BOILER CODE

STATE OF WISCONSIN

Issued by
INDUSTRIAL COMMISSION OF WISCONSIN
MADISON, WISCONSIN
1944

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INTRODUCTION

The Industrial Commission of Wisconsin is charged with the duty of fixing standards of safety in all places of employment. In performance of this duty the Industrial Commission has from time to time issued general orders establishing standards of safety to guard against hazards of various kinds.

The frequency of boiler explosions, with the resulting loss of life and damage to property, compelled the Industrial Commission almost at once after it was organized to attempt the formulation of a code of boiler rules. The first code was adopted by the Industrial Commission on December 14, 1914, and became effective January 18, 1915. This code was amended in many material respects on November 29, 1915, to correspond more closely with the standard code of boiler rules recommended by the American Society of Mechanical Engineers. Further amendments to this code were adopted on October 20, 1919, and the entire code as amended was published in the official state paper on November 3, 1919. In accordance with law this amended code became effective December 4, 1919.

On October 5, 1927 the Industrial Commission adopted a resolution which repealed all of the boiler orders contained in the "Code of Boiler Rules" of 1920. The same resolution provided for the adoption of the orders contained in the newly revised "Boiler Code of January 1928" with the provision that the effect of boiler orders in force from

July 1, 1916 to December 31, 1927 inclusive shall not be impaired as to any boiler installed between those dates. This newly revised Boiler Code became effective January 1, 1928.

There have been important changes in the field of steam boiler design and fabrication since the adoption of the 1928 Boiler Code. The demand for greater economy of operation has resulted in higher steam pressures and in higher temperatures. To maintain the required standards for reasonable safety under these changed operating conditions it has been necessary to introduce alloy steels in the design of some parts of high pressure boilers and it was necessary to resort to fusion welding of joints in order to secure the desired strength and tightness.

With a full knowledge of these changed conditions, the Industrial Commission is confident that this newly revised Boiler Code as of March 1, 1944 will adequately meet all minimum requirements for reasonable safety.

Adoption of this revised code, effective March 1, 1944, shall not be construed as effecting, except as modified, the status of previous issues of the Boiler Code for the periods in which they were administered nor of boilers which were installed while those codes were in effect.

ORDERS REVISED—MARCH 1, 1944

4103	4254	4372	4411	4455	
4207	4261	4379	4412	4470	(4) (6) (11) (13) (14) (16) (19)
4208	4271	4385	4415	4475	(1)
4209	4273	4387	4417	4476	(1) (2) (3)
4217	4274	4389	4421	4477	(1)
4220	4275	4390	4423	4479	(2)
4221	4307	4391	4425	4480	(5)
4222	4311	4394	4429	4481	(2)
4224	4316	4395	4430	4482	(1) (2) (3)
4227	4317	4398	4432	4483	(4)
4231	4318	4399	4433	4484	(3) (5) (10) (12) (14) (15)
4232	4319	4403	4436	4485	(1)
4251	4335	4405	4440	4486	(5) (6) (13)
4252	4339	4406	4446	4489	(2)
4253	4360	4409	4453	4490	(2) (4) (9) (11) (13) (14)
		4410	4454	4491	(1)

ORDERS REPEALED—MARCH 1, 1944

4226	4388	4420	4470	(17) (18)
4276	4396	4424	4479	(3) (4)
4277	4401	4437	4484	(9) (23)
4328	4407	4438	4486	(7) (8) (9) (12)
			4490	(8) (22)

ORDERS ADOPTED—MARCH 1, 1944

4226

In the preparation of boiler rules the Industrial Commission has had the assistance of the following Advisory Board.

Representing League of Wisconsin Municipalities: R. E. Cannard, Manitowoc, Wisconsin.

Representing Wisconsin State Association of the National Association of Power Engineers: E. O. Wohlust, Racine, Wisconsin.

Representing International Brotherhood of Boiler Makers, Iron Ship Builders and Helpers of America: George White, Milwaukee, Wisconsin; R. L. Ryan, Alternate.

Representing Boiler Insurance Companies: Martin E. Nelson, Milwaukee, Wisconsin.

Representing Boiler Manufacturers: M. C. Schwab, Milwaukee, Wisconsin.

Representing Boiler Manufacturers: Carl Brieman, Juneau, Wisconsin.

Representing Boiler Inspectors: R. Kunz, Chairman, Milwaukee, Wisconsin.

Representing Industrial Commission of Wisconsin: Frank J. Bishop, Milwaukee, Wis.

Representing the Industrial Commission of Wisconsin: M. A. Edgar, Secretary, Supervisor Boiler Division, Madison, Wisconsin.

101.30. Boiler Inspection, penalties. No machine, mechanical device, or steam boiler shall be installed or used in this state which does not fully comply with the requirements of the laws of this state enacted for the safety of employes and frequenters in places of employment and public buildings and with the orders of the Industrial Commission adopted and published in conformity with sections 101.01 to 101.28, inclusive, of the statutes. Any person, firm, or corporation, violating the provisions of this act shall be subject to the forfeitures provided in sections 101.18 and 101.28 of the statutes. (Stats. 1921 s. 2394—72; 1923 c. 291 s. 3) Annotated.

This code of boiler rules was adopted by the Industrial Commission under authority of Chapter 101 of the statutes. These orders have the force and effect of law. Any interested party may petition the commission for a hearing on the reasonableness of any of its orders, and if the petition be denied, he may appeal to the Circuit Court for Dane County. The orders of the commission, however, are prima facie reasonable and lawful and are valid and in force until they are found otherwise by the courts, or until they are repealed by the commission. Violation of any order is punishable by a penalty of from $10.00 to $100.00 for each offense.

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PART I

GENERAL REQUIREMENTS FOR THE INSTALLATION, OPERATION AND INSPECTION OF BOILERS

This code covers rules to be used in stationary service. Stationary boilers as herein considered include portable and tractor boilers.

A pressure vessel in which steam is generated by the application of heat resulting from the combustion of fuel shall be classed as a steam boiler.

These rules apply to the boiler proper and pipe connections up to and including the valve or valves as required by the code. Superheaters, reheaters, economizers and other pressure parts connected directly to the boiler without intervening valves shall be considered as parts of the boiler and their construction shall conform to the code rules.

4100. Safety Regulations. No boiler shall be operated at a pressure in excess of the maximum allowable working pressure allowed by the annual inspection certificate (See order 4107), which pressure is to be ascertained by means of these orders.

Steam boilers shall be equipped with such appliances as will insure safety of operation as hereinafter ordered.

No person shall remove or tamper with any safety appliance prescribed by the hereinafter orders, and no person shall in any manner load the safety valve to greater pressure than that allowed by the certificate of inspection.

In all cases boilers shall be so placed as to give ample room between any ceiling, wall or partition to connect and operate any valves or pipes or other fittings or connections used in such steam boilers.

Whoever owns, uses or causes to be used a boiler subject to inspection, unless the same is under the periodically guaranteed inspection of city, company or corporation allowed by the commission to handle their own inspections shall report to the Industrial Commission, on January 1st of each year, the location of such boilers.

The owner or user of a boiler subject to regular annual inspections by the Industrial Commission, shall immediately notify the commission in case a defect affecting the safety of the boiler is discovered.

Each steam boiler shall be relieved of steam pressure, opened up, thoroughly drained of hot water and the combustion chamber and furnace cleaned out before any repairs are made.

Note: Repairs in this case are not meant to include the adjustment or operation of valves or appliances necessary for the safe and efficient operation of the boiler while under pressure.

4101. Inspection Fees. A fee of $5.00 will be charged by the commission for a hydrostatic pressure test or an inspection of a boiler while not under pressure.

A fee of $2.00 will be charged by the commission for each external inspection of boilers while under steam pressure.

4102. Inspection of Steam Boilers. All steam boilers operated in the state of Wisconsin, except those included in order 4103, shall be subject to regular annual internal and external inspection once each year. Should operating conditions require longer periods than 12 months, an extension of time may be granted on application to the commission.

The owner or user of boiler subject to inspection by the commission shall prepare the boiler for inspection. To prepare a boiler for an internal inspection all handhole, manhole plates and wash-out plugs shall be removed. The furnace and combustion chamber shall be thoroughly cleaned.

4103. The following steam boilers will be inspected when such inspection is deemed necessary by the Industrial Commission but will not be given regular internal and external inspections each year:

1. Boilers which receive regular inspection by United States government inspectors;
2. Boilers of steam fire engines;
3. Boilers used exclusively for agricultural purposes;
4. Boilers of less than 100 sq. ft. of water heating surface;
5. Boilers on which the pressure does not exceed fifteen pounds.

4104. Insurance Inspections. All boilers subject to periodic inspections of insurance companies authorized to insure

boilers in this state, shall not be subject to annual inspection by this commission on the following conditions:

The insurance companies' regulations shall conform with the hereinafter orders.

The insurance companies' inspectors who inspect boilers operated in this state shall hold certificates of competency issued by the Industrial Commission.

Reports of all inspections shall conform to the requirements of this commission.

A copy of all reports shall be forwarded to this commission within fourteen days after the inspection is made.

Insurance companies whose inspectors hold certificates of competency shall report to this commission the name of the owner or operator, and the location of every boiler on which insurance has been refused, cancelled or discontinued, giving the reasons therefor.

4105. Steam boilers within the regular corporate limits of cities which are regularly inspected by authorized city boiler inspectors will not be subject to regular annual inspection by this commission, provided the boilers are properly installed, equipped with fittings necessary to safety, and are not operated at pressures in excess of that determined by the hereinafter orders.

4106. Steam boilers owned or operated by companies or corporations may be exempted from annual inspection by this commission provided a regular inspection service is maintained by the operators under the following conditions:

1. The inspection service shall be subject to the approval of this commission;
2. The boilers shall be properly installed and not operated at pressures in excess of that determined by the hereinafter orders;
3. Reports of inspections on all boilers shall be made to the commission on approved forms.

4107. Annual Inspection Certificate. An inspection certificate shall be issued by the city, corporation, or company employing the inspector, stating the maximum allowable working pressure for one year after an inspection has been made, to determine the safety of the boiler for that pressure.

This certificate shall be kept on file and at all times be made available when called for by a deputy of this commission.

The maximum allowable working pressure, as stated in the certificate of inspection, shall not be in excess of that determined by the orders in Part II of this code for boilers installed prior to March 1, 1944.

The maximum allowable working pressure, as indicated by the certificate of inspection or badge plate shall not be in excess of that determined by the orders in Part III of this code for boilers built and installed on or after March 1, 1944. All power boilers built and installed on or after March 1, 1944 shall be inspected and stamped in accordance with the orders contained in Part III of this code.

4108. Certificate of Competency. Certificates of competency shall be issued to persons who pass an examination which shall be prescribed by the Industrial Commission and which shall determine the fitness and competency of candidates for such certificates of competency.

A certificate of competency issued to an employe of any city, corporation or company shall be annulled upon the termination of his employment with that city, corporation or company by which he was employed at the time of the issuance of the certificate of competency; such certificate of competency may, however, be renewed without a reexamination.

A certificate of competency may be revoked at any time, but the holder of such certificate of competency shall be entitled upon demand, to a hearing before the Industrial Commission before the revocation of the certificate of competency.

Holders of certificates of competency shall comply with the hereinafter orders and copies of their reports of inspections shall be forwarded to the Industrial Commission within fourteen days after each inspection.

4109. Stamps and Numbers on Boilers. The owner or operator of a steam boiler shall number each boiler in some convenient and permanent manner.

Power boilers built and installed on or after March 1, 1944, shall comply with orders in Part III of this code, and

each boiler shall be inspected, stamped and a data or report sheet furnished the commission by the builder.

4110. Special Type of Boilers. Builders of special types of boilers subject to inspection but not covered by the hereinafter orders shall forward to the Industrial Commission blue prints and specifications of the type.

4111. Advisory Board. An advisory board of boiler rules appointed by the Industrial Commission without compensation, may hold hearings and gather such information as will assist in the formation of recommendations to the commission that will insure safety in the installation and operation of steam boilers.

BOILER ROOM RULES

A Suggested Code of Rules to be Followed by the Firemen.*

1st—Immediately upon entering the boiler room ascertain beyond a doubt, whether the water in the boiler is at the proper level.

2nd—In case of low water with fire in the furnace do not draw the fire, as this will intensify the heat and make matters worse, but immediately cover the fire with ashes or fresh coal (wet ashes or slack coal preferred) and close the ash doors. Do not under any circumstances, turn on the feed water or touch the safety valve. LET ALL the steam outlets REMAIN as they are until the boiler has cooled off.

3rd—See to it that all connections to the water column are free. Prove the water glass reading by occasional blowing.

4th—Keep boiler clean and dry on outside. Do not allow wet ashes to accumulate around water legs or other parts of boiler. Do not allow water from leaking joints or other sources to come in contact with boiler. Failure to observe these rules will cause corrosion.

5th—Leaks no matter how slight, should be repaired immediately, otherwise they will become worse and cause corrosion and grooving.

* These boiler room rules are not compulsory but are recommended as good practice.

6th—Keep boiler clean internally. Do not allow scale, mud or oily matter to settle on the fire sheets, as it may cause the sheets to become burnt, bagged or buckled; also ruptured and explosion may result.

7th—Cause the safety valves to blow at least once every twenty-four hours. They sometimes stick. Care should therefore, be exercised to keep them in good working order. If the safety valve is not blowing freely when the pressure gauge indicates the maximum allowable working pressure in the inspection certificate the cause should be ascertained immediately.

8th—The blow-off valves should be opened wide for a moment daily. This will aid in keeping boiler and blow-off pipe clean, but NEVER open the blow-off valve or cock with a jerk, as it is liable to let go and cause a serious accident.

9th—Bags should be repaired immediately. If not down too far and the metal is sound, they can sometimes be driven back, otherwise it will be necessary to cut out and patch.

10th—In case of foaming, close the throttle and open the fire doors for a few minutes, when the water will usually settle and the proper height may be ascertained. The trouble, if caused by dirty water, can easily be overcome by feeding and blowing. Where there is a surface blow it can be used to good advantage.

11th—Do not blow off under pressure when intending to clean out, as the heat of the boiler and the brickwork will bake the mud and scale on the shell and tubes, making it extremely difficult to remove. Allow the boiler and brickwork to cool. Boilers should then be drained and thoroughly cleaned and washed out both from the top and bottom. Boiler should be cleaned out at intervals frequent enough to keep it clean and free from scale.

12th—Do not close the damper entirely with fire in the furnace, as gas is liable to accumulate in the combustion chamber or tubes and cause an explosion.

13th—Keep all connections and appurtenances in good working order and keep everything about the boiler room clean and neat. In case of accident keep cool but act promptly and with precision.

14th—When Preparing for Inspection See to it That the Man and Hand Hole Plates Are Removed and That Boiler is Thoroughly Cooled and Cleaned Both Internally and Externally. The Combustion Chamber Back of the Bridge Wall Should be Thoroughly Cleaned Out. Also All Valves Should Be Tight, so That if There Are Any More Boilers in the Battery Under Steam, the Escaping Steam Will not Prevent a Thorough Internal Inspection.

Careful Attention to the Above Rules Will Go a Long Way Toward Prolonging Life of Boilers and Preventing Accidents.

PART II

ORDERS APPLICABLE TO BOILERS INSTALLED PRIOR TO MARCH 1, 1944; SECOND HAND BOILERS AND GENERAL REPAIRS

4200. Maximum Allowable Working Pressure. The maximum allowable working pressure on a steam boiler constructed wholly or principally of cast iron shall not exceed fifteen pounds per square inch.

4201. The maximum allowable working pressure on boilers, the tubes of which are secured to cast iron headers, shall not exceed one hundred and sixty pounds per square inch.

4202. The maximum allowable working pressure to be allowed on a steel or wrought iron shell or drum of a boiler shall be determined from the minimum thickness of the shell plates, the lowest tensile strength of the plates, the efficiency of the longitudinal joint, the inside diameter of the outside course and the lowest factor of safety allowed by these orders.

$$\frac{\text{T.S.} \times t \times \%}{\text{R.} \times \text{F.S.}} = \text{maximum allowable working pressure per square inch, in pounds.}$$

T.S. = tensile strength of shell plates, in pounds.
t = minimum thickness of shell plates, in inches.
% = efficiency of longitudinal joint, method of determining which is given in A–1 to A–7 inclusive of the appendix.
R = radius = one-half the inside diameter of the outside course of the shell or drum.
F.S. = lowest factor of safety allowed by order 4209.

4203. Maximum allowable working pressure on flat surfaces of boilers installed previous to March 1, 1944, will be determined by the following formula. The maximum allowable working pressure on flat surfaces of boilers installed on or after March 1, 1944, will be determined by orders in Part III.

$$\text{Maximum allowable working pressure} = \frac{\text{T} \times \text{T.S.} \times 10}{\text{A} \times \text{F.S.}}$$

Where T = Thickness of flat surface in inches.
T.S. = tensile strength of material. If actual tensile strength is unknown use that given in order 4210.
A = area of flat surface in inches (no allowance being made for the holding power of tubes or flanges.)
F.S. = factor of safety. (See order 4209)

Note: If the flat surfaces are stayed, additional pressure based on the total area of the flat surface (no allowance being made for the holding power of tubes or flanges) will be allowed for the holding power of the stays.

4204. The maximum allowable working pressure on unstayed dished heads shall be determined by the following formula, for boilers installed prior to March 1, 1944. For boilers installed on or after this date the pressure will be determined by order 4316.

Pressure on concave side.

$$\text{P} = \frac{\text{T} \times \text{T.S.}}{\text{R} \times 5}$$

Pressure on convex side.

$$\text{P} = \frac{\text{T} \times \text{T.S.} \times 0.6}{\text{R} \times 5}$$

Where P = maximum allowable working pressure.
T = thickness of head in inches.
T.S. = tensile strength of head. If actual T. S. is unknown use order 4210.
R = ½ radius of bump in inches.

4205. Collapsing pressures on furnaces and flues will be determined by orders 4358 and 4365, inclusive.

Note: When applying the formula in order 4361 to the furnaces or flues of boilers installed previous to July 1, 1916 the minimum thickness shall be ¼ inch instead of $\frac{5}{16}$ inch. If greater pressure than that given by order 4361 is required the furnaces or flues shall be stayed for such additional pressure but in no case shall the stays be pitched to exceed 8½ inches measured on the surface of the sheet to be stayed. The minimum size stay bolt to be used shall be ¾ of an inch in diameter.

4206. Cracks and Patches. A boiler on which a longitudinal lap crack is discovered, shall not have the cracked portion patched, but must be discontinued from service

until the plate or plates in which the crack was discovered, have been replaced.

4207. A patch on a boiler shell or drum shall be as nearly circular as is practical, shall be placed on the pressure side of the sheet to be patched, where possible, and in no case, when riveted or bolted shall more than three rivets or bolts be in a line parallel to the longitudinal seam.

A—A patch shall be riveted where ever practical, except where the entire pressure exerted on the patch is supported by other structure which complies with the orders of this code. Patch bolts may be used where riveting is not practical. An opening, the greatest dimension of which does not exceed 7 inches, may be patched as outlined in section D of this order.

B—A patch when exposed to the products of combustion and when not supported by other structure which complies with the orders contained in this code and patches that are exposed to the products of combustion and form pockets for the collection of foreign substances contained in the feed water, shall be placed so that the entire surface of the patch is exposed to pressure. This does not apply to that portion of a patch attached to the boiler joint.

C—A patch shall be of flange steel or fire box steel quality (See order 4254) and shall be within 1/32 of an inch as thick as the plate to which it is attached. No plate used as a patch shall be less than ¼ inch in thickness.

D—An opening, in a boiler, the greatest dimension of which does not exceed 7 inches may be closed by a strength welded patch. The patch shall be placed on the inside or pressure side of the sheet to be patched and shall lap over at least ½ inch at all edges. All other patches may be seal welded for tightness.

4208. **Secondhand Boilers.** After Jan. 1, 1917, secondhand boilers, by which is meant a boiler on which both ownership and location are changed, shall have a factor of safety of at least 5½ except where a boiler is constructed in accordance with Part III of this code where the factor of safety shall be at least 5.

After Jan. 1, 1944 secondhand boilers, as defined in the above paragraph shall comply with the following:

A—Each secondhand boiler must be inspected and a hydrostatic pressure test applied, by an authorized boiler inspector, before it is installed. The hydrostatic pressure test shall be one and one-half times the maximum allowable working pressure.

B—Secondhand boilers which comply with the orders on new construction shall be permitted a maximum allowable working pressure in accordance with those orders.

C—A secondhand boiler of the lap seam type not exceeding 36 inches in diameter and a secondhand boiler of the butt strap type, not complying with orders in Part III of this code, shall be allowed a maximum allowable working pressure based on a factor of safety of not less than 5½.

D—A secondhand boiler of the lap seam type larger than 36 inches in diameter, shall be limited to a maximum allowable working pressure not exceeding 15 pounds.

E—Boilers the longitudinal joint on which is exposed to the intense heat of the furnace, shall not be installed for any pressure.

Note: The locomotive or inside welt strap will not be considered as strengthening or changing the original type of the boiler joint.

F—All secondhand boilers when reinstalled must comply with all the orders in Part III pertaining to fittings, appliances, valves and connections, and setting or supports.

G—A portable boiler which is brought into this state for use, shall be inspected and shall be given a hydrostatic pressure test in accordance with Section A of this order and the Maximum allowable working pressure shall be determined by using the correct factor of safety according to Order 4209.

4209. Maximum allowable working pressure shall be determined by using a factor of safety of at least 5 except as provided for in order 4208.

4210. **Strength of Materials.** When the tensile strength of material is not known, it shall be taken as fifty-five thousand (55,000) pounds for steel and forty-five thousand (45,000) pounds for wrought-iron, thirty thousand (30,000)

pounds for copper, and eighteen thousand (18,000) pounds for cast iron. The resistance to crushing of mild steel shall be taken at ninety-five thousand (95,000) pounds per sq. in. of cross sectional area.

42.11 Shearing Strength of Rivets. The maximum shearing strength of rivets per square inch of cross-sectional area shall be taken as follows:

	Pounds
Iron rivets in single shear	38,000
Iron rivets in double shear	76,000
Steel rivets in single shear	44,000
Steel rivets in double shear	88,000

4212. Rivets. When the diameter of the rivet holes in the longitudinal joints of a boiler is not known, the diameter and cross-sectional area of rivets, after driving, shall be taken as follows:

Thickness of Plate	1/4" 0.25"	9/32" 0.2812"	5/16" 0.3125"	11/32" 0.34375"	3/8" 0.375"	3/8" 0.375"	13/32" 0.40625"
Diameter of rivet after driving	11/16"	11/16"	3/4"	3/4"	3/4" up to & including 2" pitch	13/16" over 2" pitch	13/16"
Cross-sectional area of rivet after driving	0.3712 sq. in.	0.3712 sq. in.	0.4418 sq. in.	0.4418 sq. in.	0.4418 sq. in.	0.5185 sq. in.	0.5185 sq. in.

Thickness of Plate	7/16" 0.4375"	7/16" 0.4375"	15/32" 0.46875"	1/2" 0.5"	9/16" 0.5625"	5/8" 0.625"
Diameter of rivet after driving	7/8" up to & including 2¼" pitch	15/16" over 2¼" pitch	15/16"	15/16"	1 1/16"	1 1/16"
Cross-sectional area of rivet after driving	0.6013 sq. in.	0.6903 sq. in.	0.6903 sq. in.	0.6903 sq. in.	0.8866 sq. in.	0.8866 sq. in.

42.13. Efficiency of Joint. The percentage of strength of the solid plate, that a unit length of joint has to a unit length or plate, shall be calculated as shown in A–1 to A–7 inclusive of the appendix. The ratio of strength of the weakest part of the joint to that of the solid plate shall be known as the efficiency of the joint.

4214. Ligament Between Parallel Tube Holes. Efficiency of ligament; when a shell or drum is drilled for tube holes in a line parallel to the axis of the shell or drum, the efficiency of the ligament between the tube holes shall be determined as shown in A–8 of the appendix.

4215. Ligament Between Diagonal Tube Holes. When a shell or drum is drilled for tube holes in a line diagonal with the axis of the shell or drum, the efficiency of the ligament between the tube holes shall be determined as shown in A–8 of the appendix.

4216. Safety Valves. The "maximum allowable working pressure" on a boiler is the safe pressure at which the boiler may be operated determined by orders 4202 to 4205 inclusive. Each boiler shall be provided with safety valve capacity sufficient to discharge all the steam that can be generated without an increase over the maximum allowable working pressure or to which the valve is set, except a 6 per cent increase while the valve is discharging.

4217. Each boiler shall have one or more safety valves set at or below the maximum allowable working pressure. The remaining valves may be set at a higher pressure in accordance with order 4392.

4218. Safety valve discharge capacity may be checked by order 4395 in Part III of this Code.

4219. When additional safety valve capacity is required the valves shall conform with orders in Part III of this code.

4220. Each safety valve shall have full-sized direct connection to the boiler, and when an escape pipe is used it shall be full sized and fitted with an open drain, to prevent water lodging in the upper part of safety valve or escape pipe. When a boiler is fitted with two safety valves on one connection, this connection to the boiler shall have a cross-sectional area equal to or greater than the combined area of the two safety valves. No valves of any description shall be placed between the safety valve and the boiler, nor on the escape pipe between the safety valve and the atmosphere. When an elbow is placed on a safety valve escape pipe it

shall be located close to the safety valve outlet, or the escape pipe shall be securely anchored and supported.

Safety valves having either the seat or disc of cast iron shall not be used.

4221. Each boiler shall have at least one water glass, equipped with a valved drain, the lowest visible part of which shall be at or above the following location and in all cases it must be so placed as to give adequate protection to those parts of a boiler proper subject to the heat of the products of combustion.

(a) Horizontal Return Tubular Boilers—not less than four (4) inches above the upper surface of the upper row of tubes except when the distance between the uppermost surface of tubes and the top of steam space is 13 inches or less the distance may be reduced to 2 inches.
(b) Locomotive Type Boilers—3 inches above the highest part of the crown sheet.
(c) Vertical Fire Tube Boilers—not less than one third the length of the tube above the lower tube sheet.
(d) Water Tube Boilers—as specified by the manufacturer.
(e) Scotch Marine Type Boilers—3 inches above the combustion chamber top. Note—For Dry Back see (a).
(f) For other types and new designs the location shall be as fixed by the manufacturer subject to approval by the Industrial Commission.

4222. Gage Cocks. Each boiler shall have three gage cocks, located within range of the visible length of water glass, when the maximum allowable working pressure exceeds fifteen pounds per square inch, except when such boiler has two water glasses, located not less than two feet apart, on the same horizontal line.

Boilers on which the maximum allowable working pressure does not exceed fifteen pounds shall have at least two gage cocks.

Locomotive type boilers not over 36 in. in diameter, or any firebox or waterleg boiler in which the water heating surface does not exceed 50 sq. feet, need have but two gauge cocks.

4223. No connections shall be placed on pipes connecting boiler with water column except connections for damper regulator, feed water regulator, steam gage or drains.

4224. Steam Gage. Each boiler shall have a steam gage connected to steam space of boiler or water column by a syphon or equivalent device sufficient to fill the gage with water. A shut off valve or cock shall be placed close to the steam gauge to permit removal for testing while the boiler is in operation.

4225. Stop Valves. Each steam discharge outlet over 2 inches diameter except safety valve and superheater connections shall be fitted with one or more stop valves, located as near the boiler as practicable. Steam boilers on which the maximum allowable working pressure does not exceed 15 pounds per square inch the use of a stop valve is optional.

4226. Fusion welding may be used in boilers in cases where the stress or load is carried by other construction which conforms to the requirements of the code or where the safety of the structure is not dependent upon the strength of the weld. Seal welding for tightness only is approved without restriction.

Note: Fusion welding done in accordance with the provisions contained in the A. S. M. E. Code is approved for all repairs.

4227. Bottom Blow-Off. Connected to the lowest water space practicable of each boiler, there shall be a bottom blow-off pipe fitted with a valve or cock. If the pipe or fittings are exposed to the products of combustion they shall be protected.

The valves shall be of straight way or angle construction, and cocks shall have the plugs held in place with a gland or guard.

Renewals shall conform to requirements in Part III of this code.

4228. Feed Pipe. Each boiler shall have a feed pipe fitted with a check valve and a stop valve or a stop cock between the check valve and the boiler. Means must be provided for feeding the boiler against the maximum allowable working pressure on the boiler.

4229. Valves on Heating Boilers. When a stop valve is used on the steam discharge outlet of a heating boiler (Gravity Return System) a check valve and a stop valve shall be placed on the return pipe. When there are two connecting boilers one check valve may be placed on the main return pipe and a stop valve on the branch return pipe to each boiler.

4230. Annual Internal Inspection. A boiler shall be prepared in accordance with order 4102 for an internal inspection by the owner or user. If a boiler has not been properly cooled down, or otherwise prepared for inspection, the boiler inspector shall decline to inspect it, and he shall not issue a certificate of inspection until efficient inspection has been made.

In making inspections, as provided by these orders, the boiler inspector shall apply the hammer test to all internal and external parts of a boiler that are accessible.

All proper measurements shall be taken by the boiler inspector, so that the maximum allowable working pressure on a boiler will conform to the orders established by the Industrial Commission; such measurements to be taken and calculations made before a hydrostatic pressure test is applied to a boiler.

The steam gage of a boiler shall be tested and its readings compared with an accurate test gage, and if, in the judgment of the boiler inspector, the gage is not reliable, he shall order it repaired or replaced.

4231. Annual External Inspection. The boiler inspector shall see that the water glass, gage cocks, water-column connections and water blow-offs are free and clear; also, that the safety valve raises freely from its seat.

Fire doors, tube doors and doors in settings shall be opened, to view as far as possible the fire surface, settings, tube ends, blow-off pipes and other parts of the boiler.

