIGS. 4,941 and 4,942.—Foster locomotive superheater, 36-unit arrangement with steel headers and expanded unit ends. Separate headers are shown for saturated and superheated steam. The superheater ***consists of*** a series of elements or units made of cold drawn steel tubing arranged to give a double run for the steam in each of the large tubes. The units are supported on lugs, rounded so as not to cut the large flues, and are tapered to a point at each end so as to give a stream line passage for gases and cinders without offering any blunt surface against which cinders or coal can bank up. The units are secured against fore and aft motion due to sudden stops, and starts by means of a simple anchorage device.

Fahr., and for steam turbines between 100 and 200°. In Europe a superheat of 300° is frequently used.

Superheaters may be classified as:

1. Attached, or
2. Separately fired.

depending upon the method of applying the heat.

An attached heater forms part of a boiler, one furnace serving not only the boiler but also the superheater, which is located within the boiler casing or setting at a point where the furnace gas temperatures are relatively high. Thus, all the steam produced by the boiler is automatically superheated before being delivered to the steam line.

Attached superheaters have been fully described in Chapter 15, as they are to be considered as part of the boiler rather than auxiliary apparatus.

A separately fired superheater is set independently of the boiler, and has its own source of heat, supplied by a special furnace using coal, oil or gas, or by waste heat often available at cement works, steel mills or blast furnaces.

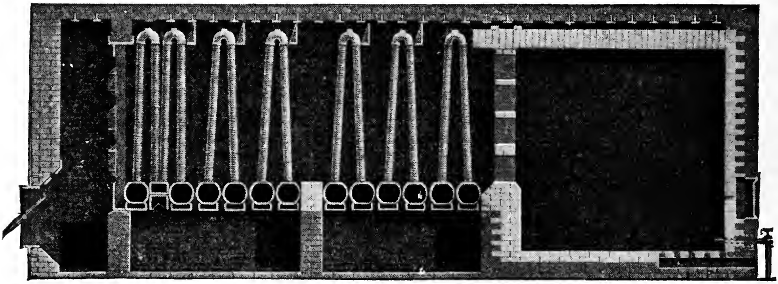


FIG. 4,943.—Foster separately fired superheater. The furnace may be arranged for fuel oil, coal or gas. High pressure or exhaust steam, air, petroleum, sulphurous oxide, etc. may be heated to any temperature up to 1,000 Fahr.

Such an arrangement has the advantage of being flexible, as the amount of superheat may be varied to suit the requirements or changed conditions. A separately fired installation may be made independently of the boilers, and one superheater may be designed to superheat all the steam from several boilers.

A study of the defects of past forms of superheaters will indicate the most important points to be covered in a good design.

The superheater must be as free as possible from liability to burn out in case of a chance overheating of the exposed surfaces.

The circulation must be properly distributed throughout the superheater at full load as well as at partial loads. The various parts must be accessible for inspection, both externally and internally, and must be readily renewable or easily repaired. There must be provision for free expansion and contraction of the parts.

Fig. 4,943 shows an approved form of separately fired superheater, and figs. 4,941 and 4,942 application of attached superheater to a locomotive.

Steam Flow Meters.—These measuring devices applied to different departments of a factory show how much steam is being used by each, and any waste will be detected. They are invaluable in the sale of steam to customers for heating or other work.

Should the steam pressure commence to drop, it is important to know whether it is caused by a sudden increase in the load or through a decrease in the steaming rate of one or more of the boilers.

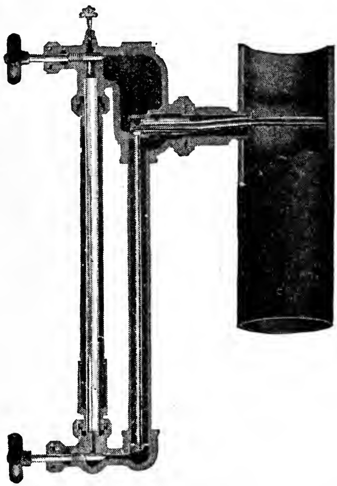


FIG. 4,944.—Gebhardt steam flow meter attached to a 3 inch pipe. ***It consists essentially of*** a water gauge glass fitted to special gauge holders. These holders are constructed so that the water of condensation will collect in the gauge, the height of the water column being a direct measure of the weight of steam flowing in the pipe to which the apparatus is connected. The meter is attached to the pipe by means of a three quarter-inch nipple, and is adapted to pipes of any size and in any position. The meter is provided with a chart graduated to read in lbs. per hour for the range of pressures required. When the reading is to be taken, the chart is turned so that the given pressure is in line with the edge of the pointer and the latter is brought on a level with the water column.

When each boiler is equipped with a meter, the fireman will know at once what is causing the drop in pressure and can bring it back to normal without loss of time.

Steam flow meters work on the same principles as water flow meters described in the first section of this chapter. A sectional view of the Gebhardt meter is shown in fig. 4,944 and described under the cut.

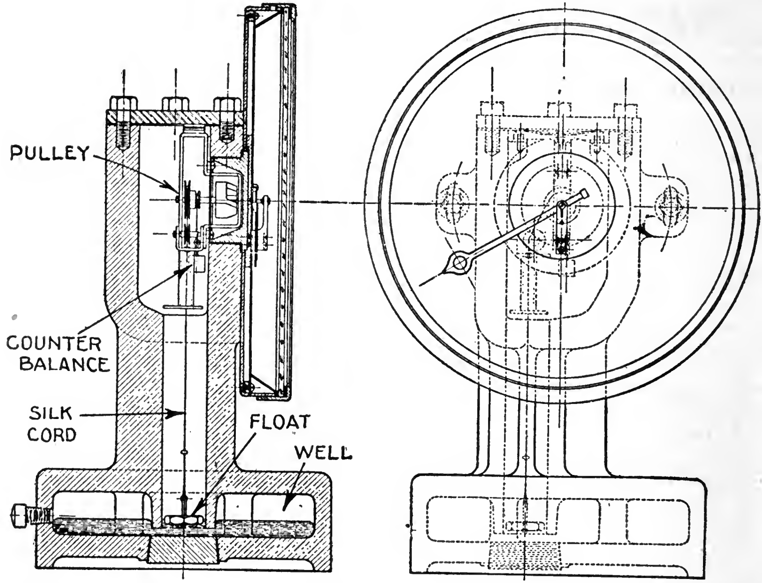


FIG. 4,945.—General Electric indicating steam flow meter for permanent installation to pipe. ***It will indicate*** the instantaneous rate of flow and give the same information as the larger type. Similar flow nozzles, orifice tubes and nozzle plugs are used with the meter as with the larger types. ***In construction*** the body of the meter consists of a casting cored out so as to form the leg and well of a U tube. The by pass valve is provided at the side of the meter to equalize the pressure at any time on the two legs of the U tube system. A small float resting on the top of the mercury in one leg of the U tube is attached to a silk cord passing over a pulley, and this cord is kept taut by a counter balance weight acting in the opposite direction. The shaft on which the pulley is mounted carries a small horseshoe magnet with its pole faces near and parallel to the inside surface of a copper plug fastened to the body of the meter. The bracket supporting the pulley system is made of copper, and the pivots and bearings of a special non-corrosive metal. A small magnet is so mounted on pivot bearings that its poles are near and parallel to the outside surface of the copper plug previously referred to, and its axis of rotation in line with the shaft carrying the magnet inside the meter. The indicating needle is attached directly to this magnet. ***In operation*** the differential pressure produced by the flow nozzle, orifice tube, or nozzle plug in the pipe is transmitted to the U tube system of the meter and causes the mercury in the well to rise into the leg of the U tube which contains the float; the height of the mercury in this leg is proportional to the differential pressure. By means of the float and cord, the pulley carrying the magnet inside the body is rotated in proportion to the change of level of the mercury. Any motion of this magnet is transmitted magnetically to the outside magnet carrying the indicating needle, causing the needle to deflect in proportion to the change in level of the mercury in the leg of the U tube which contains the float. ***The scale*** reads lbs. per hour, or boiler horse power, whichever be preferred, for a given condition of pipe diameter and temperature.

