MACHINERY'S REFERENCE SERIES

EACH NUMBER IS A UNIT IN A SERIES ON ELECTRICAL AND STEAM ENGINEERING DRAWING AND MACHINE DESIGN AND SHOP PRACTICE

No. 69

A Dollar's Worth of Condensed Information

Feed Water Appliances

Price 25 Cents

CONTENTS

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FEED WATER APPLIANCES

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CHAPTER I

IMPURITIES IN FEED WATER FOR BOILERS

Pure water is a chemical compound made up of two parts hydrogen and one part oxygen, by volume, and weighs 62.4 pounds per cubic foot at a temperature of 62 degrees F. It is never found in a pure state under natural conditions, as it absorbs large quantities of various impurities in its passage through the air, and in filtering through the earth before it reaches the wells or streams from which it is drawn for use in boiler plants or for other purposes. The impurities commonly found in feed water may be classed under three heads, as follows:

1. Those causing the formation of scale; these impurities include calcium carbonate, calcium sulphate, magnesium carbonate, and magnesium sulphate.

2. Those having a corrosive action, such as sulphuric acid, carbonic acid, magnesium chloride, calcium chloride, and sulphate of iron.

3. Alkaline impurities; these include sodium carbonate, sodium sulphate, sodium chloride, potassium carbonate, potassium sulphate, and potassium chloride.

In addition to the above impurities may be mentioned various substances held in suspension, such as organic matter, mud, oil, etc.

Calcium carbonate is commonly known as carbonate of lime, and is found in the form of limestone, marble, or chalk. It is soluble in water containing carbonic acid gas (carbon dioxide), and is more soluble in cold than in hot water. It forms only a soft mud in boilers, unless cemented into a scale by the presence of calcium sulphate. In the case of economizers, where the water is at a comparatively low temperature, a hard scale is formed.

Calcium sulphate, or sulphate of lime, is most commonly known as gypsum or plaster of paris. It is soluble in water free from carbonic acid at moderately low temperatures. Calcium sulphate in the feed water causes a hard scale which is difficult to remove. When mixed with mud, or the sludge from calcium carbonate, it also forms a scale of considerable hardness. No scale is formed in the pipes of economizers by this substance, however, on account of the low temperature of the water.

Magnesium carbonate is commonly called magnesia, and is insoluble in pure water. It is held in solution if sufficient carbonic acid gas is present, the same as calcium carbonate, and is precipitated if this gas is driven off.

Magnesium sulphate (sulphate of magnesia or Epsom salts) dissolves very slowly in cold water, but dissolves easily in warm water. It is a very common substance, and does not of itself form scale, but when present with calcium carbonate, a chemical reaction takes place which produces hydrate of magnesia and calcium sulphate, resulting in the formation of a very hard scale.

Sulphuric acid is found largely in the drainage from coal and ore mines, and also comes from paper mills, galvanizing works, chemical works, oil refineries, etc. Its presence is indicated by a dark green tinge in the water. It becomes noticeable in the boiler after a short time by giving to the water a red color, due to a combination of the acid with the iron plates of the boiler. Nitric, tannic, and acetic acids have a similar effect, although much less pronounced.

Carbonic acid. Free carbon dioxide, or carbonic acid gas, is very corrosive to boiler plates. This most frequently comes from rotting organic matter which is present in the water.

Magnesium chloride. The corrosive effects of magnesium and calcium chlorides come from the chlorine which is liberated by certain chemical changes, and which is one of the causes of so-called pitting. Magnesium chloride is very soluble in water, and evolves heat when in solution.

Sodium carbonate. The carbonates of soda and potash, known as the alkali carbonates, are often the cause of *foaming* in the boiler. The common name of sodium carbonate is soda ash; it is soluble in water, and is one of the chemicals most frequently used in the prevention of scale and corrosion.

Sodium sulphate also produces foaming when present in excessive quantities. It can be removed by blowing off the boilers when the solution becomes too concentrated. The same also applies to the potassium salts.

Sodium chloride is common salt, and is readily soluble in water. Salt itself does no particular harm except to make the water harder to boil, on account of its greater density. If, however, it comes in contact with a dry hot plate it may "bake-on," and thus cause trouble. Sodium and potassium chlorides, when present in large quantities, are objectionable on the same grounds as other chlorides, that is, they may under certain conditions become decomposed and give up chlorine which is an active corrosive.

Other Impurities

Silica is never found in large quantities in boiler water, but is often combined with aluminum in the form of a jelly-like paste which may become baked into a hard crust or scale under the right conditions. Oxides of iron and aluminum are also found in some water supplies. The former is insoluble in water or in alkaline solutions; the latter is insoluble in acids but soluble in water. Water passing over the surface of the earth at a high velocity, or collected from a heavy rain fall, will contain matter in suspension, such as clay, sand, and mud, or it may contain organic matter either in suspension or in solution. Water into which sewage has been discharged will contain suspended matter, organic matter, salts and acids.

Water from Different Sources

The impurities found in feed water will vary to some extent according to the source from which it is taken. Water from streams changes from season to season, and sometimes from day to day. In wet seasons, and just after rains, the water may be comparatively pure, having been well diluted, unless the rainfall has been sufficient to wash in sticks, leaves, mud, sand, etc. The chief danger from swift running streams is the presence of vegetable and animal matter, which will generate organic acids corroding the tubes and plates. Chemical reaction in animal matter is also likely to develop free oxygen, which has practically the same corrosive action.

Earthy matter is largely insoluble and can be easily removed by filtering. This material does no particular harm unless it becomes mixed with other substances which cement it into a hard scale. Animal matter and sewage nearly always contain acids, and oil and grease, which coat the heating surfaces and prevent the free transmission of heat. In mountain streams the water is usually pure and only requires filtering to make it safe for use. The fact that water appears to be pure is no sign that it does not contain injurious ingredients, as it is often the case that samples containing large amounts of the salts of lime and magnesia are clear and sparkling.

Water taken from reservoirs is likely to be more uniform in its composition than that taken directly from a stream, both because of its being a mixture from different streams, and because of the opportunity afforded the suspended matter to settle before the water is used. Well water and water taken from streams during dry seasons is the most likely to contain various salts in solution, because it has leached through the soil and taken up the maximum amount of mineral matter. When water is scarce, and especially when the exhaust steam is used in heating systems, the condensation is often used for feeding the boilers. This is free from mineral salts and other impurities which are commonly found in fresh water, but contains oil from the engine cylinders which must be carefully removed.

It has been stated in a general way that the presence of the various impurities above mentioned are productive of scale or incrustation, corrosion, and foaming. These effects will now be taken up in detail.

Incrustation

One of the results of incrustation is to increase the resistance to the passage of heat through the boiler plates from the fire to the water. Table I gives a conservative estimate of the additional fuel required when the heating surfaces are evenly covered with scale. Another objectional result from the formation of scale or incrustation is the liability of damage to the boiler by overheating the plates and tubes. This may occur in two ways. When the carbonates of lime and magnesia are present, they first appear in the form of a light powder held in suspension or covering the surface of the water as a scum. If oil becomes mixed with this it will offer a considerable resistance to the escape of the steam bubbles formed below. In some cases this is sufficient to form a layer of steam next to the plates which will lift the water away from them and allow them to become overheated and often seriously damaged. Again, similar results may take place if the sediment becomes baked onto the heating surfaces in the form of a hard scale. This deposit, by separating the water from the metal, causes a constant increase in the temperature of the latter as the accumulation increases, and often produces results similar to those mentioned in the first case.

Incrustation is principally caused by the throwing down, or precipitation, of the carbonates and sulphates of lime and magnesia when the water is heated in the boiler. The carbonates are held in solution by the presence of carbonic acid gas in the water. When this is driven off by the heat, they become insoluble and appear in the form of light flakes or threads which slowly settle to the bottom of the boiler as a thin mud or sludge. In this condition they may be easily removed, but if allowed to remain, they are likely to become mixed with oil, sand, or

TABLE I. ADDITIONAL FUEL REQUIRED DUE TO SCALE

Thickness of Scale, Inches	Additional Fuel Required, Per Cent	Thickness of Scale, Inches	Additional Fuel Required, Per Cent
$\frac{1}{32}$	4	$\frac{3}{8}$	48
$\frac{1}{16}$	9	$\frac{1}{2}$	60
$\frac{1}{8}$	18	$\frac{3}{4}$	90
$\frac{1}{4}$	38		

some of the sulphates, and become baked onto the hot plates in the form of a hard scale. It may also be mentioned that if the precipitate is not promptly removed, the water may re-absorb carbonic acid gas from the atmosphere or some other source, and the carbonates be again dissolved. The precipitation of the carbonates is practically complete at 212 degrees F.

The sulphates of lime and magnesia are soluble in cold water, but become insoluble and are precipitated at a temperature of about 300 degrees F. This action, however, is a gradual one, and extends over a considerable period, including temperatures both below and above 300 degrees. The sulphates settle rapidly, and unless quickly blown out, will form a hard scale upon the plates which is difficult to remove. The action of the chlorides and nitrates of lime and magnesia is similar to that of the sulphates, although they are less common in the average feed water.

Corrosion

Corrosive impurities are not as common as those which form scale, but are very destructive when present. They act on the interior surfaces of both shell and crown sheets, and are especially destructive to the tubes when they enter the headers. The action is rapid and not easily discovered, which makes it important to neutralize these elements before they enter the boiler.

The most important of the corrosive impurities have already been mentioned, and include sulphuric acid, carbonic acid, sulphate of iron, and the chlorides of lime and magnesium. Corrosion is commonly classed under three heads, known as general corrosion or wasting; pitting or honey-combing; and grooving. The first two are the direct results of chemical action, while the third is due to both chemical and mechanical action.

General corrosion or wasting acts in a uniform manner over a large surface, and is therefore difficult to detect. Sometimes the action is confined to a narrow belt at the water level, or to a few rivets in a seam, or a small section of the plate. The braces and stays are especially liable to the effects of wasting and require regular inspection. The only way to definitely determine the reduction in thickness of the shells from this cause is to drill the plates, and measure them, plugging the holes afterward.

Pitting is the formation of conical or spherical holes, either filled with a yellowish brown powder or empty. Pitting is caused by the action of oxygen released from the water as it is heated, or from the chlorine given up by organic matter and the chlorides. It is most active at moderate temperatures, and as the corrosive gases are released on heating, it most frequently occurs near the inlet of the boiler or heater. It is not usually found in the steam space except when a boiler is left idle for some time so that it sweats, and drops of water stand on the shell. When the holes are small and close together, pitting is given the name honey-combing.

Grooving is a difficulty of the same nature as pitting, but takes place at points in the shell where there is local bending caused by the expansion and contraction of the plates, due to the changes in steam pressure. Grooving commonly takes place on the heads around the edge of the angle iron, or in the root of the angle itself; it is also found in the seams and at the bend in a plate. This form of injury is especially dangerous, because it may become covered with scale, and is therefore difficult to locate. Grooving is often caused by excessive calking, which impairs the surface of the metal and exposes it to the corrosive elements in the water. The appearance of grooving is that of a fine line or crack, which, on account of its minuteness, is very difficult to discover. Cracks of this kind should be watched for as much in live steam heaters and piping as in the boiler.

Foaming

Foaming is caused by the presence of suspended matter in the water and also, to a certain extent, by the presence of oil. The alkaline salts of soda and potash may also produce the same result when found in the feed water in sufficient quantities. The direct cause of foaming is due to an increase in the surface tension of the water in the boiler. This requires a greater force for the bubbles of steam to burst through, and results in the churning of the top of the water into a foam, sometimes filling the steam space and passing over into the mains.

Classification of Feed Waters

Feed waters are commonly classified according to the quantity of incrusting solids which they contain per gallon, called the degree of hardness. Hardness is designated as *temporary* and *permanent.* The former is due to the carbonates of lime and magnesia which are precipitated by heating the water to a temperature of 212 degrees F. The second form of hardness is due to the sulphates, chlorides and nitrates of the same salts. These are not precipitated until a temperature of 300 degrees F. or more has been reached.

In classifying a water as to its value for boiler feeding, the following schedule may be used, qualifying it somewhat according to the impurities contained which determine its hardness.

TABLE II. CLASSIFICATION OF FEED WATERS

8 grains of incrusting solids per gallon	Good.
8 to 15 grains of incrusting solids per gallon	Fair.
15 to 20 grains of incrusting solids per gallon	Poor.
20 to 30 grains of incrusting solids per gallon	Bad.
30 to 40 grains of incrusting solids per gallon	Very Bad.

Testing Feed Water

Tests of feed water, which are to serve as a basis for its treatment, should in all important cases by made by an expert chemist. There are, however, simple tests which may be carried out with more or less accuracy by the engineer, and which will serve to show the general character of the water and indicate whether or not the services of an expert are necessary. The tests usually conducted in this manner are for hardness, for acidity or alkaline reaction, for both suspended and total solids, and for oil. To these may be added special tests for sulphate of lime, magnesia, carbonic acid, iron, lead, and copper.

A simple test for hardness is that known as the soap test. This requires a graduated burette for measuring liquids, and a bottle of standard soap solution which may be obtained from any chemist. In making this test, 50 cubic centimeters of the water are placed in a bottle and about 0.3 of a cubic centimeter of the soap solution added at a time, and the bottle thoroughly shaken and laid on its side between each addition. When a stiff lather or suds, ¼ inch in thickness remains over the entire surface of the water for 5 minutes it indicates that the carbonate of lime has been neutralized, and the parts in 100,000 parts of water can be determined from Table III. This test only gives the degree of hardness and does not indicate the presence of other impurities. It is also unreliable above 14 parts in 100,000, owing to the action of the alcohol contained in the soap solution.

When a scum forms on the surface while the body of water below remains clear, the lather is not a true one and should be disregarded. When the real lather appears, the water will be permanently opaque. When a thick lather is formed which disappears after 2 or 3 minutes and cannot be produced by shaking again until more soap is added, it indicates the presence of magnesia.

Another test for hardness requires a small bottle of a standard solution of hydrochloric acid, one-fifth normal strength, and a small amount of methyl-orange. In making the test, 200 cubic centimeters of the water are placed in a porcelain vessel and 2 drops of methyl-orange added. The standard acid solution is now added drop by drop from a burette, and the solution stirred constantly until its color changes from yellow, through orange, to a faint pink. The number of cubic centimeters used, multiplied by 9.5, will give the parts of carbonate of lime in 100,000 parts of water.

