# CERTIFICATE

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## THE UNITED STATES OF AMERICA
## Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. ***HEED THIS NOTICE***: Criminal penalties may apply for noncompliance.

**Document Name:** ASME UPV: Code for Unfired Pressure Vessels

**CFR Section(s):** 49 CFR 173.32(c)(4)

**Standards Body:** American Society of Mechanical Engineers

APPROVED

*Official Incorporator:*
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

A.S.M.E. CODE

# Unfired Pressure Vessels

1943

R R Banks
May 15, 1946

## NEW NUMBERS FOR MATERIAL SPECIFICATIONS

Beginning with the 1943 Edition of Section II of the Code, all Material Specification numbers will be changed to correspond with the A.S.T.M. numbers with the prefix letter S. For your convenience there is given below a list showing their new specification numbers and the corresponding old specification numbers.

| New Number | Old Number | New Number | Old Number |
|---|---|---|---|
| S-4 | S-4 | SB-11 | S-20 |
| SA-7 | S-7 | SB-12 | S-21 |
| SA-18 | S-10 | SB-13 | S-22 |
| SA-27 | S-11 | SB-25 | S-38 |
| SA-30 | S-53 | SB-42 | S-23 |
| SA-31 | S-5 | SB-43 | S-24 |
| SA-47 | S-15 | SB-61 | S-41 |
| SA-48 | S-13 | SB-62 | S-46 |
| SA-53 | S-18 | SB-75 | S-66 |
| SA-70 | S-1 | SB-96 | S-36 |
| SA-72 | S-19 | SB-98 | S-37 |
| SA-83 | S-17 | SB-111 | S-47 |
| SA-84 | S-16 | SB-126 | S-39 |
| SA-89 | S-2 | SB-127 | S-54 |
| SA-96 | S-9 | | |
| SA-105 | S-8 | | |
| SA-129 | S-25 | | |
| SA-135 | S-58 | | |
| SA-157 | S-33 | | |
| SA-158 | S-34 | | |
| SA-176 | S-61 | | |
| SA-178 | S-32 | | |
| SA-181 | S-50 | | |
| SA-182 | S-35 | | |
| SA-192 | S-40 | | |
| SA-194 | S-51 | | |
| SA-201 | S-42 | | |
| SA-202 | S-28 | | |
| SA-203 | S-43 | | |
| SA-204 | S-44 | | |
| SA-206 | S-45 | | |
| SA-209 | S-48 | | |
| SA-210 | S-49 | | |
| SA-212 | S-55 | | |
| SA-213 | S-52 | | |
| SA-216 | S-56 | | |
| SA-217 | S-57 | | |
| SA-225 | S-60 | | |
| SA-233 | S-63 | | |
| SA-240 | S-62 | | |
| SA-249 | S-64 | | |
| SA-250 | S 65 | | |

# RULES *for* CONSTRUCTION *of*

# UNFIRED PRESSURE VESSELS

## SECTION VIII

## A.S.M.E. BOILER CONSTRUCTION CODE

*1943 Edition*

*Report of Subcommittee of Boiler Code Committee on Unfired Pressure Vessels*

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

29 WEST THIRTY-NINTH STREET

NEW YORK 18, N. Y.

Printed in the United States of America
Adopted by the Council of The American Society of Mechanical Engineers, 1925.
Revised 1927, 1930, 1931, 1932, 1934, 1935, 1937, 1940, 1943.

# FOREWORD

In 1911 The American Society of Mechanical Engineers appointed a committee to formulate standard specifications for the construction of steam boilers and other pressure vessels and for their care in service, which committee has since come to be known as the Boiler Code Committee. Specifications for materials used in such constructions have been adopted and included.

As the primary object of these rules is safety, the interests of users of boilers and pressure vessels are of paramount importance. The rules have been formulated to afford reasonably certain protection of life and property and to provide a margin for deterioration in service so as to give a reasonably long, safe period of usefulness. The interests of manufacturers have also been recognized by taking into consideration advancements in design and material and the evidence of experience.

The Committee's function is the formulation of such rules and the interpretation thereof when the intent is not clearly indicated. Revisions and adoption of new rules are given consideration at regular intervals to provide for progress in the art and the use of other materials. Proposed new rules and revisions, prior to adoption, are published in Mechanical Engineering soliciting study and consideration by all interested parties.

The Boiler Code Committee does not approve, recommend, or endorse proprietary or specific designs, nor does it assume to limit in any way the builders' right to choose any method of design, or form of construction that conforms to the code rules.

The Committee meets at regular intervals for the purpose of considering inquiries relative to the Boiler Code. The ordinary procedure and handling of each case is as follows: All inquiries must be in written form and complete in detail before they are accepted for consideration. The inquiry is referred to the proper subcommittee to report its recommendation at the next or subsequent meeting of the Main Committee. The matter is then acted upon by the Main Committee at its meeting and also by letter ballot. If of general interest the reply is made by published interpretation, otherwise by letter communication. If an interpretation is approved by the Main Committee, it is submitted to the Council of the Society for its approval, after which it is issued to the inquirer and simultaneously published in Mechanical Engineering.

Each state and municipality that has accepted one or more of the sections of the Boiler Code is invited to appoint a representative to act on the Conference Committee to the Boiler Code Committee. Since the members of the Conference Committee are in active contact with the administration and enforcement of the rules, the requirements for inspections in Par. P-332 and similar paragraphs in other sections of the Code correspond with those in effect in their respective jurisdictions. The required qualifications for an authorized inspector under these rules may be obtained from the administrative authority of any state which has adopted these rules.

The National Board of Boiler and Pressure Vessel Inspectors is composed of chief inspectors of states and municipalities that have adopted the Boiler Code. This Board, since its organization in 1919, has functioned to administer uniformly and enforce the rules of the Boiler Code. The cooperation of that organization with the Boiler Code Committee has been extremely helpful. Its function is clearly recognized and, as a result, inquiries received which bear on the administration or application of the rules are referred directly to the National Board. Such handling of this type of inquiries not only simplifies the work of the Boiler Code Committee, but action on the problem for the inquirer is thereby expedited. Where an inquiry is not clearly an interpretation of the rules, nor a problem of application or administration, it may be considered both by the Boiler Code Committee and the National Board.

It should be pointed out that the state or municipality where the Boiler Code has been made effective has definite jurisdiction over any particular installation. Inquiries dealing with problems of local character should be directed to the proper authority of such state or municipality. Such authority may, if there is any question or doubt as to the proper interpretation, refer the question to the Boiler Code Committee.

The specifications for materials given in Section II of the code are identical with or similar to those of the American Society for Testing Materials as indicated, except in those cases where that organization has no corresponding specification.

The Boiler Code Committee is deeply indebted to the American Society for Testing Materials, American Welding Society, U. S. Bureau of Marine Inspection and Navigation (now under the U. S. Coast Guard), A.S.M.E. Special Research Committee on the Strength of Vessels Under External Pressure, Special Committee on Rules for Bolted Flanged Connections, and other similar organizations and committees, for their cooperation in the formulation of these rules.



*June, 1944*

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# A.S.M.E. BOILER CONSTRUCTION CODE

## SECTION VIII

## UNFIRED PRESSURE VESSELS

*These rules are not intended to apply (a) to pressure vessels which are subject to Federal control, (b) to locomotives of all types, (c) to vessels for containing only water under pressure for domestic supply including those containing air, the compression of which serves only as a cushion or in air-lift pumping systems, (d) to vessels for flammable liquids and for gases at temperatures of over 300 F, (e) to vessels subject to collapsing pressures of 15 lb or less.*

*The Code does not contain rules to cover all details of design and construction. Where complete details are not given, it is intended that the manufacturer, subject to the approval of the authorized inspector, shall provide details of design and construction which will be as safe as otherwise provided by the rules in the Code.*

*These rules are intended to apply to vessels for pressures not exceeding a range of 2500 to 3000 psi. It is recognized that for higher pressures certain deviations or additional requirements may be necessary in view of the greater thicknesses and fabrication limits involved.*

**U-1** (a) The rules of this section apply to all unfired pressure vessels except those having an external or internal pressure of 15 psi or less, irrespective of size, or having an inside diameter of 6 in. or less, irrespective of pressure.

Compliance with Par. U-65 is not required for vessels of:

(1) 5 cu ft capacity or less designed for pressures not exceeding 250 lb pressure;

(2) $1^1/_2$ cu ft capacity or less designed for pressures exceeding 250 lb pressure,

but such vessels shall be stamped with the data required in Fig. U-13 omitting the Code symbol and, if welded, the welding operators shall be qualified in accordance with the requirements of this section of the Code, in the presence of an authorized inspector.

When requested, certificates for such noninspected vessels shall be furnished as shown on form U-3.

The foregoing limitations apply to each single vessel and not to an assembly of vessels.

Vessels below the above limits may, if it is so desired, be inspected and stamped with the Code symbol as provided in Pars. U-65 and U-66.

All vessels, irrespective of size or pressure, shall be equipped with safety devices in accordance with the requirements of this section of the Code.

(b) In the absence of definite rules in this section on the construction of unfired pressure vessels, the specific provisions of Section I of the Code may be used wherever they apply, and the vessel may then be stamped as conforming with the Code.

(c) This section of the Code does not cover all types of vessels. The Code symbol shall not be applied to any vessel the material for the pressure parts of which does not all comply with the Code rules or the type of construction is not sanctioned by the rules.

(d) A vessel may be designed and constructed by a combination of the types of construction given in the Code provided that the rules applying to each type of construction are followed and the vessel is stamped as may be required by the Code to indicate the most restrictive construction requirements that have been used in its fabrication.

Such a vessel should be limited to the service permitted by that detail of construction having most restrictive requirements.

**U-2** (a) All pressure vessels shall be protected by such safety and relief valves, and indicating and controlling devices, as will insure their safe operation. These devices shall be so constructed, located, and installed that they cannot readily be rendered inoperative. The relieving capacity of safety valves shall be such as to prevent a rise of pressure in the vessel of more than 10 per cent above the maximum allowable working pressure and their discharges shall be carried to a safe place.