4232. Hydrostatic Pressure Tests. When a boiler is tested by hydrostatic pressure, the maximum pressure applied shall be one and one-half times the maximum allowable working pressure; except that twice the maximum allowable working pressure may be applied on boilers permitted to carry not over fifteen pounds pressure per square inch.

The boiler inspector, after applying a hydrostatic pressure test, shall thoroughly examine every accessible part of the boiler, both internal and external.

4233. Maintenance. The inspector shall note conditions during the internal inspection, external inspection or hydrostatic pressure test and order such changes or repairs as will place the boiler in a safe working condition.

PART III

ORDERS APPLICABLE TO POWER BOILERS BUILT AND INSTALLED ON OR AFTER MARCH 1, 1944

SELECTION OF MATERIALS

4250. Power Boiler. Any steam boiler exceeding the sizes for miniature boilers and on which the maximum allowable working pressure exceeds fifteen pounds shall be considered a power boiler.

4251. The physical and chemical properties of all materials used in the construction of steam boilers shall be as approved by the Industrial Commission.

Note: The "material specifications" in the A. S. M. E. Boiler Construction Code are approved and where "specifications" are mentioned in this code it refers to the A. S. M. E. Code.

4252. There shall be two grades of steel for boiler plates, namely FLANGE AND FIRE BOX manufactured by the open-hearth or electric furnace process. The physical and chemical properties of these two grades of steel shall be as follows:

CHEMICAL PROPERTIES

		Flange	Fire Box
Carbon	Plates ¾ inch thick or under		Not over 0.25%
	Plates over ¾ inch thick		Not over 0.30%
Manganese	Plates ¾ inch thick or under	0.80%	0.80%
	Plates over ¾ inch thick	0.80%	0.80%
Phosphorous	Acid	Not over 0.05%	Not over 0.04%
	Basic	Not over 0.04%	Not over 0.035%
Sulphur		Not over 0.05%	Not over 0.04%

PHYSICAL PROPERTIES

	Flange	Fire Box
Tensile Strength, lbs. per sq. in.	55000–65000	55000–65000
Yield point, min. lbs. per sq. in.	0.5 tens. str.	0.5 tens. str.
	1, 500, 000	1, 550, 000
Elongation in 8 in., minimum per cent	Tens. str.	Tens. str.

Note: Elongation properties may be modified to conform to A. S. M. E. specifications.

4253. Each plate and head shall be distinctly stamped with the manufacturer's name, the brand and the lowest tensile strength. Stamps to be so located as to be plainly visible when the boiler is finished.

4254. Steel plates for any part of a boiler, under pressure, shall be of flange or firebox quality as designated in the Specifications for Steel Boiler Plate.

4255. If desired, both flange and firebox steel of lower tensile strength than specified may be used for an entire boiler or part thereof, the desired tensile limits to be specified with a range of 10,000 pounds per square inch. All such steel shall conform to the Specifications for Steel Boiler Plate, excepting that the lower limit for carbon in the case of firebox steel may be less than 0.12 per cent for steels having the lower tensile strength.

4256. Braces, when welded, shall be of wrought iron of the quality designated in the Specifications for Extra-Refined Bar Iron.

4257. Manhole and handhole covers and other parts subjected to pressure, and braces, and lugs, when made of steel plate, shall be of fire box or flange quality as designated in the Specifications for Steel Boiler Plate.

4258. Steel bars or structural shapes for braces and for other boiler parts, except as otherwise specified herein, shall be of the quality designated in the Specifications for Steel Bars.

4259. Staybolts shall be of iron or steel of the quality designated in the Specifications for Staybolt Iron or in the Specifications for Staybolt Steel.

4260. Rivets shall be of steel or iron of the quality designated in the Specifications for Boiler Rivet Steel or in the Specifications for Boiler Rivet Iron.

4261. When the maximum allowable working pressure (see Order 4300) exceeds 160 pounds per square inch, cross pipes connecting the steam and water drums of water-tube boilers, headers, cross boxes and all pressure parts of the boiler proper over 2 inch pipe size, or equivalent cross-

sectional area, shall be of wrought steel, or cast steel of Class B grade, as designated in the Specifications for Steel Castings. Malleable iron, as designated in the Specifications for Malleable Castings, may be also used when the maximum allowable working pressure does not exceed 350 pounds per square inch, provided the form and size of the internal cross section perpendicular to the longest dimension of the box, is such that it will fall within a 7 inch by 7 inch rectangle.

Pipes used on boilers up to the required valve or valves on all outlets, including steam lines, feed lines, blow off lines, and drains shall conform to the specifications for pipes or tubes. Pipes or tubes which conform to the specifications may be used for drums or other pressure parts of a boiler or superheater provided the diameter of the pipe or tube does not exceed 18 in.

For sizes over 3 inch diameter, the steel pipe shall be of open hearth steel.

4262. Mud drums of boilers shall be of either wrought steel or cast steel of Class B grade, as designated in the Specifications.

4263. Pressure parts of superheaters, separately fired or attached to stationary boilers, unless of the locomotive type, shall be of wrought steel, puddled or knobbled charcoal wrought iron, or cast steel of Class B grade, as designated in the Specifications.

4264. (a) Cast iron shall not be used for nozzles or flanges attached directly to the boiler for any pressure or temperature.

(b) Cast iron may be used for boiler and superheater connections under pressure, such as pipes, fittings, valves and their bonnets, for pressures up to 250 pounds per square inch, provided the steam temperature does not exceed 450 degrees Fahrenheit.

4265. Water-leg and door-frame rings of vertical fire-tube boilers and of locomotive and other type boilers shall be of wrought iron or steel, or cast steel of Class A or

Class B grade, as designated in the Specifications. The OG or other flanged construction may be used as a substitute in any case.

Ultimate Strength of Material Used in Computing Joints

4266. Tensile Strength of Steel Plate. In determining the maximum allowable working pressure, the tensile strength used in the computations for steel plates shall be that stamped on the plates, as provided in the Specifications for Boiler Plate Steel, which is the minimum of the Stipulated range, or 55,000 pounds per square inch for all steel plates, except for special grades having a lower tensile strength.

4267. Crushing Strength of Steel Plate. The resistance to crushing of steel plate shall be taken at 95,000 pounds per square inch of cross-sectional area.

4268. Strength of Rivets in Shear. In computing the ultimate strength of rivets in shear, the following values in pounds per square inch of the cross-sectional area of the rivet shank shall be used:

Iron rivets in single shear	38,000
Iron rivets in double shear	76,000
Steel rivets in single shear	44,000
Steel rivets in double shear	88,000

The cross-sectional area used in the computations shall be that of the rivet shank after driving.

Minimum Thicknesses of Plates and Tubes

4269. Thickness of Plates. The minimum thickness of any boiler plate under pressure shall be ¼ inch. The minimum thickness of plates in stayed surface construction shall be $\frac{5}{16}$ inch.

4270. The minimum thicknesses of shell plates, and dome plates after flanging, shall be as follows:

When the Diameter of shell is			
36 Inches or Under	Over 36 Inches to 54 Inches	Over 54 Inches to 72 Inches	Over 72 Inches
¼ inch	$\frac{5}{16}$ inch	⅜ inch	½ inch

4271. The minimum thickness of butt straps for double strap joints shall be as given in Table I in which the required thickness of the shell is that obtained by the rules

given in Order 4301 employing a value of E corresponding to the efficiency of the buttstrap joint. Intermediate values shall be determined by interpolation. Where the required thickness of the plate exceeds 1½ in., the thickness of the buttstrap shall be not less than two-thirds of the required thickness of the plate. In no case shall either of the buttstraps have a lesser thickness than one half the actual thickness of the plate.

TABLE 1. MINIMUM THICKNESSES OF BUTTSTRAPS

Thickness of Shell Plate, Inches	Minimum Thickness of Buttstraps, Inches	Thickness of Shell Plates, Inches	Minimum Thickness of Buttstraps, Inches
1/4	1/4	17/32	7/16
9/32	1/4	9/16	7/16
5/16	1/4	5/8	1/2
11/32	1/4	3/4	1/2
3/8	5/16	7/8	5/8
13/32	5/16	1	11/16
7/16	3/8	1–1/8	3/4
15/32	3/8	1–1/4	7/8
1/2	7/16	1–1/2	1

4272. The minimum thicknesses of tube sheets for fire-tube boilers, shall be as follows:

When the Diameter of Tube Sheet is			
42 inches or under	Over 42 inches to 54 inches	Over 54 inches to 72 inches	Over 72 inches
3/8 inch	7/16 inch	1/2 inch	9/16 inch

4273. Tubes and Nipples for Water-Tube Boilers. The maximum allowable working pressures for steel or wrought-iron tubes or nipples used in water-tube boilers shall be as given in Table 2. Open-hearth steel pipe or wrought-iron pipe, not to exceed 1½ inch pipe size, which meets the Specifications for Steel or Wrought-Iron Pipe, may be used for water-tube boilers for a working pressure not to exceed 250 pounds per square inch, when screwed in the sheet or fittings, provided the wall thickness is at least 50 per cent greater than the minimum wall thickness by Table 2.

The maximum allowable working pressure for copper tubes or nipples used in water-tube boilers, shall be as given in Table 3, but they shall not be used for pressures exceeding 250 pounds per square inch nor for temperatures exceeding 406 degrees Fahrenheit.

TABLE 2. MAXIMUM ALLOWABLE WORKING PRESSURES FOR SEAMLESS STEEL, LAP-WELDED STEEL, LAP-WELDED WROUGHT-IRON, AND ELECTRIC-RESISTANCE WELDED STEEL TUBES OR NIPPLES FOR WATER-TUBE BOILERS FOR DIFFERENT DIAMETERS AND GAGES OF TUBES[1]

Size outside diameter, in.	Wall thickness in.	Nearest Bwg no.		½	¾	1	1⅛	1¼	1½	1¾	2	2¼	2½	2¾	3	3¼	3½	3¾	4	4½	5	Wall thickness in.
0.055	0.065	17—		330	120	220	160	120	190													0.055
0.065	0.075	16		740	390	430	350	280	330	240	170											0.065
0.075	0.085	15+		1150	670	640	530	450	530	380	270	210	160	120								0.075
0.085	0.095	14+		1570	950	840	720	620	460	360	270	210	160	120								0.085
0.095	0.105	13	I	1980	1220	1050	900	780	600	470	380	300	240	190	150							0.095
0.105	0.120	12—			1500	1360	1180	1030	810	650	530	440	370	310	260	210	180	150				0.105
0.120	0.135	11			1910	1670	1450	1280	1020	830	690	580	490	420	360	310	270	230	200			0.120
0.135	0.150	10+				1980	1730	1530	1220	1010	840	720	620	530	460	410	360	310	270	210	160	0.135
0.150	0.165	9+	II				2000	1770	1430	1180	1000	850	740	650	570	500	440	390	350	280	220	0.150
0.165	0.180	8						2020	1640	1360	1150	990	860	760	670	600	530	480	430	350	280	0.165
0.180	0.200	7							1910	1600	1360	1180	1030	910	810	720	650	590	530	440	370	0.180
0.200	0.220	6—	III							1830	1570	1360	1200	1060	950	850	770	700	640	530	450	0.200
0.220	0.240	5								2070	1770	1540	1360	1210	1080	980	890	810	740	620	530	0.220
0.240	0.260	4+									1980	1730	1530	1360	1220	1110	1010	920	840	720	620	0.240
0.260	0.280	3+										1910	1690	1510	1360	1230	1120	1030	950	810	700	0.260
0.280	0.300	2—										2100	1860	1660	1500	1360	1240	1140	1050	900	780	0.280
0.300	0.320	1											2020	1810	1640	1490	1360	1250	1150	990	860	0.300
0.320	0.340													1960	1770	1620	1480	1360	1260	1080	950	0.320
0.340	0.360														1910	1740	1600	1470	1360	1180	1030	0.340
0.360	0.380														2050	1870	1720	1580	1460	1270	1110	0.360
0.380	0.400															2000	1830	1690	1570	1360	1200	0.380
0.400	0.420																1950	1800	1670	1450	1280	0.400
0.420	0.440																2070	1910	1770	1540	1360	0.420
0.440	0.460	Lap-welded wrought iron tubes may be used for all pressures above the line marked I.																				0.440
	0.480	Lap-welded steel tubes may be used for all pressures above the line marked II.																				
0.460	0.500	Electric-resistance welded tubes may be used for all pressures above the line marked III.																				0.460
0.480		Seamless steel tubes may be used for all pressures shown in the table.																				0.480
0.500																						0.500

[1]These values have been increased to the next higher unit of 10 where the actual values exceed an even unit of 10.

TABLE 3. MAXIMUM ALLOWABLE WORKING PRESSURES FOR COPPER TUBES FOR WATER-TUBE OR FIRE-TUBE BOILERS*

(For use at pressures not to exceed 250 lb. per sq. in. or temperatures not to exceed 406 F.)

Outside diam. of tube, in., D	Gage—Bwg								
	12	11	10	9	8	7	6	5	4
2	170	240	250	250	250	250	250	250	250
3¼	-------	-------	110	150	220	250	250	250	250
4	-------	-------	-------	-------	130	160	250	250	250
5	-------	-------	-------	-------	-------	-------	150	190	230

$$P = \frac{(t - 0.039)}{D}\ 12{,}000 - 250$$

where P = maximum allowable working pressure, lb. per sq. in.,
t = thickness of tube wall, in.,
D = outside diameter of tube, in.

*These values have been rounded out to the next higher unit of 10.

TABLE 4. MAXIMUM ALLOWABLE WORKING PRESSURES FOR STEEL OR WROUGHT-IRON TUBES OR FLUES FOR FIRE-TUBE BOILERS FOR DIFFERENT DIAMETERS AND GAGES OF TUBES[1]

Size outside diameter, in.		1	1½	1¾	2	2¼	2½	3	3¼	3½	4	4½	5	5⅜	5½	6
Wall thickness, in.	Nearest Bwg no.															
0.095	13	420	280	240	210	190	170	-------	-------	-------	-------	-------	-------	-------	-------	-------
0.105	12	560	380	320	280	250	230	190	180	160	-------	-------	-------	-------	-------	-------
0.120	11	770	520	440	390	350	310	260	240	220	200	-------	-------	-------	-------	-------
0.135	10+	980	660	570	490	430	400	330	310	280	250	220	200	-------	-------	-------
0.150	9+	-------	800	680	600	530	480	400	370	340	300	270	240	230	220	-------
0.165	8	-------	940	800	700	630	560	470	430	400	350	320	280	270	260	240
0.180	7	-------	-------	920	810	720	650	540	500	460	410	360	330	300	300	270
0.200	6—	-------	-------	1090	950	840	760	630	590	540	480	420	380	360	350	320
0.220	5	-------	-------	1240	1090	970	870	730	670	620	550	490	440	410	400	370
0.240	4+	-------	-------	1410	1230	1090	990	820	760	700	620	550	490	460	450	410

$$P = 14{,}000\frac{(t - 0.065)}{D}$$

where P = maximum allowable working pressure, lb. per sq. in.,
t = minimum wall thickness, in.,
D = outside diameter of tube, in.

For pressures other than those given in the table, the allowable working pressures shall be the next higher unit of 10 above the values given by the formulas.
For pressures below those given in the table, the gage thickness shall be not less than the minimum given in the table.

[1]These values have been increased to the next higher unit of 10 where the actual values exceed an even unit of 10.

4274. Tubes for Fire-Tube Boilers. The minimum thicknesses of tubes used in fire-tube boilers, for various maximum allowable working pressures, shall be as given in Table 4.

Copper boiler tubes shall not be used for pressures in excess of 250 pounds per square inch, nor where the temperature of the water or steam in contact with tubes subjected to external pressure is in excess of 406 deg. Fahrenheit.

4275. Thickness of Steam Piping. In determining the thickness to be used for pipes at different pressures and for temperatures not exceeding 750 degrees Fahrenheit, for steel or iron pipe, and 406 degrees Fahrenheit, for brass and copper pipe, the following formulas are to be used:

For pipes having nominal diameters of from ¼ inch to 5 inches,

$$t = \frac{(P + 125)D}{2S} + 0.065$$

For pipes of nominal diameter over 5 inches,

$$t = \frac{P \times D}{2S} + 0.1$$

where

P = working pressure, lbs. per sq. in.
t = thickness of wall of pipe, inches
D = actual outside diameter of pipe, inches
S = 9,000 lbs. per sq. in. for seamless steel pipe
= 7000 lbs. per sq. in. for lap-welded steel pipe
= 5000 lbs. per sq. in. for butt-welded steel pipe
= 5300 lbs. per sq. in. for lap-welded wrought iron pipe
= 4500 lbs. per sq. in. for butt-welded wrought iron pipe
= 4500 lbs. per sq. in. for brass pipe
= 4000 lbs. per sq. in. for copper pipe

Where pipe is used pierced with tube holes, the stress in the ligaments may be taken as the stress specified above for seamless material, provided the tube holes do not pierce the weld, and provided that the pressure shall not be greater than that allowed for the unpierced pipe.

CONSTRUCTION AND MAXIMUM ALLOWABLE WORKING PRESSURES FOR STEAM POWER BOILERS

4300. Maximum Allowable Working Pressure. The maximum allowable working pressure is that determined by employing the factors of safety, stresses, and dimensions designated in these Rules.

No boiler shall be operated at a higher pressure than the maximum allowable working pressure except when the safety valve or valves are blowing, at which time the maximum allowable working pressure shall not be exceeded by more than 6 per cent.

Wherever the term maximum allowable working pressure is used herein, it refers to gage pressure, or the pressure above the atmosphere, in pounds per square inch.

4301. The maximum allowable working pressure of the shell of a boiler or drum shall be determined by the strength of the weakest course, computed from the thickness of the plate, the tensile strength stamped thereon, as provided for in the Specifications for Steel Boiler Plate, the efficiency of the longitudinal joint, or of the ligament between the tube holes in shell or drum (whichever is the least), the inside diameter of the course, and the factor of safety.

$$\frac{TS \times t \times E}{R \times FS} = \text{maximum allowable working pressure, lbs. per sq. in.}$$

where

TS = ultimate tensile strength stamped on all shell plates, as provided for in the Specifications for Steel Boiler Plate, lbs. per sq. in.
t = minimum thickness of shell plates in weakest course, inches
E = efficiency of longitudinal joint or of ligaments between tube holes (whichever is the least)
R = inside radius of the weakest course of the shell or drum, inches, provided the thickness of the shell does not exceed 10 per cent of the radius. If the thickness is over 10 per cent of the radius the outer radius shall be used for R.
FS = factor of safety, or the ratio of the ultimate strength of the material to the allowable stress.

For new construction FS in the above formula = 5.

The factor of safety used in determining the maximum allowable working pressure calculated on the conditions actually obtained in service shall not be less than 5.

Boiler Joints

4302. Efficiency of a Joint. The efficiency of a joint is the ratio which the strength of the joint bears to the strength of the solid plate. In the case of a riveted joint this is determined by calculating the breaking strength of a unit section of the joint, considering each possible mode of failure separately, and dividing the lowest result by the breaking strength of the solid plate of a length equal to that of the section considered. (See A–1 to A–7 inclusive of the Appendix for detailed methods and examples.)

43.03. The distance between the center lines of any two adjacent rows of rivets, or the "back pitch" measured at right angles to the direction of the joint, shall have the following minimum values:

a If $\frac{P}{d}$ is 4 or less, the minimum value shall be 2d;

b If P is over 4, the minimum value shall be:

$$2\,d + 0.1\,(P - 4\,d)$$

where

P = pitch of rivets in outer row where a rivet in the inner row comes midway between two rivets in the outer row, inches

P = pitch of rivets in the outer row less pitch of rivets in the inner row where two rivets in the inner row come between two rivets in the outer row, inches

(It is here assumed that the joints are of the usual construction where the rivets are symmetrically spaced.)

d = diameter of the rivet holes, inches

The back pitch of rivets shall be measured either on the flat plate before rolling, or on the median line after rolling.

4304. On the longitudinal joints, the distance from the centers of rivet holes to the edges of the plates, except rivet holes in the ends of butt straps, shall be not less than 1½ and not more than 1¾ times the diameter of the rivet holes; this distance to be measured from the center of the rivet holes to the calking edge of the plate before calking.

The plate edge shall be beveled to an angle not sharper than 70 degrees to the plane of the plate and as near thereto as practicable.

4305. (a) Circumferential Joints. The strength of circumferential joints of boilers, the heads of which are not stayed by tubes or through braces, shall be at least 50 per cent of that required for the longitudinal joints of the same structure.

(b) When 50 per cent or more of the load which would act on an unstayed solid head of the same diameter as the shell, is relieved by the effect of tubes or through stays, in consequence of the reduction of the area acted on by the

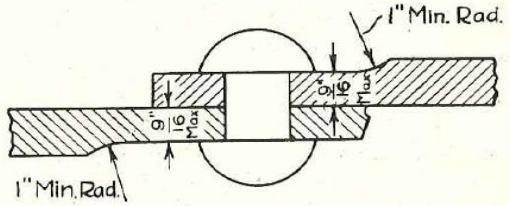


Fig. 1. Circumferential Joint for Thick Plates of Horizontal-Return Tubular Boilers.

pressure and the holding power of the tubes and stays, the strength of the circumferential joints in the shell shall be at least 35 per cent of that required for the longitudinal joints.

(c) In the portion of circumferential joints of horizontal-return tubular boilers, exposed to the products of combustion, the shearing strength of the rivets shall not be less than 50 per cent of the full strength of the plate corresponding to the thickness at the joint.

(d) The distance from the centers of rivet holes of circumferential joints to the edges of the plate shall not be less than 1¼ times the diameter of the rivet holes.

4306. When shell plates exceed ⅝ inch in thickness in horizontal-return tubular boilers, the portion of the plates forming the laps of the circumferential joints, where exposed to the fire or products of combustion, shall be planed or milled down as shown in Figure 1, to a thickness of not over $\frac{9}{16}$ inch provided the requirement in Order 4305 is

complied with, or the entire circumference may be so planed or milled. The fillet at the edge of the planing shall be not less than 1 inch radius.

4307. Welded Joints. The ultimate strength of a joint which has been properly welded by the forging process shall be taken as 35,000 pounds per square inch, with steel plates having a range in tensile strength of 45,000 to 55,000 pounds per square inch. Fusion welding may be used in boilers in cases where the stress or load is carried by other construction which conforms to the requirements of the code or where the safety of the structure is not dependent upon the strength of the weld. Seal welding for tightness only is approved without restriction.

Note: Fusion welding done in accordance with the requirements contained in the A. S. M. E. code is approved in all cases.

4308. Seamless Construction. Drums, shells or domes may be of seamless drawn construction, with or without integral heads, provided the material conforms to the requirements of the Code for shell material.

4309. (a) Riveted Longitudinal Joints. The riveted longitudinal joints of a shell or drum which exceeds 36 inches in diameter, shall be of butt and double-strap construction. This rule does not apply to the portion of a boiler shell which is staybolted to the firebox sheet.

(b) The longitudinal joints of a shell or drum which does not exceed 36 inches in diameter, may be of lap-riveted construction; but the maximum allowable working pressure shall not exceed 100 pounds per square inch.

4310. The longitudinal joints of horizontal-return tubular boilers shall be located above the fire-line of the setting.

4311. In horizontal-return tubular boilers with longitudinal lap joints, no course shall be over 12 feet long. With butt and double-strap construction, longitudinal joints of any length may be used.

4312. Butt straps and the ends of shell plates forming the longitudinal joints shall be rolled or formed by pressure, not blows, to the proper curvature.

4313. Efficiency of Ligament. When a shell or drum is drilled for tubes in a line parallel to the axis of the shell or

drum, the efficiency of the ligament between the tube holes shall be determined as shown in A–8 of the appendix.

4314. In applying reinforcing plates to the drums of water-tube boilers to strengthen the shell where the tubes enter, they shall be riveted to the shell, and where outside calking is used, the tubes shall be expanded into the inner and outer plates so that the rivets and tubes will hold the plates together in accordance with the rules for stayed surfaces.

The spacing of the rivets with respect to the tubes shall conform to Order 4320 for stayed surfaces, using a value of 135 for C, and shall be based on a unit pressure equal to the pressure that can be carried by the inner plate with a factor of safety of 5.

Note: Where a reinforcing plate is inside the steam drum it is the inner plate; where it is outside and there is no inner reinforcing plate, the unreinforced shell of the drum is the inner plate.)

The tension in rivets and tubes shall conform to Order 4341 and 4353.

The combined drum shell and reinforcing plate or plates, and riveted connections, shall have a factor of safety of not less than 5 in the ligaments, when calculated in accordance with Order 4313. When reinforcing plates or butt straps are exposed to flame or gas of the equivalent temperature, the joints shall be protected therefrom.

DOMES

4315. Domes. The longitudinal joint of a dome 24 inches or over in inside diameter shall be of butt and double-strap construction, or made without a seam of one piece of steel pressed into shape, and its flange shall be double-riveted to the boiler shell. In the case of a dome less than 24 inches in diameter, for which the product of the inside diameter and the maximum allowable working pressure does not exceed 4000 inch-pounds, its flange may be single-riveted to the boiler shell and the longitudinal joint may be of the lap type, provided it is computed with a factor of safety not less than 8.

When a dome is located on the barrel of a locomotive-type boiler or on the shell of a horizontal-return tubular boiler,

the diameter of the dome shall not exceed six-tenths the diameter of the shell or barrel of the boiler.

All domes shall be so arranged that any water can drain back into the boiler.

Flanges of domes shall be formed with a corner radius, measured on the inside, of at least twice the thickness of the plate for plates 1 inch thick or less, and at least three times the thickness of the plates for plates over 1 inch in thickness.

When boiler shells are cut to apply steam domes or manholes, the net area of metal, after rivet holes are deducted, in flange and liner, if used, must not be less than the area required by these rules for a length of boiler shell equal to the length removed. A height of vertical flange equal to three times the thickness of the flange may be included in the area of the flange.

Dished Heads

4316. Heads. The thickness required in an unstayed dished head with the pressure on the concave side, when it is a segment of a sphere, shall be calculated by the following formula:

$$t = \frac{8.33\ PL}{2\ TS}$$

where

t = thickness of plate, inches
P = maximum allowable working pressure, lbs. per sq. in.
TS = tensile strength, lbs. per sq. in.
L = radius to which the head is dished, inches

Where two radii are used the longer shall be taken as the value of L in the formula.

Where the radius is less than 80 per cent of the diameter of the shell or drum to which the head is attached the thickness shall be at least that found by the formula by making L equal to 80 per cent of the diameter of the shell or drum.

Unstayed dished heads with the pressure on the convex side shall have a maximum allowable working pressure equal to 60 per cent of that for heads of the same dimensions with the pressure on the concave side.

When a head dished to a segment of a sphere has a flanged-in manhole or access opening that exceeds 6 in. in any dimension, the thickness shall be increased by not less than 15 per cent of the required thickness for a blank head computed by the above formula, but in no case less than ⅛ in. additional thickness over a blank head. Where such a dished head has a flanged opening supported by an attached flue, an increase in thickness over that for a blank head is not required.

4317. (A) When dished heads are of a less thickness than called for by Order 4316 they shall be stayed as flat surface, no allowance being made in such staying for the holding power due to the spherical form unless all of the following conditions are met:

(a) That they be at least two-thirds as thick as called for by the rules for unstayed dished heads.

(b) That they be at least ⅞ in. in thickness.

(c) That through stays be used attached to the dished head by outside and inside nuts.

(d) That the maximum allowable working pressure shall not exceed that calculated by the rules for an unstayed dished head plus the pressure corresponding to the strength of the stays or braces secured by the formula for braced or stayed surfaces as given in Order 4320, using 70 for the value of C.

(B) If a dished head is formed with a flattened spot or surface for the attachment of a connection or flange, the diameter of the flat spot shall not exceed the value of P as given in the formula in order 4320 or in Table 6 for the pressure and thickness of head involved.

4318. The corner radius of an unstayed dished head measured on the concave side of the head shall be not less than 3 times the thickness of the material in the head; but in no case less than 6 per cent of the diameter of the shell. In no case shall the thinning down at the corner radius of the knuckle of any dished head due to the process of forming exceed 10 per cent of the thickness required by the rules in Order 4316.

4319. A flanged-in manhole opening in a dished head shall be flanged to a depth of not less than 3 times the required

thickness of the head for plate up to 1½ in. in thickness. For plate exceeding 1½ in. in thickness, the depth shall be the thickness of the plate plus 3 in. The depth of flange shall be determined by placing a straight edge across the outside opening along the major axis and measuring from the straight edge to the edge of the flanged opening. A manhole opening may be reinforced by a riveted manhole frame or other attachment in place of flanging.

Braced and Stayed Surfaces

4320. The maximum allowable working pressure for various thicknesses of braced and stayed flat plates and those which by these Rules require staying as flat surfaces with braces or staybolts of uniform diameter symmetrically spaced, shall be calculated by the formula:

$$P = C \times \frac{T^2}{p^2}$$

where

P = maximum allowable working pressure, lbs. per sq. in.

T = thickness of plate in sixteenths of an inch

p = maximum pitch measured between straight lines passing through the centers of the staybolts in the different rows, which lines may be horizontal, vertical or inclined, inches

C = 112 for stays screwed through plates not over $\frac{7}{16}$ inch thick with ends riveted over.

C = 120 for stays screwed through plates over $\frac{7}{16}$ inch thick with ends riveted over

C = 135 for stays screwed through plates and fitted with single nuts outside of plate or with inside and outside nuts omitting washers (See Order 4324)

C = 150 for stays with heads not less than 1.3 times the diameter of the stays, screwed through plates or made a taper fit and having the heads formed on the stays before installing them and not riveted over, said heads being made to have a true bearing on the plate.

C = 175 for stays fitted with inside and outside nuts and outside washers where the diameter of washers is not less than 0.4p and thickness not less than T.