Acid Test

A preliminary test to determine whether a water is acid or alkaline is made with litmus paper; this, when dipped in the water will be red, if it is acid, and blue if alkaline. If neutral, no change will take place. The acid test is made in a manner similar to the test for hardness just described, except that phenol-phthalein and a standard

TABLE III. DATA FOR TESTING HARDNESS OF FEED WATER

Cubic Centimeters of Soap Solution in 50 Cubic Centimeters of Water	Parts of Carbonate of Lime in 100,000 Parts of Water	Cubic Centimeters of Soap Solution in 50 Cubic Centimeters of Water	Parts of Carbonate of Lime in 100,000 Parts of Water
1	0.48	6	7.43
2	1.95	7	8.86
3	3.25	8	10.30
4	4.57	9	11.80
5	6.00	10	13.31

alkaline solution are used in place of the methyl-orange and standard acid solution, respectively. The alkaline solution is added drop by drop until the color of the water changes to a purple red. The number of cubic centimeters of alkaline solution used in 200 cubic centimeters of water, multiplied by 9.58, gives the parts of acid in 100,000 parts of water.

Tests for Suspended and Total Solids

The test for suspended solids is made by passing 200 cubic centimeters of the water through a filter paper, previously dried and weighed; then drying and weighing again and noting the increase in weight. The gain in weight in grams, multiplied by 500, gives the number of parts of suspended matter in 100,000 parts of water. If the dried matter is red in color, it indicates iron oxide, while a gray color indicates clay.

The total solids are obtained by evaporating 250 cubic centimeters of the water in a platinum dish over a water bath. The residue which remains is then dried in an oven at a temperature of 300 degrees F. for 3 hours, then cooled in the presence of chloride of lime to prevent the absorption of moisture, and finally weighed. The weight of the residue in grams, multiplied by 400, will give the number of parts of solid matter in 100,000 parts of water.

Test for Oil

In cases where the condensation from an exhaust steam heating system is returned to the boilers, it is often desirable to test the water for oil to see if the separators are working satisfactorily. In making this test, a sample of the water is cooled, and 250 cubic centimeters are placed in a separating funnel with 25 cubic centimeters of ether and thoroughly shaken. The funnel is then placed in an upright position and allowed to stand for fifteen or twenty minutes, after which the water is drawn off by means of the separating cock at the bottom. The ether solution floating on the water, and which contains all of the oil, is placed in a porcelain dish and evaporated over a water bath heated by steam. No open flame should be allowed in the room, as the ether vapor is very inflammable. The solution evaporates quickly, leaving any oil which may be present in the bottom of the dish. It is not usually customary to measure the oil thus found, as any amount detected in this manner is undesirable.

Tests for Other Impurities

Simple tests for other impurities found more or less frequently in feed water may be made as described in the following. To test for sulphate of lime, place about 1½ inch of water in a test tube and add a small quantity of chloride of barium. If a white precipitate is formed, which will not disappear upon the addition of nitric acid, it indicates the presence of sulphate of lime.

To test for magnesia, place the same amount of water in a test tube as in the previous test, and bring to a boiling temperature, adding small quantities of carbonate of ammonia and phosphate of soda. Then set the solution aside to cool. Magnesia, if present, is indicated by a white precipitate.

When testing for lead, place a sample of the water in a test tube and add a small quantity of dilute sulphuric acid. A white precipitate indicates the presence of lead. If the water in a test tube turns blue upon the addition of a drop of ferro-cyanide, it shows that iron is present. Copper is indicated by a blue color upon the addition of ammonia water.

To test for carbonic acid, place equal parts of lime water and the water to be tested in a test tube. If the mixture becomes milky, it indicates the presence of carbonic acid. The milkiness should disappear upon adding a small amount of hydrochloric acid. In order to make all these tests of any value, the greatest care should be taken in making all measurements, as the quantities of water used are small and the amount of contained impurities very minute.

CHAPTER II

PURIFICATION OF FEED WATER

Having taken up the impurities most frequently found in feed water together with the methods of their detection, the means commonly employed for their elimination will now be considered. The methods employed for this purpose may be classed under three general heads as follows: by filtering; by heat; and by the use of chemicals. The character of the water will indicate whether one or more of these processes must be resorted to.

Purification by mechanical means is employed only where the impurities are suspended in the water, as mud, sand, oil, vegetable matter, sewage, etc., and may be accomplished in three ways according to the substances present, and the available space for the apparatus.

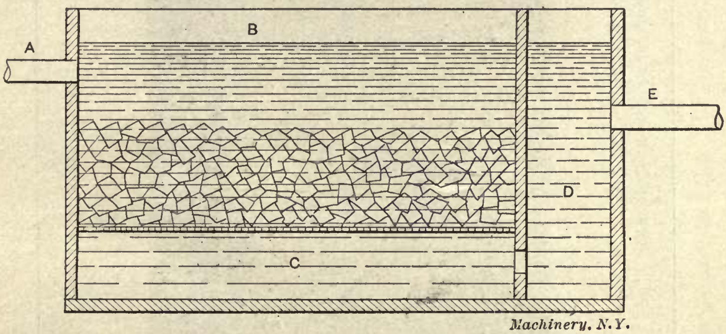


Fig. 1. Simple Form of Filter for Feed Water

The methods commonly employed for this purpose are: Settling in large tanks; filtration; and skimming. Water from streams containing sawdust, chips, sticks, etc., requires simply a strainer over the suction pipe to the pump, if no other impurities are present.

Settling Tanks

In the case of shallow running streams, the water is apt to contain clay, sand, and other sediment, which will readily settle if allowed to remain quiet for a sufficient length of time. This is accomplished by means of settling tanks in which the water remains with little or no circulation while the sediment is precipitated by gravity. When this method is employed, there should be at least two tanks or reservoirs, so that while water is being taken from one the other is undisturbed. The connections with tanks of this kind are so made that the sediment is drawn off from the bottom and the clear water taken from the upper part. The space occupied by tanks and the time required for settling are the principal objections to this method, and make it impractical for large plants.

Filters

River water often contains the discharge from sewers, fine sand, or other fine particles which will readily pass through the finest strainer and also float in still water. In cases of this kind some form of filter

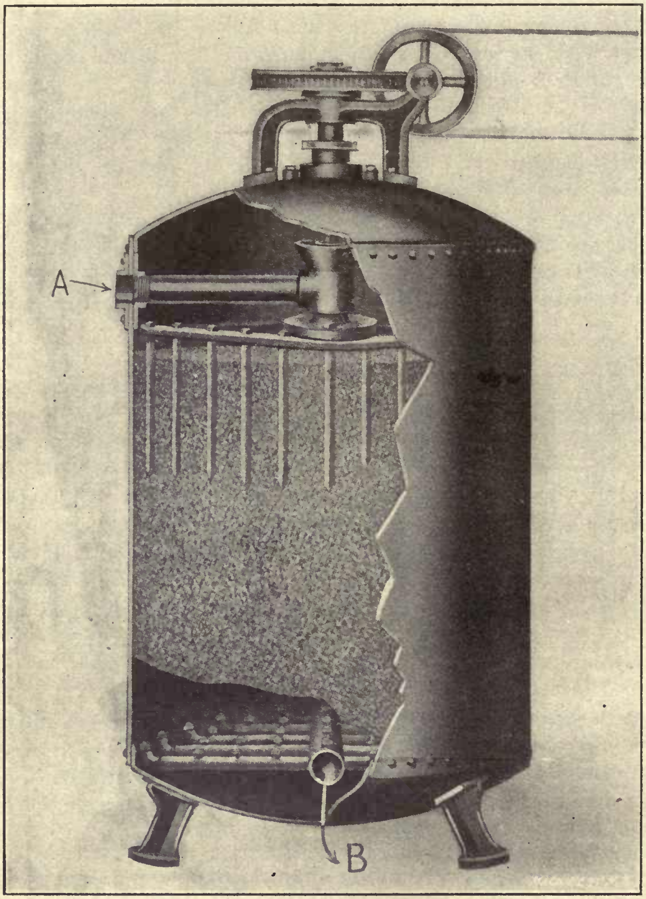


Fig. 2. Type of Feed-water Filter known as "Pressure" Filter

is necessary. Filters are usually composed of crushed quartz, coke or charcoal, excelsior, burlap, or other porous material which will pack closely and present a rough surface to which the particles of solid material will readily adhere. There are many forms of filters in use, one of the simplest being shown in Fig. 1. This consists of a wooden tank having three compartments as shown. The main compartment *B* has a perforated bottom which supports a bed of coke.

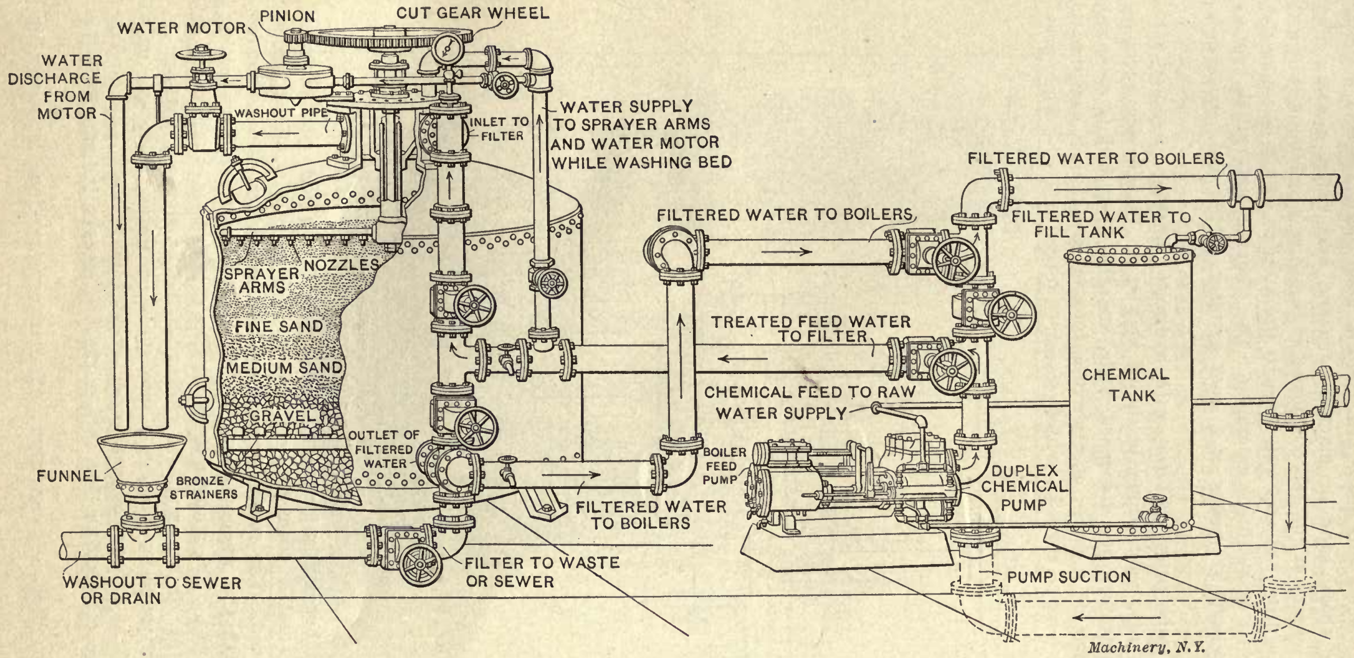


Fig. 3. The Keystone Pressure Filter

The water enters at *A* and passes through the filter into compartment *C*, from which it passes into *D* and is then drawn by the pump through the pipe *E*. Particles of coke or sand which may be carried through the filter will collect in the bottom of chamber *D*.

Another form, known as a pressure filter, is shown in

Fig. 2. The shell and heads are made of steel plate, and the filtering material is sharp sand or machine crushed and sifted quartz. The feed water enters at the top by means of the pipe *A*, passes downward through the filter bed and out through the pipe *B*, which is connected with a system of strainers as shown. The filtering material is broken up and cleansed by means of a steel agitator driven by a worm-gear at the top.

The Keystone pressure filter, with hydraulic agitator, together with its various pipe connections, is shown in Fig. 3. In this arrangement the steel agitators are dispensed with, and the filter bed is cleansed by the action of a series of revolving sprayer arms, each carrying a number of nozzles through which water is forced under a high pres-

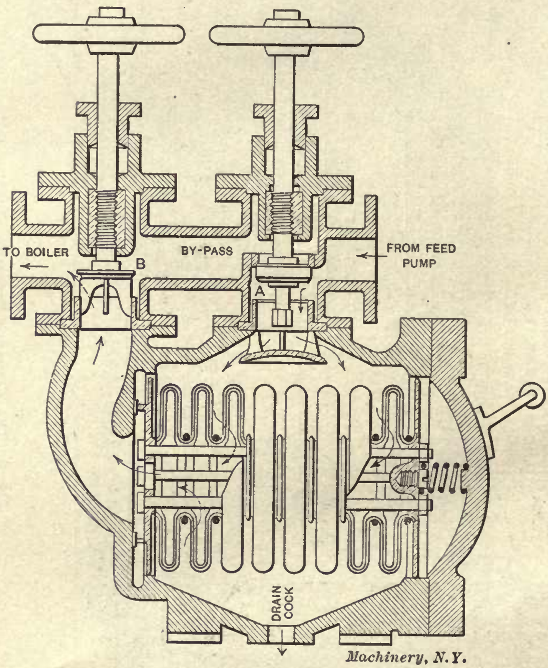


Fig. 4. The Ross Feed-water Filter

sure. This thoroughly breaks up the surface of the filter and removes the organic matter from the particles of sand by the scouring action thus produced. The water containing the impurities thus removed flows through the washout pipe at the top into a funnel connecting with the sewer. The sprayer arms may be driven by a small water or electric motor, or by hand. In the arrangement shown, provision is made for introducing chemicals into the feed water by means of a small chemical pump attached to the regular boiler feed pump. The various pipe connections for this outfit are clearly indicated in the engraving.