(b) Safety valves shall be connected to a vessel in the vapor space above any contained liquid. Additional liquid relief valves may be connected below the normal liquid level if a vessel is to contain liquid, and such relief valves may be set higher than the maximum allowable working pressure (See Par. U-19).

(c) An unfired pressure vessel which generates steam for power or heat to be used externally to itself shall be classed as an unfired steam boiler. Such vessels may be constructed under the appropriate classification of this section of the Code and shall be equipped with the safety devices required by Section I of the Code in so far as they are applicable to the service of the particular installation.

(d) The dial of a pressure gage shall be graduated to approximately double the pressure at which the relieving device is set to function but in no case less than $1^1/_2$ times that pressure.

## SAFETY VALVES FOR STEAM AND AIR

**U-3** (a) Safety valves for use on steam or air shall be of the direct spring-loaded type with a substantial lifting device so that the disk can be lifted from its seat when the pressure of the vessel is 75 per cent of that at which the safety valve is set to blow. Seats or disks of cast iron shall not be used.

(b) Each safety valve for use on steam or air, $^1/_2$ in. in size and larger, shall be plainly marked by the manufacturer in such a way that the marking 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 data:

(1) Name or identifying trademark of the manufacturer
(2) Size......in.
(Pipe size of valve inlet)
(3) Pressure......lb
(Pressure at which valve is set to blow)
(4) Relieving capacity......lb per hr for steam, and cubic feet per minute for air (valves for use on air tanks).

Note: For other substances than steam or air, the relieving capacities need not be stated.

**U-4** The pressure at which a safety valve is set to operate shall not be in excess of the maximum allowable working pressure stamped on the vessel.

**U-5** If more than one safety valve is used, the discharge capacity shall be taken as the combined capacity of all valves.

**U-6** (a) For vessels in which the pressure is not generated but is derived from an outside source, each safety valve shall be so connected to the vessel, vessels, or system which it protects as to prevent a rise in pressure, while the safety valves are blowing, of more than 10 per cent above the maximum allowable working pressure (See Par. U-2) in any vessel protected by the safety valve.

(b) For vessels in which pressure may be generated, the safety valve or valves must be connected directly to the vessel which is to be protected or to a pipe line leading to the vessel; the internal cross-sectional area of the pipe line shall be not less than the nominal area of the safety valve or valves used, and without any intervening valve between the vessel and the safety valve or valves protecting it. All vessels, the contents of which are likely to cause interference with the operation of a safety valve if attached directly to the vessel, shall have the safety valve or valves connected in such manner as to avoid such interference. When an escape pipe is used, it shall be full-sized and fitted with an open drain to prevent liquid from lodging in the upper part of the safety valve, and no valve of any description shall be placed on the escape pipe between the safety valve and the atmosphere. When an elbow is placed on an escape pipe, it shall be located close to the safety-valve outlet, or the escape pipe shall be securely anchored and supported. When two or more safety valves are placed on one connection, this connection shall have a cross-sectional area at least equal to the combined area of these safety valves.

**U-7** Every safety valve which is exposed to a temperature of 32 F, or less, shall have a drain at least $^3/_8$ in. in diameter at the lowest point where water can collect, except that safety valves $^3/_4$ in. in size and less may have drain holes as large as possible but not less than $^3/_{16}$ in. in diameter.

**U-8** Safety-valve springs shall not be adjusted to carry more than 10 per cent greater pressure than that for which the springs were made.

(*Par. U-9 has been omitted*)

**U-10** Safety valves for compressed-air tanks shall not exceed 3 in. in diameter and shall be proportioned for the maximum number of cubic feet of free air that can be supplied per minute.

## CORROSIVE SUBSTANCES

**U-11** (a) All pressure vessels which are to contain substances having a corrosive action upon the metal of which the vessel is constructed, or those subjected to erosion or mechanical abrasion, shall be designed for the pressure they are to carry, and the thickness of all parts subject to corrosion, erosion, or abrasion should be increased by a uniform amount to safeguard against early rejection.

(b) Where a vessel goes into corrosive service without previous service experience, it is recommended that service inspections be made at frequent intervals until the nature and rate of corrosion in service can be definitely established. The data thus secured should determine the subsequent intervals between service inspections and the probable safe operating life of the vessel.

## MATERIALS

**U-12** (**a**) All materials used in the construction of unfired pressure vessels for which specifications are given in Section II of the Code shall conform to such requirements, except that cast, forged, or rolled parts of small size for which it is difficult or impossible to obtain identified material, or which may be stocked and for which mill test reports or certificates cannot be economically obtained and are not customarily furnished, may be used for relatively unimportant parts or parts stressed to not more than 50 per cent of the stresses permitted by the Code, which do not appreciably affect the safety of the vessel, provided they are suitable for the purpose intended and meet the approval of the inspector.

(**b**) If, in the development of the art of pressure-vessel construction, it is desired to use materials other than those herein described, data should be submitted to the Boiler Code Committee in accordance with Pars. UA-71 to UA-81.

**U-13** (**a**) Plates for any part of a riveted vessel required to resist stress produced by internal pressure shall be of flange or firebox quality steel conforming with one of the following specifications, except as provided in (**c**):

| | |
|---|---|
| SA-30 | Specifications for Boiler and Firebox Steel for Locomotives |
| SA-70 | Specifications for Carbon-Steel Plates for Stationary Boilers and Other Pressure Vessels |
| SA-89 | Specifications for Steel Plates of Flange and Firebox Qualities for Forge Welding |
| SA-129 | Specifications for Open-Hearth Iron Plates of Flange Quality |
| SA-201 | Specifications for Carbon-Silicon-Steel Plates of Ordinary Tensile Ranges for Fusion-Welded Boilers and Other Pressure Vessels |
| SA-202 | Specifications for Chrome-Manganese-Silicon (CMS) Alloy-steel Plates for Boilers and Other Pressure Vessels |
| SA-203 | Specifications for Low-Carbon-Nickel-Steel Plates for Boilers and Other Pressure Vessels |

SA-204 Specifications for Molybdenum-Steel Plates for Boilers and Other Pressure Vessels
SA-212 Specifications for High-Tensile Strength Carbon-Silicon-Steel Plates for Boilers and Other Pressure Vessels (Plates $4^1/_2$ In. and Under in Thickness)
SA-225 Specifications for Manganese-Vanadium Steel Plates for Boilers and Other Pressure Vessels

(**b**) If desired, both flange and firebox steel of lower tensile strength than specified may be used for an entire vessel or part thereof, the desired tensile limits to be specified with a range of 10,000 psi. All such steel shall conform to Specification SA-70 except for the tensile limits.

(**c**) Steel plates for any part of a pressure vessel which is to be constructed with other than riveted joints shall be of the quality specified for the particular kind of joint used, except that when steel conforming to Specification SA-212 is employed for the construction of unstress-relieved vessels under the requirements of Par. U-69:

(**1**) It shall be of firebox quality;
(**2**) The maximum thickness of the shell plate or of a multipiece head shall not exceed 1 in.;
(**3**) The thickness of a head formed from a single plate shall not exceed 1 in. at the circumferential joint;
(**4**) The carbon content from check analyses taken from the two tension-test specimens shall not exceed 0.31 per cent.

These requirements do not apply when the vessel is to be stress-relieved, except that in any case the requirements of Par. U-76(**b**) shall be met.

Vessels made under the requirements of Pars. U-69 or U-70 from material conforming to Specifications SA-202 Grade A, SA-203, SA-204, or SA-225, shall be stress-relieved for all thicknesses.

(**d**) Cast steel may be used for specially shaped parts of vessels to which the use of rolled plates is not adapted.

(**e**) Ferrous tubes conforming with any one of the following specifications may be used in unfired pressure vessels:

SA-83 Specifications for Lap-Welded and Seamless Steel and Lap-Welded Iron Boiler Tubes
SA-178 Specifications for Electric-Resistance Welded Steel and Open-Hearth Iron Boiler Tubes
SA-192 Specifications for Seamless Steel Boiler Tubes for High-Pressure Service
SA-209 Specifications for Seamless Carbon-Molybdenum Alloy-Steel Boiler and Superheater Tubes

SA-210 Specifications for Medium-Carbon Seamless Steel Boiler and Superheater Tubes
SA-214 Specifications for Electric-Resistance-Welded Steel Heat-Exchanger and Condenser Tubes
SA-226 Specifications for Electric-Resistance-Welded Steel Boiler and Superheater Tubes for High-Pressure Service
SA-249 Specifications for Atomic-Hydrogen-Arc-Welded and Electric-Resistance-Welded Alloy-Steel Boiler and Superheater Tubes
SA-250 Specifications for Electric-Resistance-Welded Carbon Molybdenum Alloy-Steel Boiler and Superheater Tubes

(f) Open-hearth steel pipe or steel tubing in accordance with one of the following specifications may be used for the pressure part of an unfired pressure vessel provided the nominal diameter of the welded pipe or tubing is not greater than 18 in., or seamless tube or pipe not greater than 24 in.:

SA-53 Specifications for Welded and Seamless Steel Pipe
SA-72 Specifications for Welded Wrought-Iron Pipe
SA-83 Specifications for Lap-Welded Seamless and Lap-Welded Iron Boiler Tubes
SA-106 Specifications for Lap-Welded and Seamless Steel Pipe for High-Temperature Service
SA-135 Specifications for Electric-Resistance-Welded Steel Pipe
SA-178 Specifications for Electric-Resistance-Welded Steel and Open-Hearth Iron Boiler Tubes
SA-192 Specifications for Seamless Steel Boiler Tubes for High-Pressure Service
SA-206 Specifications for Seamless Carbon Molybdenum Alloy-Steel Pipe for Service at Temperatures from 750 to 1000 F
SA-209 Specifications for Seamless Carbon-Molybdenum Alloy-Steel Boiler and Superheater Tubes
SA-210 Specifications for Medium-Carbon Seamless Steel Boiler and Superheater Tubes
SA-214 Specifications for Electric-Resistance-Welded Steel Heat-Exchanger and Condenser Tubes
SA-226 Specifications for Electric-Resistance-Welded Steel Boiler and Superheater Tubes for High-Pressure Service
SA-249 Specifications for Atomic-Hydrogen-Arc-Welded and Electric-Resistance-Welded Alloy-Steel Boiler and Superheater Tubes
SA-250 Specifications for Electric-Resistance-Welded Carbon-Molybdenum Alloy-Steel Boiler and Superheater Tubes

(g) Nonferrous tubes conforming with Specification SB-111 for Copper and Copper-Alloy Seamless Condenser Tubes and Ferrule Stock may be expanded or threaded into unfired pressure vessels.

