CHAPTER VII

BOILER AND SUPERHEATER TUBES, HEADERS AND OTHER PRESSURE PARTS

TUBES

* **337. Material and Construction.**—*see* Reg. 151.

338. (*a*) The working pressure of the tubes shall be determined by the following formula:—

$$W.P. = \frac{2f(T-C)}{(D-T+C)} \quad .. \quad .. \quad .. \quad \text{Eqn. (87)}$$

where,

T = Minimum thickness of tubes, that is, nominal thickness less the permissible negative tolerances.

C = 1 mm. (0·04″) for values of W.P. up to and including 70 Kg./cm.² (1000 lb./sq. in.)

= 0·9 mm. (0·035″) for values of W.P. over 70 Kg./cm.² (1000 lb./sq. in.) and up to and including 105 Kg./cm.² (1500 lb./sq. in.)

C = 0·6 mm. (0·025″) for values of W.P. over 105 Kg./cm.² (1500 lb./sq. in.)

W.P. = Working Pressure of boiler.

D = External diameter of tube.

f = Premissible Stress for the material of the tube at the working metal temperature, to be determined on the basis given below.

The working metal temperature shall be taken as:

(*a*) For integral economiser tubes, the maximum water temperature for which the part of the element is designed plus 11°C (20°F).

(*b*) For furnace and boiler tubes, the saturation temperature corresponding to the working pressure plus 28°C (50°F).

(*c*) For convection superheater tubes, the maximum steam temperature for which the part of the element is designed plus 39°C (70°F).

* (*d*) For radiant superheater tubes, the designed maximum steam temperature plus 50°C (90°F).

* *Permissible Working Stress for tubes:*—

For temperature at or below 350°C (662°F) $\frac{T.S.}{3\cdot5}$ or $\frac{Et}{1\cdot6}$ whichever is the lower

For temperature above 350°C (662°F) $\frac{Et}{1\cdot6}$ or $\frac{SR}{1\cdot6}$ or Sc whichever is the lowest.

where,

TS = Minimum tensile strength of the material at room temperature.

Et = yield point (0·2% Proof Stress) at working metal temperature 't'.

SR=the average stress to produce rupture in 100,000 hours and in no case more than 1·33 times the lowest stress to produce rupture, at the working metal temperature.

Sc=the average stress to produce an elongation of 1% (creep) in 100,000 hours, at the working metal temperature.

(*b*) In no case, however, shall the thickness of tubes as supplied be less than those given in the table below (subject to tolerances specified in Regulations 36 (*d*), 43(*d*), 48(*c*); 53(*c*); 56A (IV) and 58(*d*),

TABLE

Outside diameter	Seamless Hot finished	Seamless Cold drawn or electric resistance welded
Up to and including 32 mm. (1¼")	2·9 mm. (0·116 in.)	2·03 mm. (0·08 in.)
Up to and including 51 mm. (2")	3. 25mm. (0.128 in.)	2·34 mm. (0·092 in.)
Over 51 mm. (2 in.) up to and including 76 mm. (3 in.)	3.35 mm. (0·128 in.)	2·64 mm. (0·104 in.)
Over 76 mm. (3 in.) up to and including 89 mm. (3-1/2 in.)	3·25 mm. (0·128 in.)	3·25 mm. (0·128 in.)
Over 89 mm (3-1/2 in.) up to and including 114 mm. (4½ in.)	3·66 mm. (0·144 in.)	3.66 mm. (0·144 in.)

In the case of coiled tubes for boilers of the forced flow or forced circulation type, the minimum thickness of tubes as supplied may, however, be as follows :—

Outside diameter of tubes in inches	Minimum thickness
Up to and including 29 mm. (13")	1·62 mm. (0·064")
Over 29 mm. up to and including 35 mm. (1⅜") ..	1·83 mm. (0·072")
Over 35 mm. (1⅜") up to and including 42 mm. (1⅝")	2·34 mm. (0·092")

(*c*) Where tubes are bent, care shall be taken to ensure that the total strain at the bend is not more than that at the straight part of the tube.

The deviation from circularity in percentage at any cross section of a bend shall be calculated by the following formula:—

$$C = \frac{Dmax - Dmin.}{D} \times 100$$

This deviation shall not exceed $\frac{20D}{R}$

where,

C=The percentage deviation of circularity.

Dmax=maximum external diameter of the tube as gauged at the bend.