The Ross filter, of somewhat different construction, is shown in

Fig. 4. In this case the filtering portion of the apparatus occupies the lower chamber, and consists of a corrugated cylinder built up of bronze sections covered with a long bag of Turkish toweling which is drawn down between the sections by means of cords, as indicated in the engraving. This manifolding of the toweling gives a large area for the water to pass through, ranging from 250 to 1000 times that of the feed pipe, and thus causes a low velocity of flow. The passage of the water through the filter is shown by the arrows, the entrance being through valve *A* and the outlet through *B*. As the impurities collect on the outside of the toweling the resistance to the flow of water increases and is indicated by pressure gages connecting with

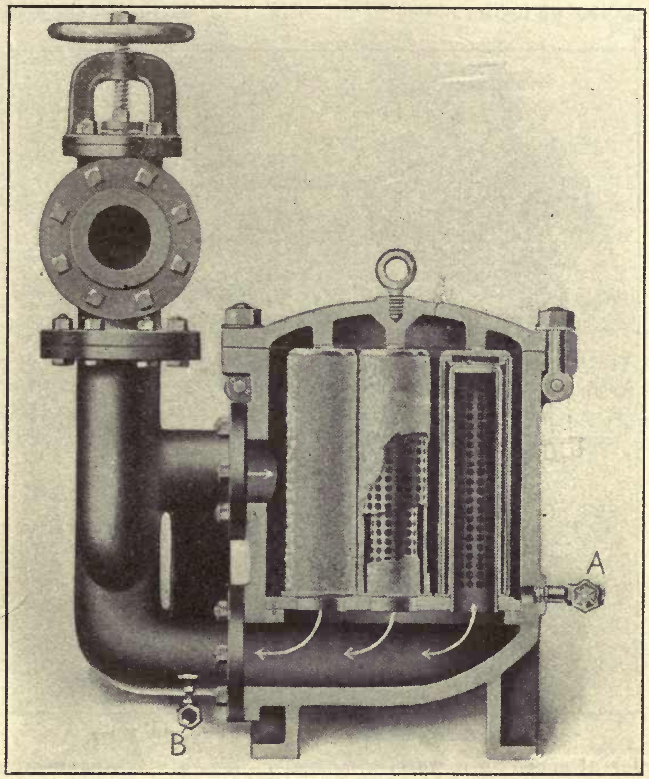


Fig. 5. Sectional View of the Blackburn-Smith Filter

each side of the filter. When the pressure difference reaches 2 or 3 pounds, the filter may be cleaned by reversing the flow of water through it by manipulation of the valves *A* and *B*, which are designed especially for this purpose.

Interior and exterior views of the Blackburn-Smith filter are shown in Figs. 5 and 6, respectively. This differs from the one just described chiefly in the form of the filter, which consists of Terry cloth drawn over perforated metal cylinders as shown in Fig. 5. The construction of these is such that double filtration is secured through two independent surfaces. The number of cylinders used varies with the size of the unit. The accumulation of foreign material is indicated by the pressure gages shown in Fig. 6, and when the pressure difference upon the two sides reaches a given point the filters are removed and cleaned. Heavy impurities which may at times settle to the bottom of the filtering chamber may be blown out through the sludge valve *A* by admitting live steam through the pipe *B*.

Skimming Devices

The skimming process may take place either in a chamber outside of the boiler or in the boiler itself. Fig. 7 shows the Buckeye floating

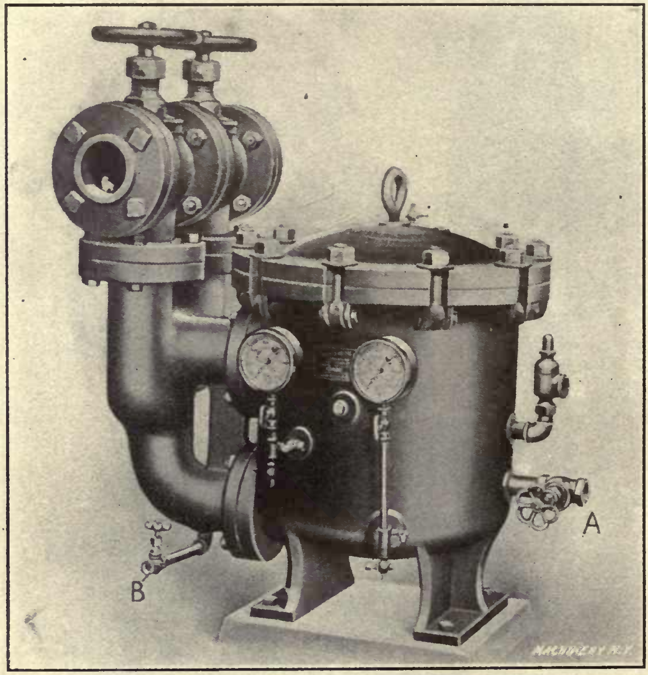


Fig. 6. Exterior View of the Blackburn-Smith Filter

skimmer attached to a water-tube boiler. In this arrangement a funnel, supported by floats, rests upon the surface of the water with the opening toward the front. As the circulation is toward the rear, the scum upon the surface is carried into the funnel, and by means of an external pipe into a separator or settling tank *A*, at the rear of the boiler. The circulation through the connecting pipes is indicated by the arrows, and is maintained by the difference in temperature of the water in the upper and lower pipes. The settling tank contains an interior chamber, open at the bottom and closed at the top. The scum is delivered above this and the pure water drawn off from the top of the interior chamber. A detail of the skimmer and its supporting floats is shown in Fig. 8.

Oil Separators

In order to purify the exhaust steam so that its condensation may be returned to the boilers, it is necessary to use some form of separator

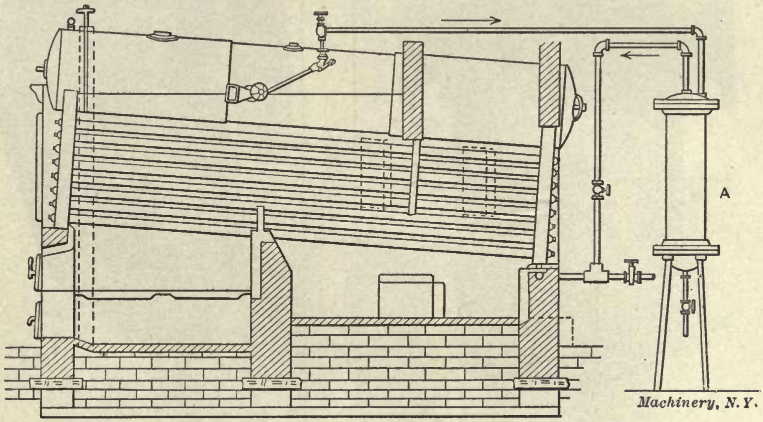


Fig. 7. The Buckeye Floating Skimmer applied to a Water-tube Boiler

for removing the cylinder oil which it contains. There are various forms of separators in common use, some of the distinctive types being shown in Figs. 9 to 17, inclusive. The interior construction of the Pittsburgh separator is shown in Fig. 9. The entering steam is thrown downward upon an annular ring having a corrugated surface and an

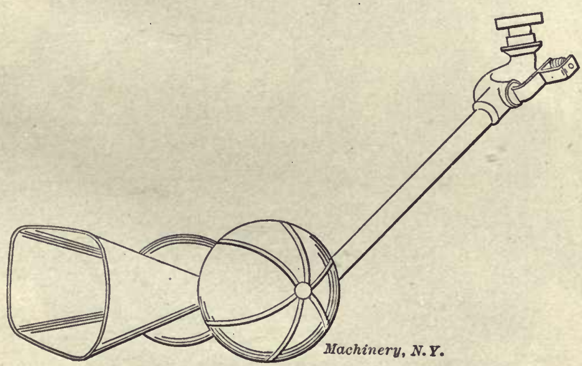


Fig. 8. Detail View of the Buckeye Skimmer

opening at the center. The outlet is downward from a point near the top, as indicated. This peculiar construction completely changes the direction of the steam, reduces its velocity, and thus allows the particles of oil to be caught by the corrugations upon the annular ring or baffle. As the oil collects it drips into the bottom of the chamber from which it is trapped to the sewer or sump well through the drip pipe at the lower end.

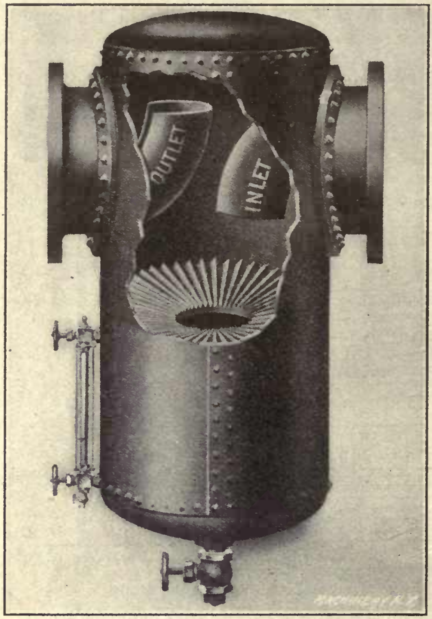


Fig. 9. Construction of the Pittsburgh Oil Separator

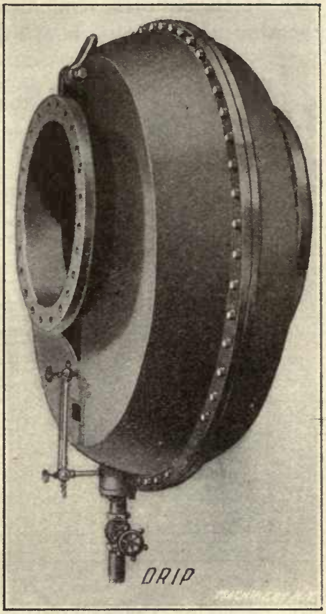


Fig. 10. The Cochrane Oil Separator

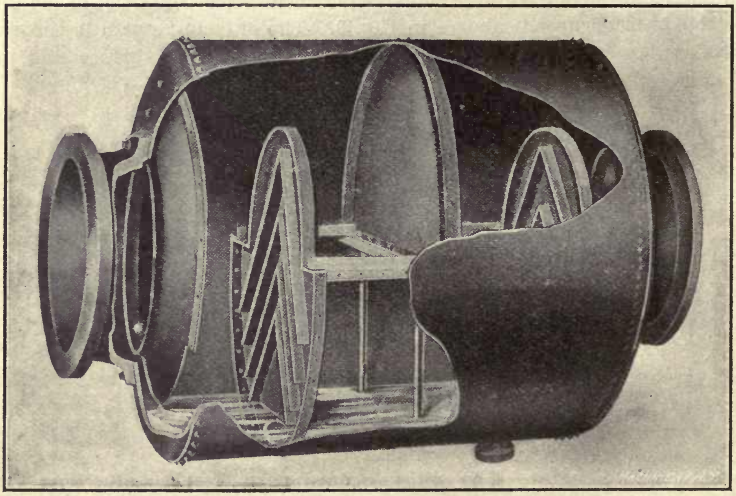


Fig. 11 The Hoppes Oil Separator

In the Webster separator, shown in section in Fig. 12, the operating principle is a combination of centrifugal force, adhesion, and the impact of particles of oil against the baffle plates, which are set at right angles to the flow of steam. The steam takes a zig-zag course without material loss of pressure, and the oil is caught on the surfaces of the baffles and flows down through suitable openings in the bottom of the baffle section to the receiver below.

The Cochrane oil separator for non-condensing systems is illustrated in Fig. 10. The separating surface consists of a baffle plate with vertical ridges, and ports at the sides for the passage of steam. This is more clearly shown in Fig. 13, which is a horizontal section through the main inlet and outlet ports. The principle depended upon in the

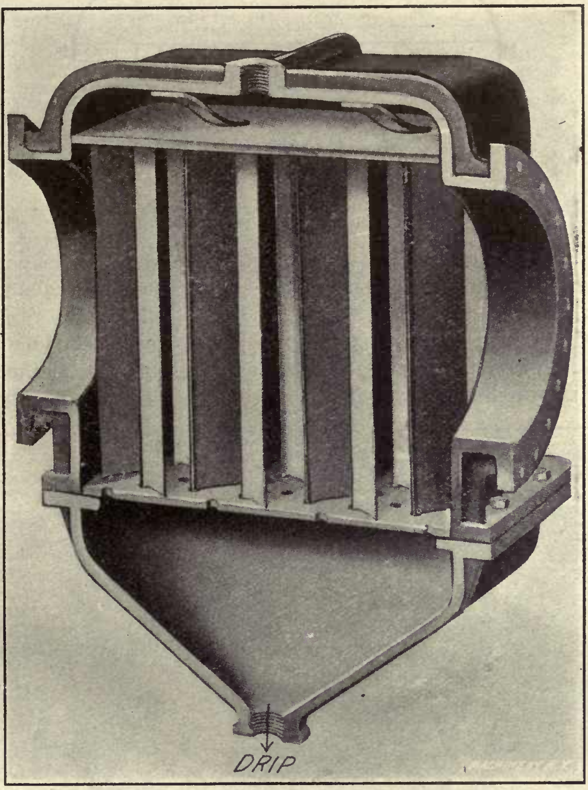


Fig. 12. The Webster Oil Separator

action of this separator is a sudden change of direction. The fact that the greater part of the oil contained in the steam runs along the lower surface of the pipes is taken advantage of, and the separator is so designed that it will break up the flow and drain the oil into a receptacle provided for it. The area of the ports at the sides of the baffle plate is made large, so that there will be little, if any, reduction in the steam pressure. In some types of separators a large chamber or expansion tank is provided to reduce the velocity of the steam, and also to equalize the pressure between the strokes of the engine.

The Hoppes separator shown in Fig. 11 has a comparatively large body. The elimination of the oil is effected by three baffle plates arranged as shown in the illustration. The construction is of steel plate, with the exception of the flanged ends, which are of cast iron. The Utility separator, Fig. 14, makes use of a series of chains hung in steel

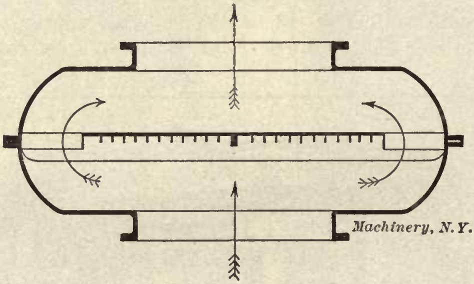


Fig. 13. Horizontal Section through Oil Separator in Fig. 10

frames in place of the usual form of baffle plate. The body of the separator is of large size, serving as an expansion or equalizing tank as well.

The Cochrane separator of the expansion type is shown in Fig. 15. This illustration is of special interest as showing the method of making the steam connections with a separator of this kind. By-pass and

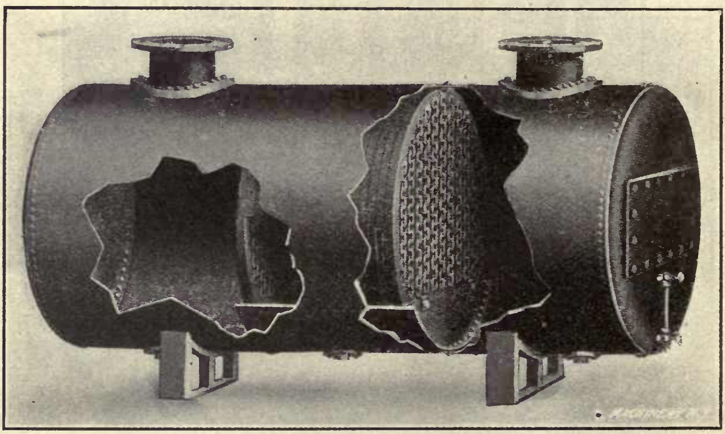


Fig. 14. The Utility Oil Separator

cut-out valves are provided so that the separator may be cut out of service for cleaning or repairs when necessary.