For stays at the upper corners of fire boxes, the pitch from the staybolt next to the corner to the point of tangency of the corner curve shall be (see Fig. 2):

$$\text{Pitch} = \frac{90\sqrt{\frac{T^2}{CP}}}{\text{Angularity of Tangent-Lines } (\beta)}$$

If a flat boiler plate not less than ⅜ inch thick is strengthened with a doubling plate covering the full area of the stayed surface and securely riveted thereto and having a thickness of not less than ⅔ T, then the value of T in the formula shall be three-quarters of the combined thickness

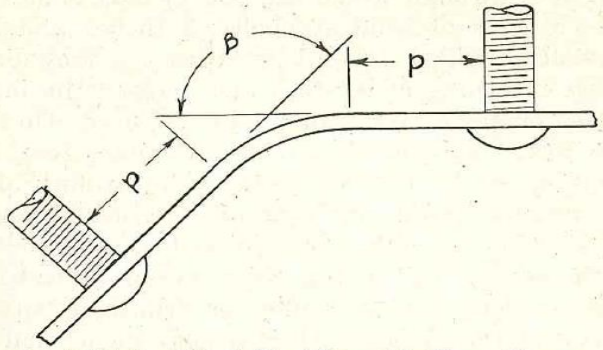


Fig. 2. Pitch of Staybolts Adjacent to Upper Corners of Fireboxes.

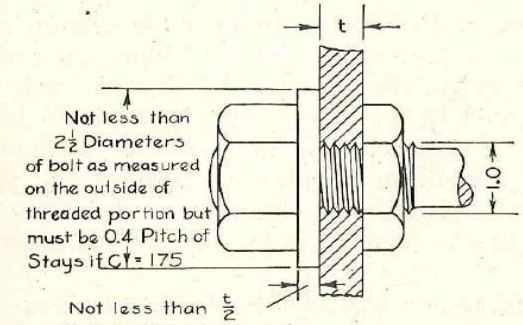


Fig. 3. Acceptable proportions for Ends of Through Stays.

of the boiler plate and doubling plate but not more than 1½ times the thickness of the boiler plate, and the value of C given above may also be increased 15 per cent.

When two sheets are connected by stays and but one of these sheets requires staying, the value of C is governed by the thickness of the sheet requiring staying.

Acceptable proportions for the ends of through stays with washers are indicated in Fig. 3.

4321. Staybolts. The ends of staybolts or stays screwed through plates, shall extend beyond the plate not less than two threads when installed, after which they shall be riveted over or upset by an equivalent process without excessive scoring of the sheets; or they shall be fitted with threaded nuts through which the bolt or stay shall extend. The outside ends of solid staybolts, 8 inches and less in length, shall be drilled with a hole at least $\frac{3}{16}$ inch diameter to a depth extending at least ½ inch beyond the inside of the plates, or hollow staybolts may be used. On boilers having a grate area not exceeding 15 square feet, or the equivalent in gas or oil-fired boilers, the drilling of staybolts is optional. Solid staybolts over 8 inches long, and flexible staybolts of either the jointed or ball-and-socket type, need not be drilled. Staybolts used in water-legs of water-tube boilers shall be hollow or drilled at both ends, irrespective of their length. All staybolts not normal to the stayed surface shall have not less than three engaging threads of which at least one shall be a full thread.

4322. Structural Reinforcements. When channels or other structural shapes are riveted to the boiler heads for attaching through stays, the transverse stress on such members shall not exceed 12,500 pounds per square inch. In computing the stress, the section modulus of the member shall be used without addition for the strength of the plate. The spacing of the rivets over the supported surface shall be determined by the formula in Order 4320 using 135 for the value of C.

If the outstanding legs of the two members are fastened together so they act as one member in resisting the bending action produced by the load on the rivets attaching the members to the head of the boiler, and provided that the spacing of these rivets attaching the members to the head is approximately uniform, the members may be computed as a single beam uniformly loaded and supported at the points where the through braces are attached.

4323. Stays. The ends of stays fitted with nuts shall not be exposed to the direct radiant heat of the fire.

4324. (a) The maximum spacing between centers of rivets or between the edges of tube holes and the centers of

rivets attaching the crowfeet of braces to the braced surface, shall be determined as in Order 4320, using 135 for the value of C.

(b) The maximum distance beween the edges of tube holes and the center of other types of stays shall be determined by the formula in Order 4320, using the value of C given for the thickness of plate and type of stay used.

(c) The maximum spacing between the inner surface of the shell and lines parallel to the surface of the shell passing through the centers of the rivets attaching the crowfeet of braces to the head, shall be determined by the formula in Order 4320, using 175 for the value of C.

(d) The maximum distance between the inner surface of the shell and the centers of braces of other types shall be determined by the formula in Order 4320, using a value of C equal to 1.3 times that value of C which applies to the thickness of plate and type of stay as therein specified.

(e) In applying these Rules and those in Order 4320 to a head or plate having a manhole or reinforced opening, the spacing applies only to the plate around the opening and not across the opening.

TABLE 6. MAXIMUM ALLOWABLE PITCH, IN INCHES, OF SCREWED STAYBOLTS, ENDS RIVETED OVER

Pressure Lbs. per Sq. In.	Thickness of Plate, Inches						
	5/16	3/8	7/16	1/2	9/16	5/8	11/16
	Maximum Pitch of Staybolts, Inches						
100	5¼	6⅜	7⅜				
110	5	6	7	8⅜			
120	4⅞	5¾	6¾	8			
125	4¾	5⅝	6⅝	7⅞			
130	4⅝	5½	6½	7⅝			
140	4½	5⅜	6¼	7⅜	8⅜		
150	4¼	5⅛	6	7⅛	8		
160	4⅛	5	5⅞	6⅞	7¾		
170	4	4⅞	5⅝	6¾	7½	8⅜	
180		4¾	5½	6½	7⅜	8⅛	
190		4⅝	5⅜	6⅜	7⅛	7⅞	
200		4½	5¼	6⅛	7	7¾	8½
225		4¼	4⅞	5⅞	6½	7¼	8
250		4	4⅝	5½	6¼	6⅞	7⅝
300			4¼	5	5⅝	6¼	7

4325. The formula in Order 4320 was used in computing Table 6. Where values for screwed stays with ends riveted over are required for conditions not given in Table 6, they may be computed from the formula and used, provided the

pitch does not exceed 8½ inches. Where the staybolting of shells of boilers is unsymmetrical by reason of interference with butt straps or other construction, it is permissible to consider the load carried by each staybolt as the area calculated by taking the distance from the center of the spacing on one side of the bolt to the center of the spacing on the other side.

For the application of Order 4326 and 4327, see Fig. A–13 in the Appendix.

4326. The distance from the edge of a staybolt hole to a straight line tangent to the edges of the rivet holes may be substituted for p for staybolts adjacent to the riveted edges bounding a stayed surface. When the edge of a flat stayed plate is flanged and riveted, the distance from the center of the outermost stays to the inside of the supporting flange shall not exceed the pitch of the stays, p, plus the inside radius of the flange.

4327. The maximum pitch p as given in Order 4320 may be increased by the staybolt hole diameter where staybolts are adjacent to a furnace door or other boiler fitting, tube hole, handhole or other opening.

4329. The diameter of a screw stay shall be taken at the bottom of the thread or wherever it is of the least diameter.

4330. The least cross-sectional area of a stay shall be taken in calculating the allowable stress, except that when the stays are welded and have a larger cross-sectional area at the weld than at some other point, the strength at the weld shall be computed as well as in the solid part and the lower value used.

4331. Holes for screw stays shall be drilled full size or punched not to exceed ¼ inch less than full diameter of the hole for plates over $\frac{5}{16}$ inch in thickness, and ⅛ inch less than the full diameter of the hole for plate not exceeding $\frac{5}{16}$ inch in thickness, and then drilled or reamed to the full diameter. The holes shall be tapped fair and true, with a full thread.

4332. The ends of steel stays upset for threading, shall be thoroughly annealed.

4333. (a) The maximum allowable working pressure for any curved stayed surface subject to internal pressure shall be obtained by the two following methods, and the minimum value obtained shall be used:

First, the maximum allowable working pressure shall be computed without allowing for the holding power of the stays, due allowance being made for the weakening effect of the holes for the stays or riveted longitudinal joint or other construction. To this pressure there shall be added the pressure secured by the formula for braced and stayed surfaces given in Order 4320, using 70 for the value of C.

Second, the maximum allowable working pressure shall be computed without allowing for the holding power of the stays, due allowance being made for the weakening effect of the holes for the stays or riveted longitudinal joint or other construction. To this pressure there shall be added the pressure corresponding to the strength of the stays or braces for the stresses given in Table 7, each stay or brace being assumed to resist the steam pressure acting on the full area of the external surface supported by the stay or brace.

(b) The maximum allowable working pressure for a stayed wrapper sheet of a locomotive-type boiler shall be determined by the two methods given above and by the method which follows, and the minimum value obtained shall be used:

$$P = \frac{11{,}000t \times E}{R - \Sigma(s \times \sin \alpha)}$$

where

P = maximum allowable working pressure, lb. per sq. in.

t = thickness of wrapper sheet, in.

E = minimum efficiency of wrapper sheet through joints or stay holes

R = radius of wrapper sheet, in.

$\Sigma(s \times \sin \alpha)$ = summated value of transverse spacing s × sin α for all crown stays considered in one transverse plane and on one side of vertical axis of boiler

s = transverse spacing of crown stays in crown sheet, in.
α = angle any crown stay makes with vertical axis of boiler
11,000 = allowable stress, lb. per sq. in.

The above formula applies to the longitudinal center section of the wrapper sheet, and in cases where E is reduced at another section, the maximum allowable working pressure based on the strength at that section, may be increased in the proportion that the distance from the wrapper sheet to the top of the crown sheet at the center, bears to the

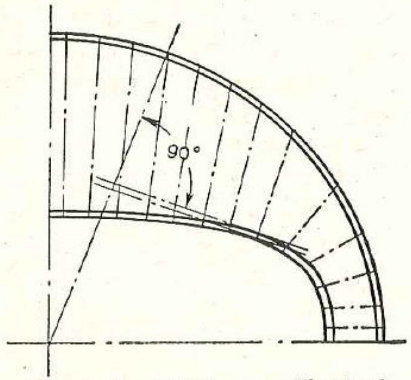


Fig. 4. Stayed Wrapper Sheet of Locomotive-Type Boiler.

distance, measured on a radial line through the other section, from the wrapper sheet to a line tangent to the crown sheet and at right angles to the radial line (see Fig. 4).

(c) A furnace, for a vertical fire-tube boiler, 38 inches or less in outside diameter, which requires staying, shall have the furnace sheet supported by one row of staybolts, or more, the circumferential pitch not to exceed 1.05 times that given by the formula in Order 4320.

The longitudinal pitch between the staybolts, or between the nearest row of staybolts and the row of rivets at the joints between the furnace sheet and the tube sheet or the furnace sheet and mud ring, shall not exceed that given by the following formula:

$$L = \left(\frac{220 \times T^2}{P \times R}\right)^2$$

where
L = longitudinal pitch of staybolts
T = thickness of furnace sheet in sixteenths of an inch
P = maximum allowable working pressure, lbs. per sq. in.
R = outside radius of furnace, inches

When values by this formula are less than the circumferential pitch, the longitudinal pitch may be as large as the allowable circumferential pitch.

The stress per square inch in the staybolts shall not exceed 7500 pounds and shall be determined in the way specified in section (d).

(d) In furnaces over 38 inches in outside diameter and combustion chambers not covered by special rules in this Code, which have curved sheets subject to external pressure, that is, pressure on the convex side, neither the circumferential nor longitudinal pitches of the staybolts shall exceed 1.05 times that given by the formula in Order 4320.

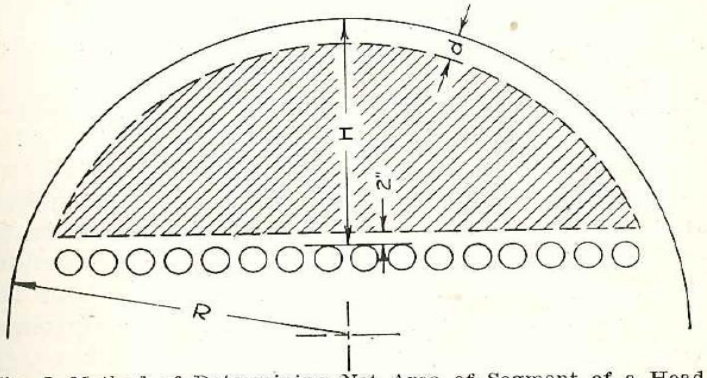


Fig. 5. Method of Determining Net Area of Segment of a Head.

The stress per square inch in staybolts shall not exceed 7500 pounds based on a total stress obtained by multiplying the product of the circumferential and longitudinal pitches, less the minimum cross-sectional area, by the maximum allowable working pressure.

4334. Staying Segments of Heads. A segment of a head shall be stayed by head to head, through, diagonal, crowfoot or gusset stays, except that a horizontal-return tubular boiler may be stayed as provided in Orders 4346 to 4350, inclusive.

4335. Areas of Heads to be Stayed. The area of a segment of a head to be stayed shall be the area enclosed by lines drawn 2 inches from the tubes and at a distance d from the shell as shown in Figures 5 and 6. The value of d used may be the larger of the following values:

(1) d = the outer radius of the flange, not exceeding 8 times the thickness of the head.

(2) $$d = \frac{5 \times T}{\sqrt{P}}$$

where

d = unstayed distance from shell, inches
T = thickness of head in sixteenths of an inch
P = maximum allowable working pressure, lbs. per sq. in.

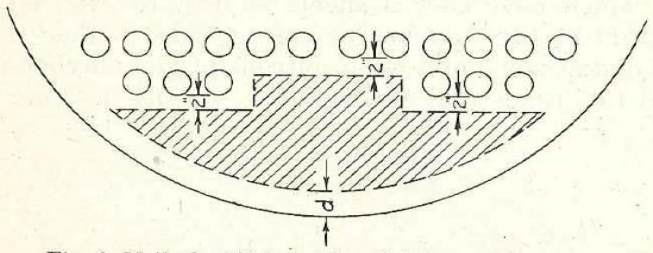


Fig. 6. Method of Determining Net Area of Irregular Segment of a Head.

In water-tube boilers, the tubes of which are connected to drum heads, the area to be stayed shall be taken as the total area of the head less the area of an annular ring of width d measured from the inner circumference of the drum shell.

The rules in order 4337 shall be used to determine if staying is required.

4336. When the tube heads of drums of water-tube boilers are 30 inches or less in diameter and the tube plate is stiffened by flanged ribs or gussets, no stays need be used if a hydrostatic test to destruction of a boiler or unit section built in accordance with the construction, shows that the factor of safety is at least 5.

4337. Stays or braces shall be used in the tube sheets of a fire-tube boiler if the distance between the edges of the tube holes exceeds the maximum pitch of staybolts for the corresponding plate thickness and pressure given in Table 6.

That part of the tube sheet which comes between the tubes and the shell need not be stayed, if the greatest distance measured along a radial line from the inner surface of the shell to the center point of the tangent common to any two tube holes on the shell side of such holes does not exceed 1.5 times the maximum pitch of staybolts for the corresponding plate thickness and pressure given in Table 6. The tube holes to which a common tangent may be drawn in applying this rule shall not be at a greater distance from edge to edge than the maximum pitch referred to.

4338. The net area to be stayed in a segment of a head may be determined by the following formula:

$$\frac{4\ (H - d - 2)^2}{3} \sqrt{\frac{2\ (R - d)}{(H - d - 2)}} - 0.608 = \text{area to be stayed, sq. in.}$$

where

H = distance from tubes to shell, inches
d = distance determined by formula, in Order 4335
R = radius of boiler head, inches

4339. When stays are required the portion of the heads below the tubes in a horizontal-return tubular boiler may be supported by through stays with nuts inside and outside at the front head and by attachments which distribute the stress at the rear head. Where a manhole opening is provided, the flange of which is formed from the solid plate and turned inward to a depth of not less than three times the required thickness of the head, measured from the outside, the area to be stayed as indicated in Fig. 6 may be reduced by 100 square inches.

The distance in the clear between the bodies of the braces, or of the inside braces where more than two are used, shall not be less than 10 inches at any point.

4340. When stay rods are screwed through the sheets and riveted over they shall be supported at intervals not exceeding 6 feet. In boilers without manholes, stay rods over 6 feet in length may be used without support if screwed through the sheets and fitted with nuts and washers on the outside, provided the least cross-sectional area of the stay rod is not less than that of a circle 1 inch in diameter.

4341. (a) The full pitch dimensions of the stays shall be employed in determining the area to be supported by a stay, and the area occupied by the stay shall be deducted therefrom to obtain the net area. The product of the net area in square inches, by the maximum allowable working pressure in pounds per square inch, gives the load to be supported by the stay.

(b) Where stays come near the outer edge of the surfaces to be stayed and special allowances are made for the spacing, the load to be carried by such stays shall be determined by neglecting the added area provided for by these special allowances.

(For example, if the minimum pitch by Table 6 would make a staybolt come 6 inches from the edge of the plate and a special allowance would make it come 7 inches, the distance of 6 inches should be used in computing the load to be carried.)

(c) The maximum allowable stress per square inch at point of least net cross-sectional area of staybolts and stays or braces shall be as given in Table 7. In determining the net cross-sectional area of drilled or hollow stay-bolts, the cross-sectional area of the hole shall be deducted.

TABLE 7. MAXIMUM ALLOWABLE STRESSES FOR STAYBOLTS OR BRACES

	Description of staybolts and stays or braces	Stresses, lbs. per sq. in.	
		For lengths between supports not exceeding 120 diameters[1]	For lengths between supports exceeding 120 diameters[1]
a	Unwelded or flexible staybolts less than twenty diameters[1] long, screwed through plates with ends riveted over	7,500	----------
b	Hollow steel staybolts less than twenty diameters[1] long, screwed through plates with ends riveted over	8,000	----------
c	Unwelded stays or braces and unwelded portions of welded stays or braces	9,500	8,500
d	Steel through stays or braces exceeding 1½ inches diameter[1]	10,400	9,000
e	Welded portions of stays or braces	6,000	6,000

[1]Diameters taken at body of stay or brace.

(d) The length of the stay between supports shall be measured from the inner faces of the stayed plates. The stresses are based on tension only. For computing stresses in diagonal stays, see Orders 4342 and 4343.

4342. Stresses in Diagonal and Gusset Stays. Multiply the area of a direct stay required to support the surface by the slant or diagonal length of the stay; divide this product by the length of a line drawn at right angles to

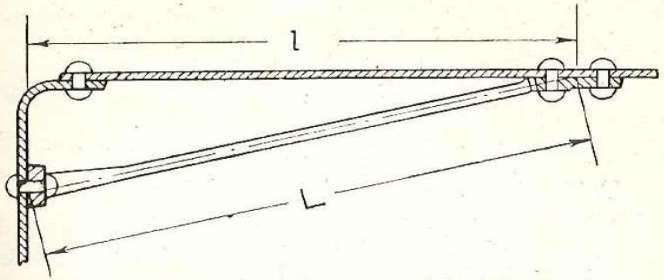


Fig. 7. Measurements for determining stresses in diagonal stays.

surface supported to center of palm of diagonal stay. The quotient will be the required area of the diagonal stay.

$$A = \frac{a \times L}{l}$$

where

A = sectional area of diagonal stay, sq. in.
a = sectional area of direct stay, sq. in.
L = length of diagonal stay, as indicated in Fig. 7, inches
l = length of line drawn at right angles to boiler head or surface supported to center of palm of diagonal stay, as indicated in Fig. 7.

Example: Given diameter of direct stay = 1 inch, a = 0.7854, L = 60 inches, l = 48 inches; substituting and solving:

$$A = \frac{0.7854 \times 60}{48} = 0.981 \text{ sectional area, sq. in.}$$

Diameter = 1.11 inches = 1⅛ inches

4343. For staying segments of tube sheets such as in horizontal-return tubular boilers, where L is not more than 1.15 times l for any brace, the stays or braces may be calculated as direct stays or braces allowing 90 per cent of the stress given in Table 7.

4344. **Design of Braces and Brace Connections.** All rivet and pin holes shall conform to the requirements in Order 4374 and the pins shall be made a neat fit. To determine the sizes that shall be used proceed as follows:

1. Determine the "required cross-sectional area of the brace" by first computing the total load to be carried by the brace, and dividing the total load by the value of allowable stress for unwelded stays or braces given in Table 7.
2. Design the body of the brace so that the cross-sectional area shall be at least equal to the "required cross-sectional area of the brace" for unwelded stays or braces. Where the stays or braces are welded, the cross-sectional area at the weld shall be at least as great as that computed for a stress of 6000 pounds per square inch (see Table 7).
3. Make the area of pins to resist double shear at least three-quarters of the "required cross-sectional area of the brace."
4. Make the combined cross-section of the eye at the side of the pin (in crowfoot braces) at least 25 per cent greater than the "required cross-sectional area of the brace."
5. Make the cross-sectional areas through the blades of diagonal stays or braces where attached to the shell of the boiler at least equal to the required rivet section; that is, at least equal to 1¼ times the "required cross-sectional area of the brace."
6. Design each branch of a crowfoot to carry two-thirds the total load on the brace.
7. Make the net sectional areas through the sides of the crowfoot, tee irons, or similar fastenings at the rivet holes at least equal to the required rivet section, that is, at least equal to 1¼ times the "required cross-sectional area of the brace."
8. Make the combined cross-sectional area of the rivets at each end of the brace at least 1¼ times the "required cross-sectional area of the brace."

4345. Gusset stays when constructed of triangular right-angle web plates secured to single or double angle bars along the two sides at right angles shall have a cross-sectional area (in a plane at right angles to the longest side and passing through the intersection of the two shorter sides) not less than 10 per cent greater than would be required for a diagonal stay to support the same surface, figured by the formula in Order 4342, assuming the diagonal stay is at the same angle as the longest side of the gusset plate.

TABLE 8. SIZES OF ANGLES REQUIRD FOR STAYING SEGMENT OF HEADS

With the short legs of the angles attached to the head of the boiler

Height of Segment, Dimension B in Fig. 8	30-inch Boiler				34-inch Boiler				36-inch Boiler				Dimension A in Fig. 8
	Angle 8"x2½"	Angle 3½"x3"	Angle 4"x3"	Angle 3½"x3"	Angle 4"x3"	Angle 5"x3"	Angle 4"x3"	Angle 5"x3"	Angle 6"x3½"				
	Thickness, Inches	Thickness, Inches	Thickness, Inches	Thickness, Inches	Thickness, Inches	Thickness, Inches	Thickness, Inches	Thickness, Inches	Thickness, Inches				
10	3/8	1/2	1/2	7/16	1/2	1/2	7/16	1/2					6½
11	7/16	5/8	5/8	1/2	5/8	5/8	1/2	5/8					7
12	1/2	7/16	7/16	9/16	7/16	1/2	5/8	5/8					7½
13	----	1/2	1/2	----	1/2	5/8	3/4	3/4					8
14	----	----	----	----	----	3/4	----	----					8½
15	----	----	----	----	----	----	----	----	3/8	3/8	3/8	3/8	9
16	----	----	----	----	----	----	----	----	7/16	7/16	7/16	7/16	9½

4346. Staying of Upper Segments of Tube Heads by Steel Angles. When the shell of a boiler does not exceed 36 inches in diameter and is designed for a maximum allowable working pressure not exceeding 100 pounds per square inch, the segment of heads above the tubes may be stayed by steel angles as specified in Table 8 and Fig. 8, except that angles of equal thickness and greater depth of outstanding leg, or of greater thickness and the same or greater depth of outstanding leg, may be substituted for those specified. The legs attached to the heads may vary in depth ½ inch above or below the dimensions specified in Table 8.

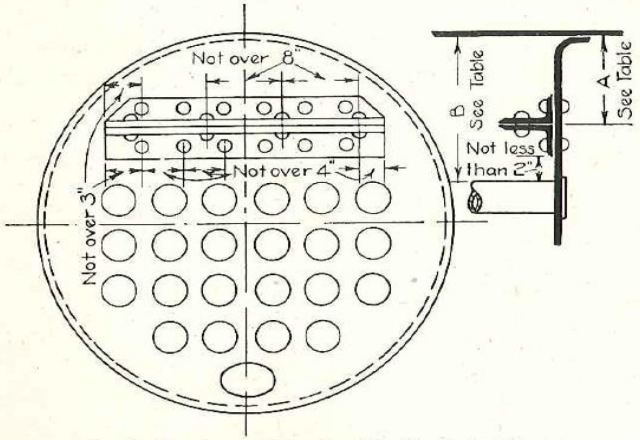


Fig. 8. Staying of Head with Steel Angles in Tubular Boiler.

4347. When this form of bracing is to be placed on a boiler, the diameter of which is intermediate to or below the diameters given in Table 8, the tabular values for the next higher diameter shall govern. Rivets of the same diameter as used in the longitudinal seams of the boiler shall be used to attach the angles to the head and to connect the outstanding legs.

4348. The rivets attaching angles to heads shall be spaced not over 4 inches apart. The centers of the end rivets shall not be over 3 inches from the ends of the angle. The rivets through the outstanding legs shall be spaced not over 8 inches apart; the centers of the end rivets shall be not

more than 4 inches from the ends of the angles. The ends of the angles shall be considered those of the outstanding legs and the lengths shall be such that the ends overlap a circle 3 inches inside the inner surface of the shell as shown in Fig. 8.

4349. The distance from the center of the angles to the shell of the boiler, marked A in Fig. 8, shall not exceed the value given in Table 8, but in no case shall the leg attached to the head on the lower angle come closer than 2 inches to the top of the tubes.

4350. When segments are beyond the range specified in Table 8 the heads shall be braced or stayed in accordance with the requirements in these Rules.

4351. Crown Bars and Girder Stays. (a) Crown bars and girder stays for tops of combustion chambers and back connections, or wherever used, shall be proportioned to conform to the following formula:

$$P = \frac{C \times d^2 \times t}{(W - p) \times D_1 \times W}$$

where

W = extreme distance between supports, inches
P = maximum allowable working pressure, lbs. per sq. in.
p = pitch of supporting bolts, inches
D_1 = distance between girders from center to center, inches
d = depth of girder, inches
t = thickness of girder, inches
C = 7000 when girder is fitted with one supporting bolt
C = 10,000 when the girder is fitted with two or three supporting bolts
C = 11,000 when the girder is fitted with four or five supporting bolts
C = 11,500 when the girder is fitted with six or seven supporting bolts
C = 12,000 when the girder is fitted with eight or more supporting bolts

Example: Given W = 34 inches, p = 7.5 inches, D_1 = 7.75 inches, d = 7.5 inches, t = 2 inches; 3 stays per girder, C = 10,000; then substituting in formula:

$$P = \frac{10{,}000 \times 7.5 \times 7.5 \times 2}{(34 - 7.5) \times 7.75 \times 34} = 161.1 \text{ lbs. per sq. in.}$$

Sling stays, if used between crown bars and boiler shell or wrapper sheet, shall be proportioned so as to carry the

entire load without considering the strength of the crown bars.

(b) In a form of reinforcement for crown sheets where the top sheet of the firebox is a part of a circle not exceeding 120 degrees in arc, and is braced with arch bars extending over the top and down below the top row of staybolts at the sides, these arch bars being riveted to the water side of the crown sheet through thimbles, the maximum allowable working pressure should be determined by adding to the maximum allowable working pressure for a plain circular furnace of the same thickness, diameter and length determined by the formula in Order 4360 and 4361, the pressure P_1 determined from the following formula, which is a modification of that in Order 4362a:

$$P_1 = 10{,}000{,}000 \frac{b \times d^3}{D_1 \times D^3}$$

provided that the maximum allowable working pressure must not exceed that determined by the formula for furnaces of the Adamson type, in Order 4363 when L is made equal to D_1, and also provided that the diameter of the holes for the staybolts in the crown bars does not exceed $\frac{1}{3}b$, and the cross-sectional area of the crown bars is not less than 4 square inches. (Order 4320 would govern the spacing of the staybolts, rivets or bolts attaching the sheet to the bars, and Order 4333d the size of the staybolts, rivets or bolts.)

where

b = net width of crown bar, inches
d = depth of crown bar, inches
D_1 = longitudinal pitch of crown bar, inches
D = 2 times radius of crown sheet.

4352. Maximum Allowable Working Pressure on Truncated Cones. (a) Upper combustion chambers of vertical submerged-tubular boilers made in the shape of a frustum of a cone when not over 38 inches diameter at the large end, may be used without stays if computed by the rule for plain cylindrical furnaces (Orders 4360 and 4361) making D in the formula equal to the diameter at the large end; provided that the longitudinal joint conforms to the requirements of Order 4361.

(b) When over 38 inches in diameter at the large end, that portion which is over 30 inches in diameter shall be fully supported by staybolts or gussets. If supported by staybolts Order 4333d shall apply. If supported by gussets the spacing of the rivets attaching the gussets to the cone sheet shall not exceed the staybolt spacing given in Order 4333d. The top row of staybolts or rivets shall be at a point where the cone top is 30 inches or less in diameter.

In calculating the pressure permissible on the unstayed portion of the cone, the vertical distance between the horizontal planes passing through the centers of the rivets at the cone top, and through the center of the top row of staybolts shall be used as L in Order 4361, and D in that order shall be the inside diameter at the center of the top row of staybolts.

4353. Stay Tubes. When stay tubes are used in multitubular boilers to give support to the tube plates, the sectional area of such stay tubes may be determined as follows:

$$\text{Total section of stay tubes, sq. in.} = \frac{(A - a)\ P}{TS}$$

where

A = area of that portion of the tube plate containing the tubes, sq. in.
a = aggregate area of holes in the tube plate, sq. in.
P = maximum allowable working pressure, lbs. per sq. in.
TS = working tensile stress allowed in the tubes (not to exceed 7000 lbs. per sq. in.).