(h) Unfired pressure vessels may be constructed wholly or in part of cast iron which meets the requirements of Specification SA-48 under the following conditions:

(1) Such vessels must not be used as containers of lethal liquids or gases;

(2) The pressure shall not exceed 160 psi, or the temperature shall not exceed 450 F for steam or other gases, or 375 F for liquids except that:

(a) Such vessels constructed wholly or in part of cast iron and used for the circulation or storage of liquids at a temperature not to exceed 120 F may be used for pressures not exceeding 200 psi;

(b) Cast iron pipe fittings conforming to the requirements of the several American Standards for cast iron fittings may be used as a whole or a part of such pressure vessels for temperatures not exceeding 450 F and for pressures not exceeding the American Standard ratings.

(3) Working stresses for the several classes of cast iron as given below shall be used in applying those formulas of the Code that are applicable to the design of cast iron parts:

| Class | Maximum Tension | Maximum Bending | Maximum Compression |
|---|---|---|---|
| 20 | 2000 | 3000 | 4000 |
| 25 | 2500 | 3750 | 5000 |
| 30 | 3000 | 4500 | 6000 |
| 35 | 3500 | 5250 | 7000 |
| 40 | 4000 | 6000 | 8000 |

(4) Ample fillets at all corners shall be provided and abrupt changes in shape and thickness shall be avoided.

(5) Such cast iron pressure vessels for use under conditions in 2(a) shall be subjected to a minimum hydrostatic test pressure of $1^1/_2$ times the maximum allowable working pressure.

(6) All other such cast iron pressure vessels or cast iron parts shall be hydrostatically tested to 2 times the maximum allowable working pressure, except that for working pressures less than 30 lb the test pressure shall be $2^1/_2$ times the working pressure but not to exceed 60 psi.

(7) Screwed fittings of cast iron or malleable iron and conforming to the requirements of the Standards for 125, 150, 250, and 300 lb pressure as referred to in Table UA-6 may be used except where otherwise specifically prohibited or where flanged fittings are specifically required. They shall not be used for temperatures over 450 F.

(i) Bolted flanged connections of cast iron for connection to external piping shall conform where possible to the several American Standards for cast iron flanges given in Tables UA-3 and UA-4.