CHAPTER 81

POWER PLANT PIPING

The term piping is here used in its broad sense, comprising:

1. Pipes;
2. Fittings;
3. Valves

and also the methods employed in erecting. To convey steam from a boiler to an engine or other apparatus would at first seem an easy problem, but in most cases it is found that the cause of bursting pipes and their fittings is due to incorrect selection or method of installing.

Pipes.—There are numerous kinds of pipe manufactured to meet the varied conditions of service, and they may be classed:

1. According to the material used, as:

   a. Copper.
   b. Brass.
   c. Wrought iron.
   d. Wrought steel.
   e. Cast iron.

2. According to the process of manufacture, as:

   a. Brazed.
   b. Butt welded.
   c. Lap welded.
   d. Riveted.

3. According to the kind of joint used, as:

a. Threaded.
b. Flanged.
c. Spigot.

Copper Pipes.—The use of copper pipes for steam mains is not so common at present as formerly, and *their use for such service should be discontinued*, as with the exception of its great ductility and ease with which complicated forms may be built up from small sheets joined by brazing, there is nothing to recommend them, but much to condemn.

Copper pipes do not have the strength or wrought iron or steel pipes, and what little strength they possess is rapidly reduced at high temperatures; moreover, the brazed joint is unreliable, rendering the actual bursting strength of the pipe an unknown quantity.

The difficulty with a brazed joint lies in the fact that copper, if heated up to nearly its melting point during the brazing operation, loses its strength, becoming weak and brittle. When in this condition the copper is called "burnt."

At a temperature of 360° Fahr., its strength is reduced 15 per cent., and on this account it should never be used for high steam pressures and temperatures; at 800° to 900° its strength is reduced about one half. Although copper does not corrode, it exercises a very destructive galvanic action upon iron and steel, if immersed together in a polarizing liquid, and is, therefore, not a desirable material on steel hulls, in places reached by salt water or bilge

Brass Pipe.—The advantage of brass pipe is that it does not rust or corrode, but in cost, is very expensive as compared with iron pipe. It is made in iron pipe sizes and is tested to a pressure of 1,000 pounds per square inch before shipment.

The temper of the brass is not strictly hard, but just sufficiently annealed to prevent cracking and to make it suitable for steam work.

Brass pipe is made by the seamless process. It comes in 12-foot lengths, up to 4 inches diameter.

Wrought Iron or Steel Welded Pipe.—For conveying steam, gas, air, and water under pressure, wrought iron and steel pipes are largely used. There is a difference of opinion as to the superiority of the one material over the other, especially in the matter of corrosion.

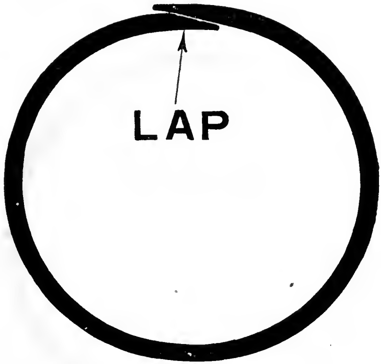


FIG. 4,946.—***Lap weld process.*** The skelp used in making lap welded tubes is rolled to the necessary width and gauge for the size tubes to be made, the edges being scarfed and overlapped when the skelp is bent into shape, thus giving a comparatively large welding surface, compared with the thickness of the plate. The skelp is first heated to redness in a "bending furnace," and then drawn from the front of the furnace through a die, the inside of which gradually assumes a circular shape, so that the skelp when drawn through is bent into the form of a tube with the edges overlapping as shown. The skelp so formed is heated evenly to the welding temperature in a regenerative furnace. When the proper temperature is obtained, the skelp is pushed through an opening in the front of this furnace into the welding rolls, passing between two rolls set one above the other, each having a semi-circular groove, so that the two together form a circular pass. Between these rolls a mandrel is held in position inside the tube, the lapped edges of the skelp being firmly pressed together at a welding heat between the mandrel and the rolls. The tube then enters a similarly shaped pass to correct any irregularities and to give the outside diameter required. It will be noted that the outside diameter is fixed by these rolls; any variation in gauge, therefore, makes a proportional variation in the internal diameter. This also applies to butt weld pipe. Finally, the tube is passed to the straightening, or cross rolls, consisting of two rolls set with their axes askew. The surfaces of these rolls are so curved that the tube is in contact with each for nearly the whole length of the roll, and is passed forward and rapidly rotated when the rolls are revolved. The tube is made practically straight by the cross rolls, and is also given a clean finish with a thin, firmly adhering scale. After this last operation, the tube is rolled up an inclined cooling table, so that the metal will cool off slowly and uniformly without internal strain. When cool enough, the rough ends are removed by cold saws or in a cutting off machine, after which the tube is ready for inspection and testing. In the case of some sizes of double extra strong pipe (3 inch to 8 inch), made by the lap weld process, the pipes are first made to such sizes as will telescope one within the other, the respective welds being placed opposite each other; these are then returned to the furnace, brought to the proper heat, and given a pass through the welding rolls. While a pipe made in this way is, in respect to its resistance to internal pressure, as strong or stronger than when made from one piece of skelp, it is not necessarily welded at all points between the two tubular surfaces; however, each piece is first thoroughly welded at the seam before telescoping.

Some think that the cinder which remains in the wrought iron breaks up the continuity of the metal and tends to retard corrosion, while others believe there is little or no difference in the rust resisting qualities of the two materials. However, judging from the amount of printed matter that has been circulated by manufacturers of steel pipe, they are having some difficulty trying to convince pipe users that steel pipe will resist corrosion as long as iron pipe.

Wrought iron pipe, because of the higher cost of manufacture, has been largely displaced by steel.

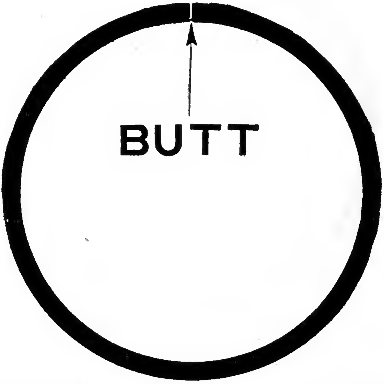
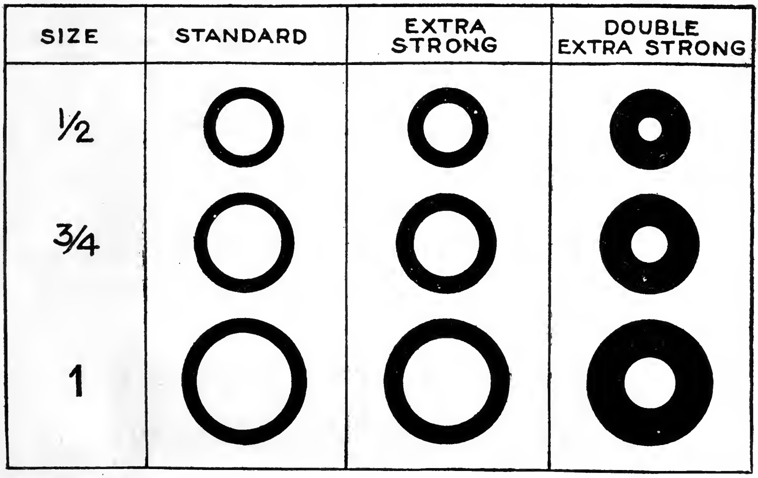