TABLE 9. VALUES OF C FOR DETERMINING PITCH OF STAY TUBES

Pitch of stay tubes in the bounding rows	When tubes have no nuts outside of plates	When tubes are fitted with nuts outside of plates
Where there are two plain tubes between two stay tubes	120	130
Where there is one plain tube between two stay tubes	140	150
Where every tube in the bounding rows is a stay tube and each alternate tube has a nut		170

4354. The pitch of stay tubes shall conform to the formula in Order 4320, using the values of C as given in Table 9.

When the ends of tubes are not shielded from the action of flame or radiant heat, the values of C shall be reduced 20

per cent. The tubes shall project about ¼ inch at each end and be slightly flared. Stay tubes when threaded shall not be less than $\frac{3}{16}$ inch thick at bottom of thread; nuts on stay tubes are not advised. For a nest of tubes C shall be taken as 140 and p as the mean pitch of stay tubes. For spaces between nests of tubes p shall be taken as the horizontal distance from center to center of the bounding rows of tubes and C as given in Table 9.

Tube Sheets of Combustion Chambers

4355. The maximum allowable working pressure on a tube sheet of a combustion chamber, where the crown sheet is not suspended from the shell of the boiler, shall be determined by the following formula:

$$P = \frac{(D - d)\ t \times 27{,}000}{W \times D}$$

where

P = maximum allowable working pressure, lbs. per sq. in.
D = least horizontal distance between tube centers on a horizontal row, inches.
d = inside diameter of tubes, inches.
t = thickness of tube plate, inches.
W = distance from the tube sheet to opposite combustion chamber sheet, inches.

Where tubes are staggered the vertical distance between the center lines of tubes in adjacent rows must be not less than

$$\tfrac{1}{2}\ \sqrt{2dD + d^2}$$

Example: Required the maximum allowable working pressure of a tube sheet supporting a crown sheet braced by crown bars. Horizontal distance between centers, 4⅛ inches; inside diameter of tubes, 2.782 inches; thickness of tube sheets, $\frac{11}{16}$ inch; distance from tube sheet to opposite combustion-chamber sheet, 34¼ inches; measured from outside of tube plate to outside of back plate; material, steel. Substituting and solving:

$$P = \frac{(4.125 - 2.782) \times 0.6875 \times 27{,}000}{34.25 \times 4.125} = 176 \text{ lbs. per sq. in.}$$

4356. Sling stays may be used in place of girders in all cases covered in Order 4355, provided, however, that when such sling stays are used, girders or screw stays of the same sectional area shall be used for securing the bottom of the combustion chamber to the boiler shell.

4357. When girders are dispensed with and the top and bottom of combustion chambers are secured by sling stays or braces, the sectional area of such stays shall conform to the requirements of rules for stays and braced surfaces.

4358. Furnaces of Vertical Boilers. In a vertical firetube boiler the furnace length, for the purpose of calculating its strength and spacing stay-bolts over its surface, shall be measured from the center of rivets in the bottom of the water-leg to the center of rivets in the flange of the lower tube sheet.

4359. When the longitudinal joint of the furnace sheet of a vertical fire-tube boiler is of lap-riveted construction and staybolted, a staybolt in each circular row shall be located near the longitudinal joint, as shown in Fig. 9.

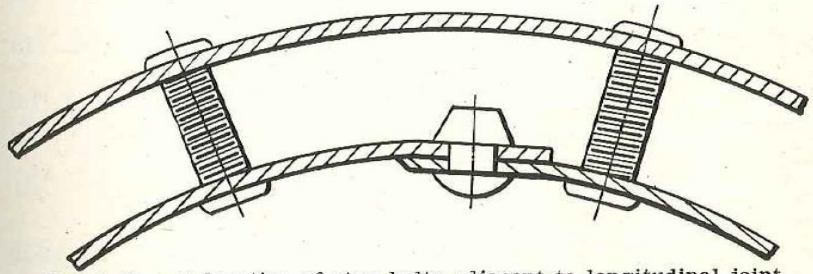


Fig. 9. Proper location of stay bolts adjacent to longitudinal joint in furnace sheet.

4360. Plain Circular Furnaces. The following rules apply in general to unstayed circular furnaces:

(a) The longitudinal joint may be riveted or lap welded by the forging process, or the furnace may be of seamless construction.

(b) The longitudinal joint if riveted, shall have an efficiency of 50 per cent or greater and in no case less than

$$\frac{P \times D}{1250 \times T}$$

P = maximum allowable working pressure, lb. per sq. in.,
D = outside diameter of furnace, in.,
T = thickness of furnace walls, sixteenths of an inch.

(c) The walls shall not be less than $\frac{5}{16}$ inch thick.

(d) Butt strap seams shall be used only where they are protected from contact with the fire or flame.

(e) The furnace may be of any length or height.

4361. The following rules apply specifically to unstayed circular furnaces 12 inches in diameter and over:

Furnaces 12 inches to 18 inches outside diameter, inclusive.

(a) A riveted longitudinal joint may be of the lap type.

(b) The maximum allowable working pressure for furnaces not more than 4½ diameters in length or height shall be determined by formulas (1) and (2) as follows:

Where the length does not exceed 120 times the thickness of the plate

$$P = \frac{51.5}{D}\left((18.75 \times T) - (1.03 \times L)\right) \text{---------(1)}$$

Where the length exceeds 120 times the thickness of the plate

$$P = \frac{4250 \times T^2}{L \times D} \text{----------(2)}$$

where

P = maximum allowable working pressure, lbs. per sq. in.

D = outside diameter of furnace, inches.

L = total length of furnace between centers of head rivet seams (not length of a section), inches.

T = thickness of furnace walls, in sixteenths of an inch.

(c) The maximum allowable working pressure for furnaces over 4½ diameters in length or height shall be determined in accordance with Order 4362.

Furnaces over 18 inches outside diameter to and including 30 inches inside diameter.

(d) A riveted longitudinal joint may be of the lap type.

(e) The maximum allowable working pressure shall be determined by formulas (1) and (2); if over 6 diameters in length or height, L in the formula shall be taken as 6 times the diameter.

Furnaces over 30 inches inside diameter to and including 36 inches inside diameter.

(f) A riveted longitudinal joint may be of the lap type provided the furnace does not exceed 36 inches in length or height.

(g) If the length of a horizontal furnace exceeds 36 inches and the joint is riveted, a butt and single or double-strap construction shall be used and shall be located below the grate.

(h) The maximum allowable working pressure shall be determined by formulas (1) and (2); if over 6 diameters in length L in the formula shall be taken as 6 times the diameter.

Furnaces over 36 inches inside diameter to and including 38 inches outside diameter.

(i) When riveted the longitudinal joint of a horizontal furnace shall be butt and single or double-strap construction and shall be located below the grate.

(j) The maximum allowable working pressure shall be determined by formulas (1) and (2); if over 6 diameters in length L in the formula shall be taken as 6 times the diameter.

4362. **Circular Flues.** The maximum allowable working pressure for seamless or welded flues more than 5 inches diameter and up to and including 18 inches diameter shall be determined by one or the other of the following formulas:

(a) Where the thickness of the wall does not exceed 0.023 times the diameter.

$$P = \frac{10{,}000{,}000 \times t^3}{D^3}$$

(b) Where the thickness of the wall is greater than 0.023 times the diameter.

$$P = \frac{17{,}300 \times t}{D} - 275$$

where

P = maximum allowable working pressure, lbs. per sq. in.

D = outside diameter of flue, inches.

t = thickness of wall of flue, inches.

(c) The above formulas may be applied to riveted flues of the sizes specified provided the sections are not over 3 feet in length and provided the efficiency of the joint is greater than

$$\frac{P \times D}{20{,}000 \times t}$$

Example: Given a flue 14 inches in diameter and $\frac{5}{16}$ inch thick. The thickness of the wall is less than 0.023 times the diameter; hence formula (a) should be used. Substituting the values in this formula:

$$P = \frac{10{,}000{,}000 \times \frac{5}{16} \times \frac{5}{16} \times \frac{5}{16}}{14 \times 14 \times 14} = 110 \text{ lbs. per sq. in.}$$

4363. Adamson Type. When plain horizontal flues are made in sections not less than 18 inches in length, and not less than $\frac{5}{16}$ inch thick:

(a) They shall be flanged with a radius measured on the fire side of not less than 3 times the thickness of the plate, and the flat portion of the flange outside of the radius shall be at least 3 times the diameter of the rivet holes.

(b) The distance from the edge of the rivet holes to the edge of the flange shall be not less than the diameter of the rivet hole, and the diameter of the rivets before driving shall be at least ¼ inch larger than the thickness of the plate.

(c) The depth of the Adamson ring between the flanges shall be not less than 3 times the diameter of the rivet holes, and the ring shall be substantially riveted to the flanges. The fire edge of the ring shall terminate at or about the point of tangency to the curve of the flange, and the thickness of the ring shall be not less than ½ inch.

The maximum allowable working pressure shall be determined by the following formula:

$$P = \frac{57.6}{D}\left((18.75 \times T) - (1.03 \times L)\right)$$

where

P = maximum allowable working pressure, lbs. per sq. in.
D = outside diameter of furnace, inches.
L = length of furnace section, inches.
T = thickness of plate, in sixteenths of an inch.

Example: Given a furnace 44 inches in diameter, 48 inches in length, and ½ inch thick. Substituting values in formula:

$$P = \frac{57.6}{44}\left[(18.75 \times 8) - (1.03 \times 48)\right] = 131 \text{ psi}$$

4364. The maximum allowable working pressure on corrugated furnaces, such as the Leeds suspension bulb, Morison, Fox, Purves, or Brown, having plain portions at the ends not exceeding 9 inches in length (except flues especially provided for) when new and practically circular, shall be computed as follows:

$$P = \frac{C \times t}{D}$$

where

P = maximum allowable working pressure, lbs. per sq. in.
t = thickness, inches—not less than $\frac{5}{16}$ inch for Leeds, Morison, Fox, and Brown, and not less than $\frac{7}{16}$ inch for Purves and other furnaces corrugated by sections not over 18 inches long.
D = mean diameter, inches.
C = 17,300, a constant for Leeds furnaces, when corrugations are not more than 8 inches from center to center and not less than 2¼ inches deep.
C = 15,600, a constant for Morison furnaces, when corrugations are not more than 8 inches from center to center and the radius of the outer corrugations is not more than one-half that of the suspension curve.
C = 14,000, a constant for Fox furnaces, when corrugations are not more than 8 inches from center to center and not less than 1½ inches deep.
C = 14,000, a constant for Purves furnaces, when rib projections are not more than 9 inches from center to center and not less than 1⅜ inches deep.
C = 14,000, a constant for Brown furnaces, when corrugations are not more than 9 inches from center to center and not less than 1⅝ inches deep.

C = 10,000, a constant for furnaces corrugated by sections not more than 18 inches from center to center and not less than 2½ inches deep, measured from the least inside to the greatest outside diameter of the corrugations, and having the ends fitted one into the other and substantially riveted together, provided that the plain parts at the ends do not exceed 12 inches in length.

In calculating the mean diameter of the Morison furnace, the least inside diameter plus 2 inches, may be taken as the mean diameter.

4365. The thickness of a corrugated or ribbed furnace shall be ascertained by actual measurement by the furnace manufacturer, by gaging the thickness of the corrugated portions. If a hole is drilled through the sheet to determine the thickness it shall be ⅜ inch. When the furnace is installed the hole shall be located beneath the bottom of the grate and closed by a plug. For the Brown and Purves furnaces, the holes shall be in the center of the second flat; for the Morison, Fox and other similar types, in the center of the top corrugation, at least as far in as the fourth corrugation from the end of the furnaces.

4366. **Cast-Iron and Malleable-Iron Headers.** The pressure allowed on a water-tube boiler shall not exceed 160 pounds per square inch when the tubes are secured to cast-iron headers, or 350 pounds per square inch when the tubes are secured to malleable-iron headers. The form and size of the internal cross-section perpendicular to the longer axis of a cast-iron or malleable-iron header at any point shall be such that it will fall within a 7 inch by 7 inch rectangle.

4367. (a) The cast iron used for the headers of water-tube boilers shall conform to the Specifications for Gray-Iron Castings, the header to be arbitrarily classified as a "medium casting" as to physical properties and tests, and as a "light casting" as to chemical properties. The malleable iron used for headers of water-tube boilers shall conform to the Specifications for Malleable Castings.

(b) A cast-iron header when tested to destruction, shall withstand a hydrostatic pressure of at least 1200 pounds

per square inch and a malleable iron header 2250 pounds per square inch. A hydrostatic test shall be applied to all such headers or elements with tubes attached. The test pressure shall be 500 pounds per square inch when cast iron headers or elements are used, and 2½ times the working pressure when malleable iron is used, except that the minimum test pressure with malleable-iron headers or elements shall be 500 pounds per square inch.

4368. Where no rules are given and it is impossible to calculate with a reasonable degree of accuracy the strength of a boiler structure or any part thereof, a full-sized sample shall be built by the manufacturer and tested in a manner to be prescribed by the Industrial Commission.

Cutting of Plate

4369. Plates may be cut by machining, punching, shearing or cutting by the electric arc or gas process, provided enough metal is left at any unfinished edges to meet the requirements of Orders 4370, 4374 and 4378.

Tubes

4370. **Tube Holes and Ends.** Tube holes shall be drilled full size from the solid plate, or they may be punched at least ½ inch smaller in diameter than full size, and then drilled, reamed or finished full size with a rotating cutter.

The sharp edges of tube holes shall be taken off on both sides of the plate with a file or other tool.

4371. A fire-tube boiler shall have the ends of the tubes firmly expanded and beaded, or expanded, beaded and welded around the edge of the bead. Where the tubes do not exceed 1½ inches in diameter, the tube sheet may be chamfered or recessed to a depth at least equal to the thickness of the tubes and the tubes expanded into place and welded.

In no case shall the tube end extend more than ⅜ inch beyond the tube sheet.

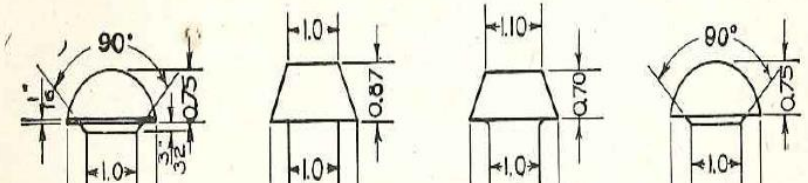
4372. The ends of all tubes, suspension tubes and nipples shall be expanded and flared not less than ⅛ inch over the diameter of the tube hole on all water-tube boilers and

super-heaters, or they may be flared not less than ⅛ inch, rolled and beaded, or flared, rolled and welded. Where pipe as provided in Order 4273 is used for tubes in water-tube boilers, it may be screwed instead of rolled and flared, and the minimum number of threads shall conform to the values given in Table 10. The closed ends of stub tubes shall be welded by the forging or fusion process.

4373. The ends of all tubes, suspension tubes and nipples of water-tube boilers and superheaters shall project through the tube sheets or headers not less than ¼ inch nor more than ½ inch before flaring. Where the tubes enter at an angle, the maximum limit of ½ inch shall apply only at the point of least projection.

Riveting

4374. **Rivet and Staybolt Holes.** All holes in braces, lugs and sheets for rivets or staybolts shall be drilled full size with plates, butt straps and heads bolted up in position, or they may be drilled or punched not to exceed ¼ inch less than full size for plates over $\frac{5}{16}$ inch in thickness and ⅛ inch less than full size for plates not exceeding $\frac{5}{16}$ inch in thickness and then drilled or reamed to full size with plates, butt straps and heads bolted up in position.



Such holes shall not be punched in material more than ⅝ inch thick.

The finished holes must be true, clean and concentric.

4375. After drilling or reaming rivet holes the plates and butt straps of longitudinal joints shall be separated, the burrs and chips removed, the plates and butt straps reassembled metal to metal with barrel pins fitting the holes, and with tack bolts.

4376. Rivets. Rivets shall be of sufficient length to completely fill the rivet holes and form heads at least equal in strength to the bodies of the rivets. Forms of finished rivet heads that will be acceptable are shown in Fig. 10.

4377. Rivets shall be so driven as to fill the holes preferably by a machine which maintains the pressure until no part of the head shows red in daylight. Barrel pins fitting the holes and tack bolts to hold the plates firmly together shall be used. A rivet shall be driven each side of each tack bolt before removing the tack bolt.

Calking

4378. **Calking.** The calking edges of plates, but straps and heads shall be beveled to an angle not sharper than 70 degrees to the plane of the plate, and as near thereto as practicable. Every portion of the unfinished surfaces of the calking edges of plates, butt straps and heads shall be planed, milled or chipped to a depth of not less than ⅛ inch. Calking shall be done with a tool of such form that there is

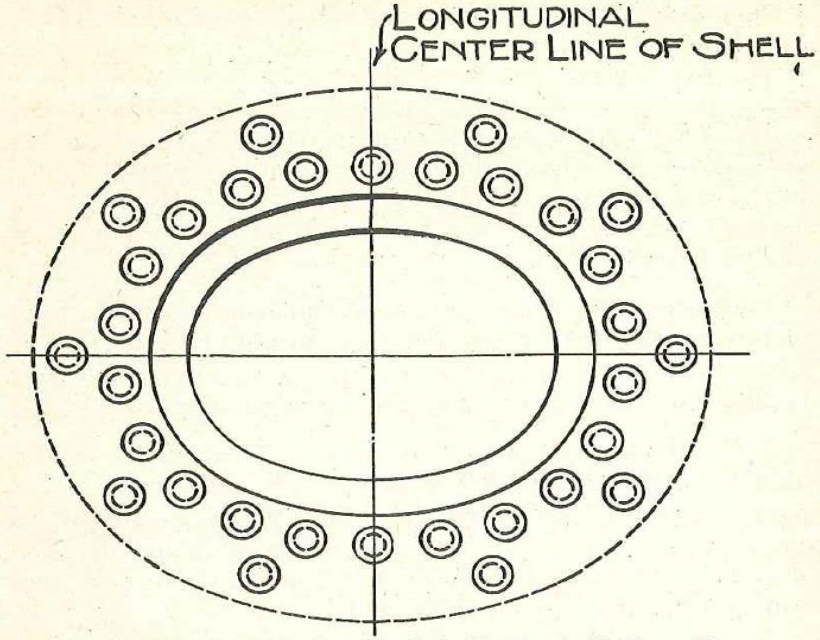


Fig. 11. Method of Riveting Manhole Frames to Shells or Drums with Two Rows of Rivets.

4380. A manhole reinforcing ring when used, shall be of wrought or cast steel, and shall be at least as thick as the shell plate thickness required by Order 4301.

4381. Manhole frames on shell or drums shall have the proper curvature, and on boilers over 48 inches in diameter shall be riveted to the shell or drum with two rows of rivets, which may be pitched as shown in Fig. 11. The strength of

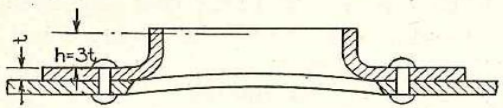


Fig. 12. Cross Section of Flanged Manhole Frame.

manhole frames and reinforcing rings shall be at least equal to the tensile strength (required by Order 4301) of the maximum amount of the shell plate removed by the opening and rivet holes for the reinforcement on any line parallel to the longitudinal axis of the shell through the manhole or other opening.

When a flanged manhole frame is used the flanged portion of the frame may be considered as reinforcement up to a height (h) of three times the flange thickness (see Fig. 12).

4382. The strength of the rivets in shear on each side of a frame or ring reinforcing manholes or other openings such as those cut for steel nozzles and boiler flanges over 3 inch pipe size, shall be at least equal to the tensile strength (required by Order 4301) of the maximum amount of the shell plate removed by the opening and rivet holes for the reinforcement on any line parallel to the longitudinal axis of the shell, through the manhole or other opening.

4383. Manhole plates shall be of wrought or cast steel.

4384. The minimum width of bearing surface, for a gasket on a manhole opening shall be $\frac{11}{16}$ inch. No gasket for use on a manhole or handhole of any boiler shall have a thickness greater than $\frac{1}{4}$ inch, when compressed.

4385. All boilers must be provided with suitable manhole or handhole openings, except special types where they are manifestly not needed or used. A manhole shall be located in the front head, below the tubes of a horizontal-return tubular boiler 54 inches or over in diameter. Smaller boilers shall have either a manhole or a handhole below the tubes. There shall be a manhole in the upper part of the shell or head of a fire-tube boiler 48 inches or over in diameter, except a vertical fire-tube boiler, or except on internally fired boilers not over 54 inches in diameter. The manhole may be placed in the head of the dome. Smaller boilers shall have either a manhole or a handhole above the tubes.

Washout Openings

4386. A traction, portable or stationary boiler of the locomotive type shall have not less than six handholes, or washout plugs, located as follows: One in the rear head below the tubes; one in the front head at or about the line of the crown sheet; four in the lower part of the waterleg; also, where possible, one near the throat sheet.

4387. A vertical fire tube boiler, except boilers 24 inches or less in diameter, shall have not less than four handholes,

located as follows: Two in the shell at or about the line of the crown sheet or lower tube sheet; two in the shell at the lower part of the waterleg. All vertical tubular boilers 24 inches or less in diameter shall have at least one opening for inspection and two openings in addition to the bottom blow off for washing out the boiler. The openings shall be at least one inch pipe size and the closing plug or cap shall be of nonferrous material.

Threaded Openings

4389. **Threaded Openings.** All pipe threads shall conform to the American Pipe Thread Standard and all connections 1 inch pipe size or over shall have not less than the number of threads given in Table 10. For smaller pipe connections there shall be at least four threads in the opening.

If the thickness of the shell of the boiler is not sufficient to give such number of threads a construction shall be employed which will provide at least the required number of threads.

Note: See Order 4379.

TABLE 10. MINIMUM NUMBER OF PIPE THREADS FOR CONNECTIONS TO BOILERS

Size of pipe connections, inches	1 and 1¼	1½ and 2	2½ to 4 incl.	4½ to 6 incl.	7 and 8	9 and 10	12
Number of threads per inch	11½	11½	8	8	8	8	8
Minimum number of threads required in opening	4	5	7	8	10	12	13
Minimum thickness of material required to give above number of threads, inches	0.348	0.435	0.875	1	1.25	1.5	1.6265

Safety Valves

4390. Each boiler shall be provided with safety valve capacity sufficient to discharge all the steam that can be generated without an increase over the maximum allowable working pressure or to which the valve is set, except a 6 per cent increase while the valve is discharging.

4391. The steam generating capacity of a boiler may be determined by one of the following:

(a) Manufacturer's rating.
(b) A–13 appendix.
(c) Evaporative test.
(d) On the basis of 6 pounds of steam per hour, per square foot of water heating surface for water tube boilers; for other types of boilers, 5 pounds of steam per hour per square foot of water heating surface when the maximum allowable working pressure exceeds 100 pounds per square inch, and 3 pounds per hour per square foot of water heating surface for pressures not exceeding 100 pounds per square inch.

Note: Compliance with order 4390 will be required in each case.

4392. One or more safety valves on the boiler proper shall be set at or below the maximum allowable working pressure. The remaining valves may be set within a range of 3 per cent above the maximum allowable working pressure, but the range of setting of all of the valves on a boiler shall not exceed 10 per cent of the highest pressure to which any valve is set.

4393. All safety valves shall be so constructed that no shocks detrimental to the valve or to the boiler are produced and so that no failure of any part can obstruct the free and full discharge of steam from the valve. Safety valves may be of the direct spring loaded pop type, with seat and bearing surface of the disk inclined at any angle between 45 degrees and 90 degrees inclusive, to the center line of the spindle. The maximum rated capacity of a safety valve shall be determined at a pressure of 3 per cent in excess of that at which the valve is set to blow and with a blow down of not more than 4 per cent of the set pressure, the blow down to be in no case less than 2 pounds.

Safety valves may be used which give any opening up to the full discharge capacity of the area of the opening of the inlet of the valve (See order 4394b), provided the movement of the valve is such as not to induce lifting of water in the boiler.

Dead-weight or weighted-lever safety valves shall not be used.

4394. Each safety valve ½ inch size and larger shall be plainly marked by the manufacturer in such a way that the markings will not be obliterated in service. The marking may be stamped or cast on the casing, or stamped or cast on a plate or plates securely fastened to the casing, and shall contain the following markings:

a. The name or identifying trademark of the manufacturer.

b. Size_____in.
The pipe size of valve inlet. (Where the valve inlet is not threaded, the initial diameter of the inlet shall be not less than the inside diameter of a standard pipe of the same nominal diameter as that of the valve.)

c. Pres_____lbs.
The steam pressure at which it is to blow.

d. B.D._____lbs.
Blow down. (Difference between the opening and closing pressures).

e. Cap_____lbs. per hr.
The weight of steam discharged in pounds per hour (at a pressure 3 per cent higher than that for which the valve is set to blow, and with the valve adjusted for the blow down given in preceding item).

4395. The relieving capacity of a safety valve may be taken as that stamped on the valve by the manufacturer but an accumulative test, under maximum operation, may be made to determine whether the safety valve, or valves, are of sufficient capacity to meet the requirements of Order 4390.

4397. When two or more safety valves are used on a boiler, they may be mounted either separately or as twin valves made by placing individual valves on Y-bases, or duplex, triplex or multiplex valves having two or more valves in the same body casing. The valves shall be made of equal sizes, if possible, and in any event if not of the same size, the smaller of the two valves shall have a relieving capacity of at least 50 per cent of that of the larger valve.

4398. The safety valve or valves shall be connected to the boiler independent of any other steam connection, and attached as close as practical to the boiler, without any unnecessary intervening pipe or fitting. Every safety valve shall be connected so as to stand in an upright position, with spindle vertical, when possible.

4399. The opening or connection between the boiler and the safety valve or valves shall have at least the area of the inlet of the valve or valves. No valve of any description shall be placed between the required safety valve or valves and the boiler, nor on the discharge pipe between the safety valve and the atmosphere. When a discharge pipe is used, the cross-sectional area shall be not less than the full area of the valve outlet or of the total of the areas of the valve outlets discharging thereinto, and shall be as short and straight as possible and so arranged to avoid undue stresses on the valve or valves.

All safety-valve discharges shall be so located or piped as to be carried clear from running boards or platforms. Ample provision for gravity drain shall be made in the discharge pipe, at or near each safety valve, and where water of condensation may collect. Each valve shall have an open gravity drain through the casing below the level of the valve seat. For iron and steel-bodied valves exceeding 2 inch size, the drain holes shall be tapped not less than ⅜ in. pipe size.

4400. If a muffler is used on a safety valve it shall have sufficient outlet area to prevent back pressure from interfering with the proper operation and discharge capacity of the valve. The muffler plates or other devices shall be so constructed as to avoid any possibility of restriction of the steam passage due to deposit.

4402. Safety valves shall operate without chattering and shall be set and adjusted as follows: To close after blowing down not more than 4 per cent of the set pressure but not less than 2 pounds in any case. For spring-loaded pop safety valves operating on pressures up to and including 300 pounds per square inch the blow down shall not be less than 2 per cent of the set pressure. To insure the guar-

anteed capacity and satisfactory operations, the blow down as marked upon the valve (Order 4394d) shall not be reduced.

4403. To insure the safety valve being free, each safety valve shall have a substantial lifting device by which the valve disk may be positively lifted from its seat when there is at least 75 per cent of full working pressure on the boiler. The lifting device shall be such that it cannot lock or hold the valve disk in lifted position when the exterior lifting force is released.

4404. The seats and disks of safety valves shall be of suitable material to resist corrosion. The seat of a safety valve shall be fastened to the body of the valve in such a way that there is no possibility of the seat lifting.

4405. Springs used in safety valves shall not show a permanent set exceeding 1 per cent of their free length 10 minutes after being released from a cold compression test closing the spring solid. The spring shall be so constructed that the valve can lift from its seat at least one-tenth the diameter of the seat before the coils are closed or before there is other interference.

4406. a. The spring in a safety valve in service for pressures up to and including 250 lbs. shall not be used for any pressure more than 10 per cent above or 10 per cent below that for which it was designed. For higher pressures the spring shall not be used for any pressure more than 5 per cent above or 5 per cent below that for which it was designed.

b. If the operating conditions of a valve are changed so as to require a new spring under (a) for a different pressure, the valve shall be adjusted by the manufacturer or his authorized representative who shall furnish and install a new name plate as required under Order 4394.

4408. When the valve casing is marked as required by Order 4394, it shall be the guarantee of the manufacturer that the valve conforms to the details of construction herein specified.

4409. Every superheater shall have one or more safety valves near the outlet. The discharge capacity of the safety

valve or valves on an attached superheater may be included in determining the number and size of the safety valves for the boiler, provided there are no intervening valves between the superheater safety valve and the boiler, and provided the discharge capacity of the safety valve or valves on the boiler, as distinct from the superheater, is at least 75 per cent of the aggregate valve capacity required.

A soot blower connection may be attached to the same outlet from the superheater that is used for the safety valve connection.

4410. Every safety valve used on a superheater discharging superheated steam at a temperature over 450 F. shall have a casing, including the base, body, bonnet, and spindle, of steel, steel alloy, or equivalent heat resisting material. The valve shall have a flanged inlet connection, and shall have the seat and disk of suitable heat erosive and corrosive resisting material, and the spring fully exposed outside of the valve casing so that it shall be protected from contact with the escaping steam.

4411. a. Every boiler shall have proper outlet connections for the required safety valve, or valves, independent of any other outside steam connection, the area of opening to be at least equal to the aggregate areas of inlet connections of all of the safety valves to be attached thereto. An internal collecting pipe, splash plate, or pan may be used, provided the total area for inlet of steam thereto is not less than twice the aggregate areas of the inlet connections of the attached safety valves. The holes in such collecting pipes shall be at least ¼ in. in diameter and the least dimension in any other form of opening for inlet of steam shall be ¼ in.

b. If safety valves are attached to a separate steam drum or dome, the opening between the boiler proper and the steam drum or dome shall be not less than required by (a).

c. When boilers allowed different pressures are connected to a common steam main and all safety valves are not set at the lowest pressure allowed no safety valve shall be set to exceed by more than fifty per cent the lowest pressure allowed.

