WATER TUBE BOILER

PLATE. 1.

—Tubes—

Tubes to be solid-drawn & Galvanised
Total No. of tubes for 1 Boiler = 730

Dia { 1⅛" outside / 1 3/16" in steam Drum / 1" in water chambers } Ordinary tubes

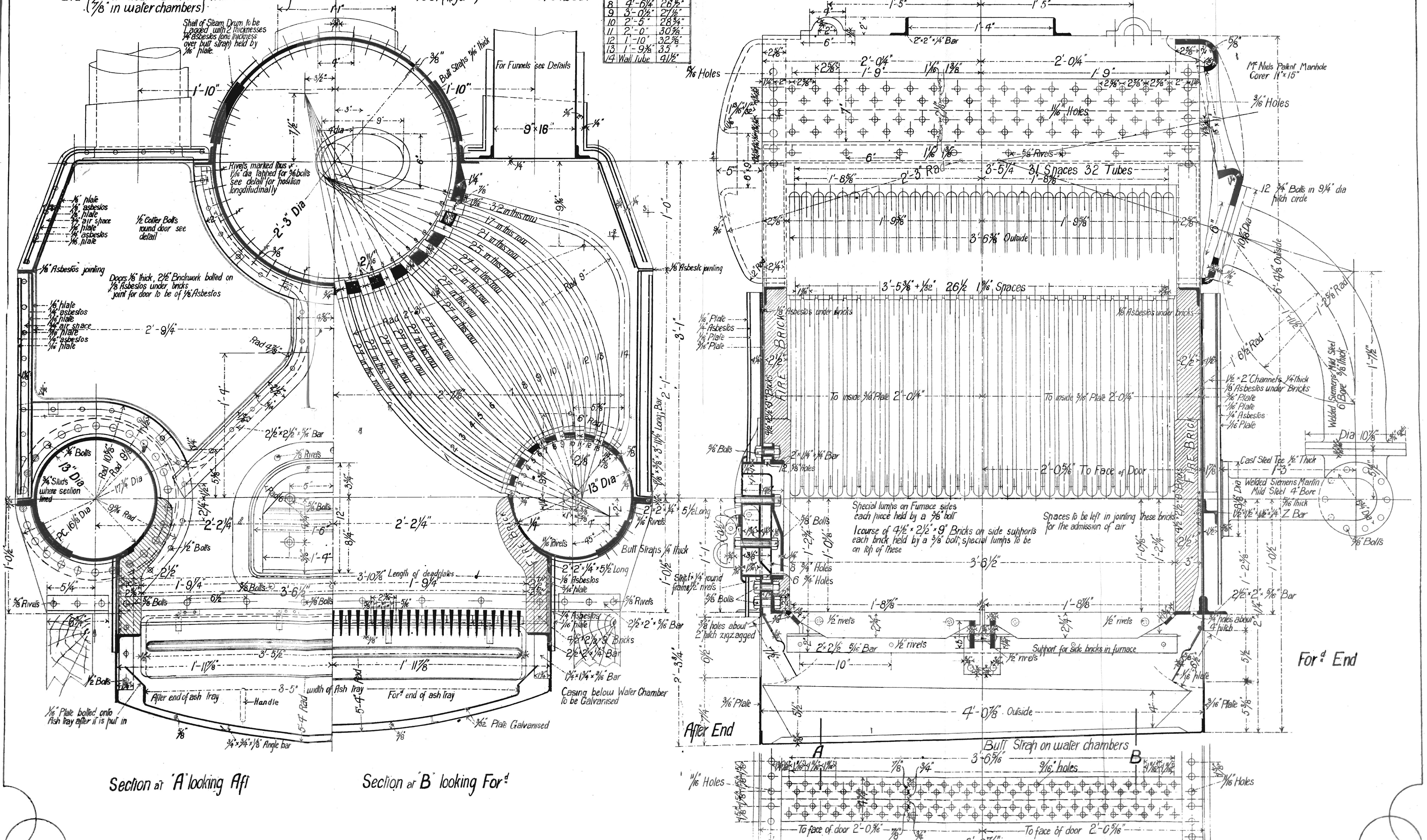
Dia { 1⅛" Outside / ⅞" in steam Drum / ⅞" in water chambers } Wall tubes

Thickness of tubes 11 L.S.G. = ·116"