FIG. 4,947.—***Butt weld process.*** Skelp used in making butt welded pipe comes from the rolling department of the steel mills with a specified length, width and gauge, according to the size pipe for which it is ordered. The edges are slightly beveled with the face of the skelp, so that the surface of the plate which is to become the inside of the pipe is not quite as wide as that which forms the outside; thus when the edges are brought together they meet squarely, as shown. The skelp for all butt welded pipe is heated uniformly to the welding temperature, in furnaces similar in general construction to those used in lap welding. The strips of steel when properly heated are seized by their ends with tongs and drawn from the furnaces through bell shaped dies, or rings. The inside of these dies is so shaped that the plate is gradually turned around into the shape of a tube, the edges being forced squarely together and welded. For some sizes, the pipes are drawn through two rings consecutively at one heat, one ring being just behind the other, the second one being of smaller diameter than the first. The pipes are then run through sizing and cross rolls similar to those used in the lap weld process, obtaining thereby the correct outside diameter and finish. The pull required to draw double extra strong (hydraulic) pipe by this process is so great, on account of the thickness of the skelp, that it is found necessary to weld a strong bar on the end of the skelp, thereby distributing the strain. With this bar the skelp is drawn through several dies of decreasing size, and is reheated between each draw until the seam is thoroughly welded. It is evident that the skelp is put to a severe test in this operation, and, unless the metal be sound and homogeneous, the ends will most always be pulled off.

The term "wrought iron pipe" is often erroneously taken to refer to pipes made to Briggs standard sizes, rather than of the material, hence discriminating buyers are cautioned to emphasize the fact that they want *iron* instead of *steel* pipe, by asking for "*genuine* wrought iron" or *guaranteed* wrought iron pipe. It is customary for manufacturers to stamp each length of such pipe as *genuine wrought iron* to distinguish it from steel, and no wrought iron pipe should be accepted as such without the stamp.

The standard system for wrought iron and steel pipes which is now universally employed was established by Robert Briggs. It was formally adopted by the "Association of Manufacturers of Wrought Iron Pipe and Boiler Tubes in the United States," at their meeting in Pittsburgh, October 27, 1886, and also adopted by the "Association of Manufacturers of Brass and Iron



FIGS. 4,948 to 4,956.—Three sizes of standard, extra strong, and double extra strong welded pipe showing relative thickness; about half size.

Steam, Gas and Water Works of the United States," at their convention in New York, December 8, 1886.

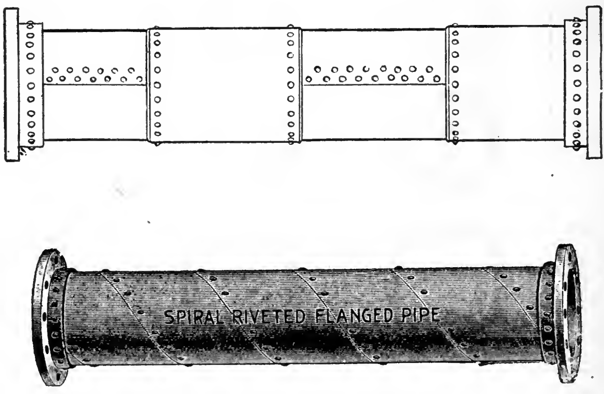
Wrought iron and steel pipe are made in three different thicknesses, known as:

1. Standard.
2. Extra strong.
3. Double extra strong.

The increased thickness is obtained by decreasing the internal diameter, that is, for a given size, the external diameter is the same for all three thicknesses.

The size of iron and steel piping is specified in terms of the nominal inside diameter. For standard pipe, the actual inside diameter is usually greater than the nominal, especially on the smaller sizes, but in the extra strong, and especially in the double extra strong, the internal diameter is less than the nominal size. The thickness of the wall and the weight per linear foot of piping varies on account of the difficulty in securing uniformity in the process of manufacture. It is assumed to be permissible for standard weight pipe to vary from 5 per cent. above to 5 per cent. below the standard weight.

A class of pipe known as *merchant pipe*, which is ordinarily carried by jobbers, is almost invariably from 5 to 10 per cent. under the nominal weight.



Figs. 4,957 and 4,958.—Straight and spiral riveted steel pipe

In specifying pipe, therefore, it should be stated whether "merchant" full weight, extra strong, or double extra strong pipe is required.

Welded pipe is submitted to the following hydraulic test pressures: from ⅛ to 2 inches, 700 pounds; from 2½ to 3 inches, 800 pounds; from 3½ to 8 inches, 1,000 pounds; 9 and 10 inches, 900 pounds; 11 and 12 inches, 800 pounds; 13 and 14 inches, 700 pounds; 15 inches, 600 pounds. Sizes up to and including 3 inches are **butt** *welded*; larger sizes are **lap** *welded*.

Riveted Steel Pipe.—Large pipes are frequently made up of steel plates with riveted joints, the seams being either longitudinal and circumferential, or spiral.

Riveted pipe is frequently used in large hydraulic installations where the ordinary pipe sizes would be of insufficient capacity for the volume of water passing through them. The helical seam riveted pipe was invented by John B. Root, and by him termed "spiral riveted pipe."

The helical seam makes it possible to obtain in a riveted pipe practically the full strength of the plate, whereas with a longitudinal riveted seam, 60 to 65 per cent. of the strength of the plate is all that is usually obtained. They may be joined by flanges of cast or pressed steel. These flanges are riveted to the ends of the pipe. The riveted ends are caulked, and then the pipe is generally galvanized.

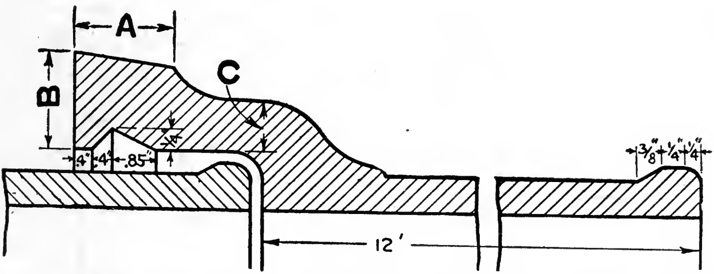


Fig. 4,959.—Cast iron pipe with bell and spigot ends proportioned according to the American Society for Testing Materials.

Cast Iron Pipe.—This kind of pipe is made with either flanged or bell and spigot ends.

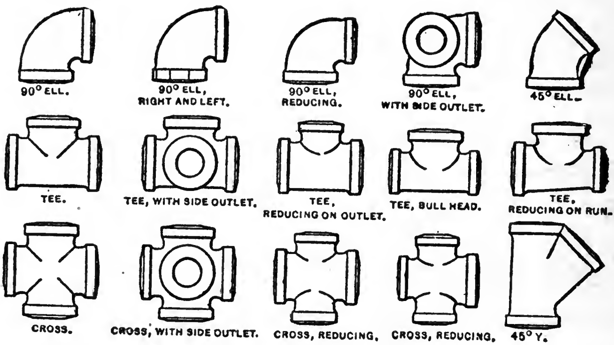
Pipe Fittings.—There are a multiplicity of parts used for connecting pipes in various ways, and known as fittings. The material used in the manufacture of these fittings may be cast iron, wrought iron, malleable iron, or brass, as is best suited to the service requirements.

The smaller sizes have screwed joints, and the larger sizes flanged for bolting them to the flanges on the pipes to which they are connected.

Cast iron fittings are made either with screw or flange joints; malleable iron fittings are made of the screwed type only.

The normal size of a fitting corresponds to the size of the pipe for which it is intended.

Figs. 4,960 to 4,974 show different kinds of screwed fittings, and 4,975 to 4,994, various flanged fittings. The subject of fittings is considered in greater detail in Volume 7, in the chapter on "Pipe and Pipe Fittings."



FIGS. 4,960 to 4,974.—Various screwed pipe fittings.

