# SELECTION, INSTALLATION AND CARE OF POWER PLANTS.

BY

G. W. BISSELL.

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## CONTENTS.

## CHAPTER VI.

### Selection of Power Plants.

It is the purpose of this report to state and discuss the principles governing the selection and installation of the engines and boiler plant which furnish the power required for working clay into brick and other marketable products.

The writer has assumed that in the selection of the power producing apparatus the following requirements exist: All machinery must be (1) simple in design, (2) strong in construction, (3) reliable in action, (4) reasonable in first cost, and (5) readily handled by men of ordinary intelligence and some mechanical aptitude.

To these requirements should be added a sixth, that of economical operation. It should be noted that the fourth and fifth requirements first enumerated may conflict with the sixth. It is the desire of the writer to impress upon clay workers the idea that the sixth requirement is very important.

By economy of operation in this connection is meant low annual expenses chargeable to power production. The items of such expense are:

(1) Fixed charges, (2) current expenses, (3) repairs.

Fixed charges include: (a) interest on the investment, (b) depreciation, (c) taxes, (d) insurance.

Current expenses include: (a) fuel, (b) labor, (c) supplies.

Repairs include: (a) labor, (b) material.

In order that the sum total of all the items shall be a minimum considerable thought should be given to the design, in general and detail, of the plant; and subsequently its operation.

## The Power House.

The building in which engines and boilers and accessories are placed need not be elaborate or expensive, but should be so constructed as to protect the machinery and its attendants from the

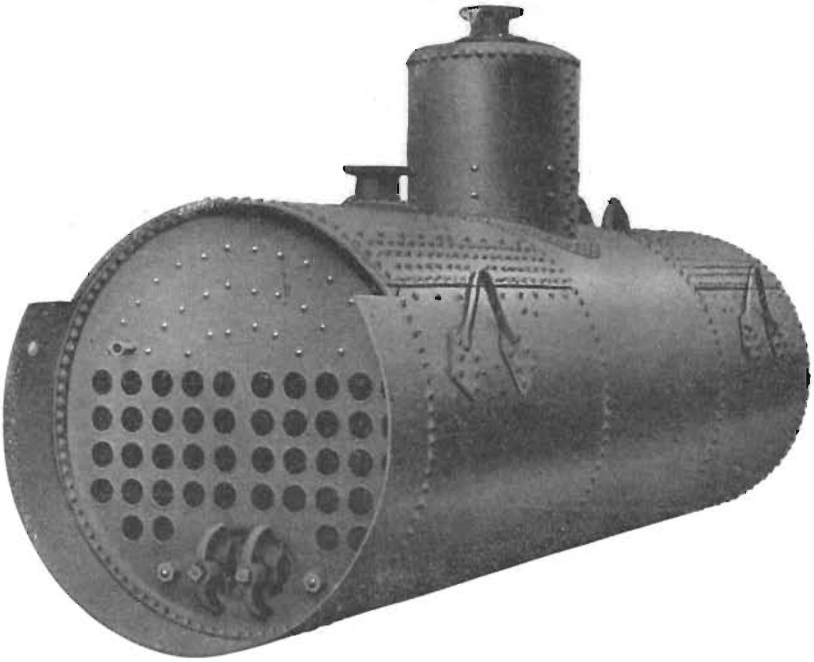


FIG. 31. Boiler with dome, shell extended for full front, wrought iron hinges.

weather while the plant is in use, should protect the machinery from meddling persons and the weather while the plant is not in use and should be located and the machinery arranged therein so that the capacity of the plant can be increased by adding to the existing building. Plenty of light and controllable ventilation are very desirable in the power house.

### Machinery.

This consists usually of engines, boilers and stacks, and feed-pumps or injectors. For most localities feed water purifiers should be added to the list.

The assumption is made here that the exhaust steam from the engine is used for drying the clay previous to burning.

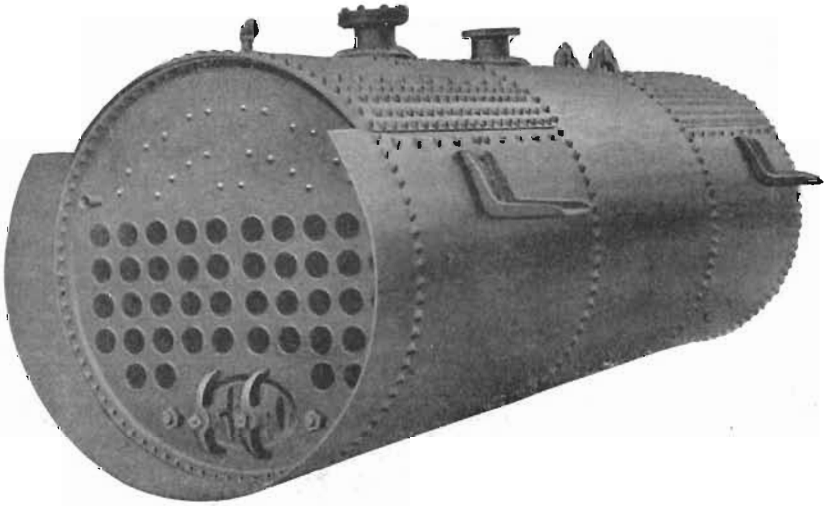


FIG. 32. Domeless boiler with nozzles, shell extended for full front, pressed steel lugs.

BOILERS.

The most satisfactory all around boiler is the well known horizontal return tubular boiler shown without the brick work and castings in Figs. 31 and 32 and Plate XI. Fig. 31 represents a boiler adapted to suspension, to which reference is made below. For Iowa coal as fuel this boiler should have relatively long tubes, should be set high above the grates, should have liberal grate surface and be connected to a stack of ample capacity.

It would be desirable in large plants to consider the use of a coking arch or, better, the "dutch oven."

Tubes 4 inches in diameter should be 18 to 20 feet long and 3½-inch tubes should be 16 feet long. Tubes smaller than 4 inches are not advisable for natural draft with Iowa coals, on account of the excessive soot accumulation in smaller tubes. With tubes of the lengths mentioned, the hot gases from the furnace will travel far enough in contact with water heating surface to reduce their temperature at the stack to a reasonable point, say 350 degrees to 450 degrees F.

The grate surface should be liberal so as to permit the use of slack or the carrying of a heavy enough fire of any grade of Iowa coal to compel a thorough mixture of the air and combustible gases of the fuel.

Twelve square feet of water heating surface per boiler horse power, and one square foot of water heating surface per boiler horse power, and one square foot of grate surface to each forty square feet of heating surface will be found satisfactory. Rocking or shaking grates are very desirable. An excellent shaking grate is shown in Fig. 33. This gives excellent results with the slack and other steam coals mined in Iowa.

Automatic stokers are not practicable in plants of less than 400 to 500 horse power capacity, because no saving in labor is possible, and the saving, if any, due to improved combustion, is offset by repairs to the stokers, and the power required to operate them.

Most boiler shells are too near the fire for the economical use of Iowa coal; in fact, the best conditions exist where, as with the coking arch or the "dutch oven," there is no water heating surface in the fire-box or furnace. With the standard surface a 72-