Tube surface - - - 500 sq ft
Grate surface - - - 12½ sq ft
Working pressure - 185 lbs □"
Test (Hydlc) - - - - 370 lbs □"

—Tubes—

No.	Radius	Length
1	2'-3" & 2'-6⅛"	31⅞"
2	2'-5"	30⅜"
3	2'-8"	28¾"
4	3'-4"	27½"
5	3'-11"	26⅝"
6	6'-2"	26¼"
7	6'-7½"	26⅛"
8	4'-6¼"	26½"
9	3'-0½"	27½"
10	2'-5"	28¾"
11	2'-0"	30⅝"
12	1'-10"	32⅝"
13	1'-9⅜"	35"
14	Wall tube	41½"



Section at "A" looking Aft

Section at "B" looking Ford

This divided into the circumference of 27·75 in. dia. gives

$$\frac{27{\cdot}75 \times 3{\cdot}14}{1{\cdot}89} = 46 \text{ rivets.}$$

This gives a pitch on the inside of

$$\frac{27{\cdot} \times 3{\cdot}14}{46} = 1{\cdot}844 = 1\tfrac{13}{16} + \tfrac{1}{32}$$

giving an efficiency of joint of 56 % which is ample, as the shell is twice as strong in a transverse as it is on a longitudinal section.

This pitch is within the maximum allowed for the type of joint which is (·375 × 1·31) + $1\frac{5}{8}$ = 2·1 and it will suit the arrangement of rivets in the butt straps.

Two lifting snugs are riveted to the top of the shell, one at each end, made $\frac{3}{4}$ in. diameter, each having two palms 2 in. × $4\frac{1}{4}$ in., riveted to shell by four $\frac{5}{8}$ in. rivets.

The manhole and sighthole are each covered with McNiel's patent stamped steel doors.

The steam drum is lagged outside by two thicknesses $\frac{1}{4}$ in. asbestos millboard, held by $\frac{1}{16}$ in. plate, except where the safety valves are fitted.

The design of the water drums is settled in a manner similar to that of the steam drum.

Tube holes ..	..	$1\frac{1}{32}$ in.
Longitudinal pitch	..	$1\frac{9}{16}$ in.
Circumferential ,,	..	$2\frac{1}{8}$ in.
Diagonal ,,	..	1·3212
Wall tubes ,,	..	$1\frac{5}{16}$ in. full.

Wall tubes dia. of hole $\frac{7}{8}$ in. + $\frac{1}{32}$ in.

% of strength of perforated plate as compared to solid plate

$$= \frac{p - d}{p} \times 100$$

% Longitudinal $\dfrac{1{\cdot}5625 - 1{\cdot}03125}{1{\cdot}5625} \times 100 = 34\ \%$

% Diagonal .. $\dfrac{1{\cdot}3212 - 1{\cdot}0312}{1{\cdot}3212} \times 100 = 22\ \%$

% Wall tubes $\dfrac{1{\cdot}3125 - {\cdot}90625}{1{\cdot}3125} \times 100 = 31\ \%$

Taking the least of the above, and using a factor of 5, which is allowable as water is now always in contact with the plates

radius of drum.

$$t = \frac{185 \times 5 \times 6{\cdot}5}{62{,}500 \times 22} = {\cdot}436$$

Lloyd's $t = \dfrac{185 \times 13{\cdot}5}{20 \times 22} + 2 = 5{\cdot}7 + 2$

= 7·7 sixteenths of an inch.
= $\frac{1}{2}$ in. say.

This plate can be thinned down and the joint made by a double riveted double butt strap. Assuming an efficiency of joint of 70 %.

$$t = \frac{185 \times 13\cdot25}{20 \times 70} + 2 = 3\cdot75 \text{ sixteenths}$$
$$= \tfrac{1}{4} \text{ in. say.}$$

Using plates $\frac{1}{4}$ in. thick, double butt straps of $\frac{1}{4}$ in. plate would be used, and the rivet holes $\frac{9}{16}$ in. dia. Using such thin plates it would be necessary to adopt as close a pitch as is practicable. Say 3 *d*, which gives $1\frac{11}{16}$ pitch. This gives an efficiency of joint of 66 %, which being substituted in the above formula gives $3\cdot\frac{84}{16}$ for *t*, which is within the thickness adopted. The actual arrangement of the joint can be settled on the drawing of the detail of the water drums.