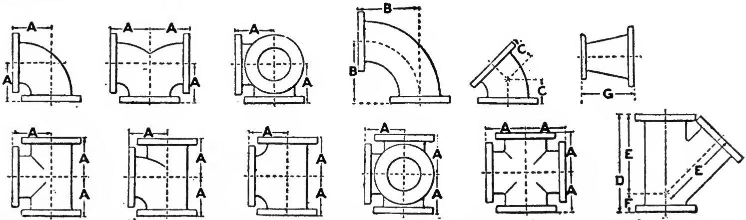
Calculation of Pipe Sizes.—To efficiently convey steam or water through a pipe under pressure, the pipe must not be too small or there will be an undue drop in pressure, nor too large, in the case of a steam pipe, because of the increased condensation.

For steam mains of short or medium length, the usual practice has been to proportion pipes for a velocity of 8,000 feet per minute for the steam supply to engine, and 4,000 feet per minute for exhaust pipe based on cylinder displacement. These values being for saturated steam, being increased about 20 per cent. for superheated steam.

Example.—What size steam and exhaust pipes are suitable for an 8×10 engine running 250 revolutions per minute with saturated steam?

Piston speed $= (10 \times 2) \times 250 \div 12 = 416.7$ ft. per minute, area. Steam pipe $= 50.27 \times 416.7 \div 8{,}000 = 2.62$ sq. ins. Nearest size from table (page 2,908), 1½ in.

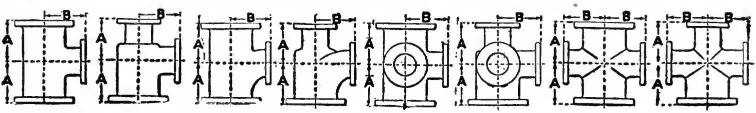
Numerous experiments have been made by different authorities to determine the flow of steam through pipes, and tables prepared



FIGS. 4,975 to 4,986.—Various standard *flanged* fittings. Straight sizes up to 20 ins.

STANDARD AND LOW PRESSURE FLANGED FITTINGS—Straight Sizes

Size........In.	1	1¼	1½	2	2½	3	3½	4	4½	5	6	7	8	9	10	12	14	15	16	18	20
AA—Face to Face, Tees and Crosses.In.	7	7½	8	9	10	11	12	13	14	15	16	17	18	20	22	24	28	29	30	33	36
A—C. to F., Elbows, Tees and Crosses.In.	3½	3¾	4	4½	5	5½	6	6½	7	7½	8	8½	9	10	11	12	14	14½	15	16½	18
B—C. to F., Long Radius Elbows...In.	5	5½	6	6½	7	7¾	8½	9	9½	10¼	11½	12¾	14	15¼	16½	19	21½	22¾	24	26½	29
C—Center to Face, 45° Elbows....In.	1¾	2	2¼	2½	3	3	3½	4	4	4½	5	5½	5½	6	6½	7½	7½	8	8	8½	9½
D—Face to Face, Laterals..In.	7½	8	9	10½	12	13	14½	15	15½	17	18	20½	22	24	25½	30	33	34½	36½	39	43
E—Center to Face, Laterals.......In.	5¾	6¼	7	8	9½	10	11½	12	12½	13½	14½	16½	17½	19½	20½	24½	27	28½	30	32	35
F—Center to Face, Laterals.......In.	1¾	1¾	2	2½	2½	3	3	3	3	3½	3½	4	4½	4½	5	5½	6	6	6½	7	8
G—Face to Face, Reducers.In.						6	6½	7	7½	8	9	10	11	11½	12	14	16	17	18	19	20
Diameter of Flanges.....In.	4	4½	5	6	7	7½	8½	9	9¼	10	11	12½	13½	15	16	19	21	22¼	23½	25	27½
Thickness of Flanges.....In.	7/16	½	9/16	⅝	11/16	¾	13/16	15/16	15/16	15/16	1	1 1/16	1⅛	1⅛	1 3/16	1¼	1⅜	1⅜	1 7/16	1 9/16	1 11/16



FIGS. 4,987 to 4,994.—Various standard *flanged* fittings, ***reducing*** tees and crosses; American standard.

GENERAL DIMENSIONS REDUCING TEES AND CROSSES—Short Body Pattern

Size.........In.	1	1¼	1½	2	2½	3	3½	4	4½	5	6	7	8	9	10	12	14	15	16	18	20	22	24	26	28	30	32	34	36	38	40
*Size of Outlet & Smlr.In.	All reducing fittings 1 inch to 16 inch, inclusive, have the same center to face dimensions as straight size fittings.																			12	14	15	16	18	18	20	20	22	24	24	26
AA—F. to F., Run....In.																				26	28	28	30	32	32	36	36	38	40	40	44
A—C. to F., Run....In.																				13	14	14	15	16	16	18	18	19	20	20	22
B—C. to F., Outlet...In.																				15½	17	18	19	20	21	23	24	25	26	28	29

Size.........In.	42	44	46	48	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100	
Size of Outlet & Smlr. In.	28	28	30	32	32	34	36	36	38	40	40	42	44	44	46	48	48	50	52	52	54	56	56	58	60	60	62	64	64	66	—
AA—F. to F., Run..In.	46	46	48	52	52	54	58	58	62	66	66	68	70	70	74	80	80	84	86	86	88	94	94	96	100	100	104	106	106	110	—
A—C. to F., Run...In.	23	23	24	26	26	27	29	29	31	33	33	34	35	35	37	40	40	42	43	43	44	47	47	48	50	50	52	53	53	55	—
B—C. to F., Outlet...In.	30	31	33	34	35	36	37	39	40	41	42	44	45	46	47	48	49	50	52	53	54	56	57	58	61	62	63	64	65	67	—

***LONG BODY PATTERNS** {Are used when outlets are larger than given in the above table, therefore have same dimensions as straight size fittings.

The dimensions of "Reducing Flanged Fittings" are always regulated by the reduction of the outlet.

FITTINGS REDUCING ON THE RUN ONLY, the long body pattern will always be used, **EXCEPT DOUBLE SWEEP TEES**, on which the reduced end is always longer than the regular fittings. Dimensions on request.

BULL HEADS OR TEES having outlets larger than the run, will be the same length center to face of all openings as a Tee with all openings of the size of the outlet. For example, a 12 x 12 x 18 inch Tee will be governed by the dimensions of the 18 inch Long Body Tee, namely, 16½ inches center to face of all openings and 33 inches face to face.

REDUCING ELBOWS carry same center to face dimension as regular elbows of largest straight size.

from formulæ based on these experiments, of which the following from Babcock and Wilcox's Steam is generally accepted.

Flow of Steam Through Pipes

Initial Gauge Pressure Pounds per Square Inch	Diameter† of Pipe in Inches. Length of Pipe = 240 Diameters													
	¾	1	1½	2	2½	3	4	5	6	8	10	12	15	18
	Weight of Steam per Minute, in Pounds, With One Pound Loss of Pressure													
1	1.16	2.07	5.7	10.27	15.43	25.38	46.85	77.3	115.9	211.4	341.1	502.4	804	1177
10	1.44	2.57	7.1	12.72	19.15	31.45	58.05	95.8	143.6	262.0	422.7	622.5	996	1458
20	1.70	3.02	8.3	14.94	22.49	36.94	68.20	112.6	168.7	307.8	496.5	731.3	1170	1713
30	1.91	3.40	9.4	16.84	25.35	41.63	76.84	126.9	190.1	346.8	559.5	824.1	1318	1930
40	2.10	3.74	10.3	18.51	27.87	45.77	84.49	139.5	209.0	381.3	615.3	906.0	1450	2122
50	2.27	4.04	11.2	20.01	30.13	49.48	91.34	150.8	226.0	412.2	665.0	979.5	1567	2294
60	2.43	4.32	11.9	21.38	32.19	52.87	97.60	161.1	241.5	440.5	710.6	1046.7	1675	2451
70	2.57	4.58	12.6	22.65	34.10	56.00	103.37	170.7	255.8	466.5	752.7	1108.5	1774	2596
80	2.71	4.82	13.3	23.82	35.87	58.91	108.74	179.5	269.0	490.7	791.7	1166.1	1866	2731
90	2.83	5.04	13.9	24.92	37.52	61.62	113.74	187.8	281.4	513.3	828.1	1219.8	1951	2856
100	2.95	5.25	14.5	25.96	39.07	64.18	118.47	195.6	293.1	534.6	862.6	1270.1	2032	2975
120	3.16	5.63	15.5	27.85	41.93	68.87	127.12	209.9	314.5	573.7	925.6	1363.3	2181	3193
150	3.45	6.14	17.0	30.37	45.72	75.09	138.61	228.8	343.0	625.5	1009.2	1486.5	2378	3481