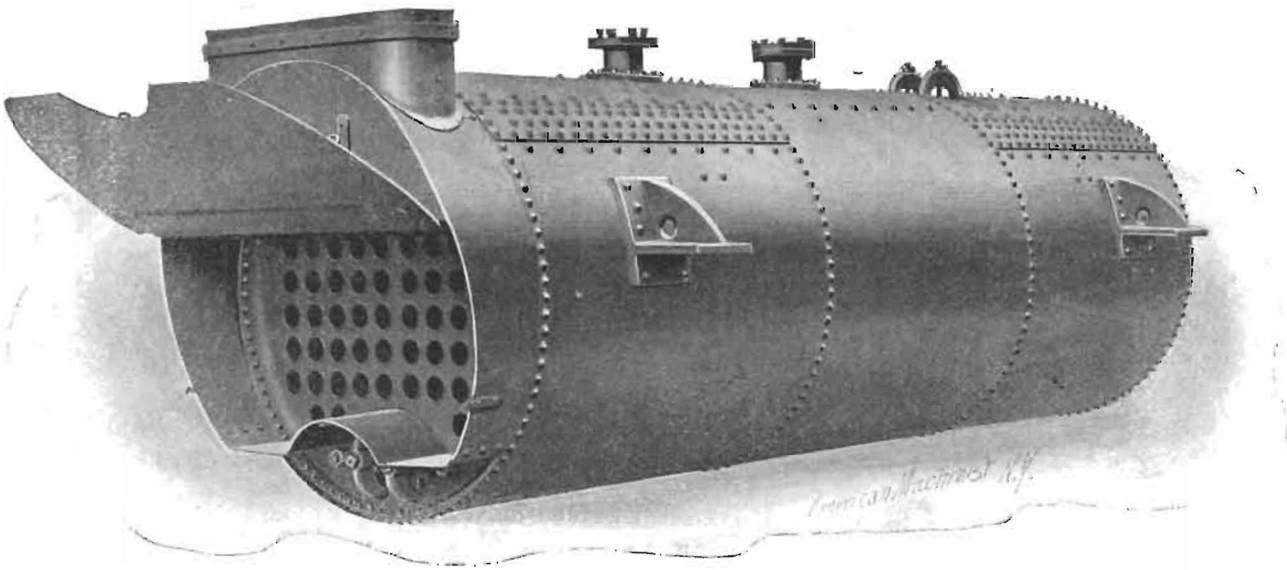


PLATE XI. Domeless boiler with nozzles, shell extended and fitted with flue door and up-take for half-arch front, manhole exposed, cast iron lugs; can be suspended.

inch boiler should be not less than 42 inches above the grate. Table No. 1 contains approved dimensions for boilers of this type for shells from 48 inches to 72 inches in diameter, and from 16 feet to 20 feet in length, with 4-inch tubes.

TABLE No. 1.

| | | | | | | |
|---|---|---|---|---|---|---|
| Diameter of boiler | | 48″ | 54″ | 60″ | 66″ | 72″ |
| Number of tubes | | 24 | 36 | 44 | 54 | 68 |
| Diameter of tubes | | 4″ | 4″ | 4″ | 4″ | 4″ |
| Thickness of shell | | $\frac{5}{16}$″ | $\frac{5}{16}$″ | $\frac{5}{16}$″ | $\frac{3}{8}$″ | $\frac{3}{8}$″ |
| Thickness of head | | $\frac{7}{16}$″ | $\frac{1}{2}$″ | $\frac{1}{2}$″ | $\frac{1}{2}$″ | $\frac{9}{16}$″ |
| Braces above tubes | | 12 | 20 | 30 | 30 | 40 |
| Braces below tubes | | 4 | 4 | 4 | 4 | 8 |
| Size of steam pipe | | $3\frac{1}{2}$″ | 4″ | $4\frac{1}{2}$″ | 5″ | 6″ |
| Size of feed pipe | | $1\frac{1}{4}$″ | $1\frac{1}{4}$″ | $1\frac{1}{2}$″ | $1\frac{1}{2}$″ | $1\frac{1}{2}$″ |
| Size of blow-off pipe | | 2″ | 2″ | 2″ | $2\frac{1}{2}$″ | $2\frac{1}{2}$″ |
| Heating surface | 16 ft | sq. ft. 520 | sq. ft. 715 | sq. ft. 864 | sq. ft. 1042 | sq. ft. 1325 |
| | 18 ft | sq. ft. 585 | sq. ft. 805 | sq. ft. 972 | sq. ft. 1270 | sq. ft. 1490 |
| | 20 ft | sq. ft. 650 | sq. ft. 894 | sq. ft. 1080 | sq. ft. 1305 | sq. ft. 1656 |
| Rated horse power | 16 ft | 43.3 | 59.5 | 72 | 87 | 110 |
| | 18 ft | 48.7 | 67 | 81 | 90 | 124 |
| | 20 ft | 54 | 74.5 | 90 | 109 | 138 |
| Grate surface | 16 ft | sq. ft. 14 | sq. ft. 18 | sq. ft. 21.6 | sq. ft. 30 | sq. ft. 33 |
| | 18 ft | sq. ft. 15.8 | sq. ft. 22 | sq. ft. 24.3 | sq. ft. 33 | sq. ft. 39.6 |
| | 20 ft | sq. ft. 17.5 | sq. ft. 24 | sq. ft. 27 | sq. ft. 33 | sq. ft. 43 |
| Diameter of 60-foot stack | | 24″ | 27″ | 30″ | 33″ | 36″ |

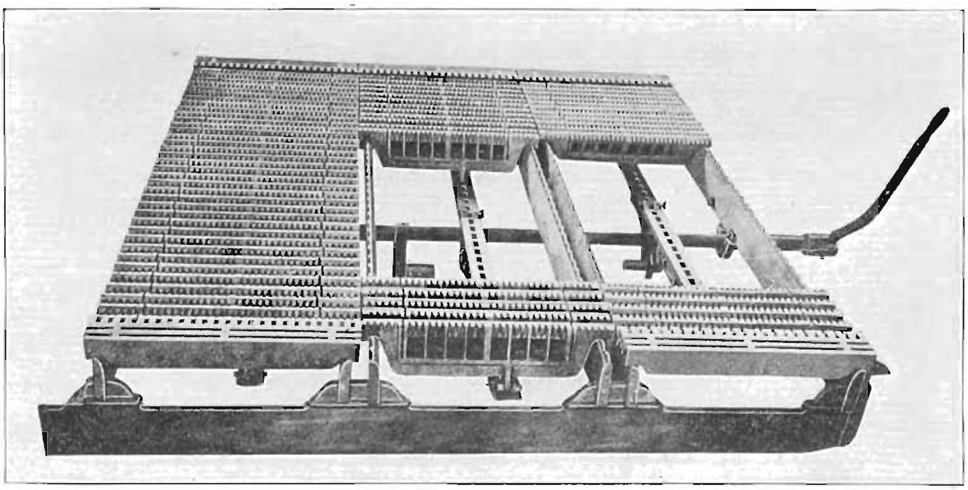


FIG. 33. A good type of rocking grate.

Herewith is a standard "Specification" for boilers of the same type, based upon the practice recommended by the Hartford Steam Boiler Inspection and Insurance Company. The principal departure therefrom consists in the overhead suspension mentioned as an alternate to the common method of supporting the boiler on the brick work.

SPECIFICATIONS FOR HORIZONTAL RETURN TUBULAR BOILER, 72 IN. BY 18 FT.

*Type.*—Horizontal return tubular.

*Dimensions.*—Seventy-two inches in diameter, eighteen feet long from outside to outside of heads, with smoke extensions eighteen inches long continuous with shell. Thickness of shell, three-eighths inch, of head one-half inch.

*Material.*—Best open hearth flange steel, having a tensile strength of not less than 57,000 nor more than 62,000 pounds, and deductility corresponding to 56 per cent reduction of area and 25 per cent of longation. All plates in finished boiler to show stamp with name of maker, quality and tensile strength.

*Tubes and Braces.*—Sixty-eight tubes, four (4) inches in diameter, 18 feet long, best lap welded or seamless drawn, carefully and properly expanded with Dudgeon expander and beaded at each end. Braces: 44 braces above tubes and four below tubes, the former crow foot form, flat or round, of not less than one square inch in area at smallest section, the latter 1¼ inches in diameter, with up-set ends for 1½-inch thread at front and crow-foot connections at back, with turned bolt 1 1-16-inch diameter. No brace less than 3 feet 6 inches long.

Details of tube sheet lay-out to be according to practice recommended by the Hartford Steam Boiler Inspection and Insurance Company.

*Riveting.*—Two lugs on each side. Front lugs to rest on cast iron plates, others on rollers and plates to permit of expansion. All plates 12 by 12 by 1½. Rollers 1 inch diameter, 9 inches long, three at each plate. *Or* two suspension loops on each side, of 1½-inch round iron securely riveted to shell. See Fig. 31.

*Construction.*—No dome. Shell in three rings, each ring formed from a single sheet, horizontal seams above the fire and to break joints. Heads machine flanged, rivet holes drilled or punched and reamed, tube holes drilled or bored.

*Openings.*—Two man-holes, 11 by 15 in top of shell, 10 by 15 in front head, under tube. 1½-inch feed-water pipe, internal from front head over tubes. Blow-off flange 2½ inches. Steam nozzle 5 inches, near back end, safety valve nozzle, 4 inches, near front end. Both nozzles flanged and fitted with companion flanges for screwed pipe of same size as nozzle.