For conditions exceeding those specified in the above paragraph the case shall be referred to the Industrial Commission for decision.

Water and Steam Gages

4412. Each boiler shall have at least one water glass, equipped with a valved drain, the lowest visible part of which shall be at or above the following location and in all cases it must be so placed as to give adequate protection to those parts of a boiler proper subject to the heat of the products of combustion.

(a) Horizontal Return Tubular Boilers—not less than 4 inches above the upper surface of the upper row of tubes except when the distance between the uppermost surface of tubes and the top of the steam space is 13 inches or less the distance may be reduced to 2 inches.
(b) Locomotive Type Boilers—3 inches above the highest part of the crown sheet.
(c) Vertical Fire Tube Boilers—not less than one-third the length of the tube above the lower tube sheet.
(d) Water Tube Boilers—as specified by the manufacturer.
(e) Scotch Marine Type Boilers—3 inches above the combustion chamber top. Note—For dry back see (a).
(f) For other types and new designs the location shall be as fixed by the manufacturer subject to approval by the Industrial Commission.

4413. Automatic shut-off valves on water gages, if permitted to be used, shall conform to the requirements given in A–19 of the Appendix.

4414. When shut-offs are used on the connections to a water column, they shall be either outside-screw-and-yoke type gate valves or stop cocks with levers permanently fastened thereto and marked in line with their passage. Where stop cocks are used they shall be of a type with the plug held in place by a guard or gland.

4415. Each boiler shall have three or more gage cocks, located within the range of the visible length of the water

glass, except when such boiler has two water glasses with independent connections to the boiler and located on the same horizontal line and not less than 2 ft. apart.

Locomotive boilers not over 36 in. in diameter, or any firebox or waterleg boiler in which the water heating surface does not exceed 50 sq. feet, need have but two gauge cocks.

4416. No connections except for damper regulator feedwater regulator, drains, steam gages, or apparatus of such form as does not permit the escape of an appreciable amount of steam or water therefrom, shall be placed on the pipes connecting a water column to a boiler.

4417. Steam Gages. Each boiler shall have a steam gage connected to the steam space or to the water column or its steam connection. The steam gage shall be connected to a siphon or equivalent device of sufficient capacity to keep the gage tube filled with water.

A shut off valve or cock shall be placed close to the steam gage to permit removal for testing while the boiler is in operation.

4418. The dial of the steam gage shall be graduated to approximately double the pressure at which the safety valve is set but in no case to less than 1½ times this pressure.

4419. Each boiler may be provided with a ¼ inch pipe size valved connection for the exclusive purpose of attaching a test gage when the boiler is in service, so that the accuracy of the boiler steam gage can be ascertained.

4421. All valves and pipe fittings shall be as approved by the Industrial Commission for the maximum allowable working pressure and temperature and subject to the requirements of Order 4264.

The number of bolts in a flange may be increased, provided they are located on the standard bolt circle.

Note: American Standards is approved for valves and pipe fittings.

4422. The minimum number of threads that a pipe or fitting shall screw into a tapped hole, shall correspond to the numerical values given for the number of threads in Table 10.

4423. Stop Valves. Each steam-discharge outlet, except safety valve and superheater connections, shall be fitted with a stop valve located as near the boiler as practicable.

4425. When two stop valves are placed in the steam connection between a boiler and the steam main there shall be an ample free blow drain between them. The discharge of this drain valve must be visible to the operator while manipulating the valve.

4426. When a stop valve is so located that water can accumulate, ample drains shall be provided.

Each dry pipe or similar apparatus shall, at suitable places, have two holes drilled into it. These holes shall be not less than ½ inch diameter each and shall be kept open so that the condensation can escape.

4427. Steam Mains. Provisions shall be made for the expansion and contraction of steam mains connected to boilers, by providing substantial anchorage at suitable points, so that there shall be no undue strain transmitted to the boiler. Steam reservoirs shall be used on steam mains when heavy pulsations of the steam currents cause vibration of the boiler shell plates.

4428. Each superheater shall be equipped with at least one drain so located as will most effectively provide for the proper operation of the apparatus.

4429. Blow-off Piping. A surface blow-off shall not exceed 2½ inch pipe size and the internal and external pipes, when used, shall form a continuous passage, but with clearance between their ends and arranged so that the removal of either will not disturb the other. A properly designed steel bushing similar to or equivalent of those shown in Fig. 13 or a flanged connection, shall be used.

4430. Each boiler shall have a bottom blow-off pipe, fitted with a valve or cock, in direct connection with the lowest water space practicable; the minimum size of pipe and fittings shall be 1 inch and the maximum size shall be 2½ inches except that for boilers with 100 sq. ft. of water heating surface or less the minimum size of pipe and fittings may be ¾ inch. Straight-run globe valves of the ordinary type or valves of such type that dams or pockets can

exist for the collection of sediment, shall not be used on such connections. Return connections of the same size or larger than the size herein specified may be used, and to which the blow-off may be connected. In such case, the blow-off must be so located that the connection may be completely drained.

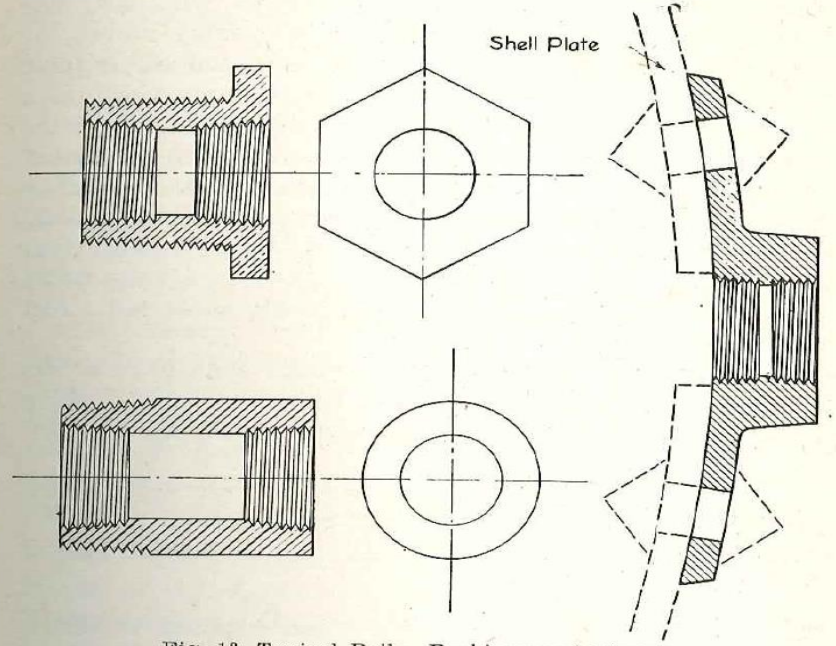


Fig. 13. Typical Boiler Bushings and Flange.

4431. A bottom blow-off cock shall have the plug held in place by a guard or gland. The end of the plug shall be distinctly marked in line with the passage.

4432. The bottom blow off pipe or pipes shall be of wrought iron or steel and shall be at least extra heavy.

Fittings between the boiler and the required bottom blow off valve or valves shall be of steel, cast steel or malleable iron and shall be not less than extra heavy construction for pressures not exceeding 150 pounds per square inch.

For pressures exceeding 150 pounds per square inch such fittings shall be of steel construction and not less than extra heavy.

Cast iron pipe and fittings shall not be used in the bottom blow off pipe between the boiler and the bottom blow off valve or valves.

4433. (a) On all boilers except those used for traction and portable purposes, when the maximum allowable working pressure exceeds 125 pounds per square inch, each bottom blow-off pipe shall have two slow-opening valves, or one slow-opening valve and a cock, and such valves, or valve and cock, shall be at least extra heavy construction. On a boiler having multiple blow-off pipes, a single master valve may be placed on the common blow-off pipe from the boiler, in which case only one valve on each individual blow-off is required. Two independent valves, or a valve and a cock, may be combined in one body provided the combined fitting is the equivalent of two independent valves, or a valve and a cock, so that the failure of one to operate could not affect the operation of the other.

(b) Every traction and portable boiler shall have a bottom blow-off valve; when the maximum allowable working pressure exceeds 125 pounds per square inch, the blow-off valve shall be at least extra heavy.

(c) For pressures exceeding 200 pounds per square inch the valves or cocks shall be of steel construction.

(d) The blow-off valve or valves shall be the full size of the blow-off pipe.

4434. A bottom blow-off pipe when exposed to direct furnace heat shall be protected by fire-brick, or other heat resisting material so arranged that the pipe may be inspected.

4435. An opening in the boiler setting for a blow-off pipe shall be arranged to provide for free expansion and contraction.

4436. Feed Piping. The feed water shall be introduced into a boiler in such a manner that the water will not be discharged directly against surfaces exposed to gases of high temperature, or to direct radiation from the fire, or close to riveted joints of shell or furnace sheets.

In horizontal return tubular boilers the feed pipe may be connected to the bottom blow off pipe and in vertical tubular

boilers the feed pipe may be connected to the blow off pipe, or it may be connected to the water leg.

Where horizontal return tubular boilers are fed through the front a boiler bushing or its equivalent (see Fig. 13) shall be used and the feedwater shall discharge at about three fifths the length of the boiler from the front head.

4439. The feed pipe shall be provided with a check valve near the boiler and a valve or cock (see Order 4431) between the check valve and the boiler, and when two or more boilers are fed from a common source, there shall also be a globe valve on the branch to each boiler, between the check valve and the source of supply. Wherever globe valves are used on feed piping, the inlet shall be under the disk of the valve.

4440. Means shall be provided for feeding a boiler against the maximum allowable working pressure or the pressure at which the safety valve is set to blow. Where a source of feed such as city supply is available at a sufficient pressure to feed the boiler against a pressure 6 per cent higher than that at which the safety valve is set to blow, this may be considered one of the means.

4441. Water Fronts. Each water jacketed boiler furnace mouth protector, or similar appliance attached to a boiler, having valves on the pipes connecting it to the boiler, shall be equipped with a spring loaded relief valve, not less than one inch in diameter and set to blow at a pressure not exceeding ten per cent above the pressure allowed on the boiler.

4442. Water Column Pipes. The minimum size of pipes connecting the water column to a boiler shall be 1 inch. Water-glass fittings or gage cocks may be connected direct to the boiler.

4443. The water connections to the water column of a boiler, when practicable, shall be provided with a cross at each right-angle turn to facilitate cleaning. The water column shall be fitted with a drain cock or drain valve with a suitable connection to the ashpit, or other safe point of waste and if the water connection thereto has a rising bend

or pocket which cannot be drained by means of the water column drain, an additional drain shall be placed on this connection in order that it may be blown off to clear any sediment from the pipe.

4444. The steam connection to the water column of a horizontal-return tubular boiler shall be taken from the top of the shell or the upper part of the head; the water connection shall be taken from the front head at a point not less than 6 inches below the center line of the shell. For the firebox types of boilers, the water connection to the water column shall be taken at a point not less than 6 inches below the lowest water line or as near thereto as possible, and in no case less than 18 inches above the mud ring.

Setting

4445. Methods of Support. A horizontal-return tubular boiler over 72 inches in diameter shall be supported from steel hangers by the outside suspension type of setting, independent of the boiler side walls. The hangers shall be so designed that the load is properly distributed between the rivets attaching them to the shell and so that no more than two of these rivets come in the same longitudinal line on each hanger. The distance girthwise of the boiler from the centers of the bottom rivets to the centers of the top rivets attaching the hangers shall be not less than 12 inches. The other rivets used shall be spaced evenly between these points.

4446. A horizontal-return tubular boiler, 14 feet or more in length, or over 54 inches and up to and including 72 inches in diameter, shall be supported by the outside-suspension type of setting, as specified in Order 4445, or at four points by not less than eight steel or cast-iron lugs set in pairs. A horizontal-return tubular boiler up to and including 54 inches in diameter shall be supported by the outside-suspension type of setting as specified in Order 4445, or by not less than two steel or cast-iron lugs on each side. The distance girthwise of the boiler from the centers of the bottom rivets to the centers of the top rivets attaching the hangers shall be not less than the square of the shell diameter divided by 675. If more than four lugs are used

they shall be set in four pairs, the lugs of each pair to be spaced not over 2 inches apart and the load to be equalized between them (see Fig. 14).

Lugs may be strength welded, without restriction along the entire periphery or contact edges on horizontal return tubular boilers provided the boiler does not exceed 36 in. in diameter and 12 feet in length. For larger sizes see note Order 4307.

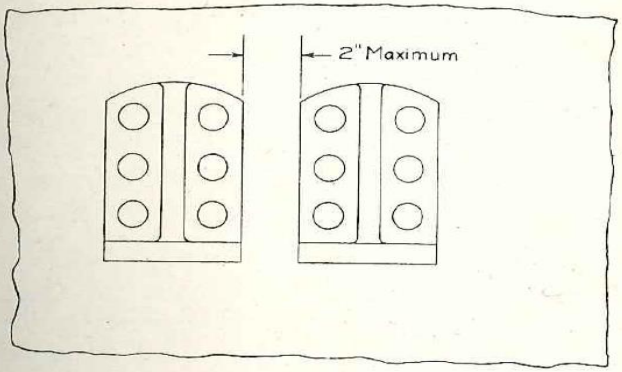


Fig. 14. Spacing of Supporting Lugs in Pairs on H. R. T. Boilers.

If the boiler is supported on structural steel work, the steel supporting members must be so located or insulated that heat from the furnace cannot impair their strength.

4447. Lugs or hangers, when used to support a boiler of any type, shall be properly fitted to the surfaces to which they are attached. Where it is impracticable to use rivets, studs with not less than 10 threads per inch may be used. In computing the shearing stresses, the area at the bottom of the thread shall be used. The shearing and crushing stresses on the rivets or studs used for attaching the lugs or brackets shall not exceed 8 per cent of the strength given in Orders 4267 and 4268.

4448. Wet-bottom stationary boilers shall have a space of not less than 12 inches between the bottom of the boiler and the floor line, with access for inspection.

The upper surface of the fire grate of an internally fired boiler of the open bottom locomotive, vertical fire tube or

similar type, shall not be below the water space in the water leg, except where the rivets at the bottom of the water leg are protected from the action of the fire and products of combustion.

4449. Access and Firing Doors. The minimum size of an access door to be placed in a boiler setting shall be 12 inches by 16 inches or equivalent area, 11 inches to be the least dimension in any case.

4450. A water-tube boiler shall have the firing doors, furnace inspection doors and clinker doors of the inward-opening type, unless such doors are provided with substantial and effective latching or fastening devices or otherwise so constructed as to prevent them, when closed, from being blown open by pressure on the furnace side.

Hydrostatic Tests

4451. Hydrostatic Pressure Tests. After a boiler has been completed, it shall be subjected to a hydrostatic test of 1½ times the maximum allowable working pressure. The pressure shall be under proper control so that in no case shall the required test pressure be exceeded by more than 6 per cent.

4452. During a hydrostatic test, the safety valve or valves shall be removed or each valve disk shall be held to its seat by means of a testing clamp and not by screwing down the compression screw upon the spring.

Stamping

4453. Stamping of Boilers. (a) In laying out shell plates, furnace sheets and heads in the boiler shop, care shall be taken to leave at least one of the stamps, required by Order 4253 so located as to be plainly visible when the boiler is completed; except that the tube sheets of a vertical fire-tube boiler and butt straps shall have at least a portion of such stamps visible sufficient for identification when the boiler is completed.

(b) It is permissible to transfer, if necessary, but without imitation, the markings on the plate, see Order 4253, under authority of an authorized inspector in charge; said inspector to make a record on the data sheet.

4454. Each boiler shall conform in every detail to these Orders, and shall be distinctly stamped, denoting that the boiler was constructed in accordance therewith.

When boilers are to be constructed to conform with the Wisconsin State Boiler Code, a certified boiler inspector is to be notified that an inspection is to be made and he shall inspect such boilers. Boilers not exceeding 200 square feet of water heating surface shall be hydrostatically tested and inspected after completion. Larger boilers shall have at least two inspections, one before reaming rivet holes and one at the hydrostatic test. In stamping the boiler after completion, if built in compliance with the Code, the builder shall stamp the boiler in the presence of the inspector, after the hydrostatic test. A data sheet shall be filled out and signed by the manufacturer and the inspector and mailed by the manufacturer to the Industrial Commission, Madison, Wis. This data sheet together with the stamp on the boiler shall denote that it was constructed in accordance with the Wisconsin State Boiler Code.

In cases where boilers cannot be completed and hydrostatically tested before shipment, the proper stampings shall be applied at the shop and two data sheets signed as herein provided by the same or different inspectors covering the portions of the inspections made at the shop and in the field, shall each be separately sent to the proper destination.

Each boiler shall be stamped as shown in Fig. 15, with the following items with intervals of about one-half inch between the lines:

1. Wis. Std. No.
2. Name of Manufacturer.
3. Maximum allowable working pressure when built.

WIS. STD. NO.

(Name of Manufacturer)

(Max. Allow. Working Pressure when Built)

Fig. 15. Form of Stamping.

The height of the letters and figures used in stamping shall be not less than five-sixteenths of an inch.

Boilers built and stamped in accordance with the requirements in the Boiler Codes of the American Society of Mechanical Engineers and stamped National Board are acceptable for use in Wisconsin in which case Wisconsin stamping may be dispensed with.

4455. Location of Stamps. The location of stamps shall be as follows:

(a) On horizontal return tubular or flue boilers—on the front head, above the central row of tubes or flues.

(b) On traction, portable or stationary boilers of the locomotive type or Star water tube boilers—on the furnace end above the handhole. Or on traction boilers of the locomotive type—on the left wrapper sheet forward of the driving wheel.

(c) On vertical firetube boilers—on the shell above the fire door—and handhole opening.

(d) On water tube boilers—on a head of the steam outlet drum near and above the manhole opening.

(e) On Scotch marine boilers—on the front head, above the center or right hand furnace.

(f) On economic boilers—on the front head above the center row of tubes.

(g) On any of the above types where there is not sufficient space in the place designated, and for other types and new designs—in a conspicuous place.

(h) On superheaters—on superheater header near the outlet.

(i) On economizers—at a handy location on water header or drums.

(j) On waterwalls—on one end of a lower header.

4456. The boiler builder's stamps shall not be covered by insulating or other material.

PART IV

ORDERS APPLICABLE TO MINIATURE BOILERS BUILT AND INSTALLED ON OR AFTER MARCH 1, 1944

4470. (1) Definition. Boilers to which the classification "Miniature" applies, embrace fired pressure vessels which do not exceed the following limits:

16 inches inside diameter of shell.
42 inches length of shell.
20 square feet water heating surface.
100 pounds per square inch maximum allowable working pressure.

Where any one of the above limits is exceeded the orders for Power Boilers shall apply.

(2) Specifications are given in Part III of the Code, for the important materials used in the construction of boilers, and the material for miniature boilers, for which specifications exist, shall conform thereto, except that steel pipe for sizes over 3 inches in diameter shall be of open hearth steel. Owing to the small size of the parts of miniature boilers, stamping as required by Order 4253 need not be visible after completing the boiler, provided the manufacturer certifies on the data slip accompanying the boiler that the material is in accordance with the requirements of the Orders for Miniature Boilers. Provisions shall be made by the manufacturer whereby he shall be able to supply complete information regarding the material and details of construction of any boiler built under the Miniature Boiler Code.

(3) Steel plate when used for any part of a miniature boiler where under pressure, shall be of the firebox or flange grades, but in no case shall steel of less than 1/4 inch thickness be used for riveted shells or less than $\frac{5}{16}$ inch thickness for seamless shells. The heads, if used as tube sheets with tubes rolled in, shall be at least $\frac{5}{16}$ inch thick.

(4) The construction of miniature boilers, except where otherwise specified, shall conform to that required for power boilers. The factor of safety and method of computing the maximum allowable working pressure shall be the same as for power boilers.

Flat surfaces exposed to pressure shall be stayed in accordance with orders in part III of the code.

(5) Heads or parts of miniature boilers, not including shell plates, when not exposed to the direct action of the fire may be made of cast iron or malleable iron provided it complies with the requirements in Order 4261 of the Boiler Code for the headers of water-tube boilers.

(6) Steam generator elements of not over 600 cubic inches in volume may be made of cast copper or bronze having a copper content of not less than 90 per cent and wall thickness of not less than ¼ inch. Such generators shall be equipped with at least one brass wash-out plug of not less than ½ inch iron pipe size and shall be tested to a hydrostatic pressure of 600 pounds per square inch.

(7) Circumferential riveted joints, where used, shall conform to the requirements in Order 4305 of the Code. Fusion welding may be used for joints in miniature boilers where the strain is carried by other construction which conforms to the requirements of this Code and where the safety of the structure is not dependent upon the strength of the weld.

(8) Tubes may be made of wrought iron, steel, drawn copper or drawn brass. Fire tubes shall have both ends substantially expanded into the tube sheet and beaded or expanded and welded. The gage of tubes shall not be less than that specified for water-tube boilers and fire-tube boilers as specified in Orders 4273 and 4274 of this Code.

(9) All rivet holes shall be drilled full size or they may be punched not to exceed ⅛ inch less than full diameter and then drilled or reamed to full diameter.

(10) The calking edges of plates, butt straps and heads shall be beveled to an angle not sharper than 70 degrees to the plane of the plate, and as near thereto as practicable. Every portion of the sheared surfaces of the calking edges shall be planed, milled or chipped to a depth of not less than ⅛ inch. Calking shall be so done that there is no danger of

scoring or damaging the plate underneath the calking edge, or splitting the edge of the sheet.

(11) Every miniature boiler shall be fitted with not less than three brass washout plugs of 1 in. pipe size, which shall be screwed into openings in the shell near the bottom. Boilers not exceeding 12 in. internal diameter and having less than 10 sq. ft. of water heating surface, need have not more than two 1 in. openings for clean outs, one of which may be used for the attachment of the bottom blow off valve; these openings shall be opposite to each other where possible.

In miniature boilers of the closed system type heated by removable internal electric heating elements, the openings for these elements when suitable for cleaning purposes may be substituted for washout plugs. All threaded openings in the boiler shall be provided with a riveted or welded reinforcement, if necessary, to give four full threads therein.

(12) Every miniature boiler shall be provided with at least one feed pump or other feeding device, except where it is connected to a water main carrying sufficient pressure to feed the boiler.

(13) Each miniature boiler shall be fitted with feed water and blow-off connections, which shall not be less than ½ inch pipe size. The feed pipe shall be provided with a check valve and a stop valve. The feed water may be delivered to the boiler through the blow-off connection, if desired. The blow-off shall be fitted with a valve or cock in direct connection with the lowest water space practicable.

All valves, pipe fittings, and appliances connected to a miniature boiler shall be equal at least to the requirements of the American Standards for 125 lbs. per sq. in.

(14) Each miniature boiler for operation with a definite water level shall be equipped with a glass water gage for determining the water level. The lowest, permissible water level shall be at a point one-third of the height of the shell, except where the boiler is equipped with internal furnace, when it shall be no less than one-third of the length of the tubes above the top of the furnace.

In the case of small steam generating units operated on the closed system where there is insufficient space for the

usual glass water gage, water level indicators of the glass bull's-eye type may be used.

(15) Each miniature boiler shall be equipped with a steam gage having dial graduated to not less than one and one-half times the maximum allowable working pressure. The gage shall be connected to the steam space or to the steam connection to the water column, by a siphon tube or equivalent device that will keep the gage tube filled with water.

(16) Each miniature boiler shall be equipped with a spring-loaded pop safety valve, not less than ½ inch in diameter, connected direct to the boiler, independent of any other connection. The safety valve shall be plainly marked by the manufacturer with a name or an identifying trademark, the nominal diameter and the steam pressure at which it is set to blow. The minimum relieving capacity shall be determined on the basis of 3 pounds of steam per hour per square foot of water heating surface.

Safety valves shall be checked by an accumulation test and the rise in pressure shall not exceed six per cent of the maximum allowable working pressure while the test is in progress. Each safety valve shall have a lifting lever.

(19) All boilers referred to in this section shall be plainly stamped with the manufacturer's name or initials, maximum allowable working pressure and a serial number. Shop inspection is not required for miniature boilers.

Serial No. _____

_____Lbs.

_____
(Name of Manufacturer)

A data sheet shall be filled out for each boiler, signed by the manufacturer, and forwarded to the Industrial Commission, Madison, Wisconsin. The data sheet shall include the most important items.

Boilers built and stamped in accordance with requirements contained in the A. S. M. E. Boiler Code are acceptable for use in Wisconsin.

MANUFACTURERS' DATA REPORT FOR MINIATURE BOILERS

1. Manufactured by _____
(Name and address of the manufacturer)

2. Manufactured for _____
(Name and address of the purchaser)

3. Type ____ Boiler No. (_____) (_____) _____Yr. built
(Manufrs.) (State and)
(Serial No.) (State No.)

Diameter of: Length of

4. Shell or Drums_____Drums_____overall_____ft._____in.
(Inside of outside course)

Material for Shell, Straps

5. Heads and Furnace Sheets made by _____
(If more than one make, give names of manufacturers in same order as parts referred to)

Has material used in boiler been checked with mill test reports _____

6. Built for maximum allowable working pressure_____lb.

7. Hydrostatic pressure applied_____lb.

8. Openings: No.__Size__in., No.__Size__in., No.__Size__in.
(Main Steam Connections) (Safety Valve) (Blow-off)

Note: The mill test reports of tests of material used in this boiler are preserved by the manufacturer as well as all data applying to the boiler called for in the data sheet for Power Boilers. This data will be supplied by the manufacturer at the request of the owner of the Boiler.

_____
(Signature)

PART V

ORDERS APPLICABLE TO HEATING BOILERS BUILT AND INSTALLED ON OR AFTER MARCH 1, 1944

These orders do not apply to economizers, feed water heaters, ordinary range water backs, range boiler and gas water heaters for the production of domestic hot-water supply.

Steel-Plate Boilers

4475. (1) These orders for steel-plate boilers shall apply:

(a) To all steam boilers for operation at pressures not exceeding 15 lbs. per sq. inch.

(b) To hot-water boilers not exceeding 160 lbs. working pressure, or temperatures not exceeding 250 degrees Fahrenheit.

(c) For conditions exceeding those specified above, the orders for construction and setting of power boilers shall apply.

(2) Whenever the term maximum allowable working pressure is used herein, it refers to gage pressure or the pressure above the atmosphere in pounds per square inch.

(3) The maximum allowable working pressure shall not exceed 15 pounds per square inch on a steel-plate boiler built under these orders to be used for low-pressure steam heating.

The maximum allowable working temperature at or near the outlet of a hot-water steel-plate boiler shall not exceed 250 degrees Fahrenheit or the maximum allowable working pressure 160 pounds per square inch.

(4) The maximum allowable working pressure on the shell or drum of steel plate steam heating and hot-water boilers shall be determined by the strength of the weakest course, computed from the thickness of the plate, the tensile strength stamped thereon, as provided for in Order 4253, the efficiency of the longitudinal joint, or of the ligament between the tube holes in shell or drum (which ever is the

least), the inside diameter of the course, and the factor of safety, but in no case shall the pressure on which the factor of safety is based be considered less than 30 pounds.

$$\frac{TS \times t \times E}{R \times FS} = \text{maximum allowable working pressure, lbs. per sq. in.}$$

where

TS = ultimate tensile strength stamped on shell plates, as provided for in the Orders for Power Boilers on marking, lbs. per sq. in.

t = minimum thickness of shell plates in weakest course, inches.

E = efficiency of longitudinal joint or of ligaments between the tube holes (whichever is the least).

R = inside radius of the weakest course of the shell or drum, inches.

FS = factor of safety, or the ratio of the ultimate strength of the material to the allowable stress.

For new constructions, FS in the above formula = 5.

Materials

4476. (1) Specifications are given in the Orders for Power Boilers for the important materials used in the construction of boilers, and where so given the materials herein mentioned for boiler parts required to resist internal pressure shall conform thereto except as specified herein for fusion welded boilers.

(2) Steel plates for any part of a boiler where under pressure, also manhole and handhole covers and other parts subjected to pressure, and braces and lugs when made of steel plate, shall be of firebox or flange quality as designated in the Specifications for Boiler-Plate Steel.

(3) Braces when made of parts welded together shall be of wrought iron of the quality designated in the Specifications for the staybolt wrought iron.

Ultimate Strength of Material

4477. (1) Tensile Strength of Steel Plate. In determining the maximum allowable working pressure, the tensile strength used in the computations for steel plates shall be that stamped on the plates as herein provided, which is the minimum specified.

(2) Crushing Strength of Steel Plate. The resistance to crushing of steel plate shall be taken at 95,000 pounds per square inch of cross-sectional area.

(3) Strength of Rivets in Shear. In computing the ultimate strength of rivets in shear, the following values in pounds per square inch of the cross-sectional area of the rivet shank shall be used:

Iron rivets in single shear	38,000
Iron rivets in double shear	76,000
Steel rivets in single shear	44,000
Steel rivets in double shear	88,000

The cross-sectional area used in the computations shall be that of the rivet shank after driving.

Minimum Thickness of Plates and Tubes

4478. (1) The minimum thickness of any boiler plate under pressure shall be ¼ inch.

(2) The minimum thickness of shell plates, heads and tube sheets for various shell diameters of steel-plate heating boilers shall be as shown in Table 12.