* D, the density, is taken as the mean of the density at the initial and final pressures.
† Diameters up to 5 inches, inclusive, are *actual* diameters of standard pipe

Example.—A 30 horse power engine operates on 20 pounds of steam per horse power hour. What size steam pipe should be used for a pressure drop of one pound between engine and boiler using steam at 80 pounds boiler pressure?

$$\text{Total steam per minute} = (30 \times 20) \div 60 = 10 \text{ pounds}$$

Referring to the steam flow table, the two nearest values are 4.82 pounds for a 1 inch pipe and 13.3 pounds for a 1½ inch pipe, accordingly a 1¼ inch pipe (not listed), nearer the correct size than either the 1, or 1½ inch size.

Piping Methods.—With the proper size of pipe to be used determined, assembling of pipes, fittings and valves, should be so arranged that there will be provision for:

1. Drainage.
2. Removal of condensate.

3. Expansion,

and the system should be properly protected against water hammer and vibration.

Pipes and their fittings, as a rule, will withstand a stress of from six to ten times the pressure under which they are intended to work; nevertheless constant annoyance, danger, and sometimes wholesale disaster, is caused by steam pipes and their fittings,

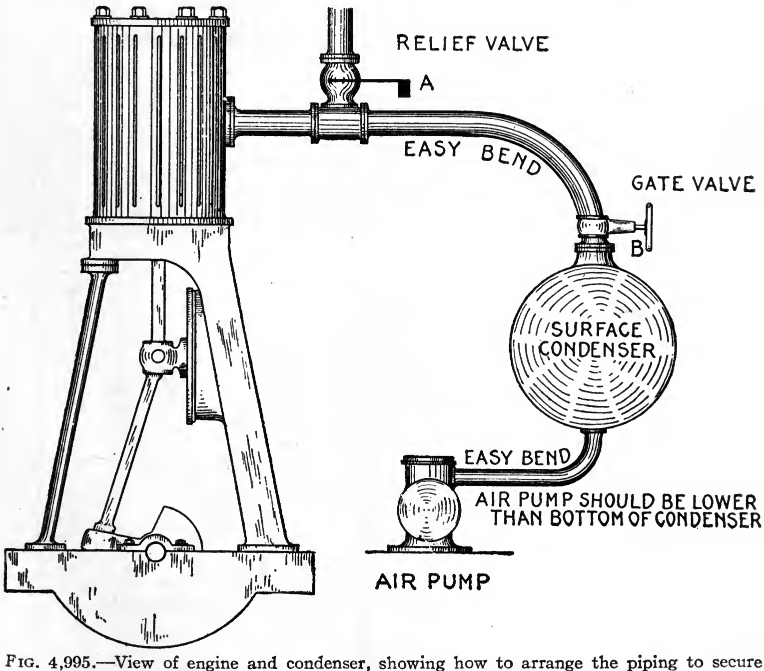


FIG. 4,995.—View of engine and condenser, showing how to arrange the piping to secure good vacuum. *Locate the condenser as near the engine as possible;* ***use easy bends*** *instead of elbows; place the pump* ***below*** *bottom of condenser so the water will drain to pump.* At A, is a relief valve, for protection in case the condenser become flooded through failure of the pump and at B, is a gate valve to shut off condenser in case atmospheric exhaust be desired to permit repairs to be made to condenser during operation. ***A water seal*** should be maintained on the relief valve and ***special attention*** *should be given to the stuffing box* of the gate valve ***to prevent air leakage.*** *The discharge valve of the pump should be water sealed.*

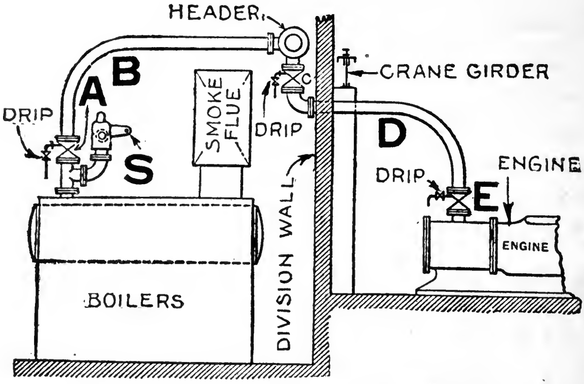


FIG. 4,996.—Objectionable arrangement of piping; it is arranged thus in order to carry the bend D, underneath the crane girder in the engine room. It is objectionable because when gate valve A on any boiler, is closed, bend B will gradually fill with condensate, the column of water being driven over into main when A is reopened. If engine be cut out of service by closing valve E, leaving C open; bend D will fill up with water which will pass into the cylinder when E is reopened. If both E and C, be closed, water will collect in main above C. Whenever a valve forms a water pocket in a steam line, as A, C, and E, the valves should be drained from above the seat.

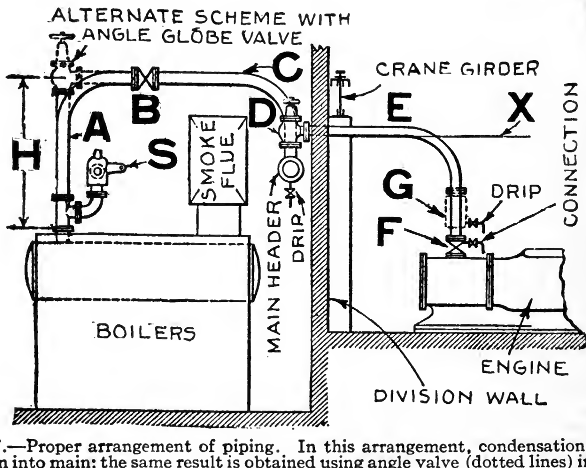


FIG. 4,997.—Proper arrangement of piping. In this arrangement, condensation on bend C will drain into main; the same result is obtained using angle valve (dotted lines) instead of B. Valves placed at some distance as H, above boiler nozzle should be anchored to prevent vibration. Any leakage through angle valve, or B, will fill bend E with condensate, hence the necessity of a separator G, placed close to the cylinder.

solely because of false erections, and to any one or a combination of the following troubles may be attributed to the break down:

Water Hammer.—The exact nature of the phenomenon known as "water hammer" has never been clearly defined, though its effects are only too well known to every engineer, the cause arising from an accumulation of condensed steam in the pipes or fittings. Should steam be suddenly admitted to a pipe partly filled with cold water, the latter will be set in violent motion and travel the length of the pipe in the form of waves and will gain sufficient velocity to rupture any valve, blank flange, or other obstruction in its path.

