# CHAPTER XLIII.—MARINE BOILERS.

BOILERS for marine engines are, in England, made of special qualities of plate, the best being termed Yorkshire, and a nearly equal grade, Staffordshire. The plates for the shell, the furnace bottoms and the gusset stays are made of Staffordshire, while the tube plates, furnace tops, and such parts as require to be flanged and are subject to more intense heat, are made of Yorkshire plate, which has more ductility.

In the United States the grades of iron used for boilers are C H No. 1 S, or charcoal hammered No. 1 shell iron, for the shell, and C H No. 1 F, or charcoal No. 1 flange iron, which is used for the furnaces and such parts as require flanging.

In both countries steel is also used for boilers, except for the tubes, for which it is not entirely reliable if very high pressures are to be used.

Both the iron and steel plates are tested for tensile strength and ductility.

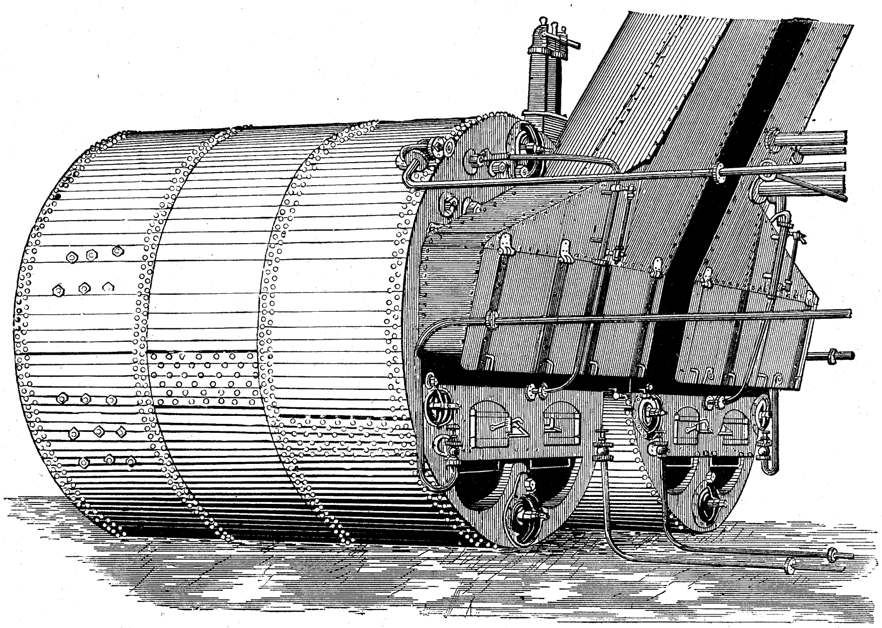

Fig. 3409.

The breaking strain is that which is sufficient to cause rupture, while the *proof strain* is that which the metal is required to withstand with safety.

The safe working strain, or working pressure, W P, is the strain under which it is considered safe to work the boiler.

The strength of a boiler of a given diameter and thickness of plate varies according to the construction of the riveted seams or joints.

Boiler stays or braces are rods, ribs, or plates for supporting the weaker parts of the boiler. Thus the tube plates may be stayed by rods passing through both plates and screwed into them, or nuts and washers may be used on the stays one on each side of each tube plate.

Gusset stays are iron plates which are riveted to **T** irons or in some cases to **L** irons, which are riveted on the surfaces to be stayed.

Stay tubes are thick tubes (usually about $\frac{3}{16}$ inch thick), which screw into the tube sheets and are riveted over at the ends. A superior construction, however, is to provide nuts and washers to the ends of the stay tubes, one on each side of each tube plate.

Boiler stays are usually made of such diameters that when new they will sustain a tensile strain of not more than 5,000 lbs. per square inch of cross section, this being the rule of the Board of Trade.

Stays are sometimes screwed into the tube plates and then riveted over at the outside ends. A better method, however, is to let the ends of the stays receive a nut on each side of each tube plate.

Boiler tubes are secured in their tube plates by being *expanded* in. This may be done by driving in a taper steel mandrel, and then clinching them over, or by using a tube expander. There are two principal kinds of tube expanders, in one of which small rolls travel around the bore of the tube and expand it, while in the other a number of segments, held together by a spring, are forced outwards by a mandrel driven in by hammer blows.

Too much expanding is apt to weaken the tube close to the inside face of the tube sheet.

Boiler tubes leak first at the end which receives the greatest heat from the fire, the leakage being caused by the expansion and contraction of the tube, which is obviously hotter than the water which causes the tube to expand more than the boiler shell. The remedy is to re-mandrel or expand the tube.

The scale that forms on the face of the tube sheet keeps the water away from contact with the plate, which with an undue thickness of scale will crack between the tube holes.

A tube that is split or that cannot be made steam tight by being re-mandrelled or expanded is plugged up at each end by means of either wooden or iron plugs. The best plan, however, is to use iron discs having a stepped diameter, so that one end will fit the bore of the tube, and the other will form a shoulder that will cover the end of the tube.

Each disc has a hole through its centre, so that a wrought iron rod or bolt may be passed through the hole and receive a nut at each end. Beneath the flange of each disc, a grummet of spun yarn and white lead is placed, so as to make a steam tight joint when the nuts are screwed home. This stays the tube plates as well as stopping the leaky tube.

If wooden plugs are used, they are made a driving fit in the tube bore, and driven through until they have passed the split, and a second wooden plug is driven tightly from the same end of the tube.

The up take of a marine boiler is the casing or passage way through which the heat and gases pass after leaving the boiler. A dry up take is one which is outside of the boiler, as in Fig. 3409, which represents an outside view of a boiler such as shown in Figs. 3410 and 3411.