Dmin=minimum external diameter of the tube as gauged at the bend.

D=nominal external diameter of the tube.

R=Radius of the bend on the central line of the bend.

* (*c*) Where tubes are bent resulting thickness of the tubes at the thinnest part shall be not less than that required for plain tubes.

HEADERS AND SIMILAR PRESSURE PARTS

* **339. Material and Construction.**—*See* Regs. 154 & 244 (*b*).

340. Rectangular Headers Symmetrical in Form.—

(*a*) The working pressure shall not exceed the smaller of the value obtained from the following formula :

(*i*) $$WP = \frac{cf\,(t-c_1)^2}{b^2} \quad .. \quad .. \quad .. \quad \text{Eqn. 88}(a)$$

(*ii*) $$WP = \frac{6{\cdot}25\,t^2.\ fE.}{W^2} \quad .. \quad .. \quad \text{Eqn. 88}(b)$$

where

W.P.=working pressure.

t=thickness.

b=internal breadth between the supporting sides of the header.

c=3·413 for wrought steel and 2·926 for steel castings;

Where the sides are corrugated or otherwise reinforced by substantial supports so that the length of the portion between the corrugations or supports does not exceed b, shall be taken as 5·82 for wrought steel and 5·12 for steel castings.

f=permissible stress at working metal temperature as given in the table under clause 'C'

c_1=0·08 cm. (0·03 in.)

w=internal width of the header between the tube plate and the opposite side.

E=efficiency of ligaments between the holes.

(*b*) If the faces of the headers are machined locally at the tube holes or hand holes the thickness at that part may be as much as 4·8 mm. (3/16 in.) less than given by the above equation; but irrespective of the thickness obtained by the use of the formulae, the thickness of the headers at the tube holes shall be not less than:

$$t = \sqrt{C \times d} + C_1 \quad .. \quad .. \quad .. \quad .. \quad .. \quad .. \quad \text{Eqn. (89)}$$

where,

t=thickness.

d=diameter of the hole.

C=0·2235 mm. (0·0088 in.)

C_1=6·4 mm. (1/4 in.)

In no case shall the thickness be less than 8mm. (5/16 in.) except that in small patches not exceeding 322 mm.² (one-half sq. in.) in area, the thickness may be 50 per cent. of the thickness used in the equations 88(*a*) and 88 (*b*)

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(c) The permissible stress at working metal temperature shall be as given in the table below:

TABLE

* PERMISSIBLE STRESS AT WORKING METAL TEMPERATURE FOR RECTANGULAR SECTION HEATERS

Working Metal Temperature in degrees		Cast steel 44-55 Kg. mm.² (28 to 35 tons/sq. in.)		Carbon and Alloy Steels
C	F	Kg./cm²	lbs./sq. in.	The lowest value obtained in each case at the specified temperature calculated on the following basis:—
288	550	703	10,000	For temperatures at or below 250°C (482°F) .. .. .. $\frac{T.S.}{4}$
316	600	633	9,000	For temperature above 250°C (482°F)
343	650	562	8,000	and at or below 350°C (662°F) (a) $\frac{T.S.}{3{\cdot}5}$ (b) $\frac{Et}{1{\cdot}6}$
371	700	532	7,560	For temperature above 350°C (662°F) (a) $\frac{Et}{1{\cdot}6}$
399	750	505	7,200	
427	800	475	6,750	(b) $\frac{S.R.}{1{\cdot}6}$
454	850	443	6,300	
482	900	309	4,400	(c) Sc

where,

T.S. = Minimum Tensile strength of the material at room temperature.

Et = Yield point (0·2% proof stress) at the working metal temperature 't'.

S.R. = the average stress at the temperature 't' to produce rupture in 100,000 hours and in no case more than 1·33 times the lowest stress to produce the rupture in 100,000 hours.

Sc. = The average stress at the temperature 't' to produce an elongation of 1% (creep) in 100,000 hours.

(d) The working metal temperature shall be taken as:—

For saturated steam and water drums and headers the saturation temperature corresponding to the working pressure of the boiler plus 28°C (50°F).

For superheater headers the designed maximum steam temperature for the header plus 28°C (50°F).

(e) Where headers are adequately protected from the gases of combustion or swept by such gases in the third or subsequent pass of a boiler, the working metal temperature shall be taken as the saturation or designed maximum steam temperature as defined above, whichever applies. A covering of refractory or insulating material which may be liable to become dislodged shall not be deemed adequate protection.