Vacuum Separators

The separators thus far described have been for use with non-condensing engines, where the pressure is slightly above that of the atmosphere. In cases of this kind the oil is drained from the separator by means of an ordinary steam trap. When the engine is run condensing, in connection with a surface condenser, and it is desired to return the water of condensation to the boilers, it is evident that the oil cannot be drained from the separator in the usual manner because the pressure in the system is less than that of the atmosphere. Although the separator itself is practically the same, except in special cases, the method of draining it is radically different.

There are several ways of doing this, one of which, the Hoppes equipment, is shown in Fig. 16. In this arrangement a receiving

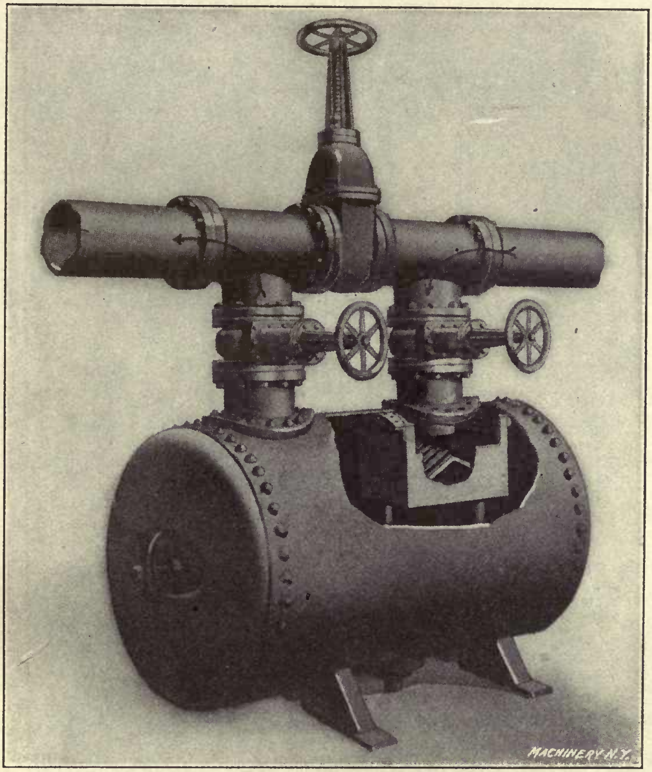


Fig. 15. Cochrane Oil Separator of the Expansion Type

tank of large size is placed beneath the receiver and connections made as shown. Pipe *A* is an equalizing pipe connected into the exhaust main; *B*, the drip from the separator; *C*, a high-pressure steam connection, into which is connected an alarm whistle operated by a float within the tank; and *D*, a blow-off or drain connection with the sewer. In operation, the valves *A* and *B* are open, while *C* and *D* are closed. As the separator and tank are under the same pressure, the oil and moisture are removed from the steam drain into the tank by gravity through *B*. When the tank becomes nearly full, the inside float rises to a point sufficiently high to open the whistle and give the alarm. The valves *A* and *B* are then closed, and *C* and *D* opened, and the contents of the tank blown into the sewer.

Other arrangements which are entirely automatic employ a return trap or a vacuum pump in place of the tank. The Austin vacuum separator is of the latter type. In this case the separator itself is different from the ordinary form used with non-condensing engines, in that it is provided with a water spray for keeping the baffle plate wet

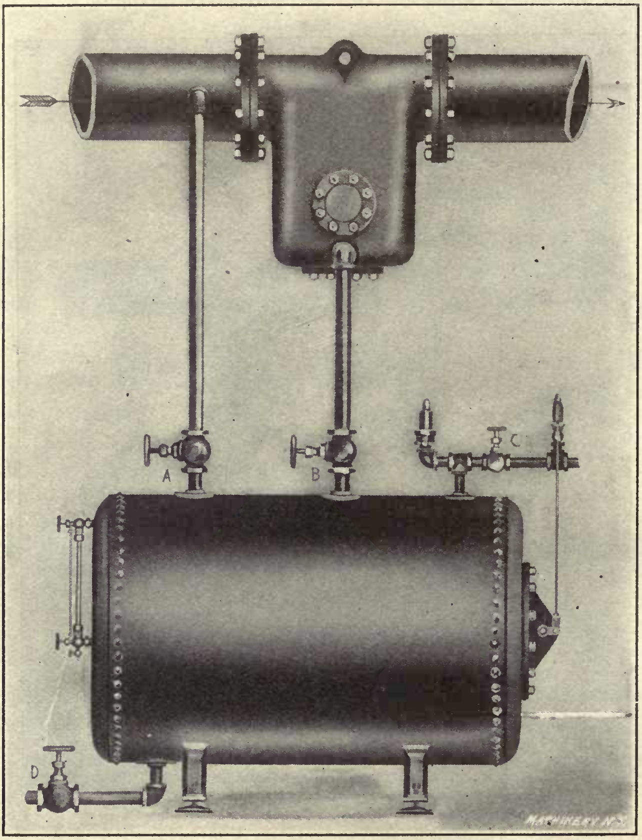


Fig. 16. The Hoppes Oil Separator for Condensing Engines

at all times, as shown in Fig. 17. It has been found by experience that the successful operation of a separator to be used under a high vacuum depends largely upon keeping the baffle plates moist. If these become dry, the oil is repelled and carried along with the steam into the condenser; hence the device mentioned is addeu to the separator when used under these conditions.

Purification by Heat

The heat purification method is used when the water contains the carbonates of lime and magnesia in combination with carbonic acid (called bicarbonates), and also when the sulphates of lime and magnesia are present. As previously stated, these carbonates are soluble only when carbonic acid is present; hence if this be removed, the bicarbonates are changed to insoluble carbonates which are precipitated in the form of a soft sludge or mud which may be easily removed from the bottom of the vessel containing the water, if done at the proper time. The removal of the carbonic acid may be brought about by heating the water, or by the use of certain chemicals. Although precipitation may take place by heating the water within the boiler itself, it is much better that this process take place in a chamber or vessel outside the boiler, especially designed for the easy removal of the precipitation thus formed. In practice this is commonly done in open feed-water heaters, live steam purifiers, and in some cases, in water softening devices.

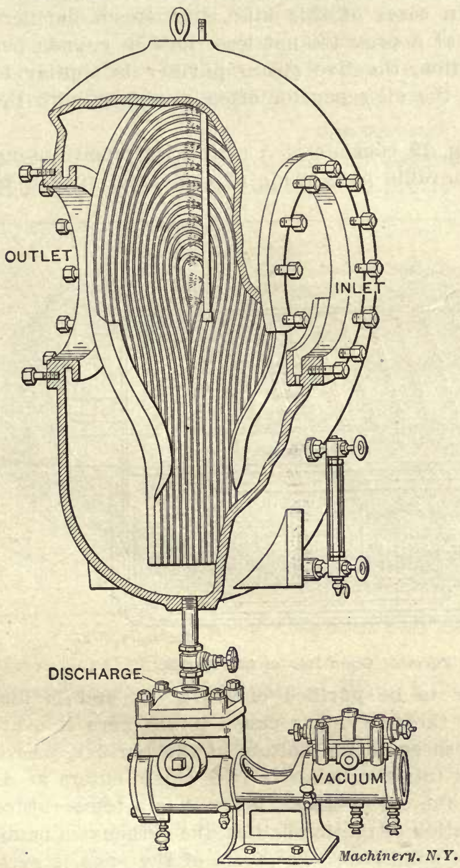


Fig. 17. The Austin Vacuum Oil Separator

Open Heaters

In case of the carbonate of lime and magnesia, which are precipitated at a temperature of 212 degrees F., an open feed-water heater using exhaust steam is commonly used. A typical form of heater and purifier of this type is shown in Fig. 18. The cold feed water is supplied at the right near the top of the heating chamber, where it flows in thin sheets over a series of trays. It thus becomes heated by direct contact with the steam, and its temperature is raised sufficiently to cause a precipitation of the carbonates. The water then passes through a coke filter and is brought to comparative rest in a settling chamber, before being drawn off by the pumps. The impurities which are thrown down, collect upon the pans and filter, and are removed from time to time through openings provided for this purpose.

Live Steam Purifiers

When the water contains the sulphates of lime and magnesia alone, or in addition to the carbonates, it must be heated to a higher temperature than can be obtained by the use of exhaust steam, about 300 degrees F. being required. In cases of this kind, live steam purifiers are employed, using steam at a pressure not less than 50 pounds per square inch. In construction, the live steam purifier is similar to the open heater, except for the oil separator often combined with the latter.

The purifier shown in Fig. 19 consists of a cylindrical shell having the interior fitted with removable pans made of thin steel riveted to

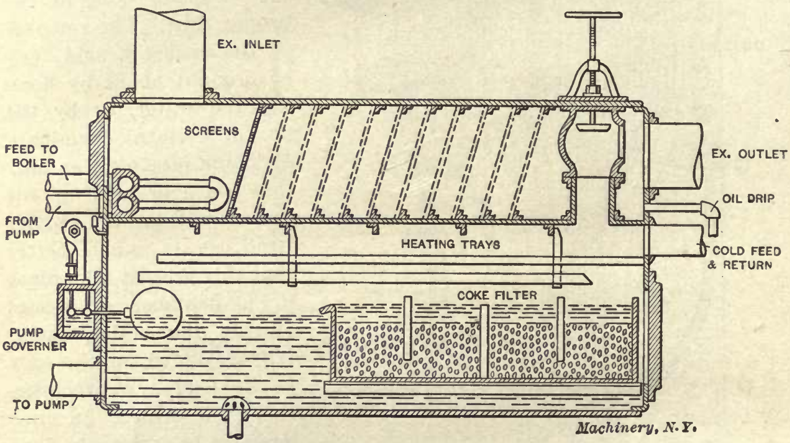


Fig. 18. Typical Form of Open Heater and Purifier

cast-iron heads. The water to be purified enters at *B*, and is discharged into the centers of the two upper pans. From here it overflows into those below, and so on to the bottom of the purifier, where it is drawn off at *D* and fed into the boilers. Live steam enters at *A*, and coming in contact with the cooler water, heats it to a temperature sufficient to cause a precipitation of the impurities, the carbonates being separated first, and then the sulphates. The form of the pans is such that as the water overflows it adheres to the under side in a thin sheet. The precipitated impurities accumulate upon both sides of the pans, although in greater quantities upon the under side, and are removed from time to time.

Purifiers of this type, to be the most efficient, must have ample capacity, it being customary to allow about ½ square foot of lime catching surface for each boiler horsepower. In using this method of purification it must be borne in mind that heating the feed water will only remove those impurities specifically mentioned in connection with this particular method of treatment. Other substances require an entirely different treatment depending upon their composition.

Purification by Chemical Means

Purification processes employing chemical means are used for the elimination of the carbonates, sulphates, nitrates and chlorides of lime and magnesia, and also in special cases where the water contains certain acids, etc. The first step in chemical purification, as in other processes, is a careful analysis of the water upon which to base the method of treatment. Water is chemically treated for the salts of lime and magnesia by three methods, known as the lime process, the soda process, and the combined lime and soda process.

Lime Process

The lime process is used for the removal of the carbonates of lime and magnesia. As in the methods previously described, the object is

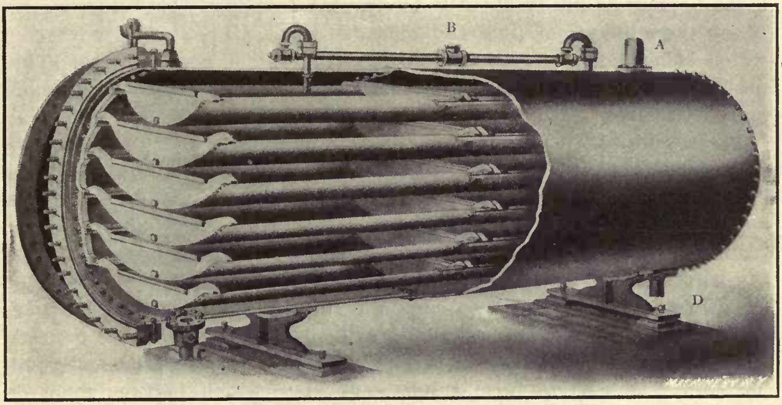


Fig. 19. Live Steam Feed-water Purifier

the removal of the carbonic acid and the precipitation of the carbonates. When limestone (carbonate of lime) is heated, the carbonic acid gas which it contains is driven off, leaving quicklime, which is a combination of lime and oxygen. Quicklime dissolved in water forms hydrate of lime, commonly called lime-water, and has a great affinity for carbonic acid. When lime-water is added to feed water containing bicarbonate of lime in solution, the carbonic acid leaves the bicarbonate and unites with the lime-water, thus changing the soluble bicarbonate into an insoluble carbonate which is precipitated to the bottom of the tank in which the action takes place. The lime-water which is added forms with the carbonic acid carbonate of lime which is also precipitated. In using this method, care should be taken to use exactly the amount of lime-water required to take up the carbonic acid in the bicarbonate to form the carbonate.

Caustic soda has the same effect as the lime water, but is more expensive. When this is used, carbonate of lime and carbonate of soda are formed, the former being precipitated as before, while the latter is soluble at all temperatures. When this process is used the boilers should be blown off occasionally to prevent the soda solution from becoming too concentrated, as it is likely to cause foaming.

Bicarbonate of magnesia is acted upon in practically the same manner as the bicarbonate of lime, so that the method of purification by this process is identical with the one described.

Soda Process

The soda process is used in heating feed water for the sulphates of lime and magnesia. The chemical usually employed for this purpose is soda ash (carbonate of soda). When this is added to water containing sulphate of lime, the resulting chemical action is the formation of carbonate of lime, which is precipitated, and sulphate of soda which is soluble at all temperatures. Here, as in the case of caustic soda, the water becomes strongly alkaline by the accumulation of soda, and must be blown out frequently to prevent foaming. The reaction between the sulphate of lime and soda ash takes place slowly unless the water is heated, hence caustic soda is sometimes used instead. This produces sufficiently good results without the use of heat, but is much more expensive.

The combined lime and soda process is used when there is an excess of carbonic acid present after the precipitation of the sulphate of lime by the soda, and also when both the carbonates and sulphates of lime and magnesia are present. When there is an excess of carbonic acid, it unites with the carbonate of lime formed by the soda process, changing it to the bicarbonate which is soluble. From this it is evident that lime-water must be added to complete the process. Sulphate of magnesia alone does not form a scale, but if bicarbonate of lime is present, the addition of lime-water to precipitate the carbonate causes the sulphate of magnesia to form sulphate of lime, which in turn must be removed by the soda process.