A wet up take is one which passes through the boiler, and therefore has fire on one side and steam on the other. It is therefore under a collapsing pressure.

The furnace of a marine boiler extends from the fire door to the combustion chamber (*i. e.*, the box in which the heat of the furnace passes before returning through the tubes).

The superheater of a marine boiler is a cylindrical vessel receiving the steam from the boiler, and delivering it to the main steam pipe, whence the steam is delivered to the engines, etc. When it has no connection with the up take, it may, however, be more properly termed a steam driver, since it serves to separate the steam from entrained water, and does not superheat the steam.

In some cases, however, the superheater takes the form of a spherical ended cylinder standing in the up take.

The receiver of a marine boiler is a drum or cylinder that receives the steam from the boiler and from which the steam passes through the steam pipe to the engine. The receiver is by some called the *steam chest* of the boiler.

The fittings essential for a marine boiler are: The safety valves; the test cocks (or gauge cocks, as they are sometimes termed); the water gauge glass; the stop valves; the check valve for the boiler feed pipe, and the valves for letting on steam to the main engine and such other engine or engines as may take steam from the main boiler; the scum cocks; the blow off cocks; and a small cock to enable the drawing of water from the boiler to test its degree of saltness.

There are two kinds of safety valves, the dead weight and the spring loaded.

A dead weight safety valve is one in which the valve is held to its seat by dead weight, the objection to which is, that when the vessel rolls the effect of the weight or weights upon the valve is diminished; hence under heavy rolling the steam may blow off at a less pressure than the valve is set for.

A lock up safety valve is a dead weight safety valve, the top of whose spindle is provided with a cast iron cap or bonnet with two handles on. This cap is keyed to the spindle, and the keyway is so disposed that no extra weight can be added to the valve, while at the same time the valve can be lifted from its seat and turned around.

A spring loaded safety valve is one in which the valve is held down by the pressure of a spiral spring, and this pressure will obviously not vary, no matter how much the ship rolls.

In proportion as the valve lifts and the spring compresses, its resistance increases, and this tends to impair the accuracy of the valve. This, however, is offset from the fact that when the valve rises from its seat it presents a greater area for the steam to act against.

The area of safety valve required by the English Board of Trade is about ½ square inch of valve area per square foot of fire grate area.*

There are three test cocks, which are sometimes placed in a diagonal row on the front of the boiler, and sometimes on the fitting for the gauge glass. The top test cock shows highest level to which the water should rise in the boiler, and the lowest one the lowest level, the middle cock indicating the average. There is usually a vertical distance of about 4 inches between the test cocks, which gives a permissible range of 8 inches in the level of the water in the boiler.

* See page 409, Vol. II., for safety valve calculations.

Test cocks are prevented from choking with scale by passing a wire through the cock and clear into the boiler, a plug being provided, which, when removed by unscrewing, permits the insertion of the wire.

This cleaning must obviously be performed when there is no steam on the boiler.

A gauge glass is a glass tube whose bore is open to the boiler. It is fitted at each end to a brass socket that is screwed into the boiler, each socket having a cock that permits communication between the gauge glass and the boiler to be shut off in case the glass should break. The bottom socket is also fitted with a cock, which, on being opened, permits the water and steam to blow through the gauge glass and clean it of scum or dirt.

The gauge glass must be plainly in sight, and placed at such a height that when the desired quantity of water is in the boiler it will half fill the gauge glass.

Glass water gauges, instead of attaching to the boiler, are sometimes fitted to a fitting that connects to the top and bottom of the boiler, with the object of attaining, for the gauge glass, water free from the scum and impurities which collect at and near the surface of the water in the boiler. This fitting should have cocks in each pipe leading to the boiler, so that in case the gauge glass breaks, steam can be shut off from the boiler.

In some cases the test cocks are also attached to this fitting, and in this case the construction should be such that shutting off communication between the gauge glass and the boiler will not at the same time shut off communication between the test cocks and the boiler.

When the boiler is priming or steaming very fast, the gauge glass may show a false water level, hence reading should be compared with that of the test cocks.

If the water gets too low, the first parts of the boiler to be injured will be the top of the flame box, or the combustion chamber, and the top row of tubes, because they are the first surfaces that the water will fall below and leave exposed to the heat without having water on the other side.*

The pressure in the boiler is shown by a steam gauge, pressure gauge, or dial gauge as it is promiscuously called.

A Bourdon dial gauge or pressure gauge consists of a dial casing, containing a hollow thin brass hoop, oval in cross section, which receives steam from the boiler.

This hoop is fixed at one end, while the other end is closed and free to move. The free end is connected by a small link to a toothed sector, which gears or engages with a small pinion fast upon the spindle of the pointer or needle. When the steam is admitted into the hoop, it straightens out or expands in diameter to an amount that is proportionate to the amount of the pressure within the hoop, and thus causes the needle or index pointer to revolve, and denote from the markings or readings of a dial plate the amount of pressure within the hoop.

If the pressure within the hoop is released, it will move to its normal or zero position. In the course of time, however, the hoop is apt to get a slight permanent set and not indicate correctly. It may, however, be approximately tested for accuracy by testing its readings with that of the safety valve.

The working parts of the gauge, and its casings also, are made of brass, so that they shall not corrode, and to prevent the heat of the steam from permeating the gauge and impairing the action from expanding the parts, a small quantity of water interposes between the gauge and the steam, the construction being as follows:

Outside the gauge casing the steam pipe is bent into a loop forming an inverted syphon which is to contain the water.

At the lowest point in the bend of the syphon a small cock is inserted, which lets the water out of the leg of the syphon nearest to the boiler, because water in that leg would, from its weight, cause the gauge to show a pressure higher than that in the boiler.