TABLE U-2 MAXIMUM ALLOWABLE WORKING STRESSES FOR FERROUS MATERIALS IN POUNDS PER SQUARE INCH

| Specification number | Grade | Spec. minimum tensile | Notes and limitations | For metal temperatures not exceeding deg F: −20 to 650 | 700 | 750 | 800 | 850 | 900 | 950 | 1000 | 1050 | 1100 | 1150 | 1200 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PLATE STEELS | | | | | | | | | | | | | | | |
| Carbon Steel | | | | | | | | | | | | | | | |
| SA-30 | Flange | 55000 | | 11000 | 10400 | 9500 | 8000 | 6300 | ... | ... | ... | .. | .. | .. | .. |
| SA-30 | Firebox Grade A | 52000 | | 10400 | 9850 | 9000 | 7700 | 6100 | 4400 | 2600 | 1350 | .. | .. | .. | .. |
| SA-30 | Firebox Grade B | 48000 | | 9600 | 9100 | 8250 | 7250 | 5850 | 4400 | 2600 | 1350 | .. | .. | .. | .. |
| SA-70 | .. | 55000 | (1) | 11000 | 10400 | 9500 | 8000 | 6300 | 4400 | 2600 | 1350 | .. | .. | .. | .. |
| SA-89 | A | 45000 | (1) | 9000 | 8800 | 8400 | 6900 | 5700 | 4400 | 2600 | 1350 | .. | .. | .. | .. |
| SA-89 | B | 50000 | (1) | 10000 | 9600 | 9000 | 7500 | 6000 | 4400 | 2600 | 1350 | .. | .. | .. | .. |
| SA-201 | A | 55000 | | 11000 | 10400 | 9500 | 8500 | 7200 | 5600 | 3800 | 2000 | .. | .. | .. | .. |
| SA-201 | B | 60000 | | 12000 | 11400 | 10400 | 9100 | 7400 | 5600 | 3800 | 2000 | .. | .. | .. | .. |
| SA-212 | A | 65000 | | 13000 | 12300 | 11100 | 9400 | 7600 | 5600 | 3800 | 2000 | .. | .. | .. | .. |
| SA-212 | B | 70000 | | 14000 | 13300 | 11900 | 10000 | 7800 | 5600 | 3800 | 2000 | .. | .. | .. | .. |
| Low-Alloy Steels | | | | | | | | | | | | | | | |
| SA-202 | A | 75000 | | 15000 | 14100 | 12400 | 10100 | 7800 | 5600 | 3800 | 2000 | .. | .. | .. | .. |
| SA-202 | B | 85000 | | 15000 | 14100 | 12400 | 10100 | 7800 | 5600 | 3800 | 2000 | .. | .. | .. | .. |
| SA-203 | A | 65000 | | 13000 | 12300 | 11100 | 9400 | 7600 | 5600 | 3800 | 2000 | .. | .. | .. | .. |
| SA-203 | B | 70000 | | 14000 | 13300 | 11900 | 10000 | 7800 | 5600 | 3800 | 2000 | .. | .. | .. | .. |
| SA-203 | C | 75000 | | 15000 | 14100 | 12400 | 10100 | 7800 | 5600 | 3800 | 2000 | .. | .. | .. | .. |
| SA-204 | A | 65000 | | 13000 | 13000 | 13000 | 12500 | 11500 | 10000 | 8000 | 5000 | .. | .. | .. | .. |
| SA-204 | B | 70000 | | 14000 | 14000 | 14000 | 13500 | 12000 | 10200 | 8000 | 5000 | .. | .. | .. | .. |
| SA-204 | C | 75000 | | 15000 | 15000 | 15000 | 14400 | 12700 | 10400 | 8000 | 5000 | .. | .. | .. | .. |
| SA-225 | A | 70000 | (13) | 14000 | 14000 | 14000 | ... | ... | ... | ... | ... | .. | .. | .. | .. |
| SA-225 | B | 75000 | (13) | 15000 | 15000 | 15000 | ... | ... | ... | ... | ... | .. | .. | .. | .. |
| Medium and High Alloy Steels | | | | | | | | | | | | | | | |
| SA-176* | 1 | 70000 | | 14000 | 14000 | 14000 | 12800 | 9500 | 6750 | 4000 | 2400 | .. | .. | .. | .. |
| SA-176 | 2 | 70000 | | 14000 | 14000 | 14000 | 12800 | 9500 | 6750 | 4000 | 2400 | .. | .. | .. | .. |
| SA-240 | 304 | 75000 | (2) | 15000 | 15000 | 14600 | 14300 | 14000 | 13400 | 12300 | 10000 | 8000 | 6000 | 4600 | 3600 |
| SA-240 | 316 | 75000 | (2) | 15000 | 15000 | 14600 | 14300 | 14000 | 13400 | 12600 | 11200 | 9000 | 7000 | 5000 | 3600 |
| SA-240 | 321 | 75000 | | 15000 | 15000 | 14600 | 14300 | 14000 | 13400 | 12300 | 10000 | 8000 | 6000 | 4600 | 3600 |
| SA-240 | 347 | 75000 | | 15000 | 15000 | 14600 | 14300 | 14000 | 13400 | 12300 | 10000 | 8000 | 6000 | 4600 | 3600 |
| PIPE AND TUBES | | | | | | | | | | | | | | | |
| Seamless Carbon Steel | | | | | | | | | | | | | | | |
| SA-53 | A | 48000 | (3) | 9600 | 9250 | 8700 | 8000 | 6850 | 5600 | 3800 | 2000 | .. | .. | .. | .. |
| SA-53 | A | 48000 | | 9600 | 9100 | 8250 | 7250 | 5850 | 4400 | 2600 | 1350 | .. | .. | .. | .. |
| SA-53 | B | 60000 | (3) | 12000 | 11400 | 10400 | 9100 | 7400 | 5600 | 3800 | 2000 | .. | .. | .. | .. |
| SA-53 | B | 60000 | | 12000 | 11400 | 9950 | 8300 | 6350 | 4400 | 2600 | 1350 | .. | .. | .. | .. |
| SA-83 | A | .... | (3) | 9400 | 9000 | 8600 | 7900 | 6800 | 5600 | 3800 | 2000 | .. | .. | .. | .. |
| SA-83 | A | .... | | 9400 | 9000 | 8150 | 7150 | 5850 | 4400 | 2600 | 1350 | .. | .. | .. | .. |
| SA-83 | B | .... | | 8000 | 7650 | 6900 | ... | ... | ... | ... | ... | .. | .. | .. | .. |
| SA-106 | A | 48000 | (3) | 9600 | 9250 | 8700 | 8000 | 6850 | 5600 | 3800 | 2000 | .. | .. | .. | .. |
| SA-106 | A | 48000 | | 9600 | 9100 | 8250 | 7250 | 5850 | 4400 | 2600 | 1350 | .. | .. | .. | .. |
| SA-106 | B | 60000 | | 12000 | 11400 | 10400 | 9100 | 7400 | 5600 | 3800 | 2000 | .. | .. | .. | .. |
| SA-192 | A | .... | | 9400 | 9000 | 8600 | 7900 | 6800 | 5600 | 3800 | 2000 | .. | .. | .. | .. |
| SA-210 | .. | 60000 | | 12000 | 11400 | 10400 | 9100 | 7400 | 5600 | 3800 | 2000 | .. | .. | .. | .. |
| Seamless Alloy Steel | | | | | | | | | | | | | | | |
| SA-158 | P3a | 60000 | | 12000 | 12000 | 12000 | 11800 | 11200 | 10000 | 8000 | 5850 | 3850 | 2200 | .. | .. |
| SA-158 | P3b | 60000 | | 12000 | 12000 | 12000 | 11800 | 11200 | 10000 | 8000 | 5850 | 3850 | 2200 | .. | .. |
| SA-158 | P5a | 60000 | (7) | 12000 | 12000 | 12000 | 11800 | 11200 | 10000 | 8000 | 5850 | 3850 | 2200 | .. | .. |
| SA-158 | P5c | 60000 | | 11000 | 11000 | 11000 | 11000 | 10850 | 10000 | 8000 | 5850 | 3850 | 2200 | .. | .. |
| SA-158 | P8a | 75000 | (2) | 15000 | 15000 | 14600 | 14300 | 14000 | 13400 | 12300 | 10000 | 8000 | 6000 | 4600 | 3600 |
| SA-158 | P8b | 75000 | | 15000 | 15000 | 14600 | 14300 | 14000 | 13400 | 12300 | 10000 | 8000 | 6000 | 4600 | 3600 |
| SA-158 | P11 | 60000 | | 12000 | 12000 | 12000 | 11800 | 11200 | 10000 | 8000 | 5850 | 3850 | 2200 | .. | .. |
| SA-206 | P1 | 55000 | | 11000 | 11000 | 11000 | 10750 | 10500 | 10000 | 8000 | 5000 | .. | .. | .. | .. |
| SA-209 | T1 | 55000 | | 11000 | 11000 | 11000 | 10750 | 10500 | 10000 | 8000 | 5000 | .. | .. | .. | .. |
| SA-209 | T1a | 60000 | | 12000 | 12000 | 12000 | 11500 | 11000 | 10000 | 8000 | 5000 | .. | .. | .. | .. |
| SA-209 | T1b | 53000 | | 10600 | 10600 | 10600 | 10400 | 10200 | 10000 | 8000 | 5000 | .. | .. | .. | .. |
| SA-213 | T3 | 60000 | | 12000 | 12000 | 12000 | 11800 | 11200 | 10000 | 8000 | 5850 | 3850 | 2200 | .. | .. |
| SA-213 | T5 | 60000 | | 12000 | 12000 | 12000 | 11800 | 11200 | 10000 | 8000 | 5850 | 3850 | 2200 | .. | .. |
| SA-213 | T11 | 60000 | | 12000 | 12000 | 12000 | 11800 | 11200 | 10000 | 8000 | 5850 | 3850 | 2200 | .. | .. |
| SA-213 | T12 | 60000 | | 12000 | 12000 | 12000 | 11800 | 11200 | 10000 | 8000 | 5850 | 3850 | 2200 | .. | .. |
| SA-213 | T14 | 60000 | | 12000 | 12000 | 12000 | 11800 | 11200 | 10000 | 8000 | 5850 | 3850 | 2200 | .. | .. |
| SA-213 | T16 | 60000 | | 11000 | 11000 | 11000 | 11000 | 10850 | 10000 | 8000 | 5850 | 3850 | 2200 | .. | .. |
| SA-213 | T8 | 75000 | (2) | 15000 | 15000 | 14600 | 14300 | 14000 | 13400 | 12300 | 10000 | 8000 | 6000 | 4600 | 3600 |
| SA-213 | T18 | 75000 | | 15000 | 15000 | 14600 | 14300 | 14000 | 13400 | 12300 | 10000 | 8000 | 6000 | 4600 | 3600 |
| SA-213 | T19 | 75000 | | 15000 | 15000 | 14600 | 14300 | 14000 | 13400 | 12300 | 10000 | 8000 | 6000 | 4600 | 3600 |
| SA-213 | T20 | 75000 | (2) | 15000 | 15000 | 14600 | 14300 | 14000 | 13400 | 12600 | 11200 | 9000 | 7000 | 5000 | 3600 |
| SA-213 | T17 | 60000 | (14) | 12000 | ... | ... | ... | ... | ... | ... | ... | .. | .. | .. | .. |
| SA-213 | T21 | 60000 | | 12000 | 12000 | 12000 | 11800 | 11200 | 10000 | 8250 | 6250 | 4800 | 3700 | 2700 | 1950 |
| SA-213 | T22 | 60000 | | 12000 | 12000 | 12000 | 11800 | 11200 | 10000 | 8250 | 6250 | 4800 | 3700 | 2700 | 1950 |
| Electric-Resistance-Welded Carbon-Steel | | | | | | | | | | | | | | | |
| SA-135 | A | 48000 | (3), (4) | 9600 | 9250 | 8700 | 8000 | 6850 | 5600 | 3800 | 2000 | .. | .. | .. | .. |
| SA-135 | A | 48000 | (4) | 9600 | 9100 | 8250 | 7250 | 5850 | 4400 | 2600 | 1350 | .. | .. | .. | .. |
| SA-135 | B | 60000 | (3), (4) | 12000 | 11400 | 10400 | 9100 | 7400 | 5600 | 3800 | 2000 | .. | .. | .. | .. |
| SA-135 | B | 60000 | (4) | 12000 | 11400 | 9950 | 8300 | 6350 | 4400 | 2600 | 1350 | .. | .. | .. | .. |
| SA-178 | A | .... | (3), (4) | 9400 | 9000 | 8600 | 7900 | 6800 | 5600 | 3800 | 2000 | .. | .. | .. | .. |
| SA-178 | A | .... | (4) | 9400 | 9000 | 8150 | 7150 | 5850 | 4400 | 2600 | 1350 | .. | .. | .. | .. |
| SA-178 | B | .... | (4) | 8000 | 7650 | 6900 | ... | ... | ... | ... | ... | .. | .. | .. | .. |
| SA-178 | C | 60000 | (3), (4) | 12000 | 11400 | 10400 | 9100 | 7400 | 5600 | 3800 | 2000 | .. | .. | .. | .. |
| SA-178 | C | 60000 | (4) | 12000 | 11400 | 9950 | 8300 | 6350 | 4400 | 2600 | 1350 | .. | .. | .. | .. |
| SA-214 | .. | None | (4) | 9400 | 9000 | 8150 | 7150 | 5850 | 4400 | 2600 | 1350 | .. | .. | .. | .. |
| SA-226 | .. | None | (3), (4) | 9400 | 9000 | 8600 | 7900 | 6800 | 5600 | 3800 | 2000 | .. | .. | .. | .. |