Water Softening Plants

A water softening plant includes the necessary equipment for automatically removing the impurities from feed water before it enters the boilers. Water softening is carried on under two different conditions, known as the cold and hot processes, the former being again divided into the continuous and intermittent methods, which differ only in the way of handling the water and chemicals. The cold process is generally used where there is no convenient means at hand for heating the water, and where large quantities are to be treated. The chemicals most frequently employed are the lime and soda solutions already described. These are added to the water automatically in the right proportions as determined by chemical analysis. The precipitates thus formed are allowed to settle in large tanks, or are removed by filtration, depending upon the form of apparatus used. In the hot process, soda ash is used the same as in the cold process, but the carbonates are precipitated by heating the water by means of exhaust steam.

The Eureka water softening apparatus is shown in Fig. 20 and consists of two principal parts, the small lime saturating tank *J*, and the large decanting tank for the precipitation and removal of the impurities from the water after being acted upon by the chemicals. The water to be treated enters the top tank *B*, from which a small portion

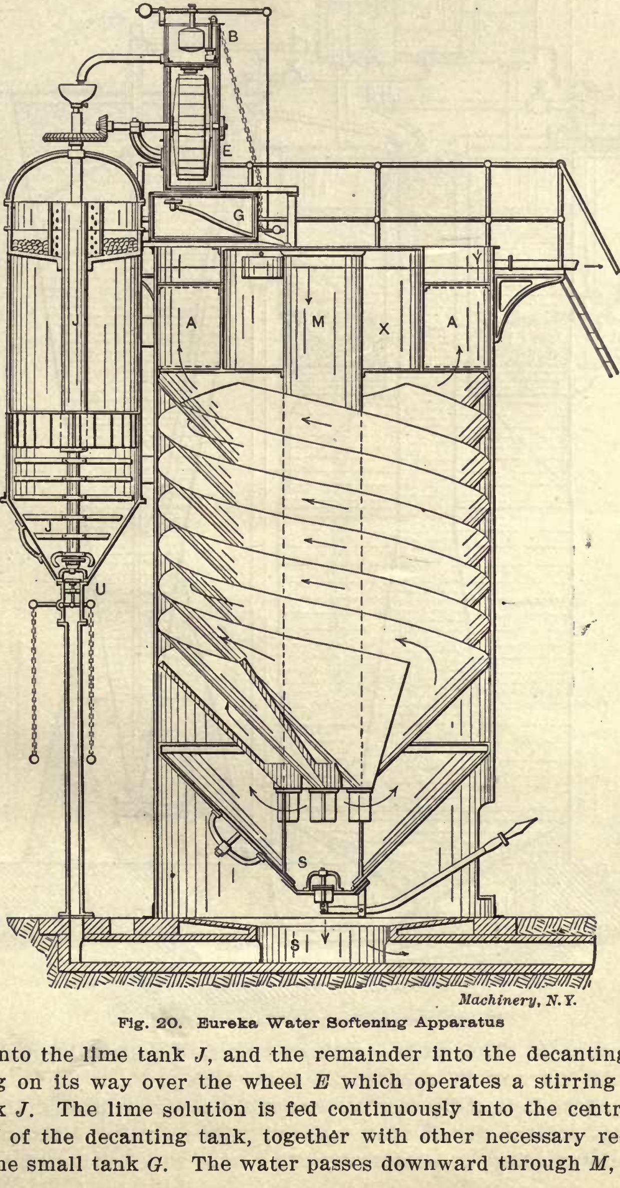


Fig. 20. Eureka Water Softening Apparatus

flows into the lime tank *J*, and the remainder into the decanting tank, passing on its way over the wheel *E* which operates a stirring device in tank *J*. The lime solution is fed continuously into the central portion *M* of the decanting tank, together with other necessary re-agents from the small tank *G*. The water passes downward through *M*, the reaction taking place meanwhile, and upward spirally between the settling plates which catch the sediment and allow it to fall by gravity to the bottom of the tank, from where it is blown off from time to time

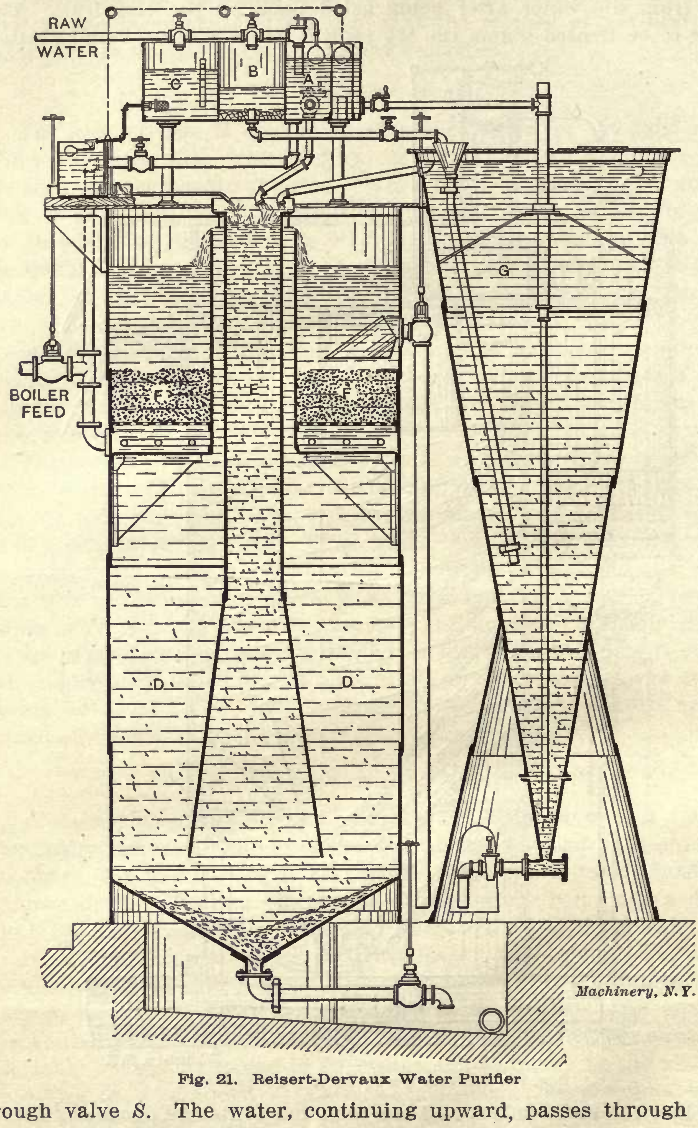


Fig. 21. Reisert-Dervaux Water Purifier

through valve *S*. The water, continuing upward, passes through the filter *A*, and is drawn off from the top of the tank at *Y*.

A type of the Reisert-Dervaux water purifier is shown in Fig. 21. Its main parts are the distributing tank with lime slaking division and soda regulator, a lime saturator, a settling tank with mixing pipe, and a gravel filter. The water to be treated enters compartment *A*, and from here a certain amount passes into the lime saturator *G*, and the remainder into the mixing pipe *E*. The quantity of lime needed for the day's run is slaked in compartment *B*, and the milk of lime drawn

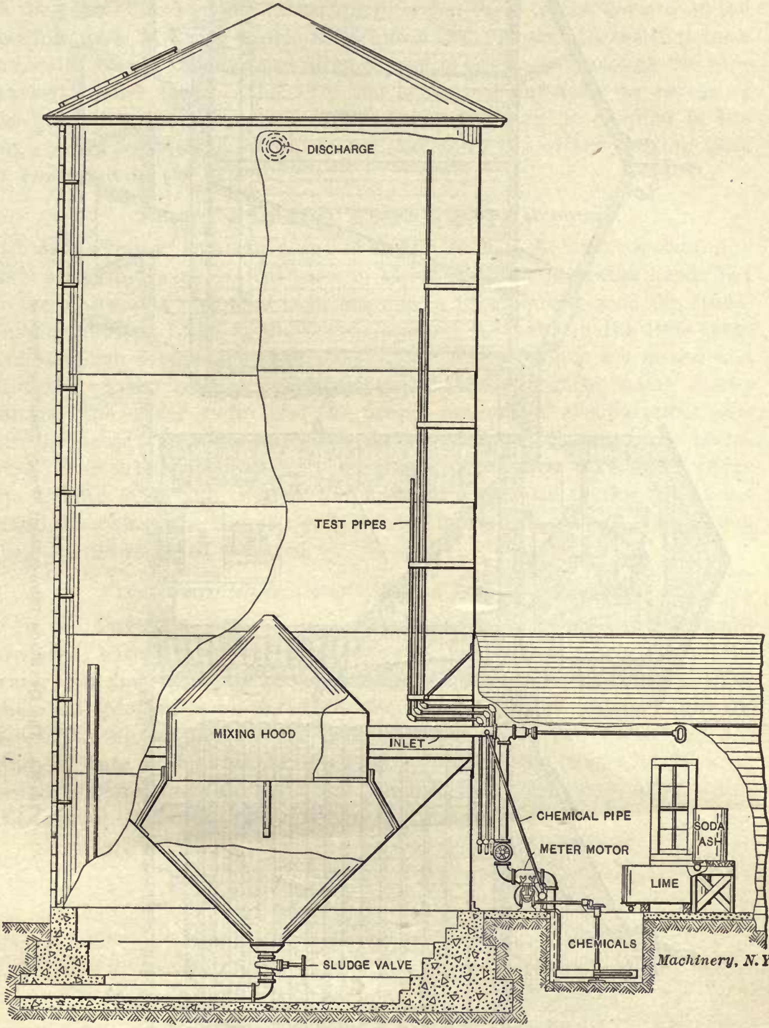


Fig. 22. The Miller Continuous Water Treating System

into the saturator *G* through the pipe and funnel shown. The constant flow of raw water through the center pipe of the lime saturator carries the particles of lime upward until the velocity of the water becomes so low, owing to the flaring form of the saturator, that they cannot follow. This results in a clear solution of lime water which overflows from the surface of *G* into the mixing pipe *E*.

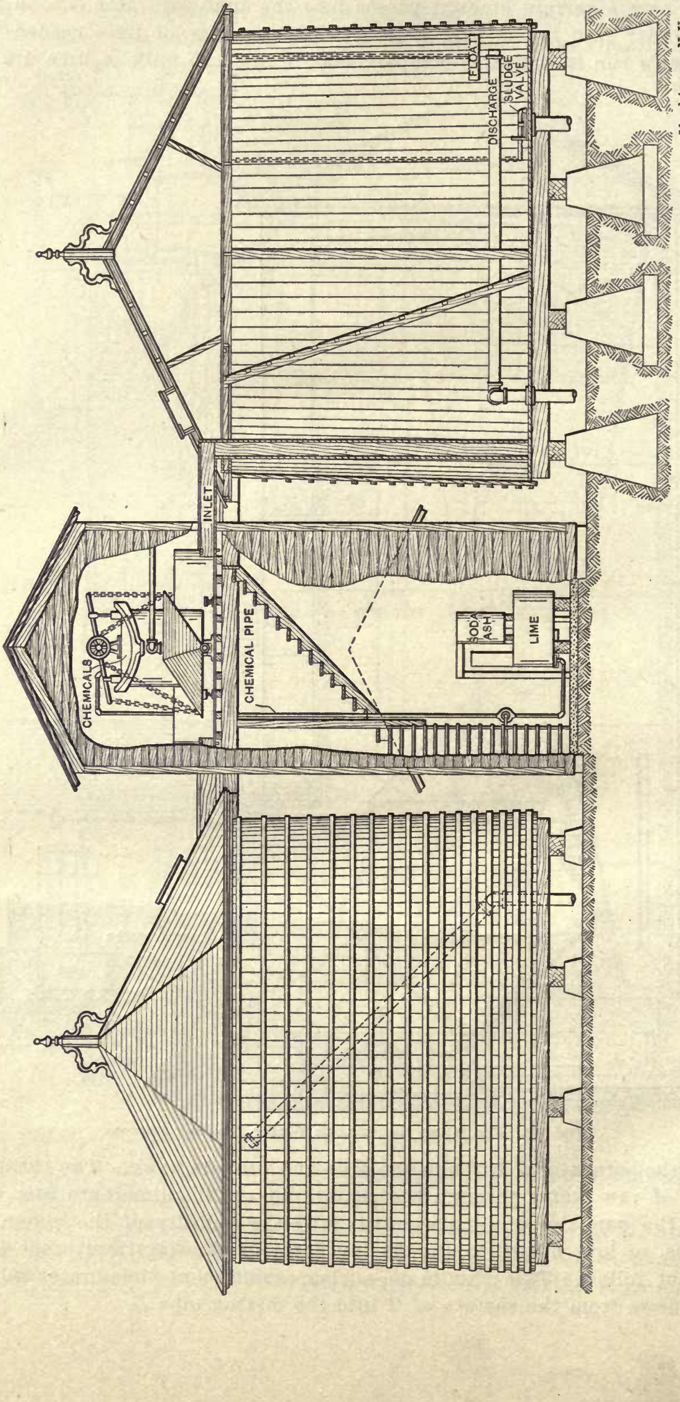


Fig. 23. The Davidson Intermittent Water Treating System

The required amount of soda ash for the day's run is dissolved in compartment *C*, and from here is discharged automatically into *E* as needed. A thorough mixture of the water and chemicals takes place in the pipe *E*, and most of the precipitation falls to the bottom of the settling tank *D*, from which it is blown off. From the settling tank the water passes through the filter *F*, and is drawn off through the pipe marked "boiler feed." The filter bed is washed out daily by reversing the flow of water through it. This apparatus may be adapted to the hot process by using a steam heater placed on top of the settling tank or embodied in the same.

Miller Continuous Water Treating System

A Miller water treating plant is shown in Fig. 22 and consists of a steel standpipe with conical bottom, above which is a mixing hood. The meter motor, and chemical tank are placed in a house beside the standpipe, as shown. Lime in the proper amount is slaked in the lime tank, and soda ash dissolved in the soda tank. The solutions are mixed and diluted and run into the chemical tank. The untreated water passes through the meter motor and the proper amount of the chemical mixture is forced under pressure into the water before it enters the standpipe. The mixing process and the resulting reaction take place under the mixing hood, the treated water rising gradually to the top of the standpipe, while the impurities fall into the conical bottom from which they are blown off as required.

Davidson Intermittent Water Treating System

In the Davidson water treating system, two or more settling tanks are used, with a treating house between them of such height that the water can flow from the proportioning machine into either tank. The chemical solution is prepared on the lower floor and pumped into the proportioning machine where it is mixed with the raw water and discharged into whichever tank is being filled. The water is then allowed to stand until reaction and precipitation take place, after which it is drawn off for use in the boilers.