The pressure shown by a steam gauge is that above atmosphere,† and not that above vacuum.

* See page 370, Vol. II., on low water in boilers.

† See page 367, Vol. II., for remarks on total pressure and pressure by gauge.

The stop valve of a marine boiler is a valve that is opened to let the steam into the main steam pipe.

A blow off cock is a cock employed to blow off, or let all, or a part of, the water out of a boiler. There are generally two, one on the bottom of the boiler, and the other at the ship's side, so that if the pipe was to break or get damaged, the cock at the vessel's side can be closed to keep the sea water out, while that on the boiler may be closed to keep the water and steam in the boiler. These two ends cannot obviously be obtained if one blow off cock only was used.

Blow off cocks are opened and closed by a spanner or key that is removable from the cock, and to prevent the possibility of taking off the spanner or key, before the blow off cock is closed, a spanner guard is employed.

A spanner guard is a cap having a lug or tongue, which projects into the hole in the spanner guard, through which the spanner or key must pass before it can fit on the head of the blow off cock, and the key or spanner has a corresponding recess, so that the spanner or key can only be put on or taken off when the cock is closed.

Blowing off a boiler is emptying it entirely, as for examining the whole interior of the boiler.

Blowing down a boiler is letting out a portion of the water, so as to carry off the loose scale, mud, or sludge that may accumulate on the bottom of the boiler. The mud or sludge would form into scale if allowed to remain.

A scum cock is a cock employed to blow off a portion of the surface water in a boiler, and thus remove the scum, salt, and impurities which float or are thrown up to the surface.

Two scum cocks are employed, one on the side of the boiler, and one on the side of the ship. These two cocks are connected by a pipe. That on the boiler is placed a little below the working level, which is supposed to be (and is kept as nearly as possible) about 9 inches above the top row of tubes.

Sluice valves are doors sliding, water tight, in ways at the entrance to the bulkheads on both sides of the ship. They should be worked from above, in order that they may be shut when the depth of water in the bulk heads might prevent them from being worked from below. These valves should be operated occasionally to ensure that they slide easily and are in working order.

Scale in marine boilers using salt water is composed of sulphate of lime. It is most objectionable on the furnace tops, on the sides and tops of the combustion chamber, on the tubes and on the tube plates. It may be prevented to some extent from forming by a rapid circulation of the water in the boiler, by blowing down the boiler through the scum cocks, by the suspension in the boiler of zinc plates in contact with iron ones, by impregnating the water with chemical antidotes, which maintain the impurities in the form of mud or sludge, and by purifying the feed water. If surface condensers are used, scaling is obviously diminished by feeding as little salt water as possible, which may be done by not getting up a steam pressure high enough to cause the safety valve to blow off, and by preserving the water from the exhausts of the donkey or other engines about the ship.

A thin coating of scale, as say $\frac{1}{32}$ inch thick, may serve as a protection against the chemical action of water that would act to corrode the surfaces, as in the case of harbors receiving the waste waters from chemical works or other impure waters. A thick coating of scale causes the plates to burn on the side receiving the furnace heat, and causes blisters to rise, while at the same time it decreases the value of the heating surface.

Scale on the tubes causes them to expand more, and therefore leak in the tube sheets.

This extra expansion sometimes breaks away the scale at the neck of the tube in the tube sheet and gives access to the water there, and the chemical action of water will in some cases cause the tube to be eaten through close to the tube plate.

Scale is removed mechanically by chisels, scrapers and chipping hammers, which are applied to all the surfaces that can be got at from the inside of the boiler (the man hole affording access to the boiler). After the scale has thus as far as possible been removed, it is washed out of the boiler. The efficiency with which scale may be removed from the tube sheets and tubes depends, to a great extent, upon the facilities the arrangement of the rows of tubes affords in giving access to the scaling chisels.

The salinometer. Salt water is heavier than fresh water, hence the amount of saltiness of water may be known from its density or weight. A salinometer is an instrument that determines from the density of the water the amount of salt contained in the water. It consists of a graduated stem at whose extremity is a weighted bulb which partially sinks the tube in the water ; the depth to which the bulb sinks shows the density of the water.

The reading of a salinometer is taken at the water level, and is read on the tube, which is graduated as follows: The mark furthest from the bulb or highest up the stem is marked 0, and if the zero line is level with the surface of the valve in which the salinometer floats, it indicates fresh water. If salt be added to the fresh water, the salinometer will rise in the water, and when the water contains 1 lb. of salt to 32 lbs. of water (which is the average degree of saltiness of sea water), the line marked $\frac{1}{32}$ on the salinometer tube will be level with the surface of the water. If the saltiness of the water be increased, the salinometer will rise in the water until, at 2 lbs. of salt to 32 lbs. of water, a line (on the tube) marked $\frac{2}{32}$ will be level with the surface of the water. The space between the $\frac{1}{32}$ and $\frac{2}{32}$ is divided into halves and quarters.

As the density of the water varies with its temperature, therefore the readings on the salinometer must agree with some specific temperature, which is usually 200° Fahrenheit, and the reading of the salinometer is correct only when the water is at that temperature. If, however, the water varies a few degrees from the standard of temperature for which the salinometer is marked, a correction of the reading may be made by adding $\frac{1}{8}$ of $\frac{1}{32}$ for each 10 degrees, that the water is hotter, or subtracting the same for each 10 degrees that it is cooler than the temperature at which the salinometer is correct.

The density or specific gravity of ordinary sea water is 1.027 (that of distilled water being unity or 1), and it contains about 4 oz. of salt per imperial gallon.

Tallow is sometimes forced into a boiler fed with salt water to stop priming, by means of a syringe that is screwed into a tallow cock provided upon the boiler below the water level. If the boiler is fed with fresh water, tallow is apt to cause priming.