| SA-226 | .. | None | (4) | 9400 | 9000 | 8150 | 7150 | 5850 | 4400 | 2600 | 1350 | .. | .. | .. | .. |
| Electric-Resistance-Welded Alloy Steel | | | | | | | | | | | | | | | |
| SA-249 | T8 | 75000 | (4) | 15000 | 15000 | 14600 | 14300 | 14000 | 13400 | 12300 | 10000 | 8000 | 6000 | 4600 | 3600 |
| SA-249 | T18 | 75000 | (4) | 15000 | 15000 | 14600 | 14300 | 14000 | 13400 | 12300 | 10000 | 8000 | 6000 | 4600 | 3600 |
| SA-249 | T19 | 75000 | (4) | 15000 | 15000 | 14600 | 14300 | 14000 | 13400 | 12300 | 10000 | 8000 | 6000 | 4600 | 3600 |
| SA-249 | T20 | 75000 | (4) | 15000 | 15000 | 14600 | 14300 | 14000 | 13400 | 12600 | 11200 | 9000 | 7000 | 5000 | 3600 |
| SA-249 | T24 | 75000 | (4) | 15000 | 15000 | 14600 | 14300 | 14000 | 13400 | 12600 | 11200 | 9000 | 7000 | 5000 | 3600 |
| SA-250 | T1 | 55000 | (4) | 11000 | 11000 | 11000 | 10750 | 10500 | 10000 | 8000 | 5000 | .. | .. | .. | .. |
| SA-250 | T1a | 60000 | (4) | 12000 | 12000 | 12000 | 11500 | 11000 | 10000 | 8000 | 5000 | .. | .. | .. | .. |
| SA-250 | T1b | 53000 | (4) | 10600 | 10600 | 10600 | 10400 | 10200 | 10000 | 8000 | 5000 | .. | .. | .. | .. |
| Lap-Welded | | | | | | | | | | | | | | | |
| SA-53 | Steel | 45000 | (4) | 9000 | 8500 | 7800 | ... | ... | ... | ... | ... | .. | .. | .. | .. |
| SA-72 | Wrought iron | 40000 | (4) | 8000 | 7650 | 6900 | ... | ... | ... | ... | ... | .. | .. | .. | .. |
| SA-83 | Steel | .... | (4) | 9000 | 8500 | 7800 | ... | ... | ... | ... | ... | .. | .. | .. | .. |
| SA-83 | Wrought iron | .... | (4) | 8000 | 7650 | 6900 | ... | ... | ... | ... | ... | .. | .. | .. | .. |
| SA-106 | .. | 45000 | (4) | 9000 | 8500 | 7800 | ... | ... | ... | ... | ... | .. | .. | .. | .. |
| Butt-Welded | | | | | | | | | | | | | | | |
| SA-53 | Steel | 45000 | (4) | 9000 | 8500 | 7800 | ... | ... | ... | ... | ... | .. | .. | .. | .. |
| SA-72 | Wrought iron | 40000 | (4) | 8000 | 7650 | 6900 | ... | ... | ... | ... | ... | .. | .. | .. | .. |
| Fusion-Welded | | | | | | | | | | | | | | | |
| SA-70 | .. | 55000 | (1), (4), (5) | 11000 | 10400 | 9500 | 8000 | 6300 | 4400 | 2600 | 1350 | .. | .. | .. | .. |
| SA-89 | B | 50000 | (1), (4), (5) | 10000 | 9600 | 9000 | 7500 | 6000 | 4400 | 2600 | 1350 | .. | .. | .. | .. |
| SA-89 | A | 45000 | (1), (4), (5) | 9000 | 8800 | 8400 | 6900 | 5700 | 4400 | 2600 | 1350 | .. | .. | .. | .. |
| FORGINGS | | | | | | | | | | | | | | | |
| Carbon Steels | | | | | | | | | | | | | | | |
| S-4 | 1 | 60000 | | 12000 | 11400 | 10400 | 9100 | 7400 | 5600 | 3800 | 2000 | .. | .. | .. | .. |
| S-4 | 2 | 70000 | | 14000 | 13300 | 11900 | 10000 | 7800 | 5600 | 3800 | 2000 | .. | .. | .. | .. |
| S-4 | 3 | 75000 | | 15000 | 14100 | 12400 | 10100 | 7800 | 5600 | 3800 | 2000 | .. | .. | .. | .. |
| SA-18 | A-Untreated | 47000 | | 9400 | 9100 | 8600 | 7150 | 5850 | 4400 | 2600 | 1350 | .. | .. | .. | .. |
| SA-18 | B-Untreated | 60000 | | 12000 | 11400 | 10400 | 8300 | 6350 | 4400 | 2600 | 1350 | .. | .. | .. | .. |
| SA-18 | C-Annealed | 60000 | | 12000 | 11400 | 10400 | 8300 | 6350 | 4400 | 2600 | 1350 | .. | .. | .. | .. |
| SA-105 | 1 | 60000 | | 12000 | 11400 | 10400 | 8300 | 6350 | 4400 | 2600 | 1350 | .. | .. | .. | .. |
| SA-105 | 2 | 70000 | | 14000 | 13300 | 11900 | 8950 | 6450 | 4400 | 2600 | 1350 | .. | .. | .. | .. |
| SA-105 | 1 | 60000 | (3) | 12000 | 11400 | 10400 | 9100 | 7400 | 5600 | 3800 | 2000 | .. | .. | .. | .. |
| SA-105 | 2 | 70000 | (3) | 14000 | 13300 | 11900 | 10000 | 7800 | 5600 | 3800 | 2000 | .. | .. | .. | .. |
| SA-181 | 1 | 60000 | | 12000 | 11400 | 10400 | 8300 | 6350 | 4400 | 2600 | 1350 | .. | .. | .. | .. |
| SA-181 | 2 | 70000 | | 14000 | 13300 | 11900 | 8950 | 6450 | 4400 | 2600 | 1350 | .. | .. | .. | .. |
| SA-181 | 1 | 60000 | (3) | 12000 | 11400 | 10400 | 9100 | 7400 | 5600 | 3800 | 2000 | .. | .. | .. | .. |
| SA-181 | 2 | 70000 | (3) | 14000 | 13300 | 11900 | 10000 | 7800 | 5600 | 3800 | 2000 | .. | .. | .. | .. |
| Alloy Steels | | | | | | | | | | | | | | | |
| SA-182 | F1 | 70000 | | 14000 | 14000 | 14000 | 13500 | 12000 | 10200 | 8000 | 5000 | .. | .. | .. | .. |
| SA-182 | F3 | 70000 | | 14000 | 14000 | 14000 | 14000 | 13400 | 11000 | 8250 | 5850 | 3850 | 2200 | .. | .. |
| SA-182 | F4 | 90000 | | 15000 | 15000 | 15000 | 14000 | 12500 | 10200 | 8000 | 5000 | .. | .. | .. | .. |
| SA-182 | F5 | 90000 | (7) | 15000 | 15000 | 15000 | 14000 | 13400 | 11000 | 8250 | 5850 | 3850 | 2200 | .. | .. |
| SA-182 | F6 | 85000 | | 15000 | 14000 | 13000 | 11500 | 9500 | 6750 | 4000 | 2400 | .. | .. | .. | .. |
| SA-182 | F7 | 100000 | | 15000 | 15000 | 15000 | 14400 | 12700 | 10400 | 8000 | 5000 | .. | .. | .. | .. |
| SA-182 | F8 | 75000 | (2) | 15000 | 15000 | 14600 | 14300 | 14000 | 13400 | 12300 | 10000 | 8000 | 6000 | 4600 | 3600 |
| SA-182 | F11 | 100000 | | 15000 | 15000 | 15000 | 14400 | 12700 | 10400 | 8000 | 5000 | .. | .. | .. | .. |
| CASTINGS | | | | | | | | | | | | | | | |
| Carbon Steels | | | | | | | | | | | | | | | |
| SA-27 | B & B2 | 70000 | (6), (8) | 14000 | 13300 | 11900 | 8950 | 6450 | 4400 | 2600 | 1350 | .. | .. | .. | .. |
| SA-95 | .. | 70000 | (8) | 14000 | 13300 | 11900 | 10000 | 7800 | 5600 | ... | ... | .. | .. | .. | .. |
| SA-216 | WCA | 60000 | (3), (8) | 12000 | 11400 | 10400 | 9100 | 7400 | 5600 | 3800 | 2000 | .. | .. | .. | .. |
| SA-216 | WCB | 70000 | (3), (8) | 14000 | 13300 | 11900 | 10000 | 7800 | 5600 | 3800 | 2000 | .. | .. | .. | .. |
| Alloy steels | | | | | | | | | | | | | | | |
| SA-157 | C1 | 70000 | (8) | 14000 | 14000 | 14000 | 13500 | 12000 | 10200 | 8000 | 5000 | .. | .. | .. | .. |
| SA-157 | C3 | 90000 | (8) | 15000 | 15000 | 15000 | 14000 | 13400 | 11000 | 8250 | 5850 | 3850 | 2200 | .. | .. |
| SA-157 | C4 | 100000 | (8) | 15000 | 15000 | 15000 | 14000 | 12500 | 10200 | 8000 | 5000 | .. | .. | .. | .. |
| SA-157 | C5 | 100000 | (7), (8) | 15000 | 15000 | 15000 | 14000 | 13400 | 11000 | 8250 | 5850 | 3850 | 2200 | .. | .. |
| SA-157 | C6 | 85000 | (8) | 15000 | 14000 | 13000 | 11500 | 9500 | 6750 | 4000 | 2400 | .. | .. | .. | .. |
| SA-157 | C9 | 70000 | (2), (8) | 14000 | 14000 | 14000 | 13900 | 13700 | 13200 | 12300 | 10000 | 8000 | 6000 | 4600 | 3600 |
| SA-157 | C11 | 100000 | (7), (8) | 15000 | 15000 | 15000 | 14400 | 12700 | 10400 | 8000 | 5000 | .. | .. | .. | .. |
| SA-157 | C12 | 90000 | (8) | 15000 | 15000 | 15000 | 14000 | 13400 | 11000 | 8250 | 5850 | 3850 | 2200 | .. | .. |
| SA-217 | WC1 | 70000 | (8), (9) | 14000 | 14000 | 14000 | 13500 | 12000 | 10200 | 8000 | 5000 | .. | .. | .. | .. |
| SA-217 | WC1A | 70000 | (8) | 14000 | 13650 | 12950 | 12000 | 9900 | 7800 | 5900 | 3500 | .. | .. | .. | .. |
| SA-217 | WC2 | 65000 | (8), (9) | 13000 | 13000 | 13000 | 12500 | 11500 | 10000 | 8000 | 5000 | .. | .. | .. | .. |
| SA-217 | WC4 | 80000 | (8), (9) | 15000 | 15000 | 15000 | 14000 | 12500 | 10200 | 8000 | 5000 | .. | .. | .. | .. |
| BOLTING | | | | | | | | | | | | | | | |
| Carbon Steels | | | | | | | | | | | | | | | |
| SA-7 | .. | 55000 | (10) | ... | ... | ... | ... | ... | ... | ... | ... | .. | .. | .. | .. |
| SA-261 | .. | 100000 | (11), (12) | 13000 | 11950 | 10000 | 8000 | 5500 | ... | ... | ... | .. | .. | .. | .. |
| Alloy Steels | | | | | | | | | | | | | | | |
| SA-96 | A | | (11), (12) | 13000 | 11950 | 10900 | ... | ... | ... | ... | ... | .. | .. | .. | .. |
| SA-96 | B | | (11), (12) | 15000 | 13750 | 12500 | ... | ... | ... | ... | ... | .. | .. | .. | .. |
| SA-96 | C | | (11), (12) | 16000 | 14700 | 13400 | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| A.S.T.M. A193-40T* | B4 | | (11), (12) | 16000 | 16000 | 16000 | 16000 | 13000 | 10000 | ... | ... | .. | .. | .. | .. |
| A.S.T.M. A193-40T* | B5 | | (7), (11), (12) | 16000 | 16000 | 16000 | 16000 | 13800 | 11000 | 8250 | 5850 | 3850 | 2200 | .. | .. |
| A.S.T.M. A193-40T* | B6 | | (11), (12) | 16000 | 14700 | 13400 | 11500 | 9500 | 6750 | ... | ... | .. | .. | .. | .. |
| A.S.T.M. A193-40T* | B7 | | (11), (12) | 16000 | 16000 | 16000 | 16000 | 13000 | 10000 | ... | ... | .. | .. | .. | .. |
| A.S.T.M. A193-40T* | B7a | | (11), (12) | 16000 | 16000 | 16000 | 16000 | 13800 | 11000 | 8250 | 5850 | 3850 | 2200 | .. | .. |
| A.S.T.M. A193-40T* | B8 | | (2), (11) | 15000 | 15000 | 14600 | 14300 | 14000 | 13400 | 12300 | 10000 | 8000 | 6000 | 4600 | 3600 |
| A.S.T.M. A193-40T* | B11 | | (11), (12) | 16000 | 16000 | 16000 | 16000 | 13800 | 11000 | 8250 | 5850 | 3850 | 2200 | .. | .. |
| A.S.T.M. A193-40T* | B13 | | (11), (12) | 16000 | 16000 | 16000 | 16000 | 13800 | 11000 | 8250 | 5850 | 3850 | 2200 | .. | .. |
| A.S.T.M. A193-40T* | B14 | | (11), (12) | 16000 | 16000 | 16000 | 16000 | 15000 | 13300 | 11400 | 8800 | 5000 | 2200 | .. | .. |
| A.S.T.M. A193-40T* | B15 | | (11), (12) | 16000 | 16000 | 16000 | 16000 | 13800 | 11000 | 8250 | 5850 | 3850 | 2200 | .. | .. |