TABLE 12. MINIMUM ALLOWABLE THICKNESS OF SHELL PLATES

Diameter of Shell, Tube Sheet or Head	Minimum Thickness Allowable Under Orders	
	Shell, inches	Tube Sheet or Head, inches
42 inches or under	¼	5/16
Over 42 inches to 60 inches	5/16	3/8
Over 60 inches to 78 inches	3/8	7/16
Over 78 inches	7/16	½

TABLE 13. MINIMUM THICKNESS OF BUTT STRAPS

Thickness of Shell Plates, inches	Minimum Thickness of Butt Straps, inches
¼	¼
9/32	9/32
5/16	5/16
11/32	11/32
3/8	3/8
13/32	13/32
7/16	7/16
15/32	15/32
½	½
17/32	17/32
9/16	9/16
19/32	19/32
5/8	5/8
21/32	21/32
¾	¾

(3) The minimum thickness of butt straps for double-strap joints shall be as given in Table 13. For plate thickness exceeding ¾ inch, the thickness of butt straps shall be not less than two-thirds of the thickness of the plate.

(4) The minimum thickness of tubes used in water-tube or fire-tube boilers measured by Birmingham wire gage, shall be as given in Table 14.

TABLE 14. TUBES FOR WATER-TUBE AND FIRE-TUBE BOILERS

		Minimum Thickness of Tubes
Diameters 1	inch or over but less than 2½ inches	No. 13 B.W.G.
Diameters 2½	inches or over but less than 3¼ inches	No. 12 B.W.G.
Diameters 3¼	inches or over but less than 4 inches	No. 11 B.W.G.
Diameters 4	inches or over but less than 5 inches	No. 10 B.W.G.
Diameters 5	inches	No. 9 B.W.G.

(5) The minimum thickness of tubes, if of copper, either straight, bent, or coiled, for use in water-tube or fire-tube boilers, shall be as follows:

In water boilers where working pressures of over 30 lbs. and not to exceed 160 lbs. per sq. in. may be used:

$$t = \frac{D}{30} + 0.03$$

Where t = thickness of tube wall in inches, and D = outside diameter of tube in inches.

For steam boilers to be used at pressures not exceeding 15 lb. per sq. in., and water boilers where the maximum allowable working pressure does not exceed 30 lbs. per sq. in.:

$$t = \frac{D}{45} + 0.03$$

In no case shall a tube thinner than No. 16 gage (B.W.G.) be used.

Joints

4479. (1) Efficiency of a Joint. The efficiency of a joint is the ratio which the strength of the joint bears to the strength of the solid plate. (See Appendix)

(2) Riveted Boiler Joints. Longitudinal lap-riveted joints will be allowed on all boilers. (Welded boiler joints—See Order 4486). If the boiler is to be operated at a working pressure above 30 pounds, the rivets must be driven in holes drilled full size or in holes punched not to exceed ¼ inch less than full diameter and then drilled or reamed to full

diameter; also, every portion of the sheared surfaces of the calking edges of plates, butt straps and heads shall be planed, milled or chipped to a depth of not less than 1/8 inch.

(5) The longitudinal joints of horizontal-return tubular boilers shall be located above the fire line of the setting.

(6) The ends of shell plates forming the longitudinal joints in either fusion welded boilers or riveted boilers and butt straps, shall be formed by pressure, not blows, to the proper curvature.

Braced and Stayed Surfaces

4480. (1) The maximum allowable working pressure for various thicknesses of braced and stayed flat plates and those which by these orders require staying as flat surfaces with braces or staybolts of uniform diameter symmetrically spaced, shall be calculated by the formula:

$$P = C \times \frac{T^2}{p^2}$$

where

P = maximum calculated allowable working pressure, lbs. per sq. in.
(not less than 30 lbs.)

T = thickness of plate in sixteenths of an inch.

p = maximum pitch measured between straight lines passing through the centers of the staybolts in the different rows, which lines may be horizontal, vertical or inclined, inches.

C = 112 for stays screwed through plates not over 7/16 inch thick with ends riveted over or for stays welded into such plates.

C = 120 for stays screwed through plates over 7/16 inch thick with ends riveted over or for stays welded into such plates.

C = 135 for stays screwed through plates and fitted with single nuts outside of plate, or for stays welded into such plates, provided they are supported at intervals not exceeding 6 feet.

C = 150 for stays with heads not less than 1.3 times the diameter of the stays, screwed through plates or made a taper fit and having the heads formed on the stays before installing them and not riveted over, said heads being made to have a true bearing on the plate.

C = 175 for stays fitted with inside and outside nuts and outside washers where the diameter of washers is not less than 0.4p and thickness not less than T.

If a flat boiler plate not less than 3/8 inch thick is strengthened with a doubling plate covering the full area of the stayed surface and securely riveted thereto and having a thickness of not less than 2/3 T, then the value of T in the formula shall be three-quarters of the combined thickness of the boiler plate and doubling plate but not more than one and one-half times the thickness of the boiler plate, and the value of C given above may also be increased 15 per cent.

When two sheets are connected by stays and but one of these sheets requires staying, the value of C is governed by the thickness of the sheet requiring staying.

Acceptable proportions for the ends of through stays with washers are indicated in Fig. 3 order 4320.

(2) **Stays.** The ends of stays fitted with nuts shall not be exposed to the direct radiant heat of the fire.

(3) The diameter of a screw stay shall be taken at the bottom of the thread, provided this is the least diameter. No screwed stay, or stay welded in by the fusion process, shall be made of stock less than 3/4 inch diameter.

(4) **Area of Heads to be Stayed.** The area of a segment of a flanged head to be stayed shall be the area enclosed by lines drawn 2 inches from the tubes and 3 inches from the shell.

TABLE 15. MAXIMUM ALLOWABLE STRESSES FOR STAYS AND STAYBOLTS

	Description of Stays	Stresses, lbs. per sq. in.	
		For lengths between supports not exceeding 120 diameters	For lengths between supports exceeding 120 diameters
a	Unwelded or flexible stays less than 20 diameters long, screwed through plates with ends riveted over, or such stays welded in by the fusion process	7, 500	----------
b	Hollow steel stays less than 20 diameters long, screwed through plates with ends riveted over, or such stays welded in by the fusion process	8, 000	----------
c	Unwelded stays and unwelded portions of welded stays, except as specified in lines a and b	9, 500	8, 500
d	Steel through stays exceeding 1 1/4 inches diameter	10, 400	9, 000
e	Welded portions of stays	6, 000	6, 000

(5) When the portion of the head below the tubes in a horizontal-return tubular boiler is provided with a manhole opening, the flange of which is formed from the solid plate

and turned inward to a depth of not less than three times the required thickness of the head, measured from the outside, the area to be stayed as indicated in Fig. 6 order 4335 may be reduced by 100 square inches.

(6) The maximum allowable stress per square inch at point of least net cross-sectional area of stays and staybolts shall be as given in Table 15. In determining the net cross-sectional area of drilled or hollow staybolts, the cross-sectional area of the hole shall be deducted.

Boiler Openings

4481. (1) All boilers shall be provided with suitable manhole openings and handhole or washout-plug openings to permit inspection and permit removal of any sediment which may accumulate. Where the size of construction is such that entrance is impractical, manhole openings may be omitted.

(2) A manhole shall be placed in the front head below the tubes of a horizontal-return tubular boiler 60 inches or over in diameter. There shall be a manhole in the upper part of shell or head of a fire-tube boiler over 60 inches in diameter, except a vertical fire-tube boiler, or except a boiler used exclusively for hot-water heating where there is no steam space.

A boiler of the locomotive or firebox type shall have one hand-hole or washout plug near each corner in the lower part of the water leg and at least one opening near the line of the crown sheet.

Vertical fire-tube or similar-type boilers shall have at least three handholes or washout plugs in the lower part of the water leg and at least two handholes or washout plugs near the line of the lower tube sheet.

(3) Washout plugs shall have threads of non-ferrous materials and shall not be less than 1½ inches pipe size.

Washout openings may be used for return pipe connections and the washout plug placed in a tee so that the plug is directly opposite and as close as possible to the opening in the boiler.

(4) **Threaded Openings.** All threaded openings in a boiler shall be tapped into material having a minimum thickness as specified for the various standard pipe sizes in Table 16.

TABLE 16. MINIMUM THICKNESS OF MATERIAL FOR TAPPINGS

Pipe Size, Inches	Minimum Thickness of Material or Length of Thread Required, inches
1 and under	¼
1¼ to 2 inclusive	5/16
2½	11/16
3 to 3½ inclusive	5/8
4 to 5 inclusive	7/8
6 to 8 inclusive	1
9 to 12 inclusive	1¼

(5) **Flanged Connections.** Openings in boilers having flanged connections shall have the flanges conform to the American Standard for the corresponding pipe size, and shall have the corresponding drilling for bolts or studs. Outlet nozzles and flanges if of steel construction may be riveted or welded to the shell, but if of cast iron construction must be riveted thereto.

Supports

4482. (1) A horizontal-return tubular boiler over 72 inches in diameter shall be supported from steel hangers by the outside suspension type of setting, independent of the boiler side walls. The hangers shall be so designed that the load is properly distributed between the rivets attaching them to the shell and so that no more than two of these rivets come in the same longitudinal line on each hanger. The distance girthwise of the boiler from the centers of the bottom rivets to the center of the top rivets attaching the hangers shall be not less than 12 inches. The other rivets used shall be spaced evenly between these points. If more than four hangers are used they shall be set in four pairs.

(2) A horizontal-return tubular boiler over 54 inches and up to and including 72 inches in diameter, shall be supported by the outside suspension type of setting, or at four points by not less than eight steel or cast-iron brackets, set in pairs. A horizontal-return-tubular boiler up to and including 54 inches in diameter shall be supported by the outside

suspension type of setting, or by not less than two steel or cast-iron brackets on each side.

(3) Lugs or hangers, when used to support a boiler of any type shall be properly fitted to the surfaces to which they are attached. The shearing and crushing stresses on the rivets used for attaching the lugs or hangers shall not exceed 8 per cent of the strength given in Order 4477. Where it is impractical to use rivets, studs with not less than ten threads per inch may be used. In computing the shearing stress, the area at the bottom of the thread shall be used.

Lugs on hangers may be strength welded, without restriction, along the entire periphery or contact edges on horizontal return tubular boilers provided the boiler does not exceed 36 inches in diameter and 12 feet in length. For larger sizes see note, Order 4307.

Setting and Installation

4483. (1) Wet-bottom steel-plate boilers shall have a space of not less than 12 inches between the bottom of the boiler and the floor line with access for inspection.

(2) The minimum size of access door used in boiler setting shall be 12 inches by 16 inches or equivalent area, the least dimensions being 11 inches.

(3) Provisions shall be made for the expansion and contraction of steam mains connected to boilers, by providing substantial anchorage at suitable points, so that there shall be no undue strain transmitted to the boiler.

(4) Means must be provided for feeding a boiler against the maximum pressure allowed on a boiler. The feed pipe shall be provided with a check valve near the boiler and a stop valve or cock between the check valve and the boiler.

Feed or make up water shall not be discharged directly into any part of a boiler exposed to the direct radiant heat from the fire.

A heater for oil or other liquid harmful to boiler operation shall not be installed directly in the steam or water space within a boiler. Where an external type heater for such service is used, positive means must be provided to

prevent the introduction into the boiler of oil or other liquid harmful to boiler operation.

(5) All hot-water heating systems shall be so installed that there will be no opportunity for the fluid-relief column to freeze or to be accidentally shut off.

(6) It is recommended that no valves be placed in the supply and return mains of single boiler installations.

(7) **Valves on Heating Boilers.** When a stop valve is used on the steam discharge outlet of a heating boiler (Gravity Return System) a check valve and a stop valve between the check valve and boiler shall be placed on the return pipe. When there are two connecting boilers one check valve may be placed on the main return pipe and a stop valve on the branch return pipe to each boiler.

The equalizing loop as shown in Fig. 16 may be used in the return pipe in place of check valves.

(8) When a valve is placed in the top connection from a hot-water supply boiler to a storage tank, an additional connection without valve shall be made between the boiler and top of storage tank.

Fittings and Appliances

4484. (1) **Connections for Safety and Water-Relief Valves.** Every boiler shall have proper outlet connections for the required safety or water-relief valves, independent of any other connection outside of the boiler. A steam equalizing pipe between boilers is not to be considered as a connection outside of the boiler in applying the requirements of this paragraph. The area of the opening is to be at least equal to the aggregate area based on the nominal diameters of all of the safety valves with which it connects. A screwed connection may be used for attaching a safety valve.

(2) **Safety Valves.** Each steam boiler shall be provided with one or more safety valves of the spring pop type adjusted to discharge at a pressure not to exceed 15 pounds per square inch. No safety valve for a steam boiler shall be smaller than ¾ inch except in case the boiler and radiating surfaces are self-contained. No safety valve shall be larger than 4½ inches.

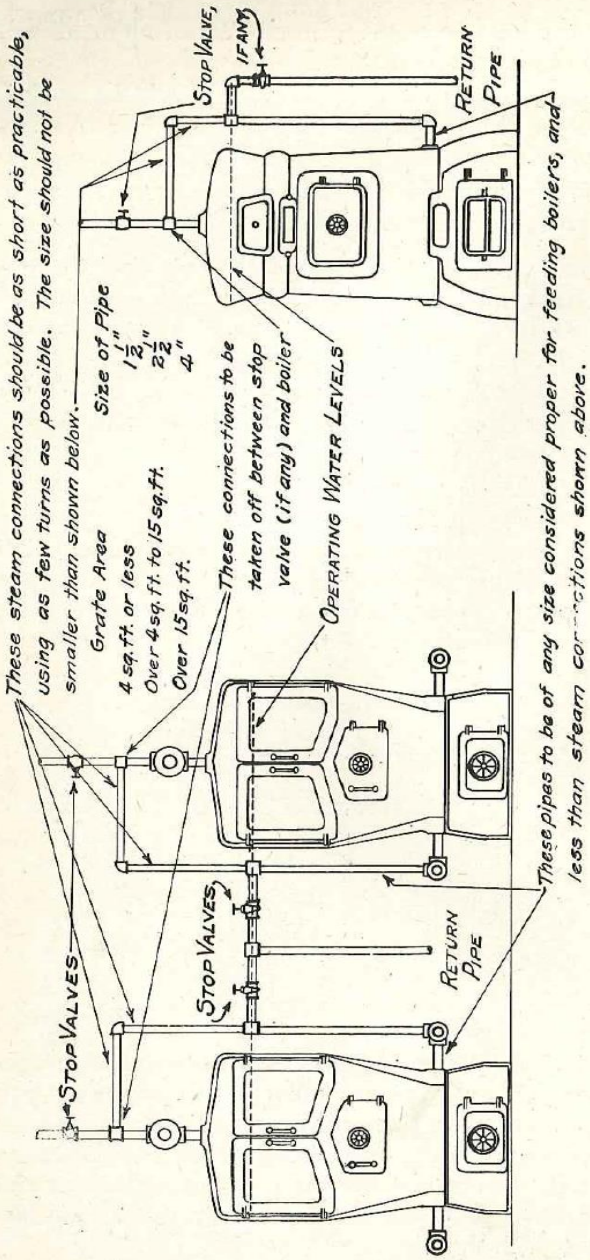


Fig. 16. Method of Equalizing One or More Boilers.

(3) **Water-Relief Valves.** Each hot water heating or hot water supply boiler shall have one or more relief valves of the spring loaded type, without disk guides on the pressure side of the valve. The valves shall be set to relieve at a pressure at or below the maximum allowable working pressure of the boiler.

Each relief valve shall have a substantial lifting device which will lift the disk from its seat at least $\frac{1}{16}$ inch when there is no pressure on the boiler.

The seats and disks shall be of material suitable to resist corrosion. No materials liable to fail due to deterioration or vulcanization when subjected to any temperature not exceeding 250 F., shall be used for any part.

No relief shall be smaller than ¾ inch nor larger than 2 inches standard pipe size. The inlet opening shall have an inside diameter approximately equal to, or greater than, the seat diameter.

(4) When two or more safety or water-relief valves are used on a boiler, they may be single, twin, or duplex valves.

(5) Safety or water-relief valves shall be attached directly or as close as possible to the boiler without any unnecessary intervening pipe or fitting except the Y-base forming a part of the twin valve or a steam equalizing pipe between boilers. A safety valve or water-relief shall not be connected to an internal pipe in the boiler. Safety valves or water-relief valves shall be connected so as to stand upright with the spindle vertical when possible.

(6) No shut off of any description shall be placed between the safety or water-relief valve and the boiler, nor on discharge pipes between such valves and the atmosphere.

(7) When a discharge pipe is used its area shall be not less than the area of the valve or aggregate area based on the nominal diameters of the valves with which it connects, and the discharge pipe shall be fitted with an open drain to prevent water from lodging in the upper part of the valve or in the pipe. When an elbow is placed on a safety or water-relief valve discharge pipe, it shall be located close to the valve outlet or the pipe shall be securely anchored and supported. The safety or water-relief valves shall be so located and piped that there will be no danger of scalding attendants.

(8) Each safety valve, ¾ inch or over, used on a steam-heating boiler, shall have a substantial lifting device by which the valve may be raised from its seat at least $\frac{1}{16}$ inch when there is no pressure on the boiler.

(10) Each safety valve or water-relief valve shall be plainly marked by the manufacturer in such a way that the markings will not be obliterated in service, by stamping or casting on the casing or body of the valve, or by stamping or casting on a plate securely fastened to the casing, the manufacturer's name or trademark, and the pressure at which it is set to blow. The seats and disks of safety or water-relief valves shall be made of non-corrosive material.

(11) The diameter of seat shall determine the nominal diameter of safety or water-relief valve as given in Tables 17 or 18. The pipe thread at the inlet shall not be less than the nominal valve size.

(12) The minimum size of safety or water-relief valve or valves for each boiler shall be governed by the amount of the grate area as given in Tables 17 or 18. In determining the minimum size of safety or water relief valves for double grate down draft boilers, the effective grate area shall be taken as the area of the upper grate plus one-eighth of the area of the lower grate.

The safety-valve capacity for each steam boiler shall be such that the safety valve or valves will discharge all the steam that can be generated by the boiler without allowing the pressure to rise more than 5 pounds above the maximum allowable working pressure of the boiler and 3 pounds above the maximum allowable working pressure of a hot water boiler.

When the size of boiler exceeds the valves given in Tables 17 or 18, safety valves or water-relief valves whose combined capacities equal the rated capacity of the boiler shall be selected from the tables.

(13) When a hot-water supply is heated indirectly, by steam in a coil or pipe, the pressure of the steam used shall not exceed the safe working pressure of the hot-water tank, and a water-relief valve of at least 1 inch in diameter, set to relieve at or below the maximum allowable working pressure of the tank, shall be used.

TABLE 17. MINIMUM ALLOWABLE SIZES OF SAFETY VALVES FOR STEAM HEATING BOILERS

Safety Valve			Area of Grate, Sq. Ft.
Diameter, Inches	Area Sq. In.	Discharge Capacity Lbs. per Hr.[1]	
¼	0.0491	15	1
⅜	0.1104	30	1.5
½	0.1963	60	2
¾	0.4418	130	3
1	0.7854	230	4
1¼	1.2272	360	6.5
1½	1.7671	515	9
2	3.1416	920	14
2½	4.9087	1435	19
3	7.0686	2070	24
3½	9.6211	2810	29
4	12.5660	3675	34
4½	15.9040	4650	39

[1]Capacity of safety valve based on 33⅓ per cent over pressure, valve set to relieve at 15 pounds per square inch.

Note: The foregoing table is based upon the following formulas:

Where grate area does not exceed 4 sq. ft.: Diam. of safety valve, in. $= \frac{\text{Grate area (sq. ft.)}}{4}$

Where grate area exceeds 4 sq. ft.: Diam. of safety valve, in. $= \frac{\text{Grate area (sq. ft.)}}{10} + 0.6$

If liquid or gaseous fuel is used a grate area shall be assumed equal to that which would be required if coal were used for fuel.

TABLE 18. MINIMUM ALLOWABLE SIZES OF WATER RELIEF VALVES FOR WATER-HEATING BOILERS AND FOR WATER-SUPPLY BOILERS

Diameter of Valve Inches	Area of Grate, Sq. Ft.	Rated Capacity in Gallons per Hour		
		25° Rise	50° Rise	100° Rise
½	1.6	540	270	135
¾	5.6	1440	750	360
1	9.6	2520	1260	630
1¼	15.75	5400	2700	1350
1½	27.	10800	5400	2700
2	49.5	21600	10800	5400

Note: The foregoing table is based upon the following formulas:

Where grate area does not exceed 12.5 sq. ft.: Diam. of safety valve, in. $= \frac{\text{Grate area (sq. ft.)}}{16} + 0.4$

Where grate area exceeds 12.5 sq. ft.: Diam. of safety valve, in. $= \frac{\text{Grate area (sq. ft.)}}{45} + 0.9$

(14) **Steam Gages.** Each steam boiler shall have a steam gage connected to the steam space or to the water column, or its steam connection, by means of a siphon or equivalent device of sufficient capacity to keep the gage tube filled with water and so arranged that the gage cannot be shut off from the boiler except by a cock placed near the gage

and provided with a tee or lever handle arranged to be parallel with the pipe in which it is located when the cock is open. The dial of a steam gage for a steam heating boiler shall be graduated to not less than 30 pounds, and shall be provided with effective stops for the indicating pointer at the zero point and at the maximum pressure point. The travel of the pointer from zero to 30 lb. pressure shall be at least 3 in.

(15) **Pressure or Altitude Gages.** Each hot-water boiler shall have a gage connected in such a manner that it cannot be shut off from the boiler except by a cock with tee or lever handle, placed on the pipe near the gage. The handle of the cock shall be parallel to the pipe in which it is located when the cock is open. The dial of the pressure or altitude gage shall be graduated to not less than 1½ times the maximum allowable working pressure, and shall be provided with effective stops for the indicating pointer at the zero point and at the maximum pressure point.

(16) **Thermometers.** Each hot-water boiler shall have a thermometer so located and connected that it shall be easily readable when observing the water pressure or altitude. The thermometer shall be so located that it shall at all times indicate the temperature in degree Fahrenheit of the water in the boiler at or near the outlet.

(17) **Temperature Combustion Regulators.** A temperature combustion regulator, which will control the rate of combustion to prevent the temperature of the water from rising above 250 degrees Fahrenheit at or near the outlet, or a thermostatic device which will relieve the pressure on the boiler when the temperature exceeds 250 degrees Fahrenheit shall be used on all hot-water heating and hot-water supply boilers.

(18) **Pressure Combustion Regulators.** When a pressure combustion regulator is used, it shall operate to prevent the steam pressure from rising above 15 pounds.

(19) **Bottom Blow-Off.** Each boiler shall have a blow-off pipe connection fitted with a valve or cock not less than ¾-inch pipe size connected with the lowest water space practicable.

(20) **Water Gage Glasses.** Each steam boiler shall have at least one water-gage glass, the lowest visible part of which shall be above the lowest permissible water level. The lowest permissible water level shall be that level fixed by the manufacturer subject to change by the order of the Industrial Commission.

(21) **Gage Cocks.** Each steam boiler shall have two or more gage cocks located within the range of the visible length of the water glass.

(22) **Water-Column Pipes.** The minimum size of pipes connecting the water column of a steam boiler shall be 1 inch. Water-glass fittings or gage cocks may be connected direct to the boiler. The steam connection to the water column of a horizontal-return tubular boiler shall be taken from the top of the shell or the upper part of the head; the water connection shall be taken from a point not less than 6 inches below the center line of the shell. No connections, except for combustion regulator, drain or steam gages, shall be placed on the pipes connecting a water column to a boiler. If the water column or gage glass is connected to the boiler by a pipe and fittings, crosses or tees shall be used on the water connection to facilitate cleaning.

Hydrostatic Test

4485. (1) All hot-water boilers, the maximum allowable working pressure of which is not in excess of 40 pounds per square inch, and steam-heating boilers, shall be subjected to a hydrostatic test of 60 pounds per square inch at the shop where constructed. Hot-water boilers, the maximum allowable working pressure of which exceeds 40 pounds per square inch shall be subjected to a hydrostatic test of 1½ times the maximum allowable working pressure at the shop where constructed.

Any hydrostatic pressure test to be made on either a steam-heating boiler or hot-water boiler, after the boiler has been in service, shall be at a pressure 1½ times the maximum allowable working pressure.

In making hydrostatic pressure tests the pressure shall be under such control that in no case shall the required test

pressure be exceeded by more than 10 pounds per square inch.

(2) Individual shop inspection shall not be required for boilers which come under the rules of this section, except for boilers constructed by fusion welding (see Order 4486–13).

(3) Each plate of a completed boiler shall bear the plate maker's name with brand and tensile strength, except that these marks need not appear on the butt straps after completion of boiler.

(4) All boilers built according to these orders shall be stamped with the manufacturer's name and maximum allowable working pressure. These markings shall be stamped with letters and figures at least ¼ inch high on some conspicuous portion of the boiler proper, preferably over or near the fire door. Boilers suitable for use for both steam and water shall have the stamps arranged substantially as follows:

Boilers constructed and stamped in accordance with the A. S. M. E. code are acceptable for use in this state.

(Manufacturer's Name)

Max. W. P., Steam 15 lb.

Water___lb.

Boilers suitable for use for water only shall have the stamps arranged substantially as follows:

(Manufacturer's Name)

Max. W. P., Water_____lb.

These stamps shall not be covered with insulating or other material.

FUSION WELDED BOILERS

4486. (1) Fusion Welds. The fusion welding process consists of welding by means of either the oxyacetylene process or the electric arc process, using a metallic electrode, either bare, coated, or covered.

(2) Steel-plate boilers constructed by fusion welding under the orders prescribed for steel-plate heating boilers may be used for steam heating at pressures not exceeding 15 pounds per square inch, or for hot-water heating at pressures not exceeding 160 pounds per square inch. For pressures in excess of 30 pounds per square inch for hot-water boilers, the factor of safety for fusion welded steel-plate boilers shall be not less than 5, assuming the strength of the welded seam at 28,000 pounds per square inch of net section of plate.

(3) Design and Construction. The design, construction, and stamping of fusion welded boilers shall in all cases conform to the formulas, specifications and data which are given in the orders prescribed for steel-plate heating boilers, unless some special requirement is necessary because of welding, in which case the requirements will be hereinafter detailed.

(4) Base Metal. The term base metal when used, shall mean the metal or metals of which the boiler is constructed and which are joined together by the welded seam.

(5) Filling Material. The term filling material shall mean the weld rod, filling rod, electrode or other metal which is used to join two sections of the base metal or metals.

The filling metal must be clean, flow freely, and shall neither "spit nor spark" appreciably during welding. Its fusing temperature shall be such as to correspond relatively with that of the sheet, or base metal. The size of the wire and the size of the tip shall be such as to enable the welder to meet the conditions required by the work he is doing with oxy-acetylene welding, and the size of the electrode and current characteristics should meet the same conditions for electric arc welding.

(6) The base metal composing the plates of fusion welded steel plate heating boilers shall be made by the open hearth process of soft and good weldable quality and shall be as approved by the Industrial Commission.

Note: Weldable steel as specified by the American Society of Mechanical Engineers is approved.

(10) **Method of welding.** Seams or joints on fusion welded steel-plate boilers may be welded on both sides by the double-V method, so-called, or on one side only with a single-V, or by using such methods as will assure a joint of sound metal thoroughly fused and to a thickness in excess of the maximum thickness of plate.

There shall be no valley either on the edge or in the center of the joint and the weld shall be so built up that the welded metal shall present a gradual increase in thickness from the surface of the sheet to the center of the weld. At no point shall the sheet on one side of the joint be offset with the sheet on the other side of the joint in excess of one quarter of the minimum thickness of the sheets or plates except where stayed plates are lap joined.

(11) **Longitudinal Joints.** Where fusion welded steel-plate heating boilers are made up of two or more courses, the welded longitudinal joints of adjacent courses shall not be less than 90 degrees apart.

(13) Every boiler, the unsupported joints of which are welded by the fusion process, shall be inspected at the shop where manufactured by a duly authorized inspector. The inspector shall subject the boiler to a hydrostatic test and make an internal inspection.

(14) Steel-plate boilers having cylindrical shells and constructed by fusion welding shall have their shell length limited to four diameters and in no case to exceed 20 feet in length.

(15) Where staybolts are to be welded into stayed plates by the fusion process the staybolt holes shall be countersunk to within at least $\frac{1}{16}$ inch of the full thickness of the plate. The base metal of the plate and staybolt shall be welded to the full thickness of the plate. The staybolts shall be of such length that they will project at least $\frac{1}{8}$ inch above the surface of the plate in which they are welded.

No form of stay may be attached by welding unless the method of attachment conforms to the requirements for welding in stay bolts.

Cast-Iron Boilers

4487. (1) These rules for cast-iron boilers shall apply:

(a) To all steam boilers for operation at pressures not exceeding 15 pounds per square inch.

(b) To hot-water boilers to be operated at pressures not exceeding 160 pounds per square inch, or temperatures not exceeding 250 degrees Fahrenheit.

(c) For conditions exceeding those specified above, cast-iron construction is not permitted.

(2) Wherever the term maximum allowable working pressure is used herein, it refers to gage pressure or the pressure above the atmosphere in pounds per square inch.

(3) The maximum allowable working pressure shall not exceed 15 pounds per square inch on a cast-iron boiler built under these rules to be used exclusively for low-pressure steam-heating.

The maximum allowable working temperature at or near the outlet of a hot-water cast-iron boiler shall not exceed 250 degrees Fahrenheit.

Boiler Openings

4488. **(1) Washout Openings.** All cast-iron steam and hot-water boilers shall be provided with suitable washout openings to permit the removal of any sediment that may accumulate therein. Washout openings may be used for return pipe connections and the washout plug placed in a tee so that the plug is directly opposite and as close as possible to the opening in the boiler.

(2) **Flanged Connections.** Flanged pipe connection openings in boilers shall conform to the American Standard for the corresponding pipe size, and shall have the corresponding drilling for bolts or studs.

(3) **Threaded Openings.** Pipe connections if threaded shall be tapped into material having a minimum thickness as specified in Table 20.