Angle irons are used in boiler construction to be riveted to plates that require supporting or strengthening, or for gusset stays to be riveted to. Flanged plates are used in the construction of the furnaces, flame, boxes or combustion chambers, boiler ends and tube plates or tube sheets.

Division plates are fitted in some boilers to prevent the water from passing from one side of the boiler to the other when the vessel rolls heavily. This prevents some of the tubes from being left uncovered by water, and thereby getting injured from undue heat.

These division plates are neither steam nor water tight, and stand fore and aft of the ship. Similar division plates are sometimes used, however, to prevent the tops of the combustion boxes from getting overheated from the motion of the ship leaving them uncovered with water, their location being subserved to this end and varying with the position of the boiler.

The superheater of a marine boiler is provided with a safety valve, and sometimes with a pressure gauge to enable the comparing of the steam pressure with that in the boiler, and should also be provided with a gauge glass, to show when heavy priming is going on.

The main stop valve is upon the superheater, as is also the blast pipe.

Priming is a lifting, into the steam space of the boiler, of a part of the water, and may arise from heavy firing, from the safety valve blowing off, from too little steam space, and from other causes.

Priming* often occurs when the boiler feed is changed from salt water to fresh water, or from fresh to salt water.

* See page 370 Vol. II., on priming.

A separator or interceptor is a device fitted to either the superheater or to the steam receiver, for separating entrained water from the steam. It consists of a rectangular box or chamber with a partition plate extending from the top half down into the box.

The entering steam strikes the face of the partition plate against which the water collects, and from which it drops to the bottom of the box, while the steam passes under the partition and out at the other side to the engine.

The draught of a boiler is caused by the heat expanding the air and lightening it, thus causing it to ascend. It can be checked by stopping the exit of heated air up the funnel by means of a damper, by checking the flow of cold air into the furnace, by closing the dampers, by opening the furnace doors and letting cold air in the furnaces above the fires.*

A blast pipe is a small pipe leading from the superheater to the funnel, and provided with a stop cock.

It is used for letting a jet of steam up the funnel to promote the draught.

Flame seen at the top of the funnel is caused by the combustion of gases that would have been consumed in the furnace had there been sufficient air or sufficient room for complete combustion. It may be caused in a variety of ways, as insufficient openings between the fire bars, too narrow a space between the bridge wall and the boiler, or too deep a fire upon the bars. It is detrimental, because it obviously wastes fuel.

Dampers are used to regulate the draught in the furnace; they are fitted to the ash-pits or to the funnel, and should be fitted to both, because closing a damper in the funnel sets up a certain amount of pressure in the furnace by holding the heat, whereas dampers at the ash pit doors and none in the funnel lets the heat out and prevents cold air from getting in to promote combustion.

When there are no dampers the furnace doors are open instead, to check the draught; this is, however, highly injurious to the boilers.

The most rapid wasting of the plates of a marine boiler occurs alongside the fire bars, on the furnace tops, at the back of the flame box or combustion chamber, and in those plates generally that receive the most intense heat, and especially when they are heavily coated with scale and are not covered with water.

The scale that forms on the face of the tube sheet keeps the water away from contact with the plate, which, with an undue thickness of scale, will crack between the tube holes.

A tube that is split or that cannot be made steam tight by being re-mandrelled or expanded is plugged up at each end by means of either wooden or iron plugs. The best plan, however, is to use iron discs having a stepped diameter, so that one end will fit the bore of the tube, and the other will form a shoulder that will cover the end of the tube.

Each disc has a hole through its centre, so that a wrought iron rod or bolt may be passed through the hole and receive a nut at each end. Beneath the flange of each disc, a grummet of spun yarn and white lead is placed, so as to make a steam tight joint when the nuts are screwed home. This stays the tube plates as well as stopping the leaky tube.

If wooden plugs are used, they are made a driving fit in the tube bore, and driven through until they have passed the split, and a second wooden plug is driven tightly from the same end of the tube.

Black smoke is an evidence of incomplete or imperfect combustion, and may be, to a great extent, prevented by careful firing, as by feeding gradually and evenly, by the admission of the proper quantity of air, or by a jet of steam admitted above the dead plates.

The furnace bars are ordinarily of cast iron about $1\frac{1}{4}$ inches thick at the top, tapered towards the bottom, and with an air space of from $\frac{1}{2}$ to $\frac{3}{4}$ inch between them.

They require less air space for Welsh than for Newcastle coal, as the latter is the flaming or gaseous coal, and burns the fastest.

* See page 368, Vol. II.

The quantity of coal burned in marine boiler furnaces is about 15 lbs. per square foot of fire grate area per hour; hence the quantity burnt per day with common average engines with 4 furnaces, 3 feet wide and 5 feet long, may be found by multiplying the area of the 4 furnaces (60 feet) by the number of lbs. (15) burned per foot of grate per hour, which will give the total lbs. weight burned per hour, which, divided by 112 lbs., will give the hundredweight burned per hour, and this, multiplied by the number of hours reckoned as constituting a day, gives the fuel consumption per day, based upon 15 lbs. coal per square foot of fire grate area.

The number of tons of steam coal burnt per day to drive an ordinary steamer of 40 feet beam 10 knots an hour by steam alone (or without sail), will depend upon the kind of engine used. Experience teaches us that with average vessels, the beam squared equals the consumption of coal for 40 days, in the case of an ordinary jet condenser engine; 50 days with a surface condensing engine; and 60 days with a compound engine; hence, in the present example, assuming the engine to be jet condensing, we may calculate the fuel consumption per day, for a vessel 40 feet beam giving 10 knots an hour, as follows:

The beam squared gives 1600 ($40 \times 40 = 1600$), which divided by 40 (40 days) gives 40 tons per day. For surface condensing the 1600 would be divided by 50, giving 32 tons per day; and for a compound engine the 1600 would be divided by 60, giving 26 tons $13\frac{1}{3}$ cwt. per day.