NOTES:

(1) Flange quality not permitted above 850 F.

(2) No allowance has been made for corrosive action in the allowable stresses given. Carbide precipitation in service is also to be expected at temperatures above 750 F.

(3) These stresses permitted only if 0.10 per cent minimum silicon is expressly specified.

(4) These are base stresses for the material; these stresses are modified in Table U-4 to take care of the type of longitudinal joint.

(5) Fusion welded in accordance with Pars. U-67 to U-79, inclusive.

(6) Sections over 2 in. thick not permitted for pressure parts.

(7) These stresses permitted only with molybdenum.

(8) To these stresses, a casting quality factor of 70 per cent shall be applied. Consideration is being given to rules for inspection and radiographing castings with the view of establishing other quality factors in proportion to the degree of inspection.

(9) These stresses apply to normalized material only.

(10) Not permitted above 450 F; allowable stress 5500 psi.

(11) These stresses are established from a consideration of strength only and will be satisfactory for average service. For bolted joints where freedom from leakage over a long period of time without retightening is required, lower stresses may be necessary as determined from the relative flexibility of the flange and bolts and corresponding relaxation properties.

(12) Between temperatures of −20 to 400 F, stresses equal to the lower of the following will be permitted: 16 per cent of tensile strength; 20 per cent of yield point stress.

(13) Between temperatures of 750 to 1000 F, the stresses given herein for killed carbon steel, Specification SA-212 Grade B, may be used until high temperature test data become available.

(14) Between temperatures of 650 to 1000 F, inclusive, the stresses given herein for killed carbon steel, Specification SA-201 Grade B, may be used until high temperature test data become available.

GENERAL:

Carbon steel materials covered by Code specifications which are not included in these tables are limited to use at temperatures of from −20 to 650 F.

The allowable stress in wrought materials is one fifth of the ultimate; in cast materials, it is one fifth of the ultimate multiplied by the applicable quality factor for design purposes.

* While these specifications have not been approved by the Boiler Code Committee for incorporation in the Code, the stresses given herein have been included to cover foreseen requests for such data.

Any material in this table may be used at temperatures below −20 F provided it complies with Par. U-142. To meet these requirements special melting practice, analyses, and treatments are generally necessary. The allowable stress shall be that given for room temperatures in the table.

(j) Nonferrous plates may be used in the construction of unfired pressure vessels when specifications are given in Section II of the Code and stresses as provided in Table U-3 are followed.

**U-14** In determining the maximum allowable working pressure, the maximum allowable working stress as herein provided shall be used in the computations.

**U-15** For resistance to crushing of steel plate, the maximum allowable working stress shall be 19,000 psi of cross-sectional area.

**U-16** In computing the maximum allowable stress on 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 | 7,600 |
| Iron rivets in double shear | 15,200 |
| Steel rivets in single shear | 8,800 |
| Steel rivets in double shear | 17,600 |

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

## CONSTRUCTION AND MAXIMUM ALLOWABLE WORKING PRESSURES

**U-17** (a) For all pressure vessels, the minimum thickness of shell plates, heads, or dome plates, after flanging, shall be $^3/_{32}$ in., except that for riveted construction the minimum thickness shall be $^3/_{16}$ in. Vessels which are of a size that will not hold their shape without additional support must be provided with

TABLE U-1 MINIMUM THICKNESS OF BUTT STRAPS

| Thickness of shell plates, in. | Minimum thickness of butt straps, in. | Thickness of shell plates, in. | Minimum thickness of butt straps, in. |
|---|---|---|---|
| $^3/_{16}$ | $^3/_{16}$ | $^1/_2$ | $^7/_{16}$ |
| $^1/_4$ | $^1/_4$ | $^{17}/_{32}$ | $^7/_{16}$ |
| $^9/_{32}$ | $^1/_4$ | $^9/_{16}$ | $^7/_{16}$ |
| $^5/_{16}$ | $^1/_4$ | $^5/_8$ | $^1/_2$ |
| $^{11}/_{32}$ | $^1/_4$ | $^3/_4$ | $^1/_2$ |
| $^3/_8$ | $^5/_{16}$ | $^7/_8$ | $^5/_8$ |
| $^{13}/_{32}$ | $^5/_{16}$ | 1 | $^{11}/_{16}$ |
| $^7/_{16}$ | $^3/_8$ | $1^1/_8$ | $^3/_4$ |
| $^{15}/_{32}$ | $^3/_8$ | $1^1/_4$ | $^7/_8$ |

## TABLE U-3 MAXIMUM ALLOWABLE WORKING STRESSES FOR NONFERROUS MATERIALS IN POUNDS PER SQUARE INCH

| Material | Spec. number | For metal temperatures not exceeding deg F | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 150(7) | 250 | 300 | 350 | 400 | 450 | 500 | 550 | 600 | 650 | 700 | 750 |
| Muntz metal | SB-43<br>SB-111 | 10000 | 9000 | 7500 | 4500 | 1500 | ... | ... | ... | ... | ... | ... | ... |
| Red brass | SB-43 | 7000 | 6500 | 5750 | 5000 | 3000 | 1000 | 800 | ... | ... | ... | ... | ... |
| High brass | SB-43 | 7000 | 6500 | 5750 | 5000 | 3000 | 1000 | 800 | ... | ... | ... | ... | ... |
| Admiralty | SB-43<br>SB-111 | 7000 | 6500 | 6250 | 6000 | 5500 | 4500 | ... | ... | ... | ... | ... | ... |
| Naval brass | (6) | 11000 | 10000 | 10000 | 6500 | 3000 | ... | ... | ... | ... | ... | ... | ... |
| Copper silicon alloy, types A and C (4) | SB-96<br>SB-98(1) | 10000 | 10000 | 7500 | 5000 | ... | ... | ... | ... | ... | ... | ... | ... |
| Steam bronze | SB-61(5) | 7000 | 7000 | 6500 | 6000 | 5500 | 5000 | 4000 | 3000 | ... | ... | ... | ... |
| Steam bronze | SB-62(5) | 6000 | 5500 | 5000 | 4500 | 3500 | ... | ... | ... | ... | ... | ... | ... |
| Monel metal (2) | SB-127 | 14000 | 14000 | 14000 | 14000 | 14000 | 14000 | 14000 | 14000 | 14000 | 14000 | 14000 | 14000 |
| Cupro nickel 70-30 | SB-111(3) | 11000 | 11000 | 11000 | 11000 | 11000 | 11000 | 10000 | 10000 | 9000 | 9000 | 8000 | 8000 |
| Cupro nickel 80-20 | SB-111(3) | 10000 | 10000 | 10000 | 10000 | 10000 | 10000 | 9000 | 9000 | 8000 | 8000 | 7000 | 7000 |
| Copper annealed, all types | SB-11<br>SB-13<br>SB-42<br>SB-111<br>SB-75 | 6000 | 5000 | 4750 | 4500 | 4000 | ... | ... | ... | ... | ... | ... | ... |
| Aluminum manganese alloy, annealed | SB-126 | 2800 | 2400 | 2100 | 1800 | 1600 | ... | ... | ... | ... | ... | ... | .. |
| Aluminum manganese alloy, quarter-hard or as-rolled | SB-126 | 3500 | 3000 | 2700 | 2400 | 2200 | ... | ... | ... | ... | ... | ... | ... |
| Copper alloy condenser tube plates | SB-171 | 10000 | 10000 | 10000 | 10000 | 10000 | 10000 | ... | ... | ... | ... | ... | ... |
| Aluminum, annealed | SB-25 | 2240 | 1680 | 1440 | 1280 | 1120 | ... | ... | ... | ... | ... | ... | ... |

The stresses given in the above table may be interpolated to determine values for intermediate temperatures.

NOTES:

(1) Types A and C only.

(2) Applies to 70,000 lb tensile strength rolled and annealed material.

(3) 70-30 Copper Nickel and 80-20 Copper Nickel, types A and B.

(4) There is doubt concerning the suitability of this material when exposed to certain products and/or high temperatures, particularly steam above 212 F and the user should satisfy himself that it is satisfactory for the service for which it is to be used.

(5) In the absence of evidence that the casting is of high quality throughout, values not in excess of 80 per cent of those given in the table shall be used. This is not intended to apply to valves and fittings made to a recognized standard.

(6) U. S. Navy Department Specification 46B-6-j.

(7) The allowable stresses given may also be used for subzero temperatures.

stiffeners so designed as to prevent distortion due to their own weight and/or to influences causing stresses other than those due to internal pressure.

(b) **Under-Tolerance.** Plate material that is not more than 0.01 in. thinner than that calculated from the formula may be used in Code constructions provided the material specification permits such plate to be furnished not more than 0.01 in. thinner than ordered.

**U-18** The minimum thicknesses of butt straps for double-strap riveted joints shall be as given in Table U-1. Intermediate values shall be determined by interpolation. For plate thicknesses exceeding $1^1/_4$ in., the thickness of the butt straps shall be not less than two thirds of the thickness of the plate.

**U-19** (a) The maximum allowable working pressure for a vessel is the maximum pressure at the top of the vessel in its normal operating position. It is determined by employing the factors of safety, stresses, and dimensions designated in these rules. No unfired pressure vessel shall be operated at a pressure higher than the maximum allowable working pressure except when the safety device is blowing, at which time the maximum allowable working pressure shall not be exceeded by more than 10 per cent.

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

(c) The Code provides the limiting stresses for use in the design of pressure vessels and it is necessary to take account of the effect of static head that may be produced in any part in order that such stress limits be not exceeded.

(d) The maximum allowable working pressure for the vessel as a whole is the least of the maximum allowable working pressures determined by computations for the various parts.

**U-20 Shells for Internal Pressure.** (a) When the thickness of the shell does not exceed one half of the inside radius, the maximum allowable working pressure on the cylindrical shell of a pressure vessel shall be determined by the strength of the weakest course computed from the thickness of the plate, the efficiency of the longitudinal joint, or of the ligament between openings (whichever is the least), the inside radius of the course, and the maximum allowable unit working stress.

$$P = \frac{SEt}{R + 0.6t} \quad \text{or} \quad t = \frac{PR}{SE - 0.6P}$$

where $P$ = maximum allowable working pressure, pounds per square inch,

$S$ = maximum allowable unit working stress, pounds per square inch, taken from Tables U-2 and U-3,

$E$ = efficiency of longitudinal joints or of ligaments between openings:

for riveted joints = calculated riveted efficiency,
for fusion-welded joints = efficiency specified in Pars. U-68 and U-69. For Par. U-70 use the values of $SE$ given in that paragraph,
for seamless shells = 100 per cent (unity),
for ligaments between openings, the efficiency shall be calculated by the rules given in Pars. P-192 and P-193 of the Code.