CHAPTER III

FEED WATER HEATING

The feed water is usually heated before discharging it into the boilers for two reasons: First, to overcome the effect of a rapid cooling of the plates which is likely to result in unequal contraction and the formation of leaks at the joints, and also because a considerable volume of cold water fed into a boiler tends to reduce the steam pressure and thus makes it necessary to force the furnace for a time after feeding; second, because feed-water heaters are nearly always arranged to utilize the waste gases from the furnace or the exhaust steam from the engines, and thus a considerable saving in fuel may be realized by their use.

The percentage of saving in fuel by the use of a feed-water heater may be obtained approximately by dividing the total rise in temperature by 11. For example, if the water enters the heater at a temperature of 50 degrees F. and leaves it at 200 degrees F., the total rise is $200 - 50 = 150$ degrees, and the percentage of saving is $150 \div 11 = 13.6$.

The proportion of the heat in the steam generated by the boiler, which is utilized in heating the feed water, may be found as follows:

If it is assumed that the water is to be raised from 50 to 210 degrees F., the heat absorbed by 1 pound will be $210 - 50 = 160$ T. U. The latent heat of steam at atmospheric pressure is 966 T. U.; hence $\frac{160}{966}$ of the heat in each pound of exhaust steam is utilized in heating the feed water. This proportion is approximately one-sixth.

Classes of Heaters

Feed-water heaters are divided into two general classes known as closed and open heaters, depending upon their construction. These are again divided into the vertical and horizontal types.

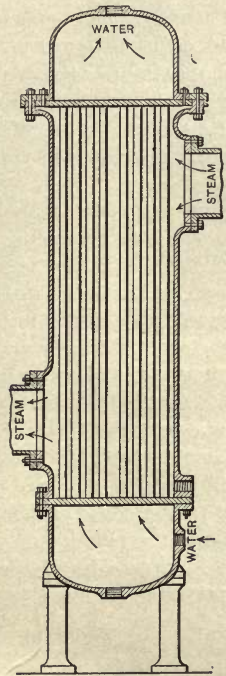
In the closed heater (see Fig. 24), the water passes through a series of brass or copper tubes which are surrounded by steam, there being no intermingling of the water and steam. The difference in construction of the various makes of closed heaters is chiefly in the arrangement of the tubes, the different types being known as single-flow, double-flow, straight-tube, bent-tube, water-tube, and steam-tube feed-water heaters.

The tube area for the flow of water depends upon the velocity, and also upon the capacity of the heater. Under ordinary conditions, the following velocities are used in the design of heaters of different types: single-flow, water-tube, 500 feet per hour; double-flow, water-tube, 750 feet per hour; coil, 8400 feet per hour.

As one boiler horsepower requires 34.5 pounds, or 0.5528 cubic foot of water per hour, the combined net area of the tubes in square feet per horsepower is found by dividing 0.5528 by the assumed velocity in feet per hour. In the case of coil heaters, a single pipe is used when the required area does not exceed that of a 3-inch pipe. For greater capacities, two or more pipes are used.

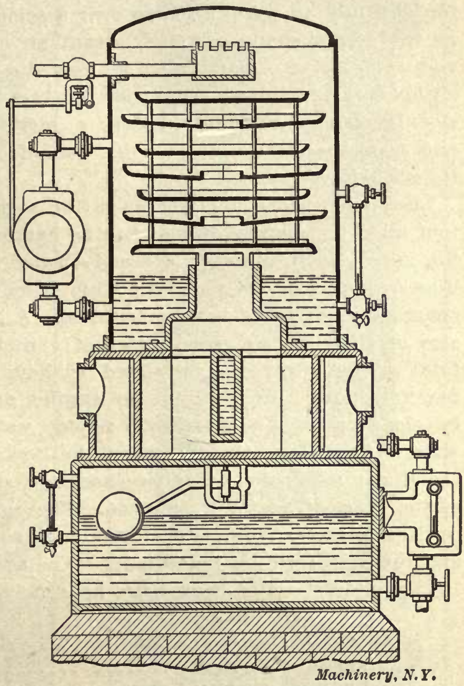
Heating Surfaces

The heating surface depends upon the relative temperatures of the steam and water, and the type of heater. Under ordinary conditions the following data may be used, which gives the heat transmission in



Machinery, N.Y.

Fig. 24. Typical Design of Closed Feed-water Heater



Machinery, N.Y.

Fig. 25. Common Form of Open Feed-water Heater

T. U. per square foot of surface per hour per degree difference in temperature between the steam and the average temperature of the water:

Straight water-tube	178 T. U.
Bent water-tube..................................	184 T. U.
Coil	200 T. U.

The temperature of steam at atmospheric pressure is 212 degrees F. Assuming initial and final feed-water temperatures of 50 and 210 degrees, respectively, the average temperature will be $\frac{210 + 50}{2} = 130$ degrees. From the above data the required amount of heating surface is easily computed for any given type and capacity of heater. Commercial heaters are commonly rated on a basis of 1/3 square foot of heating surface per boiler horsepower, when the exhaust from non-densing engines is used, and ½ square foot for condensing engines.

Open Heaters

In the open heater the steam and water mingle in the same chamber, and the water is heated by direct contact with the steam, which is condensed and mixes with the water. A common form of open heater is shown in Fig. 25. This is designed, as is usually the case, to act as a purifier, filter, and receiver. The cool water enters the heater at the top and falls in small streams over a series of trays or pans supended in the steam chamber. One advantage of the open heater over the closed is that the water may be heated to the maximum temperature without regard to the condition of the interior surfaces as regards cleanliness. When considered as a purifier, the accumulation of mud and scale beyond a certain point has, of course, a decided effect upon its efficiency.

The size of heater for a given rating will depend to a considerable extent upon the quality of water to be handled, a much larger heater being necessary in the case of muddy water than where only the salts of lime or magnesia are present. This is on account of the large settling chamber required in the former case. A common rule for finding the size of shell for an open heater of cylindrical form is to divide the total weight of water to be heated per hour by the weight of steam used per horsepower per hour by the engine, and divide this quotient by 8 for clear water, by 6 for slightly muddy water, and by 3 for very muddy water. This gives the volume of the heater in cubic feet, from which the linear dimensions may be chosen to suit the special requirements of the form of heater to be used. The pan or tray surface varies according to the quality of the water, both as regards the amount of mud and the scale-forming ingredients. The surface in square feet for each 1000 pounds of water heated per hour may be taken as follows:

	Vertical Type	Horizontal Type
Very bad water	8.5	9.0
Medium muddy water	6.0	6.5
Clear and little scale	2.0	2.2

Small pans of 2.5 square feet and less in area, are usually made circular, while those of larger size are commonly given a rectangular form. The spacing of the pans depends somewhat upon their form, being not less than 0.1 of the width of rectangular pans, nor less than 0.25 of the diameter of circular ones. The size of the settling or storage chamber, in the horizontal type, varies from 0.25 to 0.4 of the volume of the shell, depending upon the quality of the water. In the case of vertical heaters, this ratio varies from 0.4 to 0.6. Filters commonly occupy from 10 to 15 per cent of the volume of the shell in the horizontal type, and from 15 to 20 per cent in the vertical.

Types of Heaters

The following heaters shown are taken at random from among the best makes, and are used to illustrate some of the types in common use.

National heater.—This heater is shown in Fig. 26, and is of the enclosed coil water-tube type. The heating surface consists of drawn brass or copper tubing arranged as shown in the illustration. The

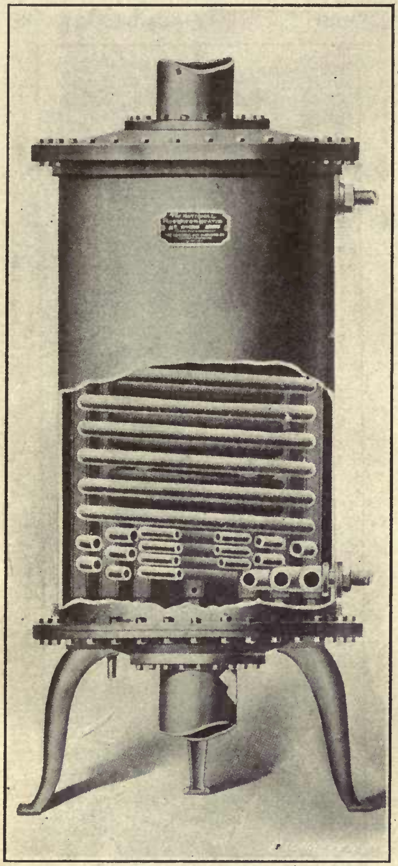


Fig. 26. The National Feed-water Heater

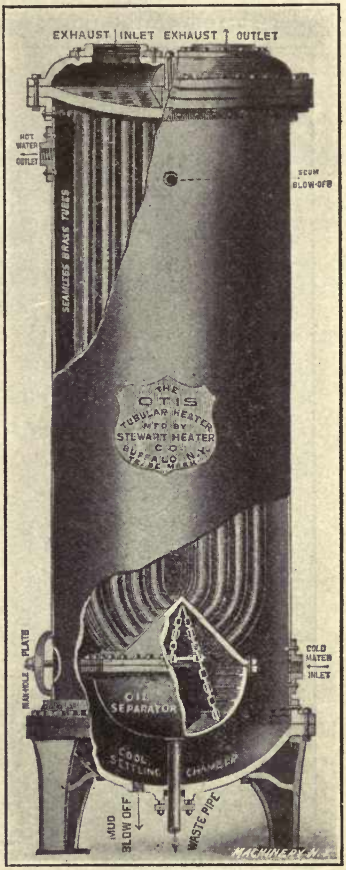


Fig. 27. The Otis Feed-water Heater

heaters are made in sizes ranging from 5 to 4000 horsepower, and commonly contain from 1 to 14 coils, depending upon the capacity. The shell is of cast iron with steam connections at top and bottom and drip pipe at one side in the lower head.

Otis heater.—This heater (Fig. 27) is of the steam-tube double-flow type, the water passing through the outer shell instead of the tubes. In operation, the exhaust steam enters and leaves the heater through the top, passing downward through one set of tubes and upward through the other. The chamber at the bottom, connecting the two sets of tubes, is provided with baffle plates and serves as an oil separator. The water enters the shell near the bottom, as shown, and passes out on the other side near the top.

Berryman heater.—This heater is shown in Fig. 28. It is a return bend steam-tube heater, with the tubes bent in the form of an inverted U, and both ends expanded into the same tube-sheet. The water in the heater surrounds the tubes, and the impurities which are precipitated

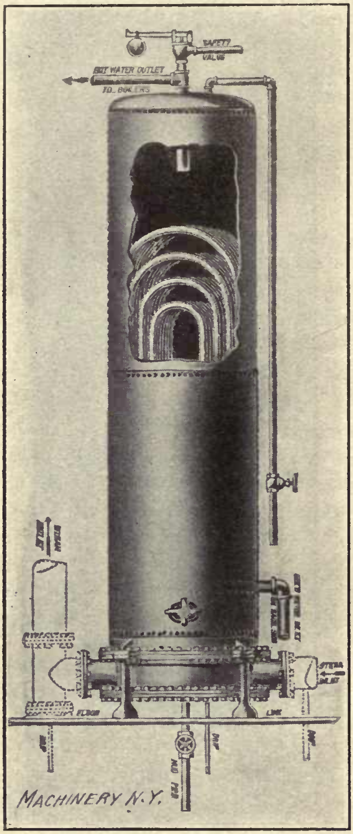


Fig. 28. The Berryman Feed-water Heater

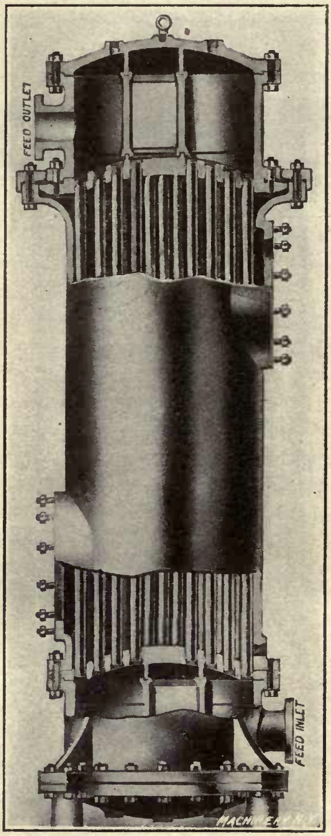


Fig. 29. The Goubert Feed-water Heater

are blown off from the bottom. The general method of making the various connections are shown in the illustration.

Goubert heater.—This heater is illustrated in Fig. 29, and is of the water-tube type containing a large number of brass or copper tubes in a cast-iron shell. The water enters at the bottom and passes upward through one group of tubes, then downward through another, and upward through a third group, and so on to the outlet near the top, having passed through the steam chamber five times.

Wainwright heater.—This heater, shown in Fig. 30, is like the one just described—a water-tube heater, but of the double-flow type. The special feature of this heater is the peculiar construction of the tubes, which are corrugated as shown, instead of being smooth like those in the makes previously described. This not only breaks up the water and causes it to absorb more heat, but also takes up the expansion of the tubes.

Wickes open heater.—The heater shown in Fig. 31 is of the open type in its simplest form. Water is admitted at the top through a

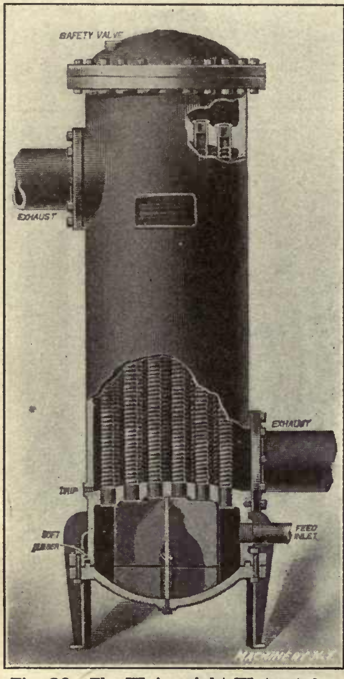


Fig 30. The Wainwright Water-tube Feed-water Heater

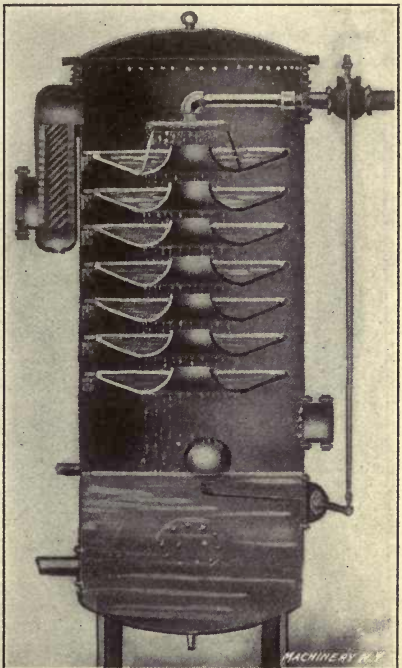


Fig. 31. The Wickes Open Type Feed-water Heater

valve operated by a float in the reservoir or receiver at the bottom, and drips from pan to pan in the presence of the steam, as shown. Scum is removed from the surface of the water through an overflow pipe, and the sediment removed from the bottom by means of a blow-off valve. Exhaust steam enters the heater through an oil separator near the top, and passes out on the other side below the pans.