TABLE 20. MINIMUM THICKNESS OF MATERIAL FOR THREADED CONNECTIONS TO BOILERS

Size of Pipe Connection, Inches	Minimum Thickness of Material Required Inches
¾ and under	5/32
1 to 2½ inclusive	7/32
3 to 3½ inclusive	9/32
4 to 5 inclusive	5/16
6 to 8 inclusive	1
9 to 12 inclusive	1¼

Installation

4489. (1) Provisions shall be made for the expansion and contraction of steam mains connected to boilers by providing substantial anchorage at suitable points, so that there shall be no undue strain transmitted to the boiler.

(2) When feed or make-up water is introduced from a pressure line, it shall be connected to the piping system and not directly to the boiler.

Means must be provided for feeding a boiler against the maximum pressure allowed on a boiler. The feed pipe shall be provided with a check valve near the boiler and a stop valve or cock between the check valve and the boiler.

A heater for oil or other liquid harmful to boiler operation shall not be installed directly in the steam or water space within a boiler. Where an external type heater for such service is used, positive means must be provided to prevent the introduction into the boiler of oil or other liquid harmful to boiler operation.

(3) All hot-water heating systems shall be so installed that there will be no opportunity for the fluid-relief column to freeze or to be accidentally shut off.

(4) It is recommended that no valves be placed in the supply and return mains of a single boiler installation.

(5) **Valves on Heating Boilers.** When a stop valve is used on the steam discharge outlet of a heating boiler (Gravity Return System) a check valve and a stop valve between the check valve and the boiler shall be placed on the return pipe. When there are two connecting boilers one check valve may be placed on the main return pipe and a stop valve on the branch return pipe to each boiler.

The equalizing loop as shown in Fig. 16 may be used in the return pipe in place of check valves.

(6) When a valve is placed in the top connection from a hot-water supply boiler to a storage tank, an additional connection without valve shall be made between the boiler and top of storage tank.

(7) **Connections for Safety and Water-Relief Valves.** Every boiler shall have proper outlet connections for the required safety or water-relief valves, independent of any other connection outside the boiler. A steam equalizing pipe between boilers is not to be considered as a connection outside of the boiler in applying the requirements of this paragraph. The area of the opening is to be at least equal to the aggregate area based on the nominal diameters of all of the safety valves with which it connects. A screwed connection may be used for attaching a safety valve.

Fittings and Appliances

4490. (1) **Safety Valves.** Each steam boiler shall be provided with one or more safety valves of the spring pop type adjusted to discharge at a pressure not to exceed 15 pounds per square inch. No safety valve for a steam boiler shall be smaller than ¾ inch except in case the boiler and radiating surfaces are assembled in a self-contained unit. No safety valve shall be larger than 4½ inches.

(2) Each hot water heating or hot water supply boiler shall have one or more relief valves of the spring loaded type, without disk guides on the pressure side of the valve. The valves shall be set to relieve at a pressure at or below the maximum allowable working pressure of the boiler.

Each relief valve shall have a substantial lifting device which will lift the disk from its seat at least 1/16 inch when there is no pressure on the boiler.

The seats and disks shall be of material suitable to resist corrosion. No materials liable to fail due to deterioration or vulcanization when subjected to any temperature not exceeding 250 F. shall be used for any part.

No relief valve shall be smaller than ¾ inch nor larger than 2 inches standard pipe size. The inlet opening shall

have an inside diameter approximately equal to, or greater than, the seat diameter.

(3) When two or more safety or water-relief valves are used on a boiler, they may be single, twin, or duplex valves.

(4) Safety or water-relief valves shall be attached directly or as close as possible to the boiler without any unnecessary intervening pipe or fitting except the Y-base forming a part of the twin-valve or a steam equalizing pipe between boilers. A safety valve or water-relief valve shall not be connected to an internal pipe in the boiler. Safety valves or water-relief valves shall be connected so as to stand upright with the spindle vertical when possible.

(5) No shut-off of any description shall be placed between the safety or water-relief valve and the boiler, nor on discharge pipes between such valves and the atmosphere.

(6) When a discharge pipe is used its area shall be not less than the area of the valve or aggregate area based on the nominal diameters of the valves with which it connects, and the discharge pipe shall be fitted with an open drain to prevent water from lodging in the upper part of the valve or in the pipe. When an elbow is placed on a safety or water-relief valve discharge pipe, it shall be located close to the valve outlet or the pipe shall be securely anchored and supported. The safety or water-relief valve shall be so located and piped that there will be no danger of scalding attendants.

(7) Each safety valve, ¾ inch or over, used on a steam-heating boiler, shall have a substantial lifting device by which the valve may be raised from its seat at least $\frac{1}{16}$ inch when there is no pressure on the boiler.

(9) Each safety valve or water-relief valve shall be plainly marked by the manufacturer in such a way that the markings will not be obliterated in service, by stamping or casting on the casing or body of the valve, or by stamping or casting on a plate securely fastened to the casing, the manufacturer's name or trade-mark and the pressure at which it is set to blow. The seat and disks of safety or water-relief valves shall be made of non-corrosive material.

(10) The diameter of seat shall determine the nominal diameter of safety or water-relief valve as given in Tables 21

or 22. The pipe thread at the inlet shall not be less than the nominal valve size.

(11) The minimum size of safety or water-relief valve or valves for each boiler shall be governed by the amount of the grate area as given in Tables 21 or 22. In determining the minimum size of safety or water relief valves for double grate down draft boilers, the effective grate area shall be taken as the area of the upper grate plus one-eighth of the area of the lower grate.

The safety valve capacity for each steam boiler shall be such that the safety valve or valves will discharge all the steam that can be generated by the boiler without allowing the pressure to rise more than 5 pounds above the maximum allowable working pressure of the boiler and 3 pounds above the maximum allowable working pressure of a hot water boiler.

When the size of a boiler exceeds the values given in Tables 21 or 22, safety valves or water-relief valves whose combined capacities equal the rated capacity of the boiler shall be selected from the tables.

TABLE 21. MINIMUM ALLOWABLE SIZES OF SAFETY VALVES FOR STEAM-HEATING BOILERS

Safety Valve			Area of Grate, Sq. Ft.
Diameter Inches	Area Sq. In.	Discharge Capacity Lbs. per Hr.[1]	
¼	0.0491	15	1
⅜	0.1104	30	1.5
½	0.1963	60	2
¾	0.4418	130	3
1	0.7854	230	4
1¼	1.2275	360	6.5
1½	1.7671	515	9
2	3.1416	950	14
2½	4.9087	1435	19
3	7.0686	2070	24
3½	9.6211	2810	29
4	12.5660	3675	34
4½	15.9040	4650	39

[1]Capacity of safety valve based on 33⅓ per cent over-pressure, valve set to relieve at 15 pounds per square inch.

Note: The foregoing table is based upon the following formulas:

Where grate area does not exceed 4 sq. ft.: Diam. of safety valve, in. $= \frac{\text{Grate area (sq. ft.)}}{4}$

Where grate area exceeds 4 sq. ft.: Diam. of safety valve, in. $= \frac{\text{Grate area (sq. ft.)}}{10} + 0.6$

If liquid or gaseous fuel is used a grate area shall be assumed equal to that which would be required if coal were used for fuel.

TABLE 22. MINIMUM ALLOWABLE SIZES OF WATER-RELIEF VALVES FOR WATER-HEATING BOILERS AND FOR WATER-SUPPLY BOILERS

Diameter Valve, Inches	Area of Grate, Sq. Ft.	Rated Capacity in Gallons per Hour		
		25° Rise	50° Rise	100° Rise
½	1.6	540	270	135
¾	5.6	1440	720	360
1	9.6	2520	1260	630
1¼	15.75	5400	2700	1350
1½	27.	10800	5400	2700
2	49.5	21600	10800	5400

Note: The foregoing table is based upon the following formulas:

Where grate area does not exceed 12.5 sq. ft.

$$\text{Diam. of safety valve, in.} = \frac{\text{Grate area (sq. ft.)}}{16} + 0.4$$

Where grate area exceeds 12.5 sq. ft.

$$\text{Diam. of safety valve, in.} = \frac{\text{Grate area (sq. ft.)}}{45} + 0.9$$

(12) When a hot-water supply is heated indirectly by steam in a coil or pipe, the pressure of the steam used shall not exceed the safe working pressure of the hot-water tank, and a water-relief valve of at least 1 inch in diameter, set to relieve at or below the maximum allowable working pressure of the tank, shall be used.

(13) **Steam Gages.** Each steam boiler shall have a steam gage connected to the steam space or to the water column, or its steam connection, by means of a siphon or equivalent device of sufficient capacity to keep the gage tube filled with water and so arranged that the gage cannot be shut off from the boiler except by a cock placed near the gage and provided with a tee or lever handle arranged to be parallel with the pipe in which it is located when the cock is open. The dial of a steam gage for a steam-heating boiler shall be graduated to not less than 30 pounds and shall be provided with effective stops for the indicating pointers at the zero point and at the maximum pressure point. The travel of the pointer from zero to 30 pounds pressure shall be at least 3 inches.

(14) **Pressure or Altitude Gages.** Each hot-water boiler shall have a gage connected in such a manner that it cannot be shut off from the boiler except by a cock with tee or lever handle, placed on the pipe near the gage. The handle of the cock shall be parallel to the pipe in which it is located when

the cock is open. The dial of the pressure or altitude gage shall be graduated to not less than 1½ times the maximum allowable working pressure, and shall be provided with effective stops for the indicating pointer at the zero point and at the maximum pressure point.

(15) **Thermometers.** Each hot-water boiler shall have a thermometer so located and connected that it shall be easily readable when observing the water pressure or altitude. The thermometer shall be so located that it shall at all times indicate the temperature in degrees Fahrenheit of the water in the boiler, at or near the outlet.

(16) **Temperature Combustion Regulators.** A temperature combustion regulator, which will control the rate of combustion to prevent the temperature of the water from rising above 250 degrees Fahrenheit, at or near the outlet, or a thermostatic device which will relieve the pressure on the boiler when the temperature exceeds 250 degrees Fahrenheit, shall be used on all hot-water heating and hot-water supply boilers.

(17) **Pressure Combustion Regulators.** When a pressure combustion regulator is used, it shall operate to prevent the steam pressure from rising above 15 pounds.

(18) **Bottom Blow-Off.** Each boiler shall have a blow-off pipe connection fitted with a valve or cock not less than ¾ inch pipe size connected with the lowest water space practicable.

(19) **Water Gage Glasses.** Each steam boiler shall have at least one water-gage glass, the lowest visible part of which shall be above the lowest permissible water level. The lowest permissible water level shall be that level fixed by the manufacturer, subject to change by order of the Industrial Commission.

(20) **Gage Cocks.** Each steam boiler shall have two or more gage cocks located within the range of visible length of the water glass.

(21) **Water Column Pipes.** The minimum size pipes connecting the water column of a steam boiler shall be 1 inch.

Water-glass fittings or gage cocks may be connected direct to the boiler. No connections, except for combustion regulator, drains, or steam gages, shall be placed on the pipes connecting a water column to a boiler. If the water column or gage glass is connected to the boiler by pipe and fittings, crosses or tees shall be used on the water connection to facilitate cleaning.

Hydrostatic Tests

4491. (1) All hot-water boilers, the maximum allowable working pressure of which is not excess of 30 pounds per square inch, and steam-heating boilers shall be subjected to a hydrostatic test of 60 pounds per square inch at the shop where made, on each individual section. Hot-water boilers, the maximum allowable working pressure of which exceeds 30 pounds per square inch, shall be subjected to a hydrostatic test of 2½ times the maximum allowable working pressure at the shop where made, on each individual section.

Any hydrostatic pressure test to be made on either a steam-heating boiler, or hot-water boiler, after the boiler has been in service, shall be at a pressure of 1½ times the maximum allowable working pressure.

In making hydrostatic pressure tests the pressure shall be under such control that in no case shall the required test pressure be exceeded by more than 10 pounds per square inch.

(2) Individual shop inspection shall not be required for boilers which come under the orders of this section.

(3) All boilers shall be plainly and permanently marked with the manufacturer's or distributor's name and the maximum allowable working pressure. All letters and figures shall be at least ¼ inch high.

The maximum allowable working pressure shall be stamped, cast, or irremovably attached to the front and rear cored sections of vertical sectional cast-iron boilers and on the dome section of horizontal sectional cast-iron boilers. The marking of maximum allowable working pressure on

cast-iron boilers suitable for use for steam or water will be as follows:

MAX, W. P. ---------- LB.
STEAM ---------- 15
WATER ----------

Boilers suitable for use as water boilers only shall be marked as follows:

MAX, W. P. ---------- LB.
WATER ----------

All boilers built according to A. S. M. E. Standards are acceptable for use in this state.

When an insulating or other form of covering is used that portion of the front cored section of vertical sectional cast-iron boilers, and the dome cored section of horizontal sectional cast-iron boilers bearing the foregoing marking, shall either be provided with a removable cover plate or be left uncovered.

APPENDIX

Explanatory of the Code and containing matter which is not mandatory unless specifically referred to in the orders of the Code.

EFFICIENCY OF JOINTS

A–1 **Efficiency of Riveted Joints.** The ratio which the strength of a unit length of a riveted joint has to the same unit length of the solid plate is known as the efficiency of the joint and shall be calculated by the general method illustrated in the following examples:

TS = tensile strength stamped on plate, lbs. per sq. in.
t = thickness of plate, inches
b = thickness of butt strap, inches
P = pitch of rivets, inches, on row having greatest pitch
d = diameter of rivet after driving, inches = diameter of rivet hole

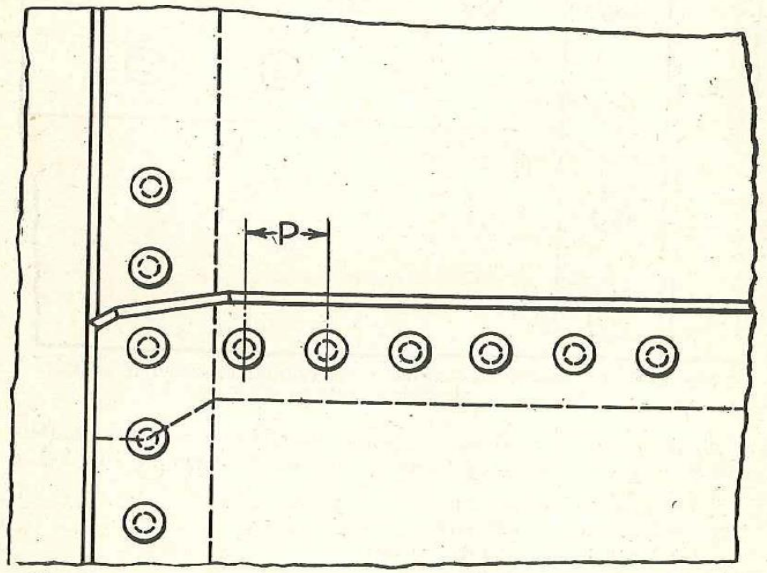


Fig. A–1. Example of Lap Point, Longitudinal or Circumferential, Single-Riveted.

a = cross-sectional area of rivet after driving, sq. in.
s = shearing strength of rivet in single shear, lbs. per sq. in., as given in Order 4268
S = shearing strength of rivet in double shear, lbs. per sq. in., as given in Order 4268
c = crushing strength of mild steel, lbs. per sq. in., as given in Order 4267
n = number of rivets in single shear in a unit length of joint.
N = number of rivets in double shear in a unit length of joint.

A–2 Example: Lap joint, longitudinal or circumferential, single-riveted.

A = strength of solid plate—P × t × TS
B = strength of plate between rivet holes = (P-d) t × TS
C = shearing strength of one rivet in single shear = n × s × a
D = crushing strength of plate in front of one rivet = d × t × c

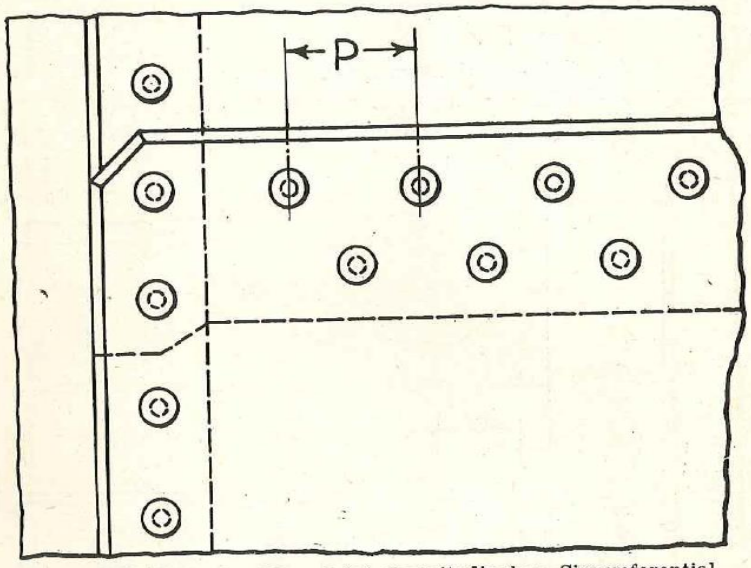


Fig. A–2. Example of Lap Joint, Longitudinal or Circumferential, Double-Riveted.

Divide B, C or D (whichever is the least) by A, and the quotient will be efficiency of a single riveted lap joint as shown in Fig. A–1.

TS = 55,000 lbs. per sq. in.
t = ¼ inch = 0.25 inches
P = 1⅝ inches = 1.625 inches
d = 11/16 inch = 0.6875 inch
a = 0.3712 sq. in.

s = 44,000 lbs. per sq. in.
c = 95,000 lbs. per sq. in.
A = 1.625 × 0.25 × 55,000 = 22,343
B = (1.625 — 0.6875) 0.25 × 55,000 = 12,890
C = 1 × 44,000 × 0.3712 = 16,332
D = 0.6875 × 0.25 × 95,000 = 16,328

$$\frac{12{,}890\ (B)}{22{,}343\ (A)} = 0.576 = \text{efficiency of joint}$$

A–3 Example: Lap joint, longitudinal or circumferential, double-riveted.

A = strength of solid plate = P × t × TS
B = strength of plate between rivet holes = (P–d) t × TS
C = shearing strength of two rivets in single shear = n × s × a
D = crushing strength of plate in front of two rivets = n × d × t × c

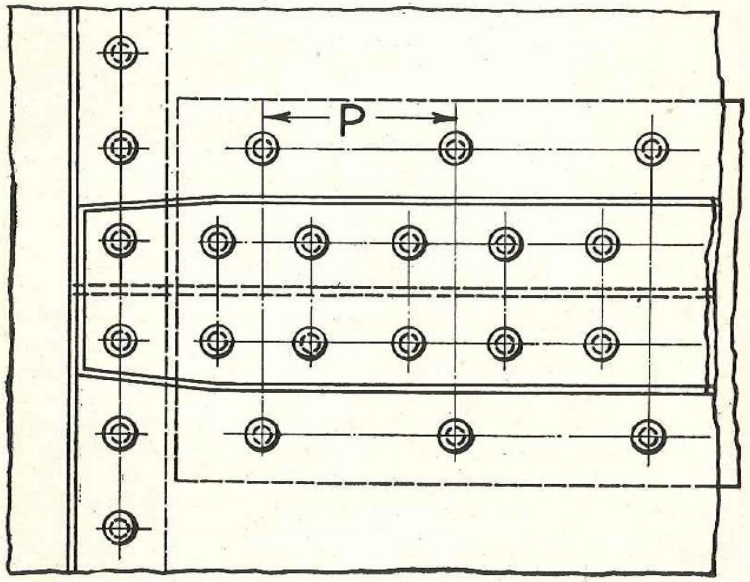


Fig. A–3. Example of Butt and Double Strap Joint, Double-Riveted.

Divide B, C or D (whichever is the least) by A, and the quotient will be efficiency of a double-riveted lap joint, as shown in Fig. A–2.

TS = 55,000 lbs. per sq. in.
t = 5/16 inch = 0.3125 inch
P = 2⅞ inches = 2.875 inches
d = ¾ inch = 0.75 inch
a = 0.4418 sq. in.

s = 44,000 lbs. per sq. in.
c = 95,000 lbs. per sq. in.
A = 2.875 × 0.3125 × 55,000 = 49,414
B = (2.875 – 0.75) 0.3125 × 55,000 = 36,531
C = 2 × 44,000 × 0.4418 = 38,878
D = 2 × 0.75 × 0.3125 × 95,000 = 44,531

$\frac{36,523\ (B)}{49,414\ (A)} = 0.739$ = efficiency of joint

A–4 Example: Butt and double strap joint, double-riveted.

A = strength of solid plate = P × t × TS

B = strength of plate between rivet holes in the outer row = (P–d) t × TS

C = shearing strength of two rivets in double shear, plus the shearing strength of one rivet in single shear = N × S × a + n × s × a

D = strength of plate between rivet holes in the second row, plus the shearing strength of one rivet in single shear in the outer row = (P–2d) t × TS + n × s × a

E = strength of plate between rivet holes in the second row, plus the crushing strength of butt strap in front of one rivet in the outer row = (P–2d) t × TS + d × b × c

F = crushing strength of plate in front of two rivets, plus the crushing strength of butt strap in front of one rivet = N × d × t × c + n × d × b × c

G = crushing strength of plate in front of two rivets, plus the shearing strength of one rivet in single shear = N × d × t × c + n × s × a

H = strength of butt straps between rivet holes in the inner row = (P–2d) 2b × TS. This method of failure is not possible for thicknesses of butt straps required by these orders and the computation need only be made for old boilers in which thin butt straps have been used. For this reason this method of failure will not be considered in other joints.

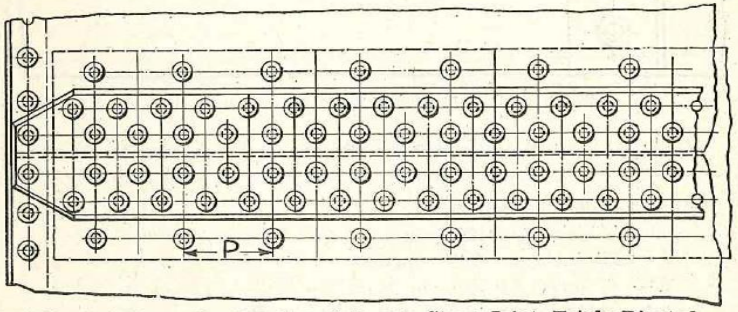


Fig. A–4. Example of Butt and Double Strap Joint, Triple-Riveted.

Divide B, C, D, E, F, G or H (whichever is the least) by A, and the quotient will be the efficiency of a butt and double strap joint, double-riveted, as shown in Fig. A–3.

TS = 55,000 lbs. per sq. in.
t = ⅜ inch = 0.375 inch
b = 5/16 inch = 0.3125 inch
P = 4⅞ inches = 4.875 inches
d = ⅞ inch = 0.875 inch
a = 0.6013 sq. in.
s = 44,000 lbs. per sq. in.
S = 88,000 lbs. per sq. in.
c = 95,000 lbs. per sq. in.

Number of rivets in single shear in a unit length of joint = 1.
Number of rivets in double shear in a unit length of joint = 2.

A = 4.875 × 0.375 × 55,000 = 100,547
B = (4.875 – 0.875) 0.375 × 55,000 = 82,500
C = 2 × 88,000 × 0.6013 + 1 × 44,000 × 0.6013 = 132,286
D = (4.875 – 2 × 0.875) 0.375 × 55,000 + 1 × 44,000 × 0.6013 = 90,910
E = (4.875 – 2 × 0.875) 0.375 × 55,000 + 0.875 × 0.3125 × 95,000 = 90,429
F = 2 × 0.875 × 0.375 × 95,000 + 0.875 × 0.3125 × 95,000 = 88,320
G = 2 × 0.875 × 0.375 × 95,000 + 1 × 44,000 × 0.6013 = 88,800

$\frac{82,500\ (B)}{100,547\ (A)} = 0.820$ = efficiency of joint

A–5 Example: Butt and double strap joint, triple-riveted.

A = strength of solid plate = P × t × TS

B = strength of plate between rivet holes in the outer row = (P–d) t × TS

C = shearing strength of four rivets in double shear, plus the shearing strength of one rivet in single shear = N × S × a + n × s × a

D = strength of plate between rivet holes in the second row, plus the shearing strength of one rivet in single shear in the outer row = (P–2d) t × TS + n × s × a

E = strength of plate between rivet holes in the second row, plus the crushing strength of butt strap in front of one rivet in the outer row = (P–2d) t × TS + d × b × c

F = crushing strength of plate in front of four rivets, plus the crushing strength of butt strap in front of one rivet = N × d × t × c + n × d × b × c

G = crushing strength of plate in front of four rivets, plus the shearing strength of one rivet in single shear = N × d × t × c + n × s × a

Divide B, C, D, E, F or G (whichever is the least) by A, and the quotient will be the efficiency of a butt and double strap joint, triple-riveted, as shown in Fig. A.–4.

TS = 55,000 lbs. per sq. in.
t = ⅜ inch = 0.375 inch
b = 11/16 inch = 0.3125 inch
P = 6½ inch = 6.5 inches
d = 13/8 inch = 0.8125 inch
a = 0.5185 sq. in.
s = 44,000 lbs. per sq. in.
S = 88,000 lbs. per sq. in.
c = 95,000 lbs. per sq. in.

Number of rivets in single shear in a unit length of joint = 1.
Number of rivets in double shear in a unit length of joint = 4.

A = 6.5 × 0.375 × 55,000 = 134,062
B = (6.5 – 0.8125) 0.375 × 55,000 = 117,304
C = 4 × 88,000 × 0.5185 + 1 × 44,000 × 0.5185 = 205,326
D = (6.5 – 2 × 0.8125) 0.375 × 55,000 + 1 × 44,000 × 0.5185 = 123,360
E = (6.5 – 2 × 0.8125) 0.375 × 55,000 + 0.8125 × 0.3125 × 95,000 = 124,667
F = 4 × 0.8125 × 0.375 × 95,000 + 1 × 0.8125 × 0.3125 × 95,000 = 139,902
G = 4 × 0.8125 × 0.375 × 95,000 + 1 × 44,000 × 0.5185 = 138,505

$$\frac{117{,}304\ (B)}{134{,}062\ (A)} = 0.875 = \text{efficiency of joint}$$

A–6 Example: Butt and double strap joint, quadruple-riveted.

A = strength of solid plate = P × t × TS
B = strength of plate between rivet holes in the outer row = (P–d) t × TS
C = shearing strength of eight rivets in double shear, plus the shearing strength of three rivets in single shear = N × S × a + n × s × a
D = strength of plate between rivet holes in the second row, plus the shearing strength of one rivet in single shear in the outer row = (P–2d) t × TS + 1 × s × a
E = strength of plate between rivet holes in the third row, plus the shearing strength of two rivets in the second row in single shear and one rivet in single shear in the outer row = (P–4d) t × TS + n × s × a
F = strength of plate between rivet holes in the second row, plus the crushing strength of butt strap in front of one rivet in the outer row = (P–2d) t × TS + d × b × c

G = strength of plate between rivet holes in the third row, plus the crushing strength of butt strap in front of two rivets in the second row and one rivet in the outer row = (P–4d) t × TS + n × d × b × c
H = crushing strength of plate in front of eight rivets, plus the crushing strength of butt strap in front of three rivets = N × d × t × c + n × d × b × c
I = crushing strength of plate in front of eight rivets, plus the shearing strength of two rivets in the second row and one in the outer row, in single shear = N × d × t × c + n × s × a

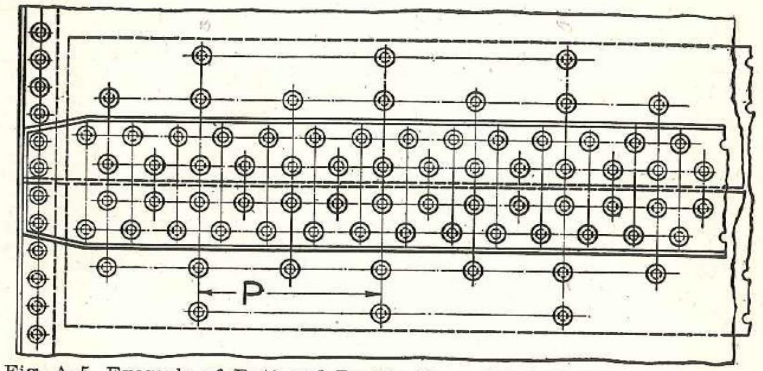


Fig. A–5. Example of Butt and Double Strap Joint, Quadruple-Riveted.

Divide B, C, D, E, F, G, H or I (whichever is the least) by A, and the quotient will be the efficiency of a butt and double strap joint, quadruple-riveted, as shown in Fig. A–5.

TS = 55,000 lbs. per sq. in.
t = ½ in. = 0.5 inch
b = 7/16 inch = 0.4375 inch
P = 15 inches
d = 15/16 inch = 0.9375 inch
a = 0.6903 sq. in.
s = 44,000 lbs. per sq. in.
S = 88,000 lbs. per sq. in.
c = 95,000 lbs. per sq. in.

Number of rivets in single shear in a unit length of joint = 3.
Number of rivets in double shear in a unit length of joint = 8.