(See Plate I.)

Circumferential Seams.

In forming the ends of the water drums two things must be borne in mind, viz.: that it is necessary to get as large an opening as possible into the drum, and also that a connection is required for the front and back casing plates.

By making this end of a plate flanged inwards to form an angle ring, going over the end of the drum, we can obtain a flat surface on which to bolt a cover, and also by extending it as necessary to joint the front plates. It will be noticed that by carrying this same plate down, feet can be made on which the boiler can be carried on the bearers. (See Plate II.)

Take a plate as suggested, $\frac{5}{8}$ in. thick, machined as required, and use $\frac{11}{16}$ in. dia. rivets (finished) for attaching it to the drums, pitch being about $1\frac{5}{8}$ in.

Covers for Water Drums.—These will be bolted into the end plates by bolts screwed through the same.

The diameter of of area under pressure will be

$$\underset{\text{Inside dia.}}{13 \text{ in.}} + \underbrace{\tfrac{1}{4} + \tfrac{1}{4} + \tfrac{1}{4} + \tfrac{1}{4}}_{\text{Thickness of shell to edge of joint.}} = 14 \text{ in.}$$

$$\therefore \text{ Load} = (14 \text{ in.})^2 \times \cdot7854 \times 185 = 28{,}500 \text{ lb.}$$

Assuming $\frac{3}{4}$ in. bolts and allowing 1,100 lb. on each bolt (which gives a stress of 4,000 lb. per square inch at the bottom of the thread) we require $\frac{28500}{1100} = 26$ bolts.

The pitch circle for these will be

$$13 \text{ in.} + \underbrace{\tfrac{1}{4} + \tfrac{1}{4}}_{\text{Shell dia. and thickness.}} + \underbrace{\tfrac{3}{8} + \tfrac{3}{8}}_{\text{Ring.}} + \underbrace{\tfrac{3}{16} + \tfrac{3}{16}}_{\text{Clearance for bolt head.}} + \underbrace{\tfrac{3}{4} + \tfrac{3}{4}}_{\frac{1}{2}\text{ bolt head.}} = 16\tfrac{1}{8} \text{ in.}$$

$$\therefore \text{ the pitch} = \frac{16\cdot125 \times 3\cdot14}{26} = 1\cdot95.$$

This pitch is close for $\frac{3}{4}$ in. bolts, giving bare room for a spanner, but under the circumstances could be adopted. The cover can be made from a $\frac{5}{8}$ steel plate, dished to a radius of 13 in., and (allowing $\frac{1}{16}$ in. for facing in a lathe) the flange thickness would be $\frac{9}{16}$ ($\frac{3}{4}$ of the stud dia.), which is enough for a steel cover with a close pitch of bolt. At the back end, the dishing would be flattened, and faced to take the flange of one of the downcomer pipes.

Downcomers.—The area of the downcomer pipes should bear some relation to the evaporation, and consequently to the heating surface or grate surface. There is great variation in the sizes used, but an allowance of 2 square in. per square foot of grate, would seem to be a fair average.

This would give $12{\cdot}5 \times 2 = 25$ sq. in., say 6 in. dia. pipe.

This has to divide into two pipes, one going to each water drum.

$\therefore$ area of each $= \frac{25}{2} = 12{\cdot}5$ sq. in., say 4 in. dia. pipe.

The pipes would be made of Siemens-Martin steel, lapwelded, with flanges welded on solid, and the strength would be taken from the formula:—

$$t = \frac{p \times d}{9{,}000} + {\cdot}1$$

The above is suitable for straight pipes, and bends must be suitably strengthened, which could be done by increasing the constant added; thus for this case:—

$$t = \frac{p \times d}{9{,}000} + {\cdot}225$$

$$\text{for 6 in. pipe } t = \frac{185 \times 6}{9{,}000} + {\cdot}225 = {\cdot}348$$

Say $\frac{3}{8}$ in.

$$\text{for 4 in. pipe } t = \frac{185 \times 4}{9{,}000} + {\cdot}225 = {\cdot}307$$

Say $\frac{5}{16}$ in.

Bolts for Pipe Connections.