It is obvious, however, that calculations of this kind, in which the ratio of expansion is not stated, are the merest approximations.

The number of tons of steam coal that will be burnt per day with a pair of average surface condensing engines having cylinders 50 inches in diameter will be, under average conditions, 16 tons per day, the calculations being based upon the common assumption that the diameter of one cylinder squared and divided by 100 gives the consumption of fuel in tons per day for condensing engines not compounded; thus, $40 \times 40 = 1600 \div 100 = 16$ tons of coal burned per day.

Here again, the ratio of expansion not being specified, the calculation has no real practical value.

If at sea and short of coal, bear in mind that the consumption of fuel per mile run is greater for fast than for slow speeds; hence the following points should be attended to:

Reduce the speed of the ship to say half the usual. Regulate the fire so as to keep up full boiler pressure without blowing off. This will allow the expansion or cut off valve to be set to cut off early in the stroke, and thus save steam. If, under these conditions, the steam should sometimes blow off at the safety valve, cover up part of the fire grate area.

Use a thin, rather than a thick, fire, but be careful that it is not so thin as to let currents of cold air pass through.

To Relieve the Boiler in Case of Emergency.—Suppose an engine breaks down at a time when the fires are heavy and going full, that the steam gauge shows blowing off pressure, but that the safety valve is stuck, or from some cause or other is prevented from blowing off, and cannot be eased or lifted, and the following is the course to be pursued:

1st. Close the ash pit dampers and open the smoke box door and fire door. If there are no ash pit doors, close the damper in the up take and open the fire and smoke box doors.

2d. Start the donkey engine to feed cold water into the boilers.

3d. Start the steam winches, and any other small engines that take steam from the main boilers.

4th. Slacken the escape valves, and open the drain cocks of the cylinders and receivers, and steam will blow through the H. P. cylinder escape valve and drain cock at once. The H. P. slide valve may then be worked by hand, back and forth, to let steam pass into the receiver and blow through its escape valves and drain cock.

5th. Open the scum or brine cocks and keep them open, also open all gauge or test cocks, etc., about the boiler.*

* It is not safe to draw the fire at a time when the pressure is at a dangerous point, especially if heavy, as disturbing it may temporarily increase the combustion and the danger of explosion.

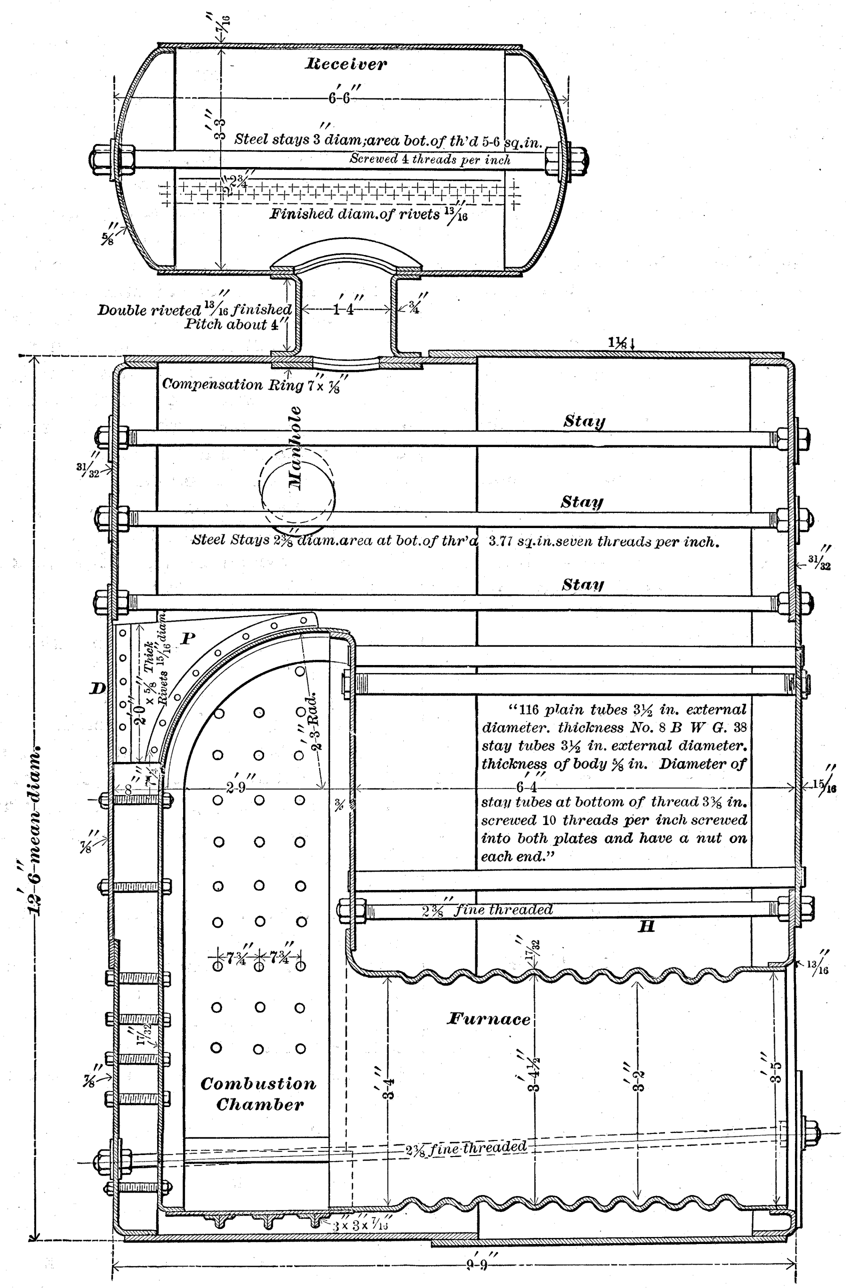


Fig. 3410.