* (f)

341. Headers Irregular in Form.—In cases where the headers are of such irregular form as to render impracticable the application of a formula for the determination of thickness, the manufacturer shall show the suitability of the headers for the working conditions by indicating practically the maximum internal hydraulic pressure which a header, made to the same design and of similar material, will withstand without permanent deformation. The

maximum working pressure for similar headers may then be determined by the following formulae:—

$$W.P. = P_1 \times \frac{\text{Permissible stress at working metal temperature}}{F \times C} \quad \text{Eqn. (90)}$$

where W.P. = The working pressure in lbs. per sq. in.

P_1 = The maximum internal hydraulic pressure withstood without permanent deformation,

F = 1·75 for wrought steel and 2 for cast steel,

C = 15500 for wrought steel of 24 tons per sq. in. minimum ultimate tensile stress,

= 16500 for wrought steel of 26 tons per sq. in. minimum ultimate tensile stress,

= 18000 for wrought steel of 28 tons per sq. in. minimum ultimate tensile stress,

= 21000 for wrought steel of 32 tons per sq. in. minimum ultimate tensile stress,

= 22000 for wrought steel of 34 tons per sq. in. minimum ultimate tensile stress, and

= 15500 for cast steel of 28 tons per sq. in. minimum ultimate tensile stress.

* **342. Cylindrical Headers.**—Where cylindrical headers are provided their working pressure shall be determined by Equation 72.

(*c*) The permissible stress at working metal temperature shall be as given in the table below:

TABLE

* PERMISSIBLE STRESS AT WORKING METAL TEMPERATURE FOR RECTANGULAR SECTION HEATERS

Working Metal Temperature in degrees		Cast steel 44-55 Kg. mm.² (28 to 35 tons/sq. in.)		Carbon and Alloy Steels
C	F	Kg./cm²	lbs./sq. in.	The lowest value obtained in each case at the specified temperature calculated on the following basis:—
288	550	703	10,000	For temperatures at or below 250°C (482°F) .. .. .. $\frac{T.S.}{4}$
316	600	633	9,000	For temperature above 250°C (482°F)
343	650	562	8,000	and at or below 350°C (662°F) (a) $\frac{T.S.}{3\cdot5}$ (b) $\frac{Et}{1\cdot6}$
371	700	532	7,560	For temperature above 350°C (662°F) (a) $\frac{Et}{1\cdot6}$
399	750	505	7,200	
427	800	475	6,750	(b) $\frac{S.R.}{1\cdot6}$
454	850	443	6,300	
482	900	309	4,400	(c) Sc

where,

T.S.=Minimum Tensile strength of the material at room temperature.

Et=Yield point (0·2% proof stress) at the working metal temperature 't'.

S.R.=the average stress at the temperature 't' to produce rupture in 100,000 hours and in no case more than 1·33 times the lowest stress to produce the rupture in 100,000 hours.

Sc.=The average stress at the temperature 't' to produce an elongation of 1% (creep) in 100,000 hours.

(*d*) The working metal temperature shall be taken as:—

For saturated steam and water drums and headers the saturation temperature corresponding to the working pressure of the boiler plus 28°C (50°F).

For superheater headers the designed maximum steam temperature for the header plus 28°C (50°F).

(*e*) Where headers are adequately protected from the gases of combustion or swept by such gases in the third or subsequent pass of a boiler, the working metal temperature shall be taken as the saturation or designed maximum steam temperature as defined above, whichever applies. A covering of refractory or insulating material which may be liable to become dislodged shall not be deemed adequate protection.

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maximum working pressure for similar headers may then be determined by the following formulae:—

$$W.P. = P_1 \times \frac{\text{Permissible stress at working metal temperature}}{F \times C} \quad \text{Eqn. (90)}$$

where W.P.=The working pressure in lbs. per sq. in.

P_1=The maximum internal hydraulic pressure withstood without permanent deformation,

F=1·75 for wrought steel and 2 for cast steel,

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=21000 for wrought steel of 32 tons per sq. in. minimum ultimate tensile stress,

=22000 for wrought steel of 34 tons per sq. in. minimum ultimate tensile stress, and

=15500 for cast steel of 28 tons per sq. in. minimum ultimate tensile stress.

* **342. Cylindrical Headers.**—Where cylindrical headers are provided their working pressure shall be determined by Equation 72.