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

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

Welded tubing or piping enumerated in Par. U-13(f) may be used for the shells of Par. U-69 or U-70 vessels, in which case the factor $SE$ shall be as given in Table U-4.

The maximum allowable working pressure for shells other than cylindrical or spherical, and for heads and other parts, shall be determined in a similar manner using the formulas appropriate for the parts, as otherwise given in the Code.

(b) When the thickness of the shell exceeds one half of the inside radius, the maximum allowable working pressure on the cylindrical shell of a pressure vessel shall be determined by the formulas given in Par. UA-100.

(c) When the thickness of the shell of a wholly spherical vessel does not exceed 20 per cent of the inside radius, the maximum allowable working pressure in the shell of the pressure vessel shall be computed by the formula:

$$P = \frac{2\,tSE}{R} \quad \text{or} \quad t = \frac{PR}{2\,SE}$$

The symbols are as defined in (a), except that $R$ is to be the inside radius of the sphere in all cases, and $E$ the efficiency of any joint or of ligaments between openings.

(d) **For External Pressure.** The maximum allowable working pressure for cylindrical vessels subjected to external or collapsing pressure shall be determined either by the rules in Pars. U-120 to U-138, or Par. U-51.

(e) **Tubes and Pipes Used as Tubes.** The maximum allowable working pressure in pounds per square inch for ferrous and nonferrous tubes and pipes shall be determined by the following formulas:

FERROUS TUBES AND PIPES, INTERNAL PRESSURE

$$P = \frac{2.3\ St}{D} - \frac{S}{30}$$

where $P$ = maximum allowable working pressure, pounds per square inch,
$t$ = minimum wall thickness, inches,[1]
$S$ = maximum allowable working stress from Table U-2 for seamless tubes or pipes, or Table U-4 for welded tubes or pipes,
$D$ = outside diameter of pipe, inches.

NONFERROUS TUBES AND PIPES, INTERNAL PRESSURE

$$P = \frac{2\ St}{D}$$

where $P$ = maximum allowable working pressure, pounds per square inch,
$t$ = minimum wall thickness, inches,[1]
$S$ = maximum allowable working stress from Table U-3,
$D$ = outside diameter of pipe, inches.

FERROUS TUBES AND PIPES, EXTERNAL PRESSURE

The maximum allowable external pressure shall be determined from Fig. U-1, using stresses as provided in Table U-2.

NONFERROUS TUBES AND PIPES, EXTERNAL PRESSURE

The maximum allowable external pressure shall be determined from Fig. U-1 using the stresses provided in Table U-3.

The foregoing rules are subject to the following restrictions:

(1) Applicable only to outside diameters of 1/2 in. to 6 in., inclusive, and for wall thicknesses not less than 0.049 in.;

(2) Additional wall thickness should be provided when corrosion or wear due to cleaning operations is expected;

[1] If pipe is ordered by its nominal weight or wall thickness, as is customary in trade practice, the manufacturing tolerance on wall thickness must be added to the $t$ determined by the formula. The next heavier commercial wall thickness may then be selected from standard thickness schedules as given in ASA B36.10. The manufacturing tolerances are given in the several pipe specifications listed in Table U-4.

TABLE U-4 VALUES OF FACTORS FOR FERROUS PIPE AND TUBES TO BE USED IN FORMULAS IN PAR. U-20 (a) FOR SHELLS AND PAR. U-20(e) FOR PIPE AND TUBES

| Spec. No. | Grade | Weld | For temperatures not exceeding deg F | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 650 | 700 | 750 | 800 | 850 | 900 | 950 | 1000 | 1050 | 1100 | 1150 | 1200 |
| SA-53 | Steel | Lap | 7300 | 6800 | 6250 | ... | ... | ... | ... | .. | .. | .. | .. | .. |
| SA-53 | Steel | Butt | 5400 | 5100 | 4700 | ... | ... | ... | ... | .. | .. | .. | .. | .. |
| SA-72 | Wrought iron | Lap | 5600 | 5300 | 4800 | ... | ... | ... | ... | .. | .. | .. | .. | .. |
| SA-72 | Wrought iron | Butt | 4800 | 4600 | 4150 | ... | ... | ... | ... | .. | .. | .. | .. | .. |
| SA-83 | Steel | Lap | 7300 | 6800 | 6250 | ... | ... | ... | ... | .. | .. | .. | .. | .. |
| SA-83 | Wrought iron | Lap | 5600 | 5300 | 4800 | ... | ... | ... | ... | .. | .. | .. | .. | .. |
| SA-106 | A, Silicon 0.10% | ... | 9600 | 9250 | 8700 | 8000 | 6850 | 5600 | 3800 | 2000 | .. | .. | .. | .. |
| SA-106 | A | ... | 9600 | 9100 | 8250 | 7250 | 5850 | 4400 | 2600 | 1350 | .. | .. | .. | .. |
| SA-106 | B, Silicon 0.10% | ... | 12000 | 11400 | 10400 | 9100 | 7400 | 5600 | 3800 | 2000 | .. | .. | .. | .. |
| SA-106 | .. | Lap | 7300 | 7000 | 6650 | ... | ... | ... | ... | .. | .. | .. | .. | .. |
| SA-135 | A, Silicon 0.10% | Resis. | 8150 | 7850 | 7400 | 6800 | 5800 | 4750 | 3250 | 1700 | .. | .. | .. | .. |
| SA-135 | A | Resis. | 8150 | 7750 | 7000 | 6150 | 4950 | 3750 | 2200 | 1150 | .. | .. | .. | .. |
| SA-135 | B, Silicon 0.10% | Resis. | 10200 | 9700 | 8850 | 7750 | 6300 | 4750 | 3250 | 1700 | .. | .. | .. | .. |
| SA-135 | B | Resis. | 10200 | 9700 | 8450 | 7050 | 5400 | 3750 | 2200 | 1150 | .. | .. | .. | .. |
| SA-178 | A, Silicon 0.10% | Resis. | 8000 | 7650 | 7300 | 6700 | 5800 | 4750 | 3250 | 1700 | .. | .. | .. | .. |
| SA-178 | A | Resis. | 8000 | 7650 | 6950 | 6100 | 4950 | 3750 | 2200 | 1150 | .. | .. | .. | .. |
| SA-178 | B | Resis. | 6800 | 6500 | 5850 | ... | ... | ... | ... | .. | .. | .. | .. | .. |
| SA-178 | C, Silicon 0.10% | Resis. | 10200 | 9700 | 8850 | 7750 | 6300 | 4750 | 3250 | 1700 | .. | .. | .. | .. |
| SA-178 | C | Resis. | 10200 | 9700 | 8450 | 7050 | 5400 | 3750 | 2200 | 1150 | .. | .. | .. | .. |
| SA-192 | A | ... | 9400 | 9000 | 8600 | 7900 | 6800 | 5600 | 3800 | 2000 | .. | .. | .. | .. |
| SA-206 | P1 | ... | 11000 | 11000 | 11000 | 10750 | 10500 | 10000 | 8000 | 5000 | .. | .. | .. | .. |
| SA-209 | T1 | ... | 11000 | 11000 | 11000 | 10750 | 10500 | 10000 | 8000 | 5000 | .. | .. | .. | .. |
| SA-209 | T1a | ... | 12000 | 12000 | 12000 | 11500 | 11000 | 10000 | 8000 | 5000 | .. | .. | .. | .. |
| SA-210 | .. | ... | 12000 | 11400 | 10400 | 9100 | 7400 | 5600 | 3800 | 2000 | .. | .. | .. | .. |
| SA-213 | T17 | ... | 12000 | ... | ... | ... | ... | ... | ... | .. | .. | .. | .. | .. |
| SA-213 | T21 | ... | 12000 | 12000 | 12000 | 11800 | 11200 | 10000 | 8250 | 6250 | 4800 | 3700 | 2700 | 1950 |
| SA-213 | T22 | ... | 12000 | 12000 | 12000 | 11800 | 11200 | 10000 | ... | .. | .. | .. | .. | .. |
| SA-214 | .. | Resis. | 8000 | 7650 | 6950 | 6100 | 4950 | 3750 | 2200 | 1150 | .. | .. | .. | .. |
| SA-226 | Silicon 0.10% | Resis. | 8000 | 7650 | 7300 | 6700 | 5800 | 4750 | 3250 | 1700 | .. | .. | .. | .. |
| SA-226 | .. | Resis. | 8000 | 7650 | 6950 | 6100 | 4950 | 3750 | 2200 | 1150 | .. | .. | .. | .. |
| SA-249 | T8 | Resis. | 12750 | 12750 | 12400 | 12150 | 11900 | 11400 | 10450 | 8500 | 6800 | 5100 | 3900 | 3050 |
| SA-249 | T18 | Resis. | 12750 | 12750 | 12400 | 12150 | 11900 | 11400 | 10450 | 8500 | 6800 | 5100 | 3900 | 3050 |
| SA-249 | T19 | Resis. | 12750 | 12750 | 12400 | 12150 | 11900 | 11400 | 10450 | 8500 | 6800 | 5100 | 3900 | 3050 |
| SA-249 | T20 | Resis. | 12750 | 12750 | 12400 | 12150 | 11900 | 11400 | 10700 | 9500 | 7650 | 5950 | 4250 | 3050 |
| SA-249 | T24 | Resis. | 12750 | 12750 | 12400 | 12150 | 11900 | 11400 | 10700 | 9500 | 7650 | 5950 | 4250 | 3050 |
| SA-250 | T1 | Resis. | 9350 | 8350 | 9350 | 9150 | 8950 | 8500 | 6800 | 4250 | .. | .. | .. | .. |
| SA-250 | T1a | Resis. | 10200 | 10200 | 10200 | 9800 | 9350 | 8500 | 6800 | 4250 | .. | .. | .. | .. |
| SA-250 | T1b | Resis. | 9000 | 9000 | 9000 | 8850 | 8650 | 8500 | 6800 | 4250 | .. | .. | .. | .. |