Figs. 3410 and 3411 represent an example of a steel marine boiler, designed for a working pressure of 160 lbs. per square inch, with a margin of safety of 5.

The dimensions are as follows:

| | | |
|---|---|---|
| Diameter of shell | 12 feet 6 | inches. |
| Shell plate | 1 1/8 | " thick. |
| Front and back upper plates | 31/32 | " " |
| Back rivet plates | 7/8 | " " |
| Back lower plates | 7/8 | " " |
| Front tube plate | 15/16 | " " |
| Front lower plate | 13/16 | " " |
| Furnaces | 17/32 | " " |
| Inner tube plate | 3/4 | " " |
| Combustion chamber back | 17/32 | " " |
| Combustion chamber sides | 17/32 | " " |
| Outer sides of wing combustion chambers | 9/16 | " " |
| And bottom of centre one to be | 9/16 | " " |
| Shell of receiver | 7/16 | " " |
| Beds of receiver | 5/8 | " " |
| Receiver connecting pipe | 3/4 | " " |

The riveted joints have all holes drilled. The longitudinal seams are made with butt joints treble riveted, and with double butt straps.

The circumferential seams are lapped and treble riveted.

Fig. 3412 represents the "Martin" boiler for marine engines. In the return flue there are a number of vertical water tubes which are very effective in promoting circulation as well as in generating steam. These boilers are used largely in the United States navy for moderate pressures.

The following upon the testing and examining of a boiler of this class is from *Modern Steam Boilers*:

"Every new boiler should, when complete, be tested by water pressure to double the amount of the intended working pressure; for while the wisdom of applying as high a pressure as three times the working pressure, which is sometimes done, may be questionable, experience has shown that a test by hydraulic pressure will reveal defects that would otherwise be apt to pass unnoticed.

"For instance, when the top plate of a combustion box is stayed against the pressure by girder stays that are not stayed to the boiler shell, the girder stay merely acts to stiffen the top plate, and as a result the whole pressure on the area of the top plate falls on the walls of the combustion box. The back tube plate therefore springs down and transfers part of this pressure to the furnace, causing it to become elliptical, as may generally be found by the application of rod gauges fitted to it before testing and tried while the pressure is on.

"This flattening under test naturally drew attention to the defective shape, pulling the tube sheet back and flattening the furnace. The amount of distortion may be only $\frac{1}{16}$ inch in some cases, but that is sufficient to show the existence of unequal strains which require attention in boiler designing.

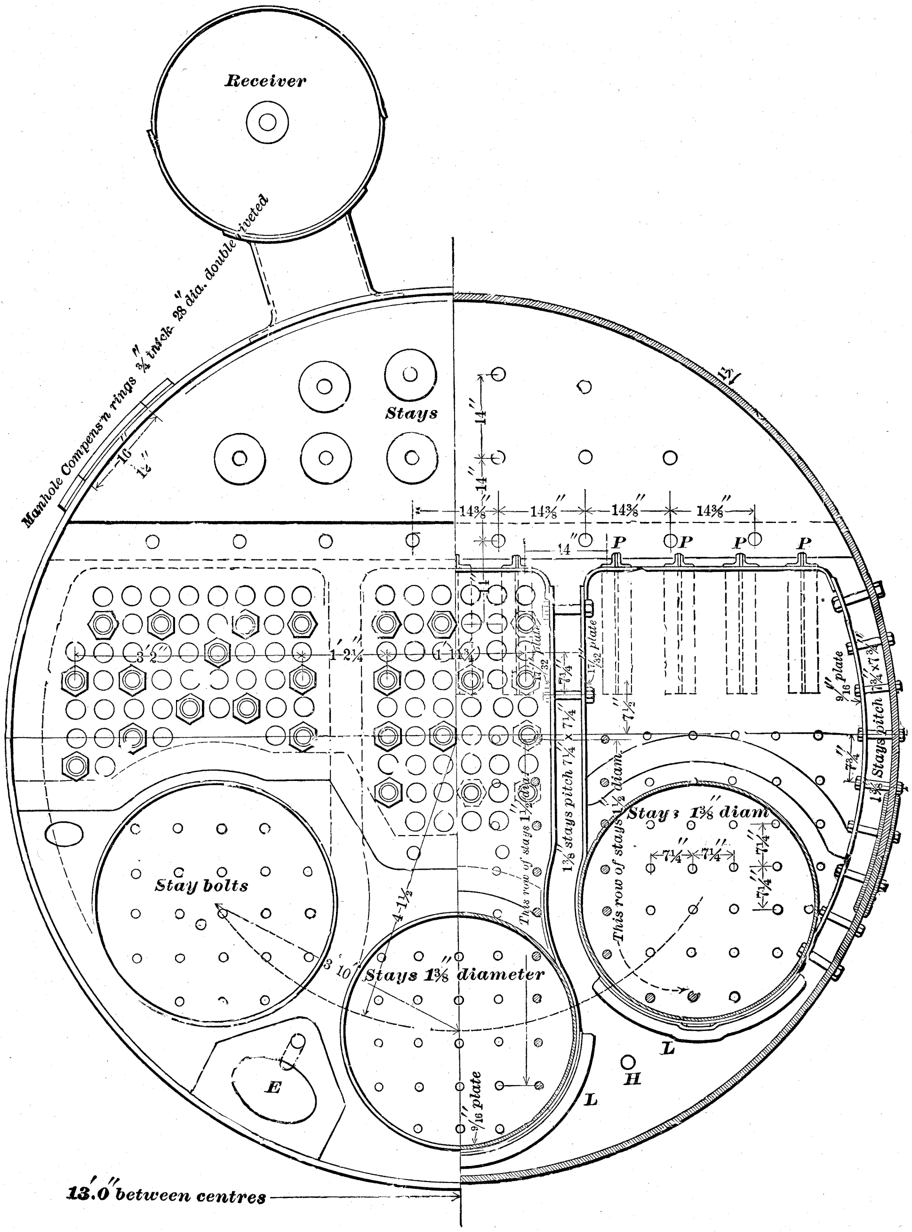


Fig. 3411.