Expansion of Pipe

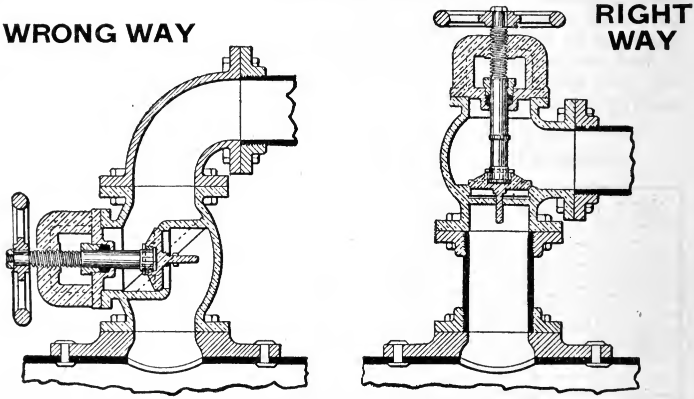
Increase in Length—Inches per 100 Feet

Temperature, Degrees F.	Steel	Wrought Iron	Cast Iron	Brass and Copper
0	0	0	0	0
20	.15	.15	.10	.25
40	.30	.30	.25	.45
60	.45	.45	.40	.65
80	.60	.60	.55	.90
100	.75	.80	.70	1.15
20	.90	.95	.85	1.40
40	1.10	1.15	1.00	1.65
60	1.25	1.35	1.15	1.90
80	1.45	1.50	1.30	2.15
200	1.60	1.65	1.50	2.40
20	1.80	1.85	1.65	2.65
40	2.00	2.05	1.80	2.90
60	2.15	2.20	1.95	3.15
80	2.35	2.40	2.15	3.45
300	2.50	2.60	2.35	3.75
20	2.70	2.80	2.50	4.05
40	2.90	3.05	2.70	4.35
60	3.05	3.25	2.90	4.65
80	3.25	3.45	3.10	4.95
400	3.45	3.65	3.30	5.25
20	3.70	3.90	3.50	5.60
40	3.95	4.20	3.75	5.95
60	4.20	4.45	4.00	6.30
80	4.45	4.70	4.25	6.65
500	4.70	4.90	4.45	7.05
20	4.95	5.15	4.70	7.45
40	5.20	5.40	4.95	7.85
60	5.45	5.70	5.20	8.25
80	5.70	6.00	5.45	8.65
600	6.00	6.25	5.70	9.05
20	6.30	6.55	5.95	9.50
40	6.55	6.85	6.25	9.95
60	6.90	7.20	6.55	10.40
80	7.20	7.50	6.55	10.95
700	7.50	7.85	7.15	11.40
20	7.80	8.20	7.45	11.90
40	8.20	8.55	7.80	12.40
60	8.55	8.90	8.15	12.95
80	8.95	9.30	8.50	13.50
800	9.30	9.75	8.90	14.10

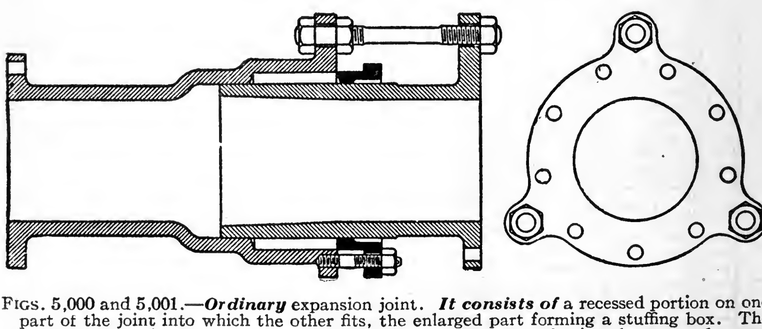
The extent of the rupture depends on the velocity of the incoming steam; for instance, if the valve controlling the entrance of the steam to a pipe partly filled with water be opened suddenly, a violent explosion is almost certain to follow, but if the valve be opened very gradually, while there may be a certain amount of noise and vibration, no serious results will occur.

Expansion.—To expansion and contraction can be attributed most of the trouble arising from leaky joints. Too much stress cannot be laid on the importance of proper provision for expansion, nevertheless the same is often overlooked.

Bends are frequently used to take up expansion strains, and the number



Figs. 4,998 and 4,999.—Points on placing stop valves. The first and most important feature is to ascertain whether the valve will act as a water trap for condensed steam. Fig. 4,998 illustrates a common error in the placing of valves, as this arrangement permits an accumulation of condensed steam above the valve when closed, and should the engineer be careless and open the valve suddenly, serious results might follow owing to water hammer Fig. 4,999 illustrates the correct method of placing the valve. It sometimes occurs, however, that it is not convenient to place the valve as shown in fig. 4,999 and that fig. 4.993 is the only manner in which the valve can be placed. In such cases, the valve should have a drain, and this drain should always be opened before the large valve is opened.

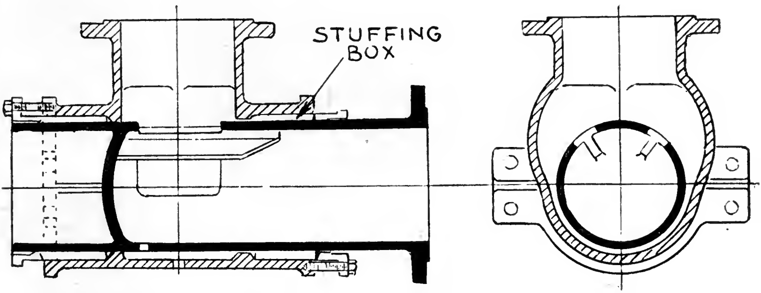


Figs. 5,000 and 5,001.—***Ordinary*** expansion joint. ***It consists of*** a recessed portion on one part of the joint into which the other fits, the enlarged part forming a stuffing box. The tie rods connecting the two flanges prevent the steam pressure forcing the two ends apart especially if it contain a bend or elbow.

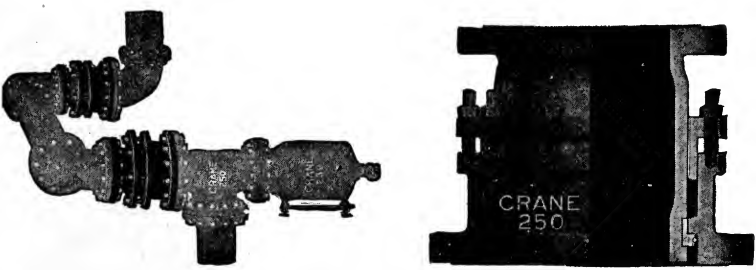
of joints is materially reduced. When used for the purpose of taking up expansion, it is well to make them as light as is consistent with safety.

Want of Alignment.—This sometimes causes trouble by throwing excessive strains on the flanges of stop valves, separators, etc., and is brought about, as a rule, by the flanges having been forced into contact with each other by means of the joining bolts instead of fitting into place as they should.

The flanges of modern steel pipes and valves are usually of ample thickness, and if they do not come together fairly, they should be taken down and replaced and a thin ring of metal put in to make up the length, if necessary.



FIGS. 5,002 and 5,003.—***Balanced*** expansion joint used in place of an elbow. The closed end of the pipe takes the thrust, hence there is no tendency for the parts to separate. It should be noted that two stuffing boxes are required with this form of joint.



FIGS. 5,004 and 5,005.—Crane extra heavy ***swivel*** expansion joint for steam pressures up to 250 lbs. Fig. 5,004, method of placing swivel joints in a steam line; fig. 5,005, detail of joint. ***In construction,*** the male part of the joint is provided with a collar which bears against an internal ring cast on the sleeve and which prevents the two ends being forced apart by the steam pressure.