(3) Where tube ends are threaded, additional wall thickness is to be provided in the amount of $\frac{0.8}{n}$ (where $n$ equals the number

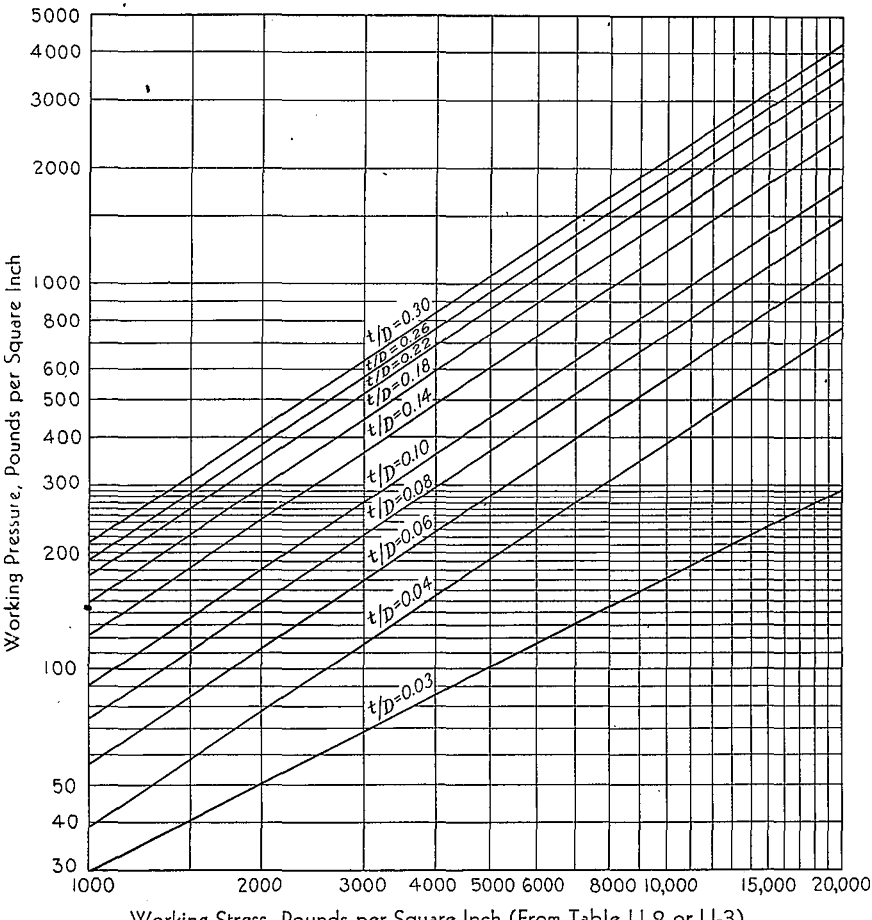



FIG. U-1 CHART FOR DETERMINING WALL THICKNESS OF TUBES UNDER EXTERNAL PRESSURE

of threads per inch);

(4) The requirements for rolling, expanding, or otherwise seating

tubes in tube plates may require heavier tube walls and careful choice of materials because of possible relaxation due to differential expansion stresses.

(f) **Fabricated Pipe Bends.** Fabricated pipe bends may be made by welding together beveled sections of straight pipe provided:

(1) The angle between the axes of the adjoining sections does not exceed 30 deg;

(2) The thickness is at least $\frac{(k - 0.5)}{(k - 1)}$ times the required thickness of the straight pipe to which the bend is joined,

where $k$ = ratio of the radius of the bend (from center of curvature to center of pipe) to one half the inside diameter of the pipe.

(g) **Nonferrous Plates.** Maximum allowable working stresses for nonferrous materials conforming to specifications given in Section II of the Code shall not exceed the values given in Table U-3 for metal temperatures shown.

(h) All valves and fittings shall be marked with the name, trademark, or other identification of the manufacturer, and the maximum allowable working pressure. Additional markings as called for in the American Standards are recommended if the size and shape of the valve or fittings permit.

(i) Bronze valves and fittings made of material complying with Specification SB-62 shall be limited to temperatures of 406 F. If made of material complying with Specification SB-61, the maximum allowable temperature is 550 F. Allowable working stresses are not to exceed the values given in Table U-3.

## JOINTS

**U-21** The joints of pressure vessels, if of riveted construction, shall conform to the requirements of Pars. U-26 to U-35.

**U-22** Pressure vessels may be fabricated by means of fusion welding under the rules given in Pars. U-67 to U-79, provided the construction is in accordance with the requirements for material and design as required by this Code and the fusion welding process used conforms to the specifications for the welding indicated for each type of vessel.

**U-23** Pressure vessels and pressure parts of vessels may be fabricated by means of electric-resistance butt welding when the rules given in Pars. U-110 to U-114 are followed.

**U-24** Pressure vessels may be fabricated by means of forge welding when the rules given in Pars. U-80 to U-90 are followed.

**U-25** Pressure vessels for use at any temperature not exceeding 406 F may be fabricated by means of the brazing process when the rules given in Pars. U-91 to U-96 are followed.

## RIVETED JOINTS

**U-26** The efficiency of a joint is the ratio which the strength of the joint bears to the strength of a 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 a length of a solid plate equal to that of the section considered.

**U-27** (a) 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:

(1) If $\frac{P}{d}$ is 4 or less, the minimum value shall be $1^3/_4\,d$;

(2) If $\frac{P}{d}$ is over 4, the minimum value shall then be:

$$1^3/_4\,d + 0.1\,(P - 4d)$$

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

= pitch of rivets in the outer row less pitch of rivets in the inner row when 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 when the rivets are symmetrically spaced.)

$d$ = diameter of the rivet holes, inches.

(b) The back pitch of rivets in circumferential joints may be less than that called for by the above formulas provided the ligaments between rivets in a circumferential direction, as well as those in a diagonal direction as determined by the rules in Par. P-193 of Section I of the Code, are sufficient to withstand the stress due to pressure, together with any stress due to weight components in support of the vessel structure, with a factor of safety of five.

(c) The back pitch of rivets shall be measured either on the flat plate before rolling, or on the median line after rolling, and the back pitch as there measured shall govern the locations of rivet holes in the butt straps.

**U-28** On 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 $1^1/_2$ times and not more than $1^3/_4$ 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 corresponding distance for circumferential seams shall be not less than $1^1/_4$ times the diameter of the rivet holes.

**U-29** (a) The strength of circumferential joints of pressure vessels, 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, in consequence of the holding power of the tubes and stays, relieved by the effect of through tubes or stays, the strength of the circumferential joints in the shell shall be at least 35 per cent of that required for the longitudinal joints.

**U-30** The riveted longitudinal joints of a shell which exceeds $^1/_2$ in. in thickness shall be of butt-and-double-strap construction. This rule does not apply to the portion of a shell which is staybolted to an inner sheet.

**U-31** (a) The longitudinal joints of a shell not more than $^1/_2$ in. in thickness, with the exception given below, may be of lap-riveted construction; but the maximum allowable working pressure of such construction shall not exceed 200 psi for vessels less than 24 in. in diameter, nor 150 psi for vessels 24 in. in diameter or over.

(b) When a vessel is used for a purpose that makes it necessary to provide in its construction for extraordinary wear, corrosion, or other deterioration in service and plates of greater thickness are used than would otherwise be required, the longitudinal joints of shells exceeding 1/2 in. in thickness may be lap riveted if the following conditions are met:

(1) The operating pressure shall not exceed 50 psi;

(2) The plate thickness shall be at least 1.8 times the required plate thickness;

(3) Telltale holes may be drilled as provided for in Par. U-62(**b**).

(**c**) The spherical portion of vessels of any diameter which are wholly spherical or partly hemispherical may be constructed with lap joints provided that if the plate thickness exceeds 3/8 in., the several spherical sections of plate shall be hot pressed to the proper radius of curvature. When the vessel cannot be completed in the shop, the whole structure shall be carefully and completely fitted up ready for riveting before shipment.

**U-32** Butt straps and the ends of shell plates forming the longitudinal joints shall be rolled or formed to the proper curvature by pressure and not by blows.

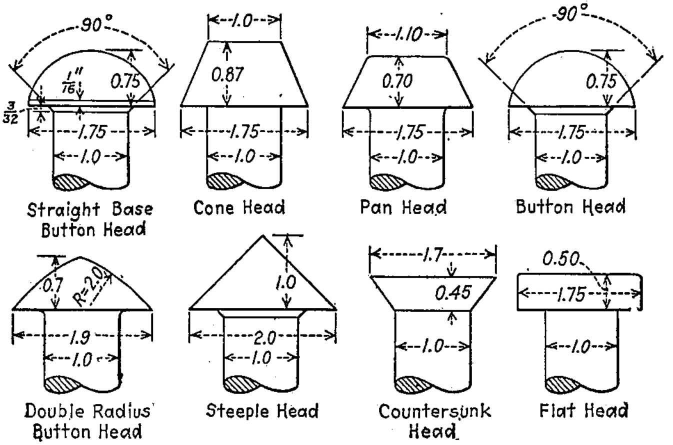
When the butt strap of a longitudinal joint does not extend the full length of the shell plates, the abutting edges of the shell plate may be welded provided the distance from the end of the butt strap to the edge of the flange of the head or adjacent shell plate is not greater than 2 1/2 in. When so constructed the vessel need not be stamped with the paragraph number as provided in Par. U-66.

**U-33** (**a**) The longitudinal joint of a riveted dome 24 in. or over in inside diameter shall be of butt-and-double-strap construction, or the dome may be made without a seam of one piece of steel pressed into shape; and its flange shall be double riveted to the shell. In the case of a dome less than 24 in. in diameter, for which the product of the inside diameter in inches and the maximum allowable working pressure in pounds per square inch does not exceed 4000, its flange may be single riveted to the shell and the longitudinal joint may be of the lap type provided it is computed with a factor of safety of not less than 8.

The longitudinal joint of a dome may be butt welded and the dome flange may be double full-fillet lap-welded to the pressure vessel, in place of riveting, if the welding complies fully with the requirements for the particular class of vessel to which the dome is