A = 15 × 0.5 × 55,000 = 412,500
B = (15–0.9375) 0.5 × 55,000 = 386,718
C = 8 × 88,000 × 0.6903 + 3 × 44,000 × 0.6903 = 577,090
D = (15–2 × 0.9375) 0.5 × 55,000 + 1 × 44,000 × 0.6903 = 391,310

$E = (15\text{–}4 \times 0.9375)\ 0.5 \times 55{,}000 + 3 \times 44{,}000 \times 0.6903 = 400{,}494$

$F = (15\text{–}2 \times 0.9375)\ 0.5 \times 55{,}000 + 0.9375 \times 0.4375 \times 95{,}000 = 399{,}902$

$G = (15\text{–}4 \times 0.9375)\ 0.5 \times 55{,}000 + 3 \times 0.9375 \times 0.4375 \times 95{,}000 = 426{,}269$

$H = 8 \times 0.9375 \times 0.5 \times 95{,}000 + 3 \times 0.9375 \times 0.4375 \times 95{,}000 = 473{,}145$

$I = 8 \times 0.9375 \times 0.5 \times 95{,}000 + 3 \times 44{,}000 \times 0.6903 = 447{,}369$

$\frac{386{,}718\ (B)}{412{,}500\ (A)} = 0.937$ = efficiency of joint

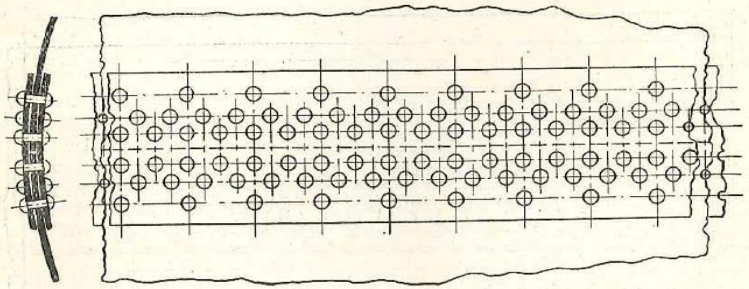


Fig. A–6. Illustration of Butt and Double Strap Joint with straps of equal width.

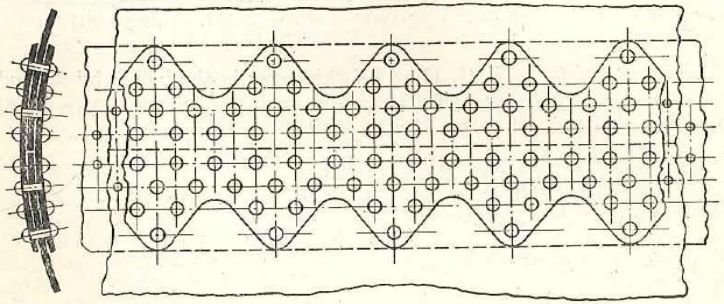


Fig. A–7. Illustration of Butt and Double Strap Joint of the Saw-Tooth Type.

A–7 Figs. A–6 and A–7 illustrate other joints that may be used in which eccentric stresses are avoided. The butt and double strap joint with straps of equal width shown in Fig. A–6 may be so designed that it will have an efficiency of from 82 to 84 per cent and the saw-tooth joint shown in Fig. A–7 so that it will have an efficiency of from 92 to 94 per cent.

LIGAMENTS

A–8 **Efficiency of Ligament.** When a shell or drum is drilled for tubes in a line parallel to the axis of the shell or drum, the efficiency of the ligament between the tube holes shall be determined as follows:

a When the pitch of the tube holes on every row is equal (Fig. A–8), the formula is:

$$\frac{p - d}{p} = \text{efficiency of ligament}$$

where

p = pitch of tube holes, inches
d = diameter of tube holes inches

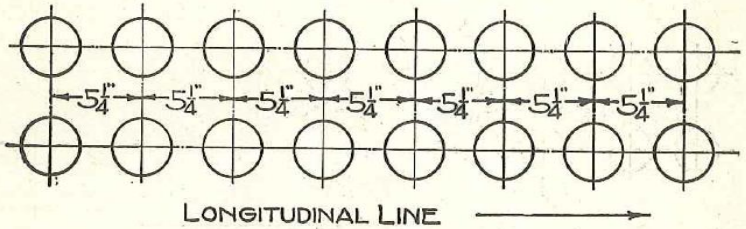


Fig. A–8. Example of Tube Spacing with Pitch of Holes Equal in Every Row.

The pitch of tube holes shall be measured either on the flat plate before rolling, or on the median line after rolling.

Example: Pitch of tube holes in the drum as shown in Fig. A–8 = 5¼ inches, diameter of tubes = 3¼ inches, diameter of tube holes = $3\frac{2}{3}$ inches.

$$\frac{p - d}{p} = \frac{5.25 - 3.281}{5.25} = 0.375, \text{ efficiency of ligament}$$

b When the pitch of the tube holes on any one row is unequal (as in Figs. A–9 or A–10), the formula is:

$$\frac{p - nd}{p} = \text{efficiency of ligament}$$

where

p = unit length of ligament, inches
n = number of tube holes in length, p
d = diameter of tube holes, inches

Example: Spacing shown in Fig. A–9. Diameter of tube holes = $3\frac{2}{3}$ inches.

$$\frac{p - nd}{p} = \frac{12\text{–}2 \times 3.281}{12} = 0.453, \text{ efficiency of ligament}$$

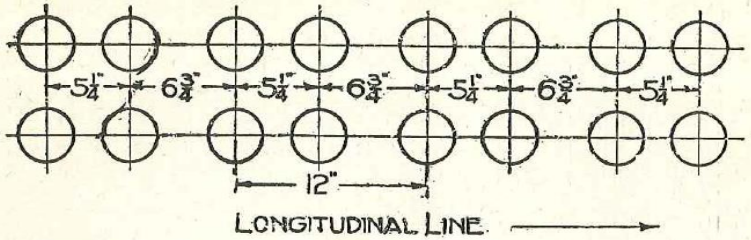


Fig. A–9. Example of Tube Spacing with Pitch of Holes Unequal in Every Second Row.

Example: Spacing shown in Fig. A–10. Diameter of tube holes = $3\frac{8}{32}$ inches.

$$\frac{p - nd}{p} = \frac{29.25 - 5 \times 3.281}{29.25} = 0.439 \text{ efficiency of ligament}$$

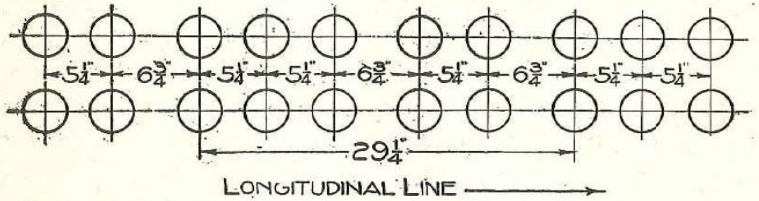


Fig. A–10. Example of Tube Spacing with Pitch of Holes Varying in Every Second and Third Row.

c The strength of those ligaments between the tube holes which are subjected to a longitudinal stress shall be at least one-half the required strength of those ligaments which come between the tube holes which are subjected to a circumferential stress.

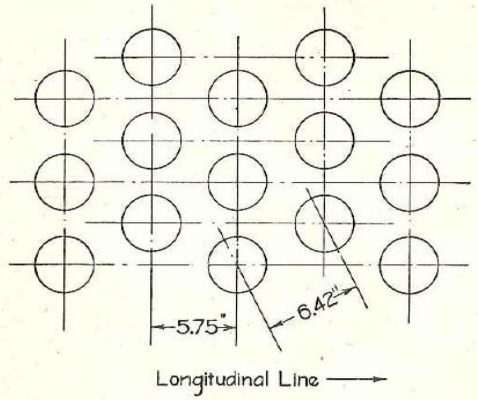


Fig. A–11. Example of Tube Spacing with Tube Holes on Diagonal Lines.

d When a shell or drum is drilled for tube holes so as to form diagonal ligaments as shown in Fig. A–11, the efficiency of these ligaments shall be that given by the diagram, Fig. A–12.

In this diagram the abscissae are $\frac{p}{d}$ and the ordinates $\frac{p'}{p}$ where

p = longitudinal pitch of tube holes, or distance between centers of tubes in a longitudinal row, inches
p' = diagonal pitch of tube holes, inches
d = diameter of tube holes, inches

To use the diagram, Fig. A–12, the values of $\frac{p}{d}$ and $\frac{p'}{p}$ are computed and the efficiency for the corresponding points is read off from the diagram. Should the point fall above the curve of equal efficiency for the diagonal and longitudinal ligaments, the longitudinal ligaments will be the weaker, in which case the efficiency is computed from the following formula:

(1) $$\frac{p - d}{p}$$

Examples: 1st, diagonal pitch of tube holes in drum as shown in Fig. A–11 = 6.42 inches

Diameter of holes = $4\frac{1}{32}$ inches
Longitudinal pitch of tube holes = 11½ inches

$$\frac{p}{d} = \frac{11.5}{4.031} = 2.853$$

$$\frac{p'}{p} = \frac{6.42}{11.5} = 0.558$$

The point corresponding to these values is shown at A on the diagram Fig. A–12, and the corresponding efficiency is 35.3 per cent. As the point falls below the curve of equal efficiency for the diagonal and the longitudinal ligaments, the diagonal ligament is the weaker.

2d, diagonal pitch of tube holes in drum = 6 35/64 inches
Diameter of tube holes = $4\frac{1}{64}$ inches
Longitudinal pitch of tube holes = 7 inches

$$\frac{p}{d} = \frac{7}{4.0156} = 1.743$$

$$\frac{p'}{p} = \frac{6.547}{7} = 0.935$$

The point corresponding to these values is shown at B, and it will be seen that it falls above the line of equal efficiency for the diagonal and longitudinal ligaments, in which case the efficiency is computed from formula (1). Applying formula (1), we have

$$\frac{7 - 4.0156}{7} = 0.426, \text{ efficiency of ligament, or 42.6 per cent.}$$

BRACED AND STAYED SURFACES

A–9 The allowable loads based on net cross-sectional areas of staybolts with V-threads, are computed from the following formula. The use of Whitworth threads with other pitches is permissible.

The formula for the diameter of a staybolt at the bottom of a V-thread is:

$$D - (P \times 1.732) = d$$

where

d = diameter of staybolt at bottom of threads, inches

P = pitch of threads, inches

d = diameter of staybolt at bottom of threads, inches

1.732 = a constant

When U. S. threads are used, the formula becomes $D - (P \times 1.732 \times 0.75) = d$

Tables A–1 and A–2 give the allowable loads on net cross-sectional areas for staybolts with V-threads having 12 and 10 threads per inch.

TABLE A–1. ALLOWABLE LOADS ON STAYBOLTS WITH V-THREADS, 12 THREADS PER INCH

Outside Diameter of Staybolts, Inches		Diameter at Bottom of Thread, Inches	Net Cross-Sectional Area (at Bottom of Thread) Sq. In.	Allowable Load at 7500 lbs. stress, per Sq. In.
3/4	0.7500	0.6057	0.288	2160
13/16	0.8125	0.6682	0.351	2632
7/8	0.8750	0.7307	0.419	3142
15/16	0.9375	0.7932	0.494	3705
1	1.0000	0.8557	0.575	4312
1 1/16	1.0625	0.9182	0.662	4965
1 1/8	1.1250	0.9807	0.755	5662
1 3/16	1.1875	1.0432	0.855	6412
1 1/4	1.2500	1.1057	0.960	7200
1 5/16	1.3125	1.1682	1.072	8040
1 3/8	1.3750	1.2307	1.190	8925
1 7/16	1.4375	1.2932	1.313	9849
1 1/2	1.5000	1.3557	1.444	10830

TABLE A–2. ALLOWABLE LOADS ON STAYBOLTS WITH V-THREADS, 10 THREADS PER INCH

Outside Diameter of Staybolts, Inches		Diameter at Bottom of Thread Inches	Net Cross-Sectional Area (at Bottom of Thread) Sq. In.	Allowable load at 7500 lbs. stress per Sq. In.
1 1/4	1.2500	1.0768	0.911	6832
1 5/16	1.3125	1.1393	1.019	7642
1 3/8	1.3750	1.2018	1.134	8505
1 7/16	1.4375	1.2643	1.255	9412
1 1/2	1.5000	1.3268	1.382	10365
1 9/16	1.5625	1.3893	1.515	11362
1 5/8	1.6250	1.4518	1.655	12412

A–10. Table A–3 shows the allowable loads on net cross-sectional areas of round stays or braces.

TABLE A–3. ALLOWABLE LOADS ON ROUND BRACES OR STAY RODS

Minimum Diameter of Circular Stay, Inches		Net Cross-sectional area of Stay, in Sq. In.	Allowable Stress, in Lbs. per Sq. In., Net Cross-sectional Area		
			6000	8500	9500
			Allowable Load, in Lbs. on Net Cross-sectional Area		
1	1.0000	0.7854	4712	6676	7462
1 1/16	1.0625	0.8866	5320	7536	8423
1 1/8	1.1250	0.9940	5964	8449	9443
1 3/16	1.1875	1.1075	6645	9414	10521
1 1/4	1.2500	1.2272	7363	10431	11658
1 5/16	1.3125	1.3530	8118	11501	12854
1 3/8	1.3750	1.4849	8909	12622	14107
1 7/16	1.4375	1.6230	9738	13796	15419
1 1/2	1.5000	1.7671	10603	15020	16787
1 9/16	1.5625	1.9175	11505	16298	18216
1 5/8	1.6250	2.0739	12443	17628	19702
1 11/16	1.6875	2.2365	13419	19010	21247
1 3/4	1.7500	2.4053	14432	20445	22852
1 13/16	1.8125	2.5802	15481	21932	24512
1 7/8	1.8750	2.7612	16567	23470	26231
1 15/16	1.9375	2.9483	17690	25061	28009
2	2.0000	3.1416	18850	26704	29845
2 1/8	2.1250	3.5466	21280	30147	33693
2 1/4	2.2500	3.9761	23857	33797	37773
2 3/8	2.3750	4.4301	26580	37656	42086
2 1/2	2.5000	4.9087	29452	41724	46632
2 5/8	2.6250	5.4119	32471	46001	51413
2 3/4	2.7500	5.9396	35638	50487	56426
2 7/8	2.8750	6.4918	38951	55181	61673
3	3.0000	7.0686	42412	60083	67152

A–11. Table A–4 gives the net areas of segments of heads for use in computing stays.

TABLE A–4. NET AREAS OF SEGMENTS OF HEADS WHERE d AS GIVEN IN ORDERS 4335 AND 4338 IS EQUAL TO 3 INCHES

Height from Tubes to Shell, Inches	Diameter of Boiler, Inches												
	24	30	36	42	48	54	60	66	72	78	84	90	96
	Area to be Stayed, Sq. In.												
8	28	33	37	40	43	47	51	53	55	58	60	63	65
8½	35	41	46	51	55	59	63	66	70	74	76	80	82
9	42	49	56	62	67	72	76	82	86	90	92	95	98
9½	50	58	66	70	80	86	91	96	101	105	111	116	119
10	57	68	77	85	93	99	106	112	117	123	129	132	137
10½	66	78	89	98	107	114	123	131	135	142	147	153	160
11	74	88	100	111	121	130	138	147	155	161	169	174	183
11½	83	99	112	124	137	146	156	165	173	181	189	196	204
12	91	109	125	139	151	163	174	184	194	203	213	219	230
12½	----	120	138	153	167	180	193	204	216	224	234	243	252
13	----	132	151	168	183	197	211	224	235	247	256	267	279
13½	----	143	164	183	200	216	230	246	258	270	282	293	302
14	----	155	178	199	217	234	250	266	280	294	305	319	331
14½	----	167	192	215	235	254	271	287	303	318	333	345	360
15	----	178	206	231	252	273	291	309	326	343	357	372	386
15½	----	------	220	247	271	291	312	332	350	368	382	400	417
16	----	------	235	263	289	312	334	355	374	394	411	423	443
16½	----	------	249	281	308	332	357	380	399	420	436	457	475
17	----	------	264	297	326	353	378	402	425	447	467	486	502
17½	----	------	------	314	345	374	400	426	449	471	494	516	536
18	----	------	------	331	365	396	424	450	476	500	520	543	564
18½	----	------	------	349	384	417	448	476	501	526	552	577	598
19	----	------	------	366	404	439	470	500	529	555	580	604	631
19½	----	------	------	384	424	461	496	528	558	584	613	641	663
20	----	------	------	401	444	483	519	552	583	613	642	667	699
20½	----	------	------	------	464	505	543	578	613	643	675	706	729
21	----	------	------	------	485	528	568	604	640	673	705	733	766
21½	----	------	------	------	505	551	594	632	669	703	739	766	797
22	----	------	------	------	526	574	618	658	697	734	769	800	835
22½	----	------	------	------	------	597	643	687	726	765	800	835	867
23	----	------	------	------	------	620	668	713	754	796	830	869	906
23½	----	------	------	------	------	642	695	740	784	827	866	904	945
24	----	------	------	------	------	667	719	768	814	859	897	939	978
24½	----	------	------	------	------	689	745	797	843	892	934	975	1018
25	----	------	------	------	------	714	771	825	875	922	966	1010	1051
25½	----	------	------	------	------	737	798	855	907	956	1003	1047	1092
26	----	------	------	------	------	761	824	882	936	987	1035	1083	1126
26½	----	------	------	------	------	------	850	909	968	1024	1073	1120	1167
27	----	------	------	------	------	------	877	939	998	1053	1106	1157	1202
27½	----	------	------	------	------	------	904	968	1030	1089	1145	1195	1243
28	----	------	------	------	------	------	930	997	1060	1120	1177	1232	1279
28½	----	------	------	------	------	------	------	1028	1092	1157	1211	1270	1321
29	----	------	------	------	------	------	------	1056	1123	1187	1248	1305	1360
29½	----	------	------	------	------	------	------	1084	1155	1221	1284	1347	1400
30	----	------	------	------	------	------	------	1115	1187	1255	1321	1382	1442
30½	----	------	------	------	------	------	------	------	1218	1290	1358	1424	1480
31	----	------	------	------	------	------	------	------	1252	1324	1394	1459	1523
31½	----	------	------	------	------	------	------	------	1286	1359	1433	1496	1561
32	----	------	------	------	------	------	------	------	1317	1394	1467	1538	1605
32½	----	------	------	------	------	------	------	------	------	1430	1508	1575	1650
33	----	------	------	------	------	------	------	------	------	1465	1542	1617	1687
33½	----	------	------	------	------	------	------	------	------	1500	1578	1655	1733
34	----	------	------	------	------	------	------	------	------	1536	1617	1695	1770
34½	----	------	------	------	------	------	------	------	------	------	1654	1735	1816
35	----	------	------	------	------	------	------	------	------	------	1692	1775	1856
35½	----	------	------	------	------	------	------	------	------	------	------	1810	1900
36	----	------	------	------	------	------	------	------	------	------	------	1857	1941
36½	----	------	------	------	------	------	------	------	------	------	------	------	1984
37	----	------	------	------	------	------	------	------	------	------	------	------	2026

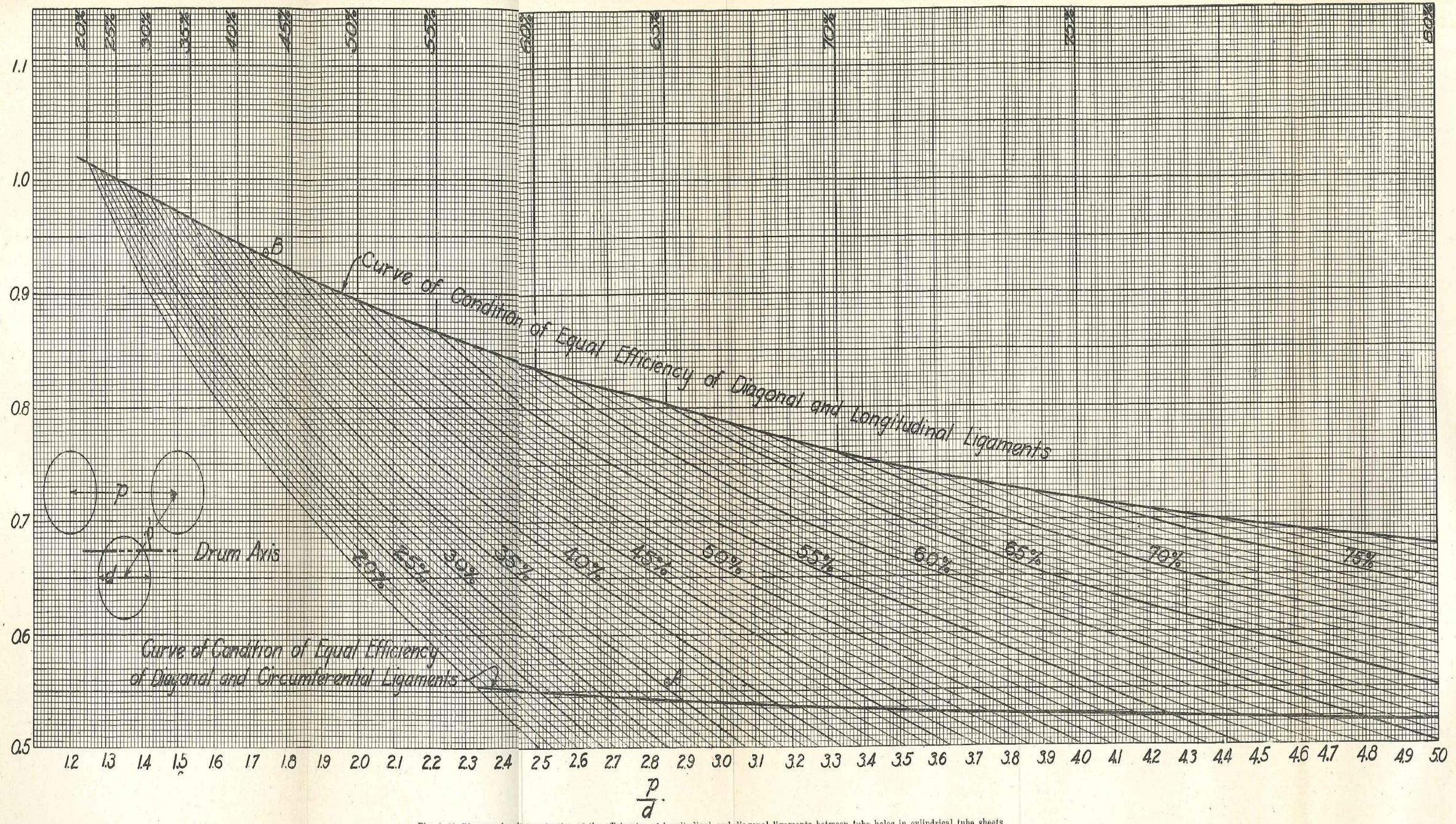


Fig. A–12. Diagram for dietermination of the efficiencies of longitudinal and diagonal ligaments between tube holes in cylindrical tube sheets.

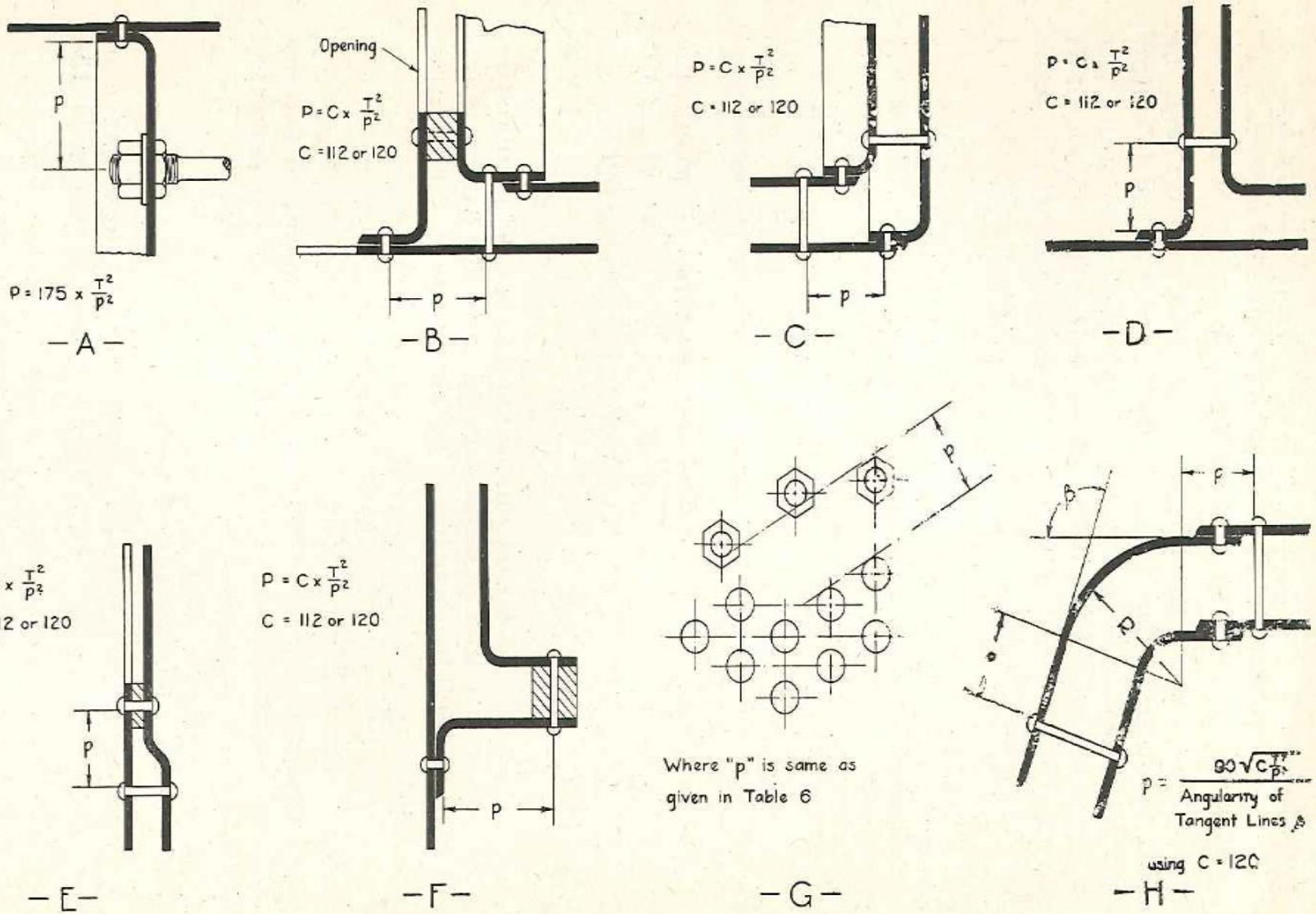


Fig. A–13. Details Showing Application of orders 4326 and 4327 to the Staying of Boilers.

Method of Checking the Safety Valve Capacity by Measuring the Maximum Amount of Fuel That Can Be Burned

A–13 The maximum quantity of fuel C that can be burned per hour at the time of maximum forcing is determined by a test. The maximum number of heat units per hour, or C × H is then determined, using the values of H given in A–18. The weight of steam generated per hour is found by the formula:

$$W = \frac{C \times H \times 0.75}{1100}$$

where

W = weight of steam generated per hour, lbs.
C = total weight or volume of fuel burned per hour at time of maximum forcing, lbs. or cu. ft.
H = heat of combustion of fuel, B.t.u. per lb. or per cu. ft. (See A–18)

The sume of the safety valve capacities marked on the valves shall be equal to or greater than W.

A–14 Example 1: A boiler at the time of maximum forcing uses 2150 lbs. of Illinois coal per hour of 12,100 B.t.u. per lb. Boiler pressure, 225 lbs. per sq. in. gage.

$C \times H = 2150 \times 12{,}100 = 26{,}015{,}000$
$W = C \times H \times 0.75 \div 1100 = 17{,}740$

A–15 Example 2: Wood shavings of heat of combustion of 6400 B.t.u. per lb. are burned under a boiler at the maximum rate of 2000 lbs. per hour. Boiler pressure, 100 lbs. per sq. in. gage.

$C \times H = 2000 \times 6400 = 12{,}800{,}000$
$W = C \times H \times 0.75 \div 1100 = 8730$

A–16 Example 3: An oil-fired boiler at maximum forcing uses 1000 lbs. of crude oil (Texas) per hour. Boiler pressure, 275 lbs. per sq. in. gage.

$C \times H = 1000 \times 18{,}500 = 18{,}500{,}000$
$W = C \times H \times 0.75 \div 1100 = 12{,}620$

A–17 Example 4: A boiler fired with natural gas consumes 3000 cu. ft. per hour. The working pressure is 150 lbs. per sq. in gage.

$C \times H = 3000 \times 960 = 2{,}800{,}000$
$W = C \times H \times 0.75 \div 1100 = 1960$

A–18 For the purpose of checking the safety valve capacity as described in A–13, the following values of heats of combustion of various fuels may be used:

	H = B.t.u. per lb.
Semi-bituminous coal	14,500
Anthracite	13,700
Screenings	12,500
Coke	13,500
Wood, hard or soft, kiln dried	7,700
Wood, hard or soft, air dried	6,200
Wood shavings	6,400
Peat, air dried, 25 per cent moisture	7,500
Lignite	10,000
Kerosene	20,000
Petroleum, crude oil, Penn.	20,700
Petroleum, crude oil, Texas	18,500

	H = B.t.u. per cu. ft.
Natural gas	960
Blast-furnace gas	100
Producer gas	150
Water gas, uncarbureted	290

Automatic Water Gages

A–19 Automatic shut-off valves on water gages, if permitted to be used, shall conform to the following requirements:

a. Check valves in upper and lower fittings must be of the solid non-ferrous ball type to avoid corrosion and the necessity for guides.
b. Ball check valves in upper and lower fittings must open by gravity and the lower ball check valve must rise vertically to its seat.
c. The check balls must not be smaller than ½ inch diameter, and the diameter of the circle of contact with the seat must not be greater than ⅔ of the diameter of the check ball. The space around each ball must not be less than ⅛ inch and the travel movement from the normal resting place to the seat must not be less than ¼ inch.
d. The ball seat in the upper fitting must be a flat seat with either a square or hexagonal opening, or otherwise arranged so that the steam passage can never be completely closed by this valve.

e. The shut-off valve in the upper fitting must have a projection which holds the ball at least ¼ inch away from its seat when the shut-off valve is closed.

f. The balls must be accessible for inspection. Means must be provided for removal and inspection of the lower ball check valve, while the boiler is under steam pressure.

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Where "A" precedes a number reference will be found in the appendix