When erecting heavy pipes, every length should be placed in position and properly supported and leveled by its own slings and brackets, when it will usually be found that several lengths have to be altered before the

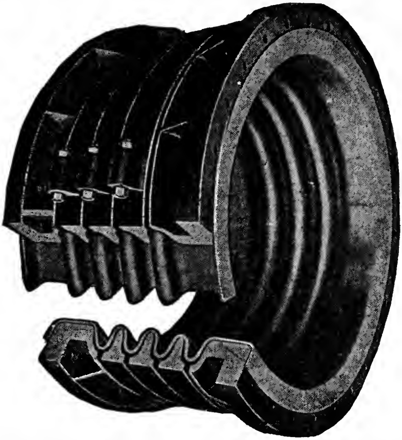
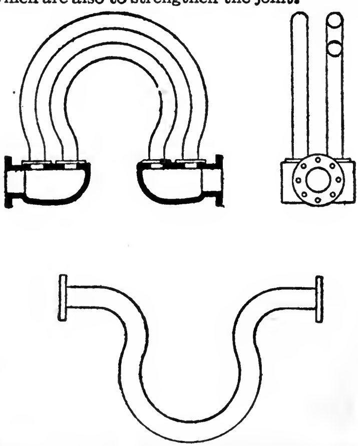


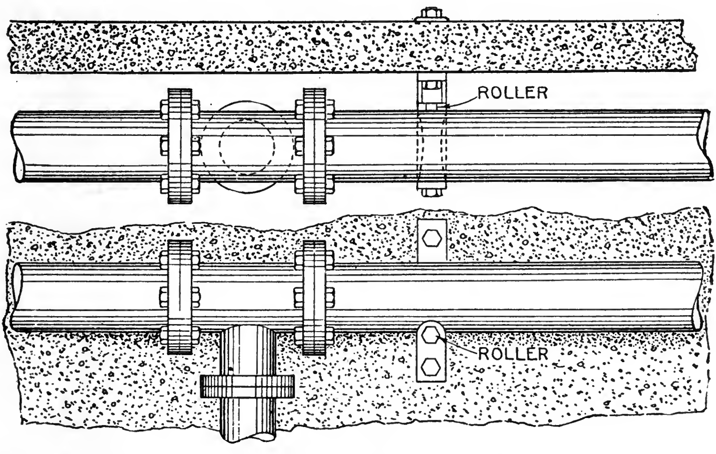
FIG. 5,006.—Badger ***corrugated*** expansion joint. It is made of corrugated copper with equalizing rings for distributing the expansion equally on all the corrugations. The equalizing rings are of cast steel, which are also to strengthen the joint.



FIGS. 5,007 to 5,009.—Expansion bends. When the line is not too long and there is sufficient space this forms a good means of providing for expansion. The figures show several pipes arranged in parallel, although one large pipe may be and is frequently used, the single pipe requiring of course a larger radius of bend than the nest of small pipes.

flange faces come into alignment, and not until this has been done and every pair of flanges inspected by some responsible person, should the various lengths be bolted together permanently.

Vibration.—When a number of small or moderate sized engines are connected with the same pipe system and stand on the same foundation, or at least in the same building, it is sometimes difficult to prevent the pipes vibrating and at the same time insure the necessary freedom for expansion and contraction. The pipes should therefore be arranged in such a way that they are quite free to move in one direction, parallel with their length, movement in other directions being restricted as far as possible.



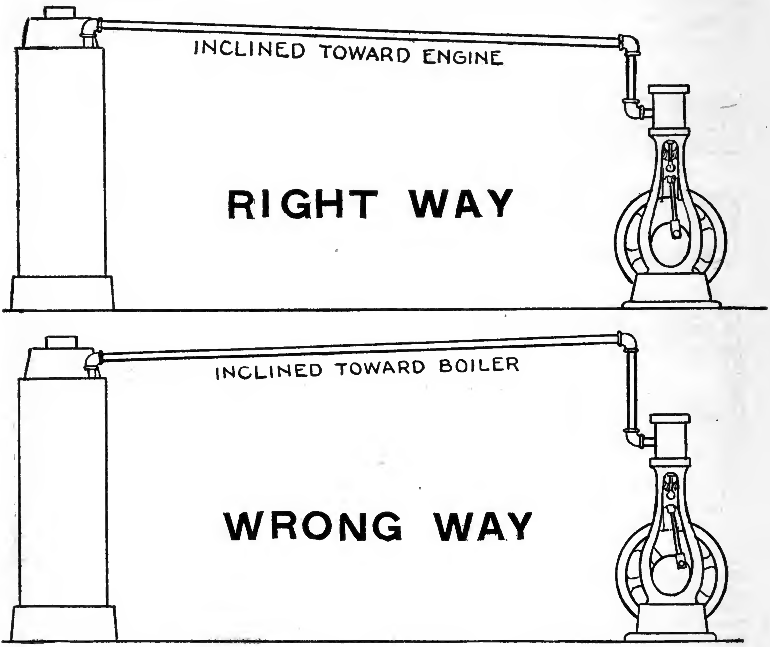
FIGS. 5,010 and 5,011.—Method of preventing vibration and of supporting pipes. The figures show top and side views of a main header carried in suitable frames fitted with adjustable roller. While the pipe is illustrated as resting on the adjustable roller, nevertheless the roller may also be placed at the sides or on top of the pipe to prevent vibration, or in cases where the thrust for a horizontal or vertical branch has to be provided for. This arrange ment will take care of the vibration without in any way preventing the free expansion and contraction of the pipe.

Corrosion.—If the feed water contain lime salts, the latter will deposit in the economizer and feed connection, and more or less effectually protect the pipes from internal corrosion, but if the water be free from lime, and air be introduced by the feed pump, internal pitting will be set up and probably do considerable damage before it is discovered and steps taken to prevent further mischief.

External corrosion does not as a rule, give much trouble, but under certain conditions the combined action of heat and moisture on asbestos pipe covering will set up pitting. This, however, can be prevented by painting the pipes with any good graphite paint, before the covering is applied.

Condensation.—To clean the system of condensate, the piping should be arranged according to the following suggestions:

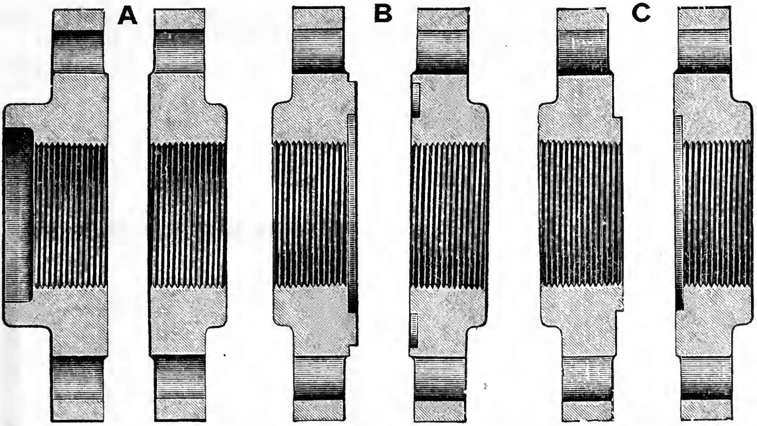
The pitch of all pipes should be in the direction of the flow of steam. Wherever a rise is necessary, a drain should be installed. All main headers and important branches should end in a drop leg and each such drop leg



FIGS. 5,012 and 5,013.—Right and wrong way to pitch main steam pipe between boiler and engine. *The pipe should always be pitched to draw toward engine* as in fig. 5,012, otherwise the condensate tending to return to boiler, as in fig. 5,013, is opposed by the flow of steam in the opposite direction, resulting in the accumulation of considerable condensate in the pipe, all of which, on a sudden demand for steam, may be forced into the cylinder as a solid slug of water with probably disastrous results.

and any low points in the system should be connected to the drainage pump. A similar connection should be made to every fitting where there is danger of a water pocket.

Branch lines should never be taken from the bottom of a main header but where possible should be taken from the top. Each engine supply pipe



FIGS. 5,014 to 5,019.—Three styles of flange connections. At **A**, the two smooth faces are brought together and bolted; at **B**, a circular lug fits into a circular channel, insuring tight joint; at **C**, the ends are cut so that one fits into the other.