Hoppes open heater.—This heater is shown in Fig. 32, and is constructed on the same general plan as the live steam purifier already described, and illustrated in Fig. 19. The only radical difference is that the heating agent is exhaust instead of live steam, and for this reason an oil separator is provided just inside the steam inlet.

Webster open heater and purifier.—This device is a typical heater, purifier, and receiver, and is shown in section in Fig. 33. The water is admitted at the top through an automatic valve, and then becomes heated by dripping over a series of trays in the presence of steam. From the settling chamber it flows downward by way of a central pipe and then rises upward through a coke filter to the outlet. The greater part of the impurities thrown down collect in the settling chamber beneath the filter, and may be blown out as required. The separator for removing the oil from the entering steam is seen at the right.

Cochrane heater, purifier and receiver.—This heater is similar in principle to the one just described, and is shown in Fig. 34. The cold water is supplied at the top, where it enters the trays, while the gravity returns from the heating system are brought in by a separate pipe

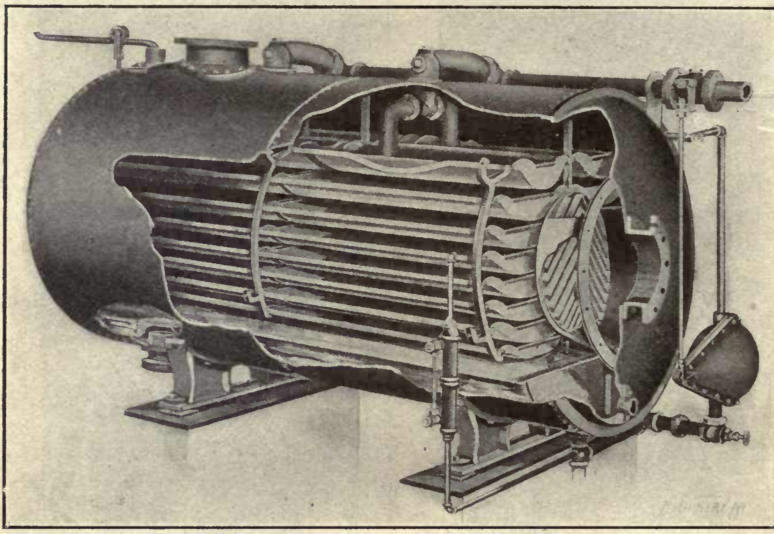


Fig. 32. The Hoppes Open Type Feed-water Heater

lower down. A filter and settling chamber occupy the lower part of the heater, as shown.

Economizers

An economizer is a device for utilizing the heat from the waste gases passing to the chimney. Although this heat is commonly used in warming the feed water, the term feed-water heater is only applied to devices employing either live or exhaust steam. The diagram shown in Fig. 35 is from the catalogue of the B. F. Sturtevant Co., and illustrates the action of an economizer with reference to the flow of the gases from the boilers to the chimney. The hot gases leave the boilers *A*, pass through flue *B*, and enter the economizer casing at *C*. The gases then pass by and around the economizer pipes filled with feed water, heating the water to a high temperature. After reducing their heat in raising the temperature of the feed water, the gases pass through flue *D* to chimney *E*. The feed water from the pump passes through the economizer pipes and enters the boilers through pipe *G*, having been greatly raised in temperature by the impinging hot gases; *H* is the by-pass damper which compels the gases to go through the

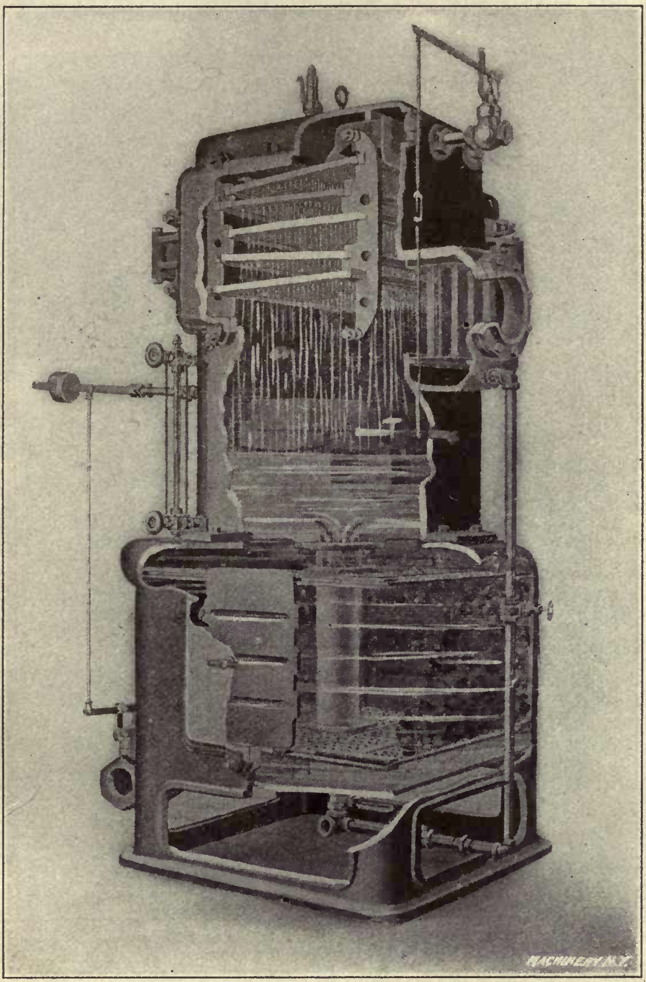


Fig. 33. The Webster Feed-water Heater and Purifier

economizer; *I* and *J* are dampers, by shutting which and opening the by-pass damper *H*, the gases can be passed directly to the chimney.

There are two advantages to be gained by the use of an economizer: First, a saving in heat which would otherwise be wasted, this commonly ranging from 10 to 20 per cent, and in addition to this, the efficiency of the boiler is increased, because of the higher temperature of the gases passing over its heating surfaces, the final cooling to a comparatively low temperature being carried on in the economizer after the gases have passed out of the boiler proper; second, the effect upon the durability of the boiler is of much importance; this is, of course, similar to that already mentioned in connection with feed-water heaters. In this case, however, the water may be heated to a much

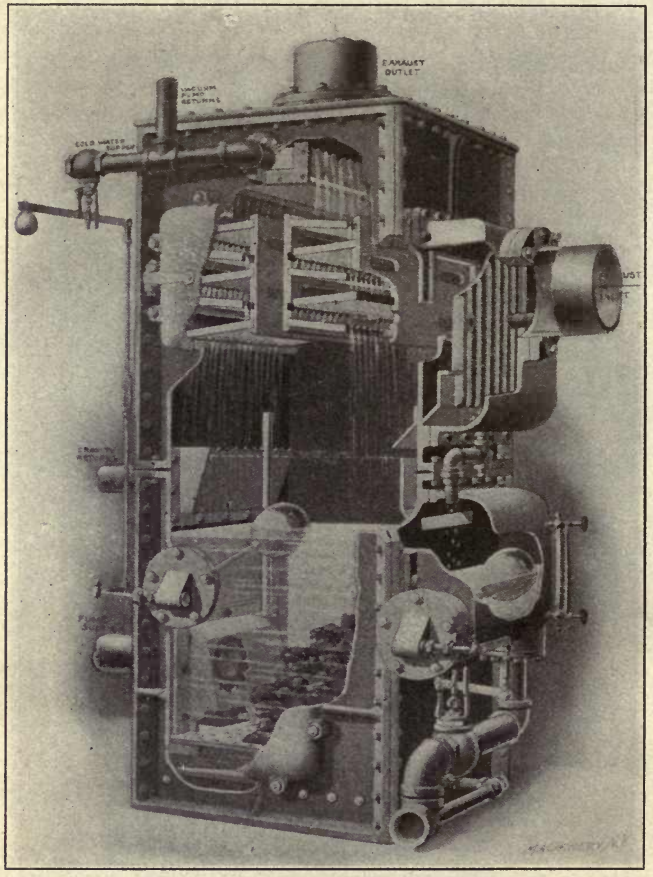


Fig. 34. The Cochrane Heater, Purifier and Receiver

higher temperature, so that the office of the boiler is practically reduced to a steam generator. In some plants the feed water is raised to a temperature of about 200 degrees F. in a steam heater, and then to 350 degrees F., or thereabout, in an economizer, thus being delivered to the boilers at a temperature corresponding to a pressure of 150 pounds per square inch. In other cases all of the heating is done in the economizer, especially where the exhaust steam can be utilized in other ways.

The heating surface depends upon the volume of water to be heated, and the initial and final temperatures of both the water and the gases. Under average conditions, from 4 to 5 square feet of heating surface are provided in the economizer for each boiler horsepower, and the

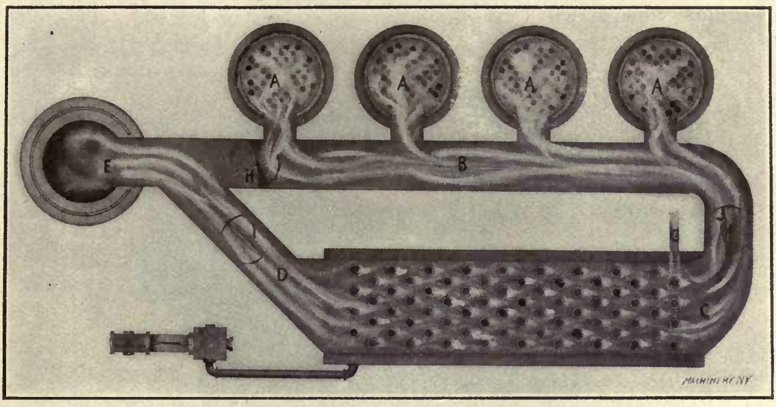


Fig. 35. Flow of Gases through an Economizer

gases are cooled about 200 degrees for each rise of 100 degrees in the feed water.

Economizer Details

An end view of the Sturtevant economizer is shown in Fig. 37. This is made up of a large number of sections, depending upon the heating

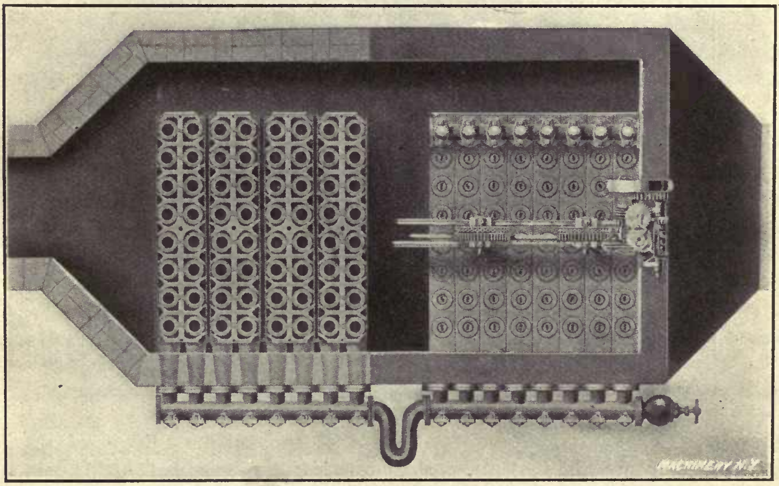


Fig. 36. Plan View of the Green Economizer

surface required, and is enclosed by brick side walls, not shown in the engraving. The bottom headers are connected on one side to the wall box, which runs at right angles to them, while a manifold connects the top headers, thus completing the circuit for the circulation of water.

An important feature of an economizer is the device for removing the soot which collects upon the pipes. This device consists of a steel scraper surrounding each pipe, which is moved slowly up and down by a special system of gearing shown at the top.

A plan view of a Green economizer is shown in Fig. 36. This engraving shows the enclosing side walls of the economizer, and also

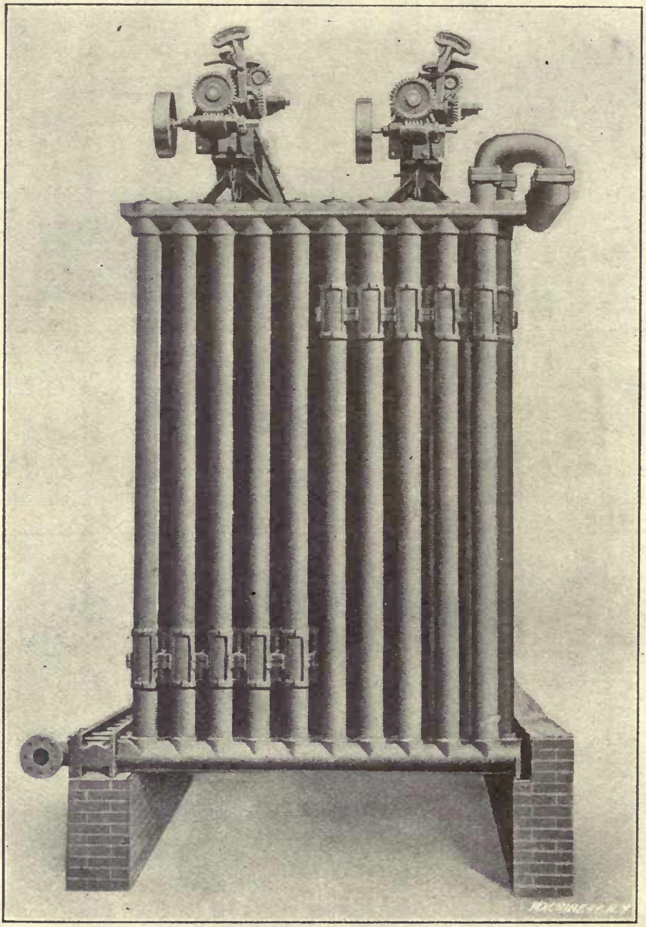


Fig. 37. The Sturtevant Economizer

the expansion loop in the water header at the bottom. Some of the latest installations of this make of economizer are provided with a special sectional covering which replaces the brick-work of the side walls. This covering consists of asbestos or mineral wool between two sheets of iron, and is easily removed for inspection or repairs.