*Castings.*—Fronts. Ornamental three-quarter arch for overhanging extension. Fronts designed to allow not less than 36 inches between grate and boiler shell and to have fire-door frames for 8-inch wall. Tight fitting fire, ash-pit and smoke extension doors, saddle for breaching connection with balanced butterfly damper, or columns and double channels for overhead suspension, with equalizing I-beam at back end.

Eight wall binders, binder rods, anchor rods for front, soot door and skeleton frames for fire brick arch at back.

Uptake 14 by 60.

Rocking or shaking grates of approved design to work from front of boiler.

*Fittings.*—Eight-inch brass steam gauge, combination water column, 4-inch pop safety valve, 1½-inch check and stop valves and 2½ inch asbestos blow-off cock.

*Inspection and Test.*—Before shipment test with cold water at 150 pounds per square inch and furnish certificate of inspection from the Hartford Steam Boiler Inspection and Insurance Co. and insurance policy in the same company for one year in the sum of $2,000.00 for both boilers.

#### ALTERNATE SPECIFICATIONS FOR BOILER 66 IN. BY 18 FT.

Complying with specifications for the 72-inch boiler, except as follows:

Diameter, 66 inches. Length, outside to outside, 18 feet.

Thickness of shell, 3/8 inch. Riveting, double riveted lap for longitudinal seams.

54 tubes, 4 inches by 18 feet.

Braces above tubes, 34.

Braces below tubes, 4.

Uptake, 12 by 54.

Steam pipe, 4½ inch. Safety valve, 3½ inch.

Blow off, 2 inch.

Feed pipe, 1½ inch.

#### ALTERNATE SPECIFICATIONS FOR BOILER 60 IN. BY 18 FT.

Complying with the specifications for the 72-inch boiler, except as follows:

Diameter, 60 inches. Length, outside to outside, 18 feet.

Thickness of shell, 5-16 inch. Riveting, double riveted lap for longitudinal seams.

44 tubes, 4 inches by 18 feet.

Braces above tubes, 30.

Braces below tubes, 4.

Uptake, 12 by 42.

Steam pipe, 4 inch. Safety valve, 3½ inch.

Blow off, 2 inch.

Feed pipe, 1¼ inch.

Complete specifications and setting plans for any size of horizontal return tubular boiler can be had by applying to the Hartford Steam Boiler Inspection and Insurance Co. In the judgment of the writer, they should be modified along the lines suggested in the above specifications.

The capacity of the stack depends upon its cross-sectional area, its height, the temperature inside and outside and general atmospheric conditions.

Table No. 2, adapted from a more complete table in Snow's "Steam Boiler Practice", p. 236, gives the capacities in horse power of chimneys or stacks of various heights and diameters for ordinary conditions as to temperature of the hot gases and for average atmospheric conditions.

TABLE No. 2

| INSIDE DIAMETER INCHES. | EFFECTIVE AREA SQ. FT. | HEIGHT OF CHIMNEY IN FEET. | | | | |
|---|---|---|---|---|---|---|
| | | 60 | 80 | 100 | 125 | 150 |
| 18 | 0.97 | 25 | 29 | | | |
| 24 | 2.08 | 54 | 62 | | | |
| 30 | 3.58 | 92 | 107 | 119 | | |
| 36 | 5.47 | 141 | 163 | 182 | 204 | |
| 42 | 7.76 | | 231 | 258 | 289 | 316 |
| 48 | 10.44 | | | 348 | 389 | 426 |
| 54 | 13.51 | | | 449 | 503 | 551 |
| 60 | 16.98 | | | 565 | 632 | 692 |
| 84 | 34.76 | | | | 1,294 | 1,418 |

A substantial brick stack is better than an unlined steel stack such as is commonly furnished with boilers, but a self supporting steel stack lined to the top with brick is considered good and costs somewhat less than an all-brick stack.

For Iowa feed-water the boiler should be made as accessible as possible for interior examination and cleaning. To this end a man-hole below as well as above the tubes is a necessity.

A dome is not necessary, and its cost can be save by omitting it from the specifications.

The feed-water should be introduced at the front and above the tubes, below the water line, into a pipe extending to within two feet of the back head, and discharged downwards between the tubes and the shell.

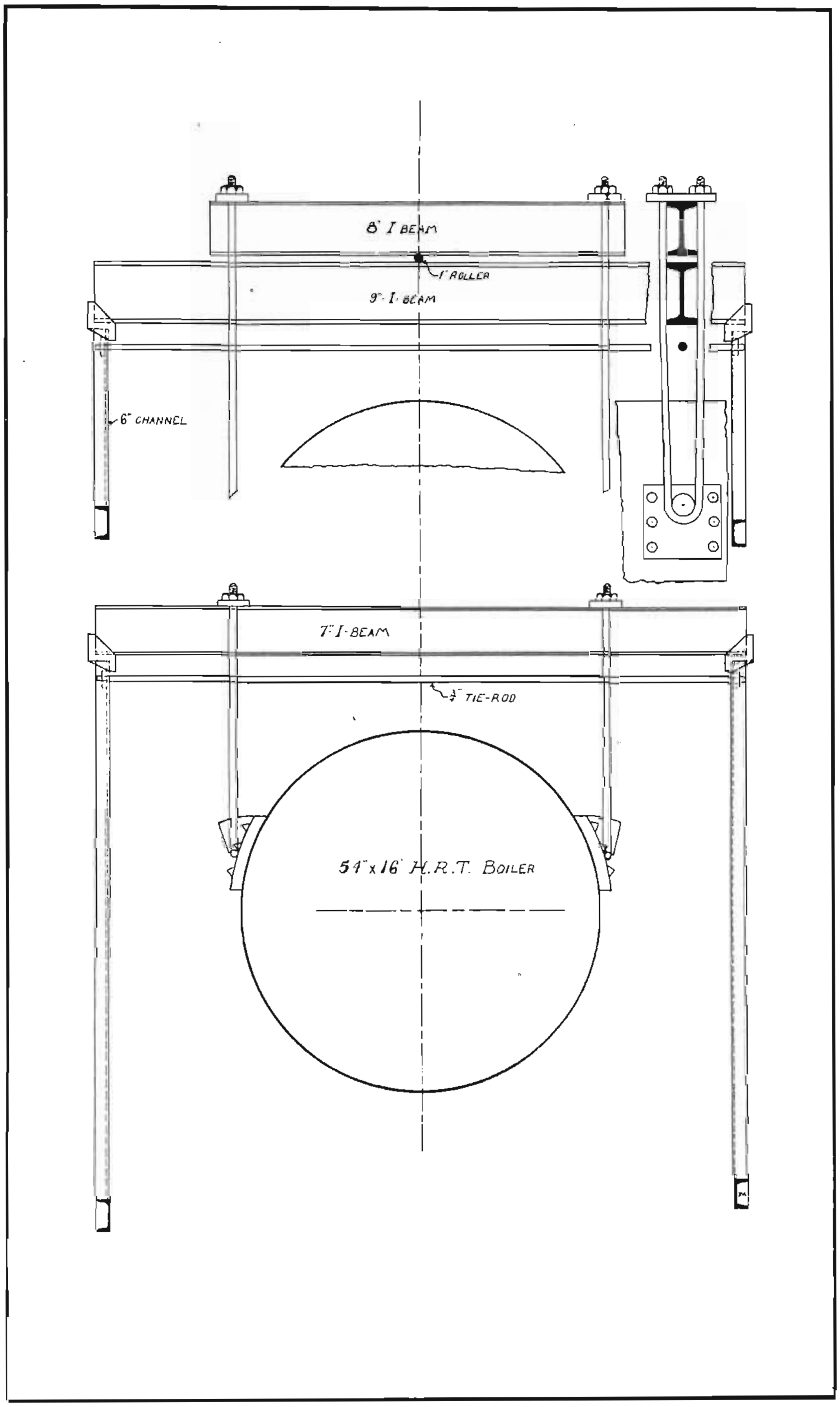



PLATE XII. Method of hanging a shell boiler.