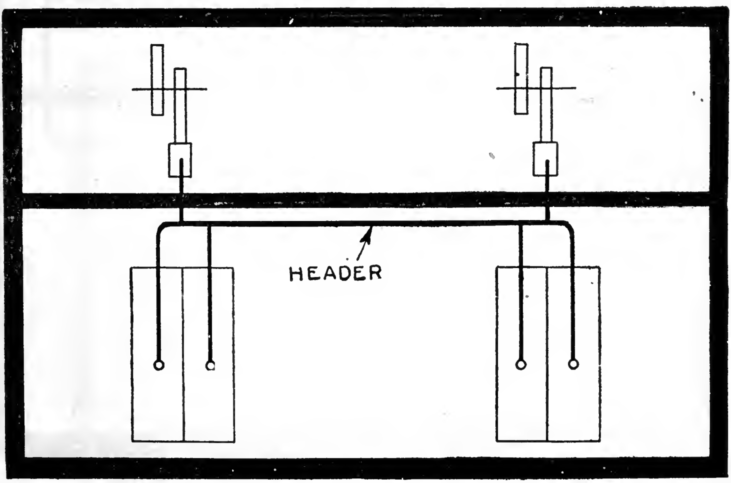


FIG. 5,020.—***Header*** system of piping. The header receives the boiler branches and the outlet to engines is from the middle, the header should increase in size from the ends at each branch connection to boiler, but for a very variable load it may at small additional expense be made same size throughout to act as a receiver.

should have its own separator placed as near the throttle as possible. Such separators should be drained to the drainage system.

Check valves are frequently placed in drain pipes to prevent steam entering any portion of the system that may be shut off.

Valves should be so located that they cannot form water pockets when either open or closed. Globe valves will form a water pocket in the piping to which they are connected unless set with the stem horizontal, while gate

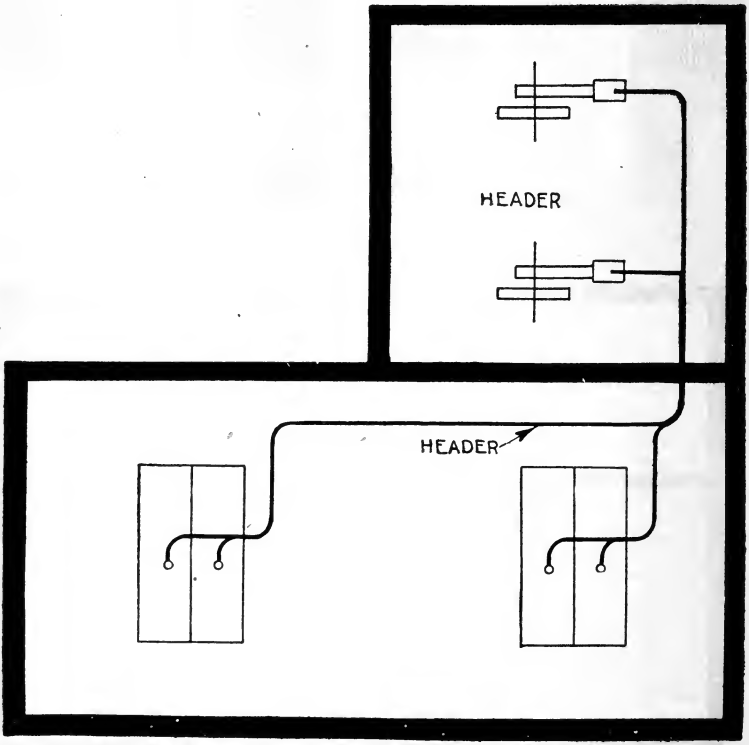


FIG. 5,021.—***Auxiliary header*** system of piping. Where boilers and engine are located as above a larger header is required than in fig. 5,020. The section farthest from the engine may be made just large enough to serve the branch connection to end boilers, and its size progressively enlarged at each branch connection. The reverse treatment may be applied to the header serving the engines, thus reducing radiation surface and cost.

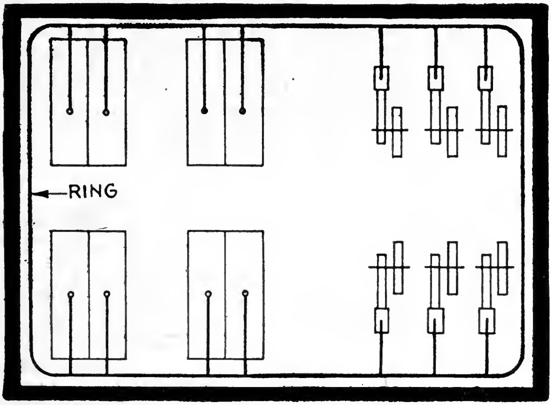


FIG. 5,022.—***Ring*** system. The only reason for installing such a system is to provide maximum insurance against complete breakdown. The system otherwise is objectionable in that it requires a multiplicity of valves, fittings, large amount of pipe, is expensive to install, and because of the large amount of radiation surface is very wasteful. With the high grade of piping materials now obtainable, the ring system is not so much in favor as formerly, and may now be considered as being extremely objectionable.

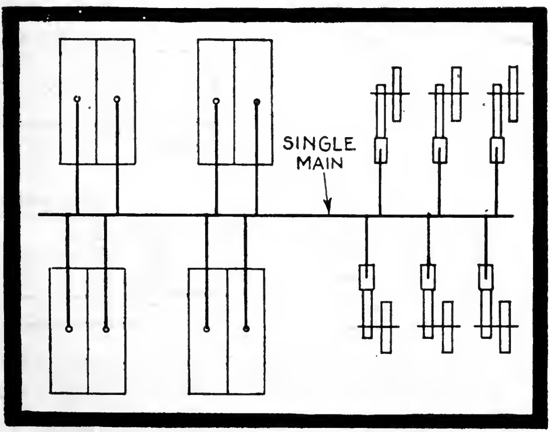
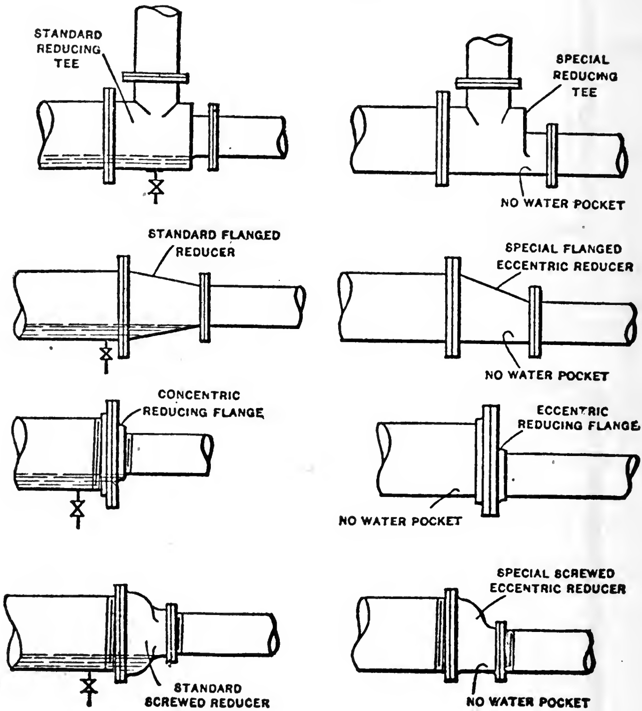


FIG. 5,023.—***Single main*** system. In contrast with the long length of pipe required for the ring system, here only a single main or header is used. This header may be conveniently suspended from the roof trusses. The arrangement as shown gives direct flow of steam from the boilers to the engines.

valves may be set with the spindle vertical or at an angle. Where valves are placed directly on the boiler nozzle, a drain should be provided above them.

High pressure drains should be trapped to both feed heaters and waste headers. Traps and meters should be provided with by passes. Cylinder



FIGS. 5,024 to 5,031.—Application of special fittings to avoid water pockets in pipe lines.

drains, heater blow offs and drains, boiler blow offs and similar lines should be led to waste. The ends of cylinder drains should not extend below the surface of water, for on starting up or on closing the throttle valve with the drains open, water may be drawn back into the cylinders.

READY REFERENCE INDEX

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