The general arrangement of an economizer will depend entirely upon its size, the relative location of the boilers and chimney, and the available space. A typical layout for a plant provided with both forced and induced draft is shown in Fig. 38. In this case the economizer is

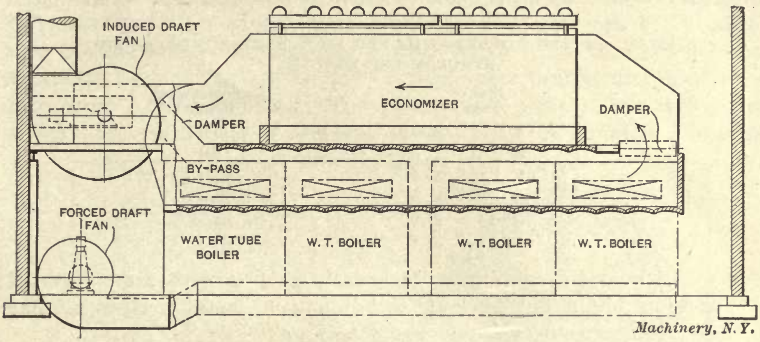


Fig. 38. General Arrangement of Boilers, Economizer and Fans for Forced and Induced Draft

placed above the boilers, and is provided with dampers so that the gases may be made to pass either around it or through it as desired.

CHAPTER IV

FEEDING AND REGULATING DEVICES

Pumps, injectors, and return traps are the devices most commonly used for feeding water into boilers under pressure, the first two being the most extensively used in power plant practice.

Pumps

A typical direct-acting steam pump for boiler feeding is shown in Fig. 39. Pumps of this class are wasteful in the use of steam, but if the exhaust can be used for feed-water heating, this is not of so much importance.. On the other hand, they are easily regulated to furnish the required amount of feed water under varying conditions, and are extensively used for this purpose. The ratio of the diameter of steam to water cylinder is commonly made about 1.25, this surplus area being sufficient to overcome any usual friction in the pump and piping, and to force the water into the boiler. The horsepower developed in either cylinder of the pump may be found by multiplying the area of the cylinder in square inches by the pressure per square inch, and this in turn by the piston speed in feet per minute, and dividing the result by 33,000.

Steam pumps for boiler feeding are commonly rated at the boiler horsepower which they will supply at different rates of speed. Table IV gives the boiler horsepower which duplex pumps will supply when running at an average speed of 50 strokes per minute.

When the temperature of the water to be handled is over 190 degrees F., it should flow to the pump by gravity, as it is likely to break into steam if an attempt is made to lift it by suction. The water piston

TABLE IV. BOILER HORSEPOWER FED BY DUPLEX PUMPS, AT FIFTY STROKES PER MINUTE

Size of Pump	Horsepower of Boiler
2″ x 1⅛″ x 2¾″	10
3″ x 1¾″ x 3″	40
4½″ x 2¾″ x 4″	120
5¼″ x 3½″ x 5″	250
6″ x 4″ x 6″	375
7½″ x 4½″ x 6″	475

of a pump used for cold water is usually packed with some form of soft packing, but if hot water is to be pumped, metallic rings similar to those in the steam cylinder should be used.

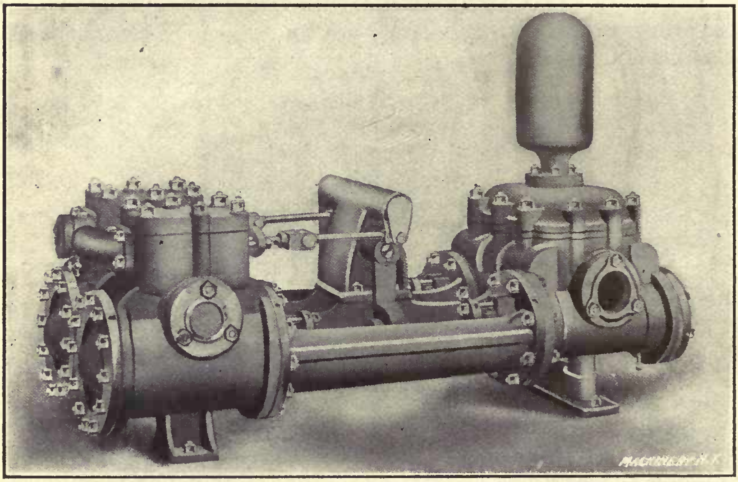


Fig. 39. Direct-acting Steam Pump for Boiler Feeding

Fig. 40 shows a power pump for boiler feeding. This type of pump is usually run at a fixed speed sufficient to supply the maximum requirements of the boiler. Any variation in the amount required is cared for by the use of a by-pass valve which allows the surplus to return to the suction pipe. A centrifugal pump driven by a steam turbine is shown in Fig. 41. These pumps are coming into use to a considerable extent for boiler feeding in the case of large power plants. Fig. 42 illustrates a combined pump and receiver for use in combined power and heating plants. In this case the condensation from the heating system is trapped into the receiving tank and returned to the boiler automatically by means of the pump which is operated by a float within the tank. Any additional feed water required is discharged into the tank with the condensation.

Injectors

An injector uses the full heat value of the steam, but cannot be controlled as to the amount fed into the boiler, and must work either at full capacity or not at all. The double tube injector can be regulated to a certain extent, but not over a wide range. Injectors are not conveniently used in connection with a feed-water heater, and are, therefore, more commonly employed in power plant work in the capacity of a relay, for use in case of accident or repairs to the pumps. The satis-

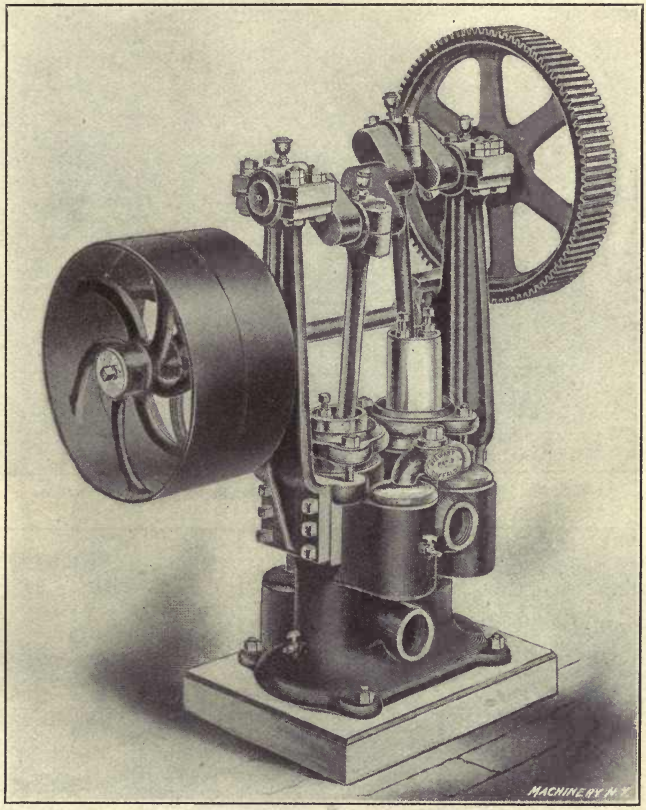


Fig. 40. Power Pump for Boiler Feeding

factory operation of an injector depends upon the steam pressure, height of lift and temperature of the feed water; hence, the proper combination of these conditions is an important consideration in their use.

The Powell automatic injector is shown in Fig. 44. This injector is of the so-called self-starting type, and the various connections are made as indicated in the engraving. It is started by opening the valves for *B*, *C*, and *D*, in succession, and shut off by the reverse operation. The check valve in the overflow pipe is automatic in its operation.

The Sherwood injector, illustrated in Fig. 45, is of the double-jet type, one jet serving to lift the water and the other to force it into the boiler. Injectors of this type are automatic, requiring no manipulation after once being started, although the steam pressure should vary. They will handle water at a higher temperature and under a greater lift than the single-tube devices.

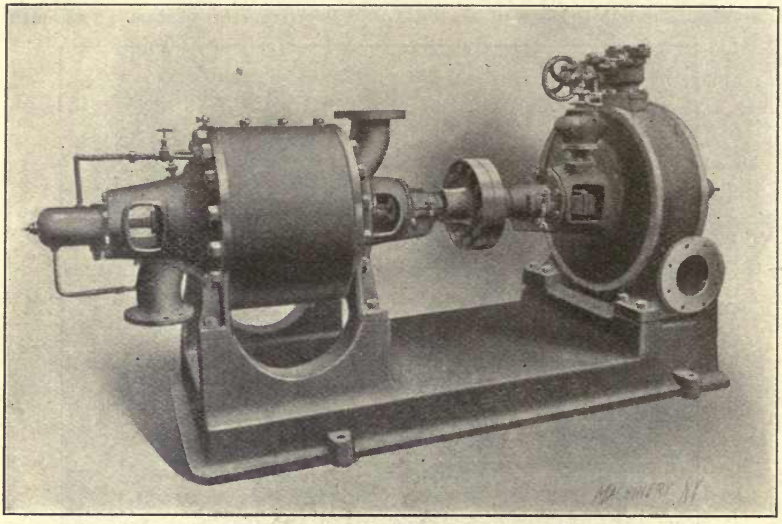


Fig. 41. Alberger Centrifugal Pump Driven by a Steam Turbine

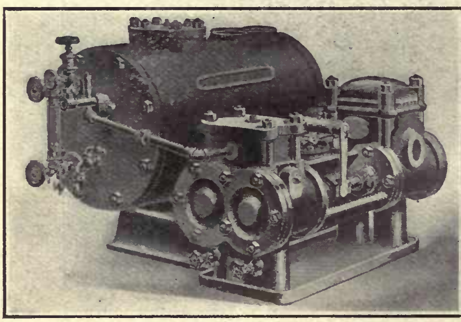


Fig. 42. Combined Pump and Receiver

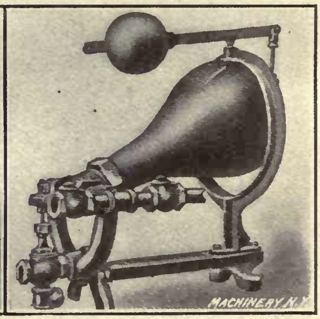


Fig. 43. The Bundy Return Trap

Return Traps

Return traps are especially adapted to returning the water of condensation from a heating system back to the boiler, and for handling the water from both open and closed heaters, as they operate equally well under all temperatures and pressures. They are simple in construction and not liable to get out of order. The principle of operation is that of allowing water under a low pressure to enter a chamber elevated above the boiler, and when filled, of closing the connection with the low pressure system and admitting steam at boiler pressure, thus causing the water to flow into the boiler by gravity. In actual

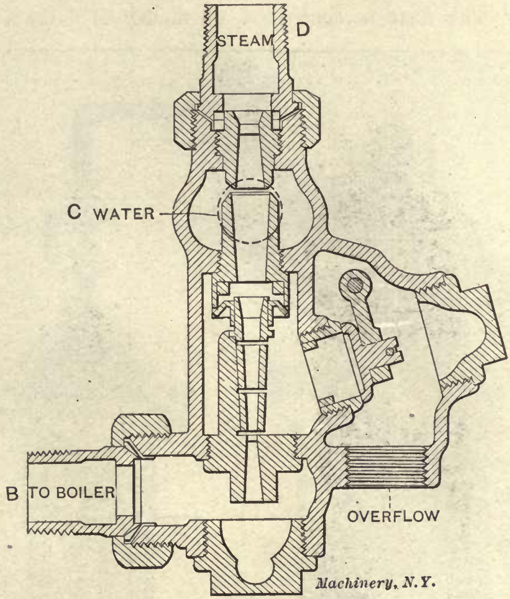


Fig. 44. The Powell Automatic Injector

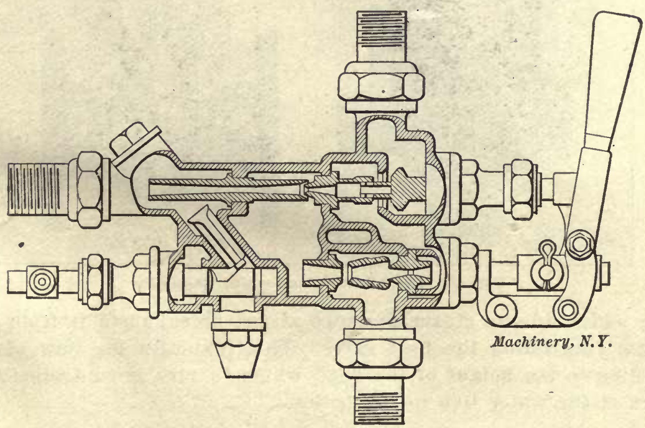


Fig. 45. The Sherwood Injector

practice these operations are all automatic. The Bundy return trap, which is typical of this class, is shown in Fig. 43.

Regulating Devices

There are many devices upon the market for automatically regulating the height of the water-line in a steam boiler. Among these the Liberty feed-water regulator, shown in Fig. 46, will serve to illustrate the general principle upon which many of them operate. This consists of a float chamber connected with the boiler both above and below the water line. The float is connected by means of levers with a pilot

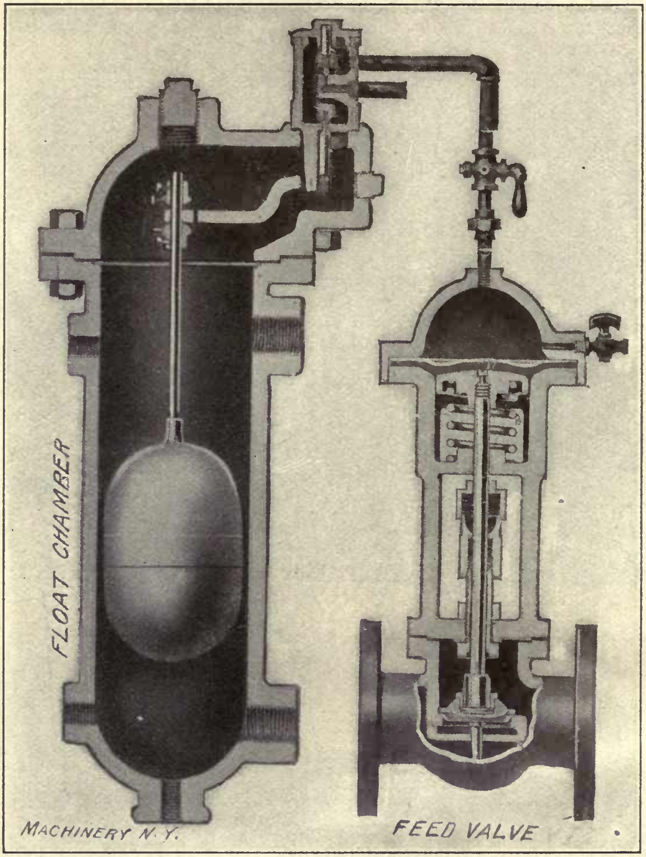


Fig. 46. The Liberty Feed-water Regulator

valve which admits steam pressure above, or exhausts it from a diaphragm controlling the feed valve. This regulates the flow of water according to the height of the float, which in turn is controlled by the height of the water line in the boiler.

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