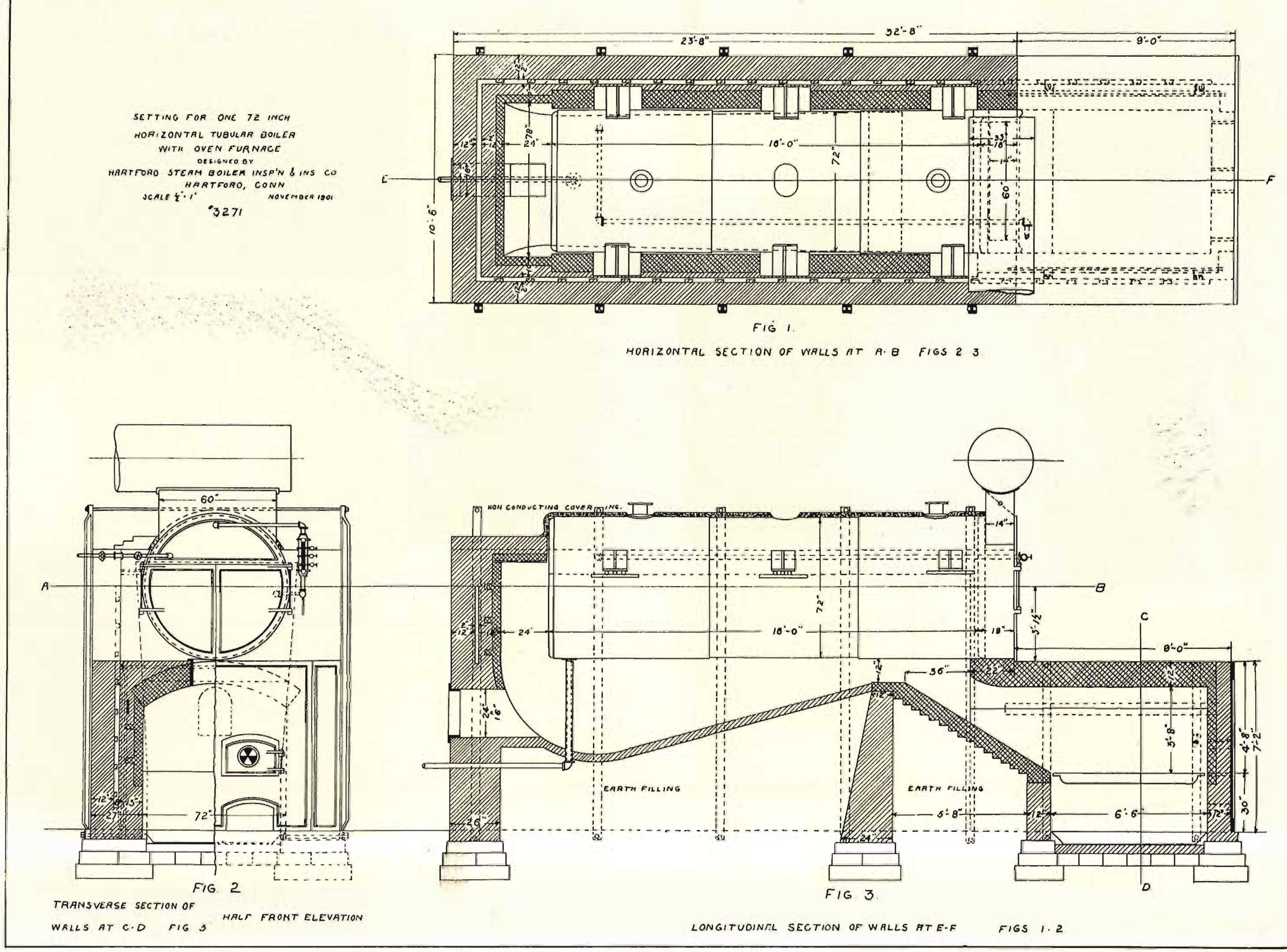

SETTING FOR ONE 72 INCH
HORIZONTAL TUBULAR BOILER
WITH OVEN FURNACE
DESIGNED BY
HARTFORD STEAM BOILER INSP'N & INS CO
HARTFORD, CONN
SCALE ¼" = 1'   NOVEMBER 1901
#3271
32'-8"
23'-8"
9'-0"
18'-0"
72"
10'-6"
E
F
FIG 1.
HORIZONTAL SECTION OF WALLS AT A-B FIGS 2 3
A
B
C
D
60"
72"
NON CONDUCTING COVERING
24"
18"
14"
36"
8'-0"
5'-8"
6'-6"
7'-2"
4'-8"
30"
EARTH FILLING
EARTH FILLING
FIG 2.
TRANSVERSE SECTION OF WALLS AT C-D FIG 3
HALF FRONT ELEVATION
FIG 3.
LONGITUDINAL SECTION OF WALLS AT E-F FIGS 1-2

PLATE XIII

The boiler should be hung on columns by means of equalizing levers and hangers, so as to keep the shell free from strains due to settling of the brick work.

A method of hanging a shell boiler which can be applied to a boiler of any size is shown in Plate XII as designed by the writer for a 54-inch boiler, 16 feet long.

Plate XIII shows the construction of a "dutch oven" for a 72-inch by 18-foot boiler. The dimensions are governed in part by the size of the grate, but the thickness of the brick work would be practically the same for all sizes.

The construction should be very substantial in order to stand the high temperature.

Plate XIV shows the standard setting plans for a 72-inch by 18-foot boiler. For other sizes the thickness of walls would be the same, but the general dimensions would conform to the size of the boiler shell, as shown in Fig. 32. The overhanging front shown is better than the flush front. Two lugs on each side would be better than three, as shown.

## BOILER FEEDING.

The most reliable boiler feeder is a direct acting single or duplex pump as illustrated in Figures 34 and 35, and Plate XV.

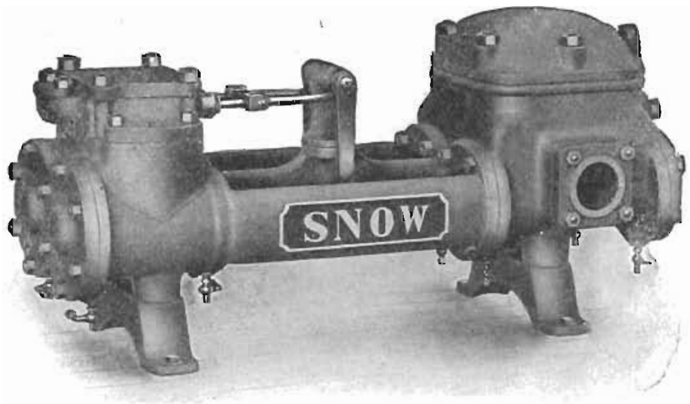



FIG. 34. Type of boiler feed-pump; duplex.

The exhaust therefrom can be used to help in the heating of the feed-water as explained later. A second pump, or an injector, should be installed in reserve.

The use of cold feed-water, where it can be heated by otherwise waste heat, is uneconomical. It is perfectly practicable by means of exhaust steam from the auxiliary engines (pumps), or the main engine, to heat the feed-water to 200 degrees F., or even 210 degrees F. This will effect a saving of 10 per cent or more in the fuel consumed by the boiler.

The use of cold feed-water is also bad for the boiler, because of sudden strains thrown upon the shell plates and seams, which lessen the life of the boiler.

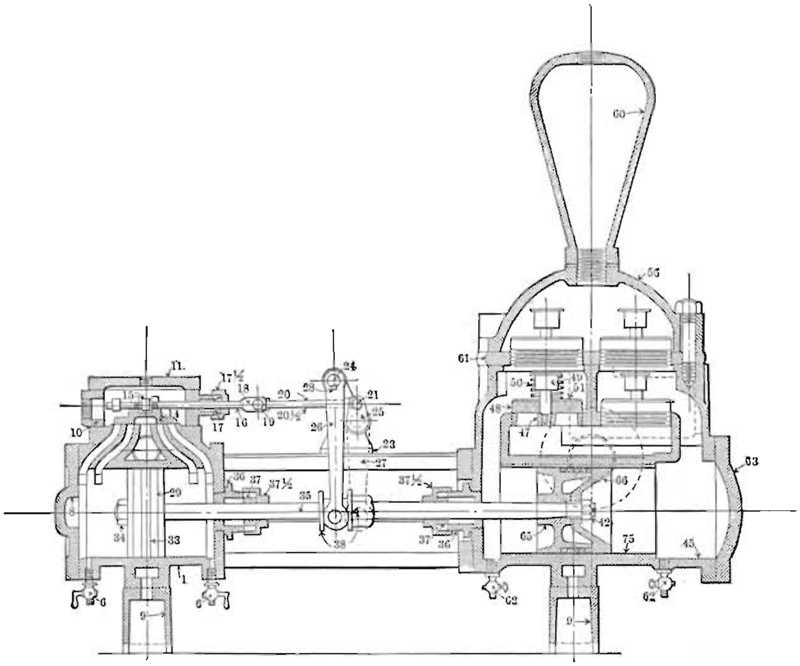


FIG. 85. Duplex pump in section.

Feed-water heaters can be built so that they will act as purifiers. Carbonates of lime and some other solids are precipitated from water which is heated to about 180 degrees F., and in some cases nearly complete purification would result.

Setting for One 72 Inch Horizontal Tubular Boiler.

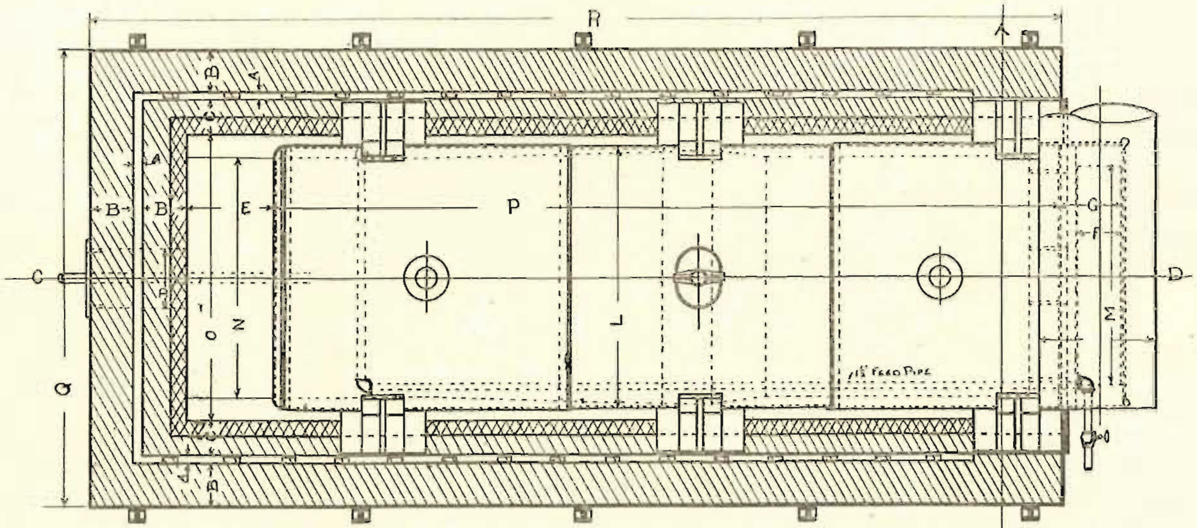
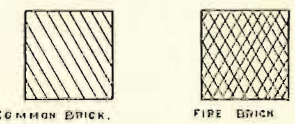



Fig. 1.
Horizontal Section of Walls at "E-F" Figs 2 & 3.



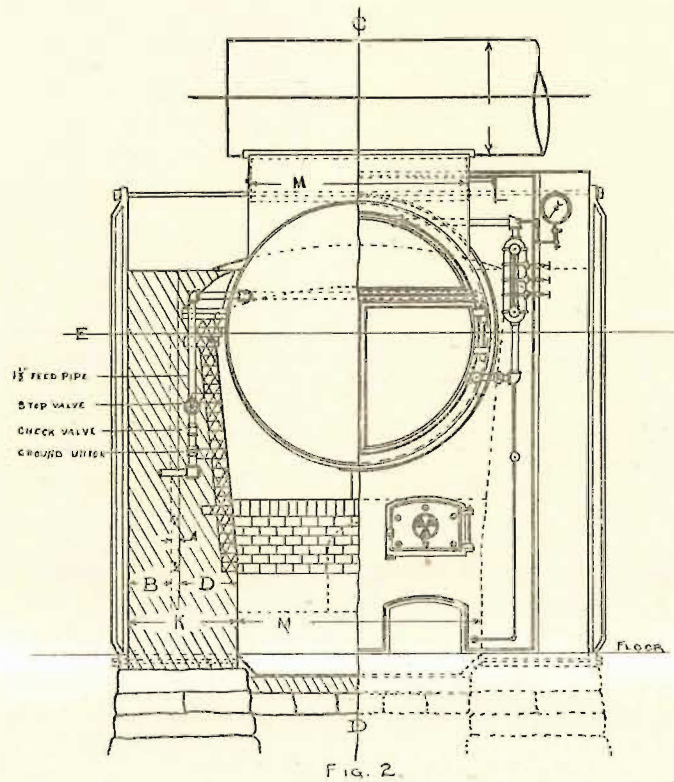




Fig. 2.
Transverse Section of Walls at "A-B" Figs. 1 & 3. Front Elevation

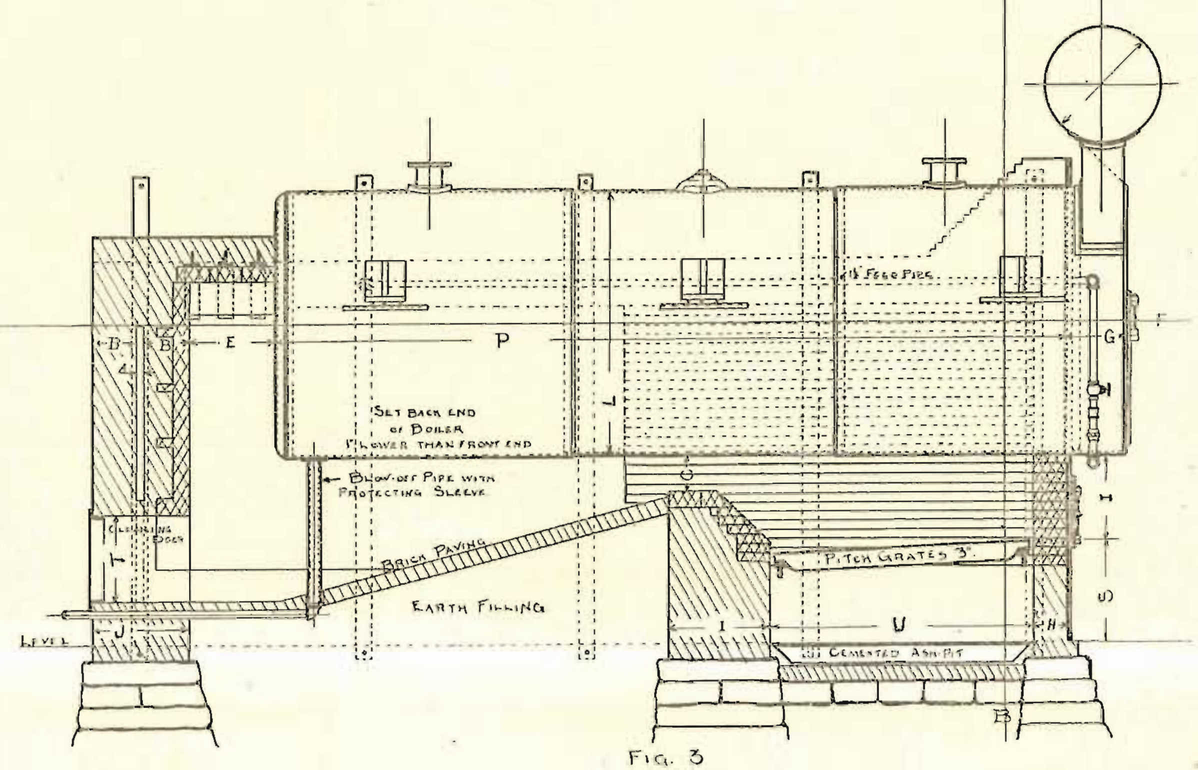



Fig. 3
Longitudinal Section of Walls at "C-D" Figs 1 & 2.

Plate XIV.

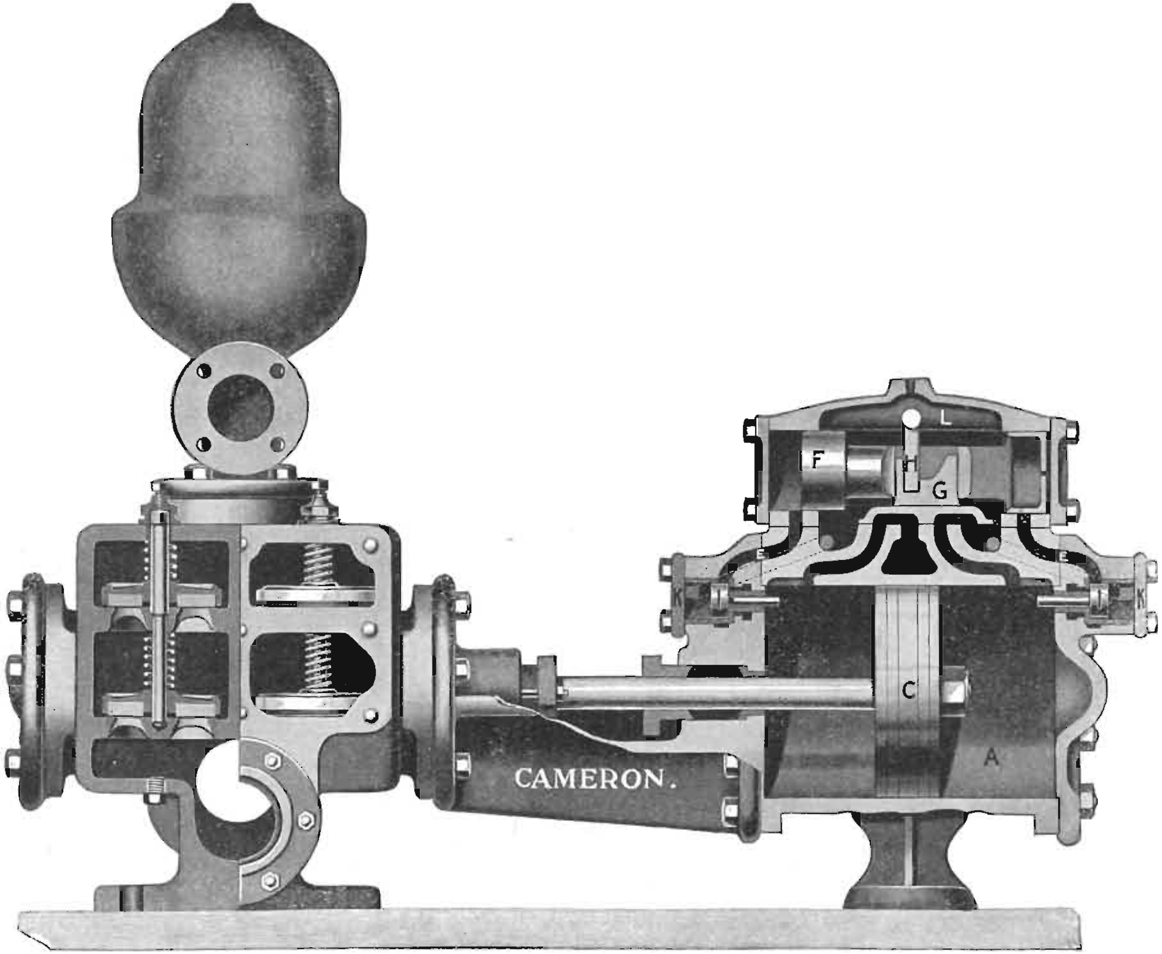



PLATE XV. Type of boiler feed-pump; simple, direct acting, in section.

The cost of a heater and purifier is insignificant compared with the saving effected by its installation and use.

When waste heat is applied to the feed-water the saving which may be effected is given by the following table:

TABLE 3—PERCENTAGE OF FUEL SAVED BY HEATING FEED-WATER.

(Steam Pressure, 80 pounds.)

| INITIAL TEMPERATURE OF WATER. | TEMPERATURE OF WATER ENTERING BOILER—DEG. F | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 160° | 180° | 200° | 202° | 204° | 206° | 208° | 210° | 212° |
| 40° | 10.23 | 11.93 | 13.64 | 13.81 | 13.87 | 14.15 | 14.32 | 14.49 | 14.66 |
| 50° | 9.46 | 11.18 | 12.90 | 13.07 | 13.24 | 13.41 | 14.58 | 13.75 | 13.92 |
| 60° | 8.67 | 10.40 | 12.13 | 12.31 | 12.48 | 12.65 | 12.83 | 13.00 | 13.17 |
| 70° | 7.87 | 9.62 | 11.37 | 11.54 | 11.72 | 11.89 | 12.06 | 12.24 | 12.41 |
| 80° | 7.08 | 8.85 | 10.61 | 10.78 | 10.95 | 11.12 | 11.29 | 11.46 | 11.63 |

For additional tables on savings by heating of feed-water see Kent's Hand Book, p. 727, Fifth Edition.

With proper arrangement the average temperature of the feed-water can be kept at 200 degrees F. This means a saving in fuel of 12.9 per cent for cold water averaging 50 degrees F. and steam at 80 pounds per square inch.

There are many forms of exhaust feed-water heaters on the market. They may be classified as open heaters and closed heaters.

Fig. 36 shows in diagram the essential features of the open heater, and Fig. 37 those of the closed heater.

Figs. 38 and 39 show commercial forms, respectively, of the open and closed heaters. Both are of the vertical type, which is more economical of floor space than the horizontal type.

Two principal differences are noted. In the open heater the steam and the feed-water are in contact and the feed-water is not under pressure. In the closed heater the steam and the feed-water are under pressure.

In general there are claimed for the open heater the following principal advantages:

1. The open heater is essentially more efficient than the closed heater, because the steam which furnishes the heat comes into intimate contact with the water to be heated, and the resulting temperature of the latter is higher than can be in the case of the closed heater, wherein all heat transfer must be effected through metal partitions which offer some resistance to such transfer. With water free from scale-forming solids and from grease, this

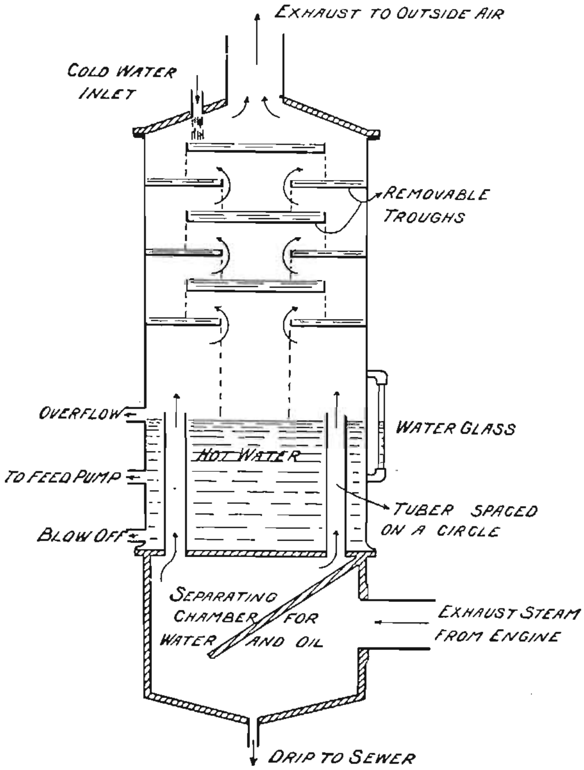



FIG. 5.

FIG. 36. Feed-water heater.

resistance is practically negligible where the metal partitions are of clean copper, but in the majority of cases the feed-water is far from pure and the conductivity of the metal partitions is seriously impaired by scale and grease.

2. The open heater, as usually constructed, (See Fig. 36), is provided with pans, trays or troughs over which the feed-water passes at a low velocity, depositing thereon much of the scale-forming matter; in fact, a portion of the scale is deposited in the heater instead of in the boiler. This partial purification is effected without impairing the efficiency of the heater. In the closed heater the deposition of the scale on the metal partition is objectionable as above stated.