Assuming the pressure to act up to the insides of the bolts (as is usual in pipe work), the diameter of area under load for the 6 in. pipe becomes

$$6 + \tfrac{3}{4} + 1 \text{ in.} + \tfrac{3}{4} = 8\tfrac{1}{2} \text{ in. dia.}$$

dia. + thickness + clearance and radius of root at flange + bolt dia.

$\therefore$ load $\underline{8{\cdot}5^2 \times {\cdot}7854 \times 185} = 10{,}500$ lb.

Assuming $\frac{3}{4}$ in. bolts, 1,100 lb. safe stress on each, number required $= \frac{10{,}500}{1{,}100}$ say 10, but should fit 12 as there is room for them on a $9\frac{1}{4}$ in. pitch circle.

For 4 in. pipes:—

Dia. of area for load $= 4 \text{ in.} + \frac{5}{8} \text{ in.} + \frac{7}{8} \text{ in.} + \frac{5}{8} \text{ in.} = 6\frac{1}{8}$ in. dia.

Load $= 185 \times 6{\cdot}125^2 \times {\cdot}7854 = 5{,}500$ lb.

Assume $\frac{5}{8}$ bolts and allow 650 lb on each bolt (which is a stress of 3,200 lb. square inch at bottom of thread), and the number of bolts required is 9, but 10 would be fitted on a $6\frac{3}{4}$ in. dia. pitch circle.

The Tee piece for the connections would be cast steel $\frac{1}{2}$ in. thick, with flanges to suit pipes, and would be provided on the underside with a blank flange, as for a 4 in. pipe, to facilitate cleaning.

The flanges for the 6 in. pipe would be $\frac{11}{16}$ thick, and for the 4 in. pipe $\frac{5}{8}$ in. thick.

This practically finishes the calculations required for the boiler, the remainder of the design being a matter of judgment, and the selection of such an arrangement of parts as to make them fit for their purpose.

A description of these will now be given, and also some details of construction.

Method of Manufacture of the Drums.

Steam Drum.—The portion containing the tubes has to be thinned off for the longitudinal joints and the ends. The $1\frac{1}{4}$ in. plate is bent to a diameter of 2 ft. 3 in., and is then mounted on a strong wooden drum or frame, which in turn is mounted on a shaft, running in bearings, and capable of receiving a rotary motion by means of a worm and wheel. The whole is fixed to the table of a planing machine, and a rachet on the worm shaft is made to come into action with each travel of the table. This causes the drum to slowly revolve bringing a fresh cut on to the tool which is kept as a fixture in the ordinary tool box. This removes the cut in a circular direction, and the longitudinal joints are thus thinned down. The ends are turned down, by placing the drum in a lathe and turning off in the usual manner.

The $\frac{3}{8}$ in. plate is also bent to $2\frac{1}{3}$ in. diameter, and the edges of both parts of the drum having been tooled to give a truly circular form to the whole; the straps are bent to the proper radius, clamped in place, rivet holes marked off, a few holes drilled and the whole bolted up. The ends are fitted (these are flanged by a press in the usual way) and then whole is bolted together and the rivet holes drilled.

The water drums are planed in a similar manner, it being necessary to reduce about two-thirds of the circumference to the lesser thickness.

Tube Holes.

In arranging the tubes it is necessary to make the ends enter the drum at an angle as nearly normal as possible. The variation allowed is to an angle of about 10° to the normal, drilling being fairly easy at such a rate. Bearing this in mind, it can be seen that the curves to which the tubes are bent should tangent to lines that are within this variation, at a point outside the middle thickness of the tube plate. Suitable curves are obtained by trial, and the lines to which they are drawn are dimensioned on the drawing. In drilling, these lines are laid down on a dummy end, which is fixed in the drum, so that the driller can tell when the drum is in its correct position with regard to the line of the drill.

It can he seen that with the tubes arranged as shewn, the boiler proper is self supported (the tubes alone support the top drum) and yet is elastic under changes of temperature. In putting in the tubes, a few long bolts with double nuts at each end are passed through the tube holes, and adjusted so as to bring the drums into their proper relative positions. The tubes are then inserted and expended by means of a machine, the mandril of the expander being rotated in an adjustable head, and worked by bevel gearing.

Casings.—The casing for the boiler is formed generally of light steel plates, flanged where required, all joints being made with $\frac{1}{8}$ in. asbestos millboard.