fectiveness of girder stays. Another instance may be given with reference to gusset stays, which, if fitted so as to support too large

"This brings us to the important fact that in almost every instance where the furnaces of marine boilers collapse, they come

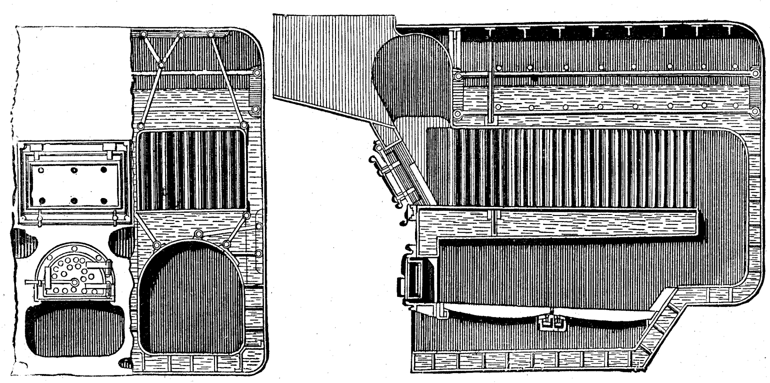

Fig. 3412.

an area of back plate, in proportion to the area of combustion box it supports, may cause the combustion box to distort from its nat-

down at the sides, notwithstanding that when collapse occurs from overheating, the crown of the furnace must have been left bare of water first, and should therefore come down first, flattening the furnace at the top. This points to the conclusion, that the top of the furnace received some extraneous support.

"When a furnace collapses from corrosion, it naturally gives way at the most corroded part. An hydraulic test to twice the working pressures is recommended for new boilers only, unless it be small vertical cylindrical and steam launch boilers, which may always be subjected to the same test as new main boilers.

"In the case of old main boilers, however, and particularly rectangular ones, an hydraulic test of less than twice the working pressure may be employed, the amount being governed by the circumstances of the case. If, for instance, a boiler has undergone a thorough repair and received new furnaces, then every part of the boiler should have received proportionate consideration and an hydraulic test depending upon the judgment of the responsible engineer, but not less than one and one-half times the working pressure should be made, while one of one and three-quarter times could scarcely be objected to. This, however, is a subject upon which there is some controversy, especially in the case of old boilers having a good foundation of strength, but patched or local weak spots, such as combustion chamber backs and sides, these patches having been, perhaps, made with a view to a more extensive repair in the near future.

"In such a case as this an hydraulic test sufficient to prove the tightness of the seams and joints may, perhaps, be all that is absolutely essential.

"After a boiler has been tested by hydraulic pressure it should be examined internally, as it sometimes occurs that a stay may break under the test (especially if gusset stays are employed), and the extra strain thrown on the adjacent parts may cause them to fail, and thus cause the destruction of the boiler when under strain.

"When an examination is to be made inside and outside of a boiler, the boiler must be properly prepared for the same, which may be done as follows:

"The tubes should be swept; the furnace cleaned out; the fire bars should be taken out; the bridges in the furnace should be taken down; the up take smoke box and combustion box should be cleaned out and swept; every man hole and hand hole or peep hole door should be removed; the bottom of the boiler should be cleaned out and dried (in damp weather a little heat may be necessary for this purpose); all impediments, if any, should be removed in order to allow the bottom outside to be inspected; at the time of inspection a few mats, good lights, a hand hammer and small chipping hammer should be at hand. In the case of a boiler having any plates weakened by corrosion, a $\frac{5}{8}$ inch tapping drill with a drilling brace should also be provided to test the thickness of such plates if considered necessary.

"The safety valves should invariably be taken out for examination, and it is a commendable feature sometimes followed to take out the feed valves, stop valves, blow off and brine cocks; at the same time, all the deposits that would prevent a thorough examination of the boiler should be removed. In some cases, however, there may not be time for the scaling before it is necessary for the repairs to be gone on with, and, in that case, a good examination may with care be made by an experienced man.

"To proceed, then, with the examination, the boiler should be entered through the man hole door beneath the furnaces, examining the boiler bottom and the bottom and sides of the furnaces all the way along, and on arriving at the end of the boiler the water space and stays at the backs of the combustion boxes can be examined as well as the midship combustion box stays and plates. In an old and corroded boiler it may be found necessary to use a chipping hammer very freely about the furnaces, particularly below the lap of the furnace.

"The most corroded part of a furnace will generally be found about on a line with the fire bars, but the furnaces may have suffered from some other cause than the corrosion due to ordinary wear, as, for example, from chemical or galvanic action, and in that case they may be found comparatively good at the sides but with the extreme bottoms in a *dangerously* corroded state, perhaps in the form of pit holes extending half through the plate and *hidden by a coating of red scale, which requires to be chipped away before the pit holes are brought to light.*

"Corrosion by galvanic action may have produced honey combing or a general attack over the surfaces, which have a dark or *dark and sparkling appearance*, the latter more particularly when corrosive action has been very active.