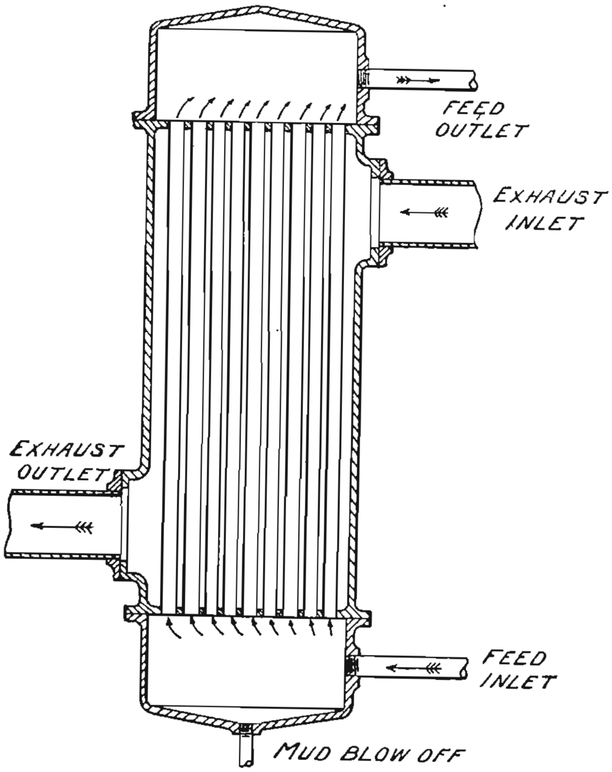



FIG. 6.

FIG. 37. Feed water heater.

3. If, for any reason, the exhaust steam of the main engine is otherwise utilized, the exhaust steam from the feed pump and other auxiliaries can be used in either style of heater. In either case most or all of it will be condensed by the feed-water. In

the open heater this results in a direct saving in the amount of water required for the plant.

4. In the open heater, the air in the free-water is largely liberated by the heat and passes off with the exhaust steam. In general the closed heater should be used if the water is very free

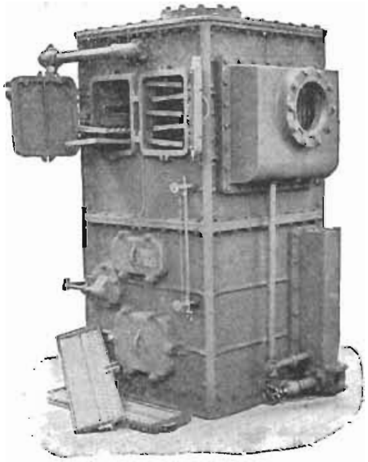


FIG. 38. Type of open feed-water heater.

from mineral impurities or contains only those impurities which will not precipitate at the temperatures attainable with exhaust feed-water heaters.

If the closed heater is used it should be placed in the main exhaust pipe and the feed-water should be handled with an injector arranged to deliver to the boiler through the heater. All things taken into account, the open heater will best meet the needs of the plants under consideration.

In selecting an open heater the following features should be required:

1. A separator, either as an integral part of the heater itself, as indicated in Fig. 40, or as a separate appliance in the main exhaust pipe, or in each of the exhaust pipes of all engines discharging their exhaust through the heater. The former design is preferred.

2. A reservoir or receiver for the heated water, so designed that the water is kept hot until withdrawn by the pump. One

way of constructing such a reservoir is shown in Fig. 40. The exhaust steam passes through a number of tubes surrounded by the feed-water.

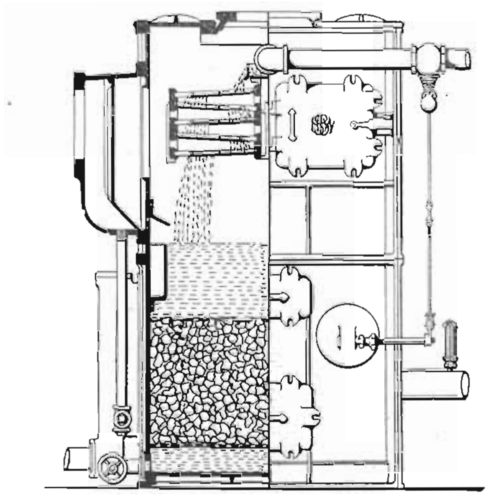


FIG. 39. Sectional view of open feed-water heater.

3. The reservoir should be capacious and provided with blow-off overflow and water glass. The feed pump connection should be a few inches above the blow-off.

4. A large heating and purifying chamber containing pans, trays or troughs arranged so that the cold feed-water shall flow over all of them at the same time so that the exhaust steam shall be compelled to come in contact with the water on every tray.

5. The trays should be readily removable and of such construction that the accumulation of scale thereon can be knocked off or picked off without injury to the trays.

It is a good plan to extract the grease from the exhaust steam used for heating the feed-water, because most cylinder oils are injurious to a boiler when allowed to accumulate therein.

The extraction of the grease can be accomplished by the use of "separators" which are essentially enlargements of the exhaust pipes wherein the steam throws down its entrained water and oil which are led off by a drip-pipe.

## FIRING.

A bad fireman is a poor investment, even if he pay for the privilege of firing, and a good fireman is a jewel. In spite of the extensive use of automatic stokers in large plants, it remains a fact that intelligent hand firing is more economical than machine firing for most plants. It is a mistake to suppose because the power station uses but a small portion of the whole coal of the works, that economy in firing is unimportant. The expense account is made up of a few large items and many small ones. If the small ones are expunged or reduced the credit margin is increased. The secret of good firing is in securing the right amount of air at all points in the fire. The top of the stack is a good indicator of the economy of the fire box, and a window in the roof of the boiler room, with a man under it who will look up, are useful adjustments to any boiler room.

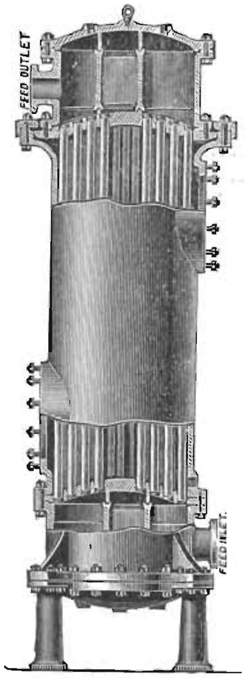


FIG. 40. Type of closed feed water heater.

For the proper handling of his fuel the fireman should have knowledge of its properties. For the information of users of Iowa coal the following discussion will be found of value:

Iowa coals are almost entirely bituminous and non-coking. "In nearly all cases ordinary breakage of coal yields more or less of cubical blocks of varying size" which are much broken up by transportation and weathering. The amount of breakage depends also upon whether the "long wall" or "shooting" method of mining is used. In the former the coal is undermined and broken off by settling of the roof or wedged down, and in the latter the coal is removed by drilling and blasting. The latter process breaks up the coal very thoroughly and is a quicker process, but lessens the value of the product.

An average of 64 analyses by the State Geologist gives the following chemical composition:

| | |
|---|---|
| *Moisture | 8.57 |
| Fixed carbon | 45.42 |
| Volatile matter | 39.24 |
| Ash | 6.77 |
| | 100.00 |

Analyses of coal from 16 mines in the Des Moines River district gives:

| | |
|---|---|
| **Moisture | 8.08 |
| Fixed carbon | 45.60 |
| Volatile | 38.14 |
| Ash | 8.18 |
| | 100.00 |
| Sulfur | 3.42 |

or on the basis of oven dried samples,

| | |
|---|---|
| **Fixed carbon | 49.62 |
| Volatile matter | 41.49 |
| Ash | 8.89 |
| | 100.00 |
| Sulfur | 3.72 |

In 1901-02, at the Iowa State College, Mr. F. M. Weakly made a study of the chemical compositions of Iowa coals, from which the following is quoted:

"The moisture in Iowa coals varies (for the coals tested) from 4.03 to 17.47, the average being 8.08. This moisture is high, as compared with that in coals of other states.

"Eliminating moisture from our comparisons, in volatile matter the Iowa coals are rich, varying from 36.94 to 48.69, with an average of 41.49.

"The fixed carbon ranges from 44.86 to 54.91, with an average of 49.62, slightly lower than that of many coals from other states.

*Steam Boiler Economy, Kent, p. 74.
**F. M. Weakley, The Iowa Engineer, June, 1902.

"Total combustibles are high, running from 84.88 to 95.91, with an average of 91.11.

"Ash is low, being from 4.09 to 15.12, with average of 8.89.

"Sulfur is high, from 2.27 to 7.41, with an average of 3.72.

"The coals high in sulfur are also high in ash."

Concurrently with the work of Mr. Weakly, Messrs. Austin and Peshak, under the direction of the writer, determined the calorific power of samples of coal from twenty or more mines from the same district, fourteen of the samples being the same as used by Mr. Weakley.

The Parr calorimeter was used. The results are a minimum of 11941, a maximum of 13141 and an average of 12343 B. T. U. per pound of oven dried coal.

The following table exhibits the results of the work of Messrs. Austin and Peshak:

CALORIFIC POWER OF IOWA COALS AND OTHER FUELS.

| | B T U. |
|---|---|
| Slack coal, Marquisville, Iowa | 10574 |
| Spring Valley, Ill. | 12608 |
| West Virginia screenings | 11331 |
| Lumsden Coal and Mining Company | 12097 |
| Des Moines Coal and Mining Company | 12041 |
| Whitebreast Fuel Company, Hilton, Iowa | 12396 |
| Whitebreast Fuel Company, Pekay, Iowa | 13050 |
| Hocking Valley Coal Company, Mine No. 1 | 12037 |
| Hocking Valley Coal Company, Mine No. 2 | 12560 |
| Lumsden Coal Company, Bloomfield, Iowa | 13204 |
| Kalo, Iowa | 10451 |
| Centerville Block Coal Company | 12681 |
| Eldon Coal and Mining Company, Laddsdale | 13141 |
| Consolidated Coal Company, Buxton, No. 10 | 12030 |
| Consolidated Coal Company, Buxton, No. 11 | 10585 |
| Lodwick Brothers Coal Company, Mystic | 12780 |
| Carbon Coal Company, Willard | 12245 |
| Crowe Coal Mining Company, Boone | 12729 |
| Corey Coal Company, Lehigh | 12431 |
| Platt Pressed and Fire Brick Company, Van Meter | 11941 |
| Jasper County Coal and Mining Company, Colfax | 12134 |
| Empire Coal Company | 10881 |
| A. A. Conway Coal Company | 10132 |
| Anthracite coal | 12532 |
| Crude petroleum Beaumont, Texas | 19000 |
| Crude petroleum, Chanute, Kansas | 19488 |
| Lamp black | 14467 |

In 1900 boiler tests at the Iowa State College gave the results exhibited in Table No. 4.

TABLE No. 4.

| KIND OF FUEL. | Cost per Ton of 2,000 lbs. | Fuel Cost of 1,000 lbs. Steam from and at 212°. |
|---|---|---|
| Marquisville slack | $1.43 | 14.9 cents |
| Marquisville steam | 2.35 | 21.2 cents |
| Marquisville nut | 2.54 | 21.5 cents |
| Marquisville lump | 2.28 | 24 0 cents |
| Coke, eastern foundry | 8.00 | 60.4 cents |
| Anthracite nut | 8.95 | 52.8 cents |

The interesting feature of these results are the prohibitive cost of anthracite and coke and the advantage of slack over the better grades of coal from the same mine.

It is evident that transportation charges will materially change the relative values of coal for steam generation. It is also true that the method of handling, the design of the boiler setting and the character of the fuel itself as to ash, sulfur and moisture will materially influence the cost of generating a unit quantity of steam.

*Methods of Firing.*—Frequent and small charges of fuel intelligently distributed will enable the burning of the poorest fuel with a minimum of smoke and a maximum of economy even in furnaces which are not ideal in their construction. Slack and steam coal should be fired in thin beds, three to six inches, and lump coal ten to twelve inches, and the fires should not be disturbed too often by shaking or poking.

Wetting the fuel before firing is sometimes useful in promoting coking and preventing the carrying off through the chimney of small particles of unburned coal.

Flues should be frequently cleaned by scraping or blowing with steam or air. A steam jet over the fire is useful when the coal is freshly fired, but is detrimental at other times.

If used continuously the loss of heat in the steam is appreciable, and being useless, is inexcusable.

The ideal conditions for combustion exist when the air supply is from one and one-half to two times the theoretical amount and when the same is thoroughly mixed with the combustible portion of the fuel at a temperature equal to or greater than the temperature of ignition. These conditions can be very nearly attained for Iowa coal if the principles of the boiler and the furnace design and operation above enumerated are followed.

## ENGINES.

The selection of an engine is not governed by rules so much as by the individual judgment of the purchaser. Consequently, engines vary more in detail than boilers of the type above discussed.

The writer is of the opinion that up to 100 horse power the moderate speed throttling or automatic engine will best meet the needs of clay workers, and for large powers the Corliss engine may be used to advantage. For either type the following general proportions should be observed:

Diameter of steam pipe equal to one-third cylinder diameter.

Diameter of exhaust pipe equal to one-half cylinder diameter.

Diameter of piston rod equal to one-sixth cylinder diameter.

Diameter of shaft equal to one-half cylinder diameter.

Diameter of crank pin equal to one-third to one-half cylinder diameter.

Length of connecting rod equal to three times length of stroke.

The effective power of a single high or medium speed engine can be calculated by use of the formula:

Horse power $= 0.002 \times L \times A \times N$ wherein

$L$ = length of stroke in feet.

$A$ = area of piston in square inches.

$N$ = number of revolutions per minute.

For a simple Corliss engine the corresponding formula is

Horse power $= 0.0018 \times L \times A \times N$.

Both engines are supposed to use steam at 80 pounds, boiler pressure. Increase in boiler pressure will give a proportionate increase in capacity of engine in either case.

In addition, it should be remembered that durability is proportional to weight, and that weight is cheap in first cost, that convenience in adjustment, simplicity of detail and perfect lubricating devices are essential.

Engine foundations should be massive and well built. They should rest on hard and natural soil or rock, and the engine should be securely bolted thereto.

### MINOR ITEMS.

All live steam pipes and fittings and the tops of boilers should be thoroughly lagged with sectional non-conducting covering or its equivalent. Such covering, if of good quality, will last ten or fifteen years and will pay for itself in three years in heat saved that would otherwise be lost by radiation. It is important that the pipe covering should be applied with care in order to have the pipe completely covered, by the covering, and not merely by the canvass wrapper. The latter should be thoroughly pasted down and the metal bands tightened.

Self-oiling bearings or other continuous oiling devices and an oil filter will save their cost in a year and will last many years.

When properly cared for, the leather belt is the most satisfactory in the long run, but the writer believes that rope transmission will be found to be adapted to clay work, by the reason of its flexibility and its ability to endure exposure.

Narrow double belts are better than wide single belts of the same weight.

A belt speed of 3,000 feet per minute gives good results. At this speed a double belt, glued joints, one inch wide, will transmit easily four to five horse power if the pull is steady and not jerky.

A rope can be safely run at 4,500 feet per minute, and a one-inch rope at this speed will transmit from a single groove pulley not less than 13 horse power.

In order to heat the drying rooms successfully and economically, the exhaust steam from the engine should be utilized.

At the same time the back pressure on the engine should be kept low. This can be accomplished and at the same time a good circulation of the steam in the coils obtained, if the coils are built as manifold or heater coils, but not if the return bend coils are used. The latter offer too much resistance to the flow of the steam. The heating main, or exhaust pipe continued, should be carried up to and along the ceiling of the drying room and hung with a pitch downward away from the engine. The furthest point of the main should be connected by a large drip to the return main, which should be two-thirds the diameter of the steam main and should pitch downward toward the hot well or heater in the boiler room.

The supply of pipes for the several coils should be taken from the top of the steam main and should pitch downward toward the coils which connect them with the return main. The point of discharge of the return main into the hot well or heater should be the lowest point on the system, so as to insure a "dry" return, and a trap should be provided at this point to prevent the steam from blowing through. The main exhaust of the engine should be provided with a back pressure or relief valve set to work at a lower pressure than the trap, and a grease extractor should be placed in the heating main to keep oil from being carried through the system to the hot well. The construction here outlined will secure, in addition to its main object, the incidental and important advantage of a supply of condensed steam from the boiler feed, and this at a temperature such that the waste steam from the pumps will be able to raise the temperature of the feed well towards the atmospheric boiling point by means of the heater and purifier above mentioned.

Ventilation is essential and can be secured by stacks or fans, or both. Generally speaking, a fan is a more economical method of moving air than is a column of hot air, and is more easily controlled, but the stack is simpler and therefore frequently more desirable.