"Of these various classes of corrosion that which is the most deceiving is that which attacks the plates over the largest surface of the plate, leaving at the same time an apparently smooth exterior surface, for in this case the extent of the waste cannot be so clearly detected by the eye, and the only reliable way of testing the thickness is by drilling a hole through the plate.

"The flanges of the furnaces should always be examined in the bends, for flaws, for such defects, although not very common, do at times unexpectedly make their appearance, and might, if not detected, be the means of breaking the boiler down at sea. This part of the inspection being made, any drilling that is to be done to ascertain the thickness of suspected plates may be proceeded with before the rest of the inspection is made.

"It may, however, be well to remark that a very common defect is the wasting away of the combustion box plates around the necks of the stays or the internal surface of the plates, and it is a usual thing for deposits to accumulate around these necks, hence, unless these deposits have been removed (particularly in the case of boilers about three years old), the true condition of the boiler may not be known.

"The plate around the man hole door should next be examined, a great defect from waste at the surface that makes the water tight joint. Next comes the man hole door itself, which should have the rubber or other material used to make the joint cleaned off, for cases have occurred where the surface beneath was found apparently sound, whereas the application of a chisel showed that the iron was so corroded that but little iron was left in the flange, causing great surprise that the whole door had not blown out. This defect may generally be looked for in old boilers, and serves to emphasize the necessity for strong wrought iron doors.

"The outside surfaces of the end plate in the vicinity of the furnace fronts are a great source of trouble in some boilers, particularly where plane furnaces are fitted and flush rivets used for connecting them to the end shell plates.

"The insides of the furnaces and combustion boxes next require attention. The most common defects here are lamination of the furnace plate (if of iron), slight collapsing of furnaces, wasting of the furnace plates (particularly when anthracite coal has been used), and wasting when the fire bar bearers or bridges have rested against the plate.

"In the combustion box the buckling of flat plates may have occurred; plates may have wasted from leaks, distortion of the crown sheet from shortness of water may have occurred, or tubes may leak, and whenever, after sounding with the hammer, doubt exists as to the strength of the plate, a hole should be drilled through to test the thickness.

"The wing sides of the furnace may next be examined (through the usual peep holes or by having a boiler mounting taken off for the purpose), and the shell plating on the sides of the boiler, paying special attention to the plates where the feed water enters.

"We may next examine the outside of the bottom of the boiler, which should never be totally inaccessible to the eye, and should always be capable of being reached by a long-handled paint brush, for if kept well painted, the bottom of the boiler is, so far as the exterior is concerned, as durable as the other parts of the shell.

"If, however, the bottom is not kept painted and gets damp, and more particularly from bilge water, it will corrode rapidly, and the boiler must be lifted for examination. Under these circumstances a new boiler *must* at five years, at the very most, be lifted for examination, and if found comparatively good it should not be taken as an indication of the probable condition of any other boiler working under similar conditions, for the only means of avoiding a great risk in this matter is to rigidly inspect.

"In the case of flat bottomed boilers in small vessels a good result has obtained by placing them on a bed of cement, which if properly done excludes the bilge water from approaching the plate;

but even this precaution would scarcely be sufficient to justify an engineer in neglecting to lift the boiler at reasonable periods for examination of the bottom.

"The internal examination of the boiler is continued from the top by examining the stays in the steam space, the tube and tube plates, getting down between the nests of tubes and reaching the crowns of the furnaces. The surface of the shell plates should also be examined, more particularly if the boiler contains plates subject to heat on the outside and steam on the other (as in the case of wet up take boilers), for under these conditions a steel plate may become as weak and unreliable as a piece of cast iron.

"If the boiler is fitted with the superheater, the examination of the latter is of the utmost importance, as rapid destruction is here a common occurrence. In the case of a circular marine boiler of any size, nothing need be taken for granted, even though an hydraulic test be made up to twice the working pressure, because there is room for a thorough internal inspection which may disclose defects that would not be shown from the hydraulic test. The proper proportions of fire grate surface, heating surface, steam space, etc., in a marine boiler differ with the type of boiler and engine, and the steam pressure and degree of expansion employed.

"Upon the question of steam space, for example, it is asserted by many that marine boilers are not so liable to prime under the higher pressures, and as a result of this asserted fact the steam receiver is in some cases being dispensed with.

"It may be observed, however, that priming to any extent is so costly and detrimental that much consideration needs to be exercised before dispensing with the provisions ordinarily made to prevent it.

"For circular tubular boilers, having a working pressure of from 60 to 80 lbs. per square inch and to be used for compound engines, the following proportions represent current practice.

"1st. One square foot of fire grate area to every indicated horse power of the engine.

"2d. 28 square feet of heating surface * to 1 square foot of fire grate area.

"3d. $6\frac{1}{2}$ to 8 cubic feet of steam space to each square foot of fire grate area

"4th. 8 to 10 square feet of tube surface to the total heating surface in single ended boilers.

"5th. $8\frac{1}{2}$ to 10 is about the ratio of tube surface to the total heating surface in double ended boilers.

"6th. The diameters of boiler tubes should be about one-half inch for each foot of length of tube. If less, the tube is liable to choke. About 14 cubic feet of steam (of from 60 to 80 lbs. pressure) should be made for each square foot of fire grate area.

"Each square foot of fire grate will burn from 13 to 18 lbs. of steam coal per hour. About $1\frac{1}{2}$ cubic feet of live steam (of the above pressure) is required for each indicated horse power."

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* The heating surface here referred to includes the total interior surface of the tubes, the sides, backs, crowns and tube plates of the combustion boxes, and that part of the furnace that is above the level of the fire bars, but does not include the front tube plate (*i. e.*, the tube plate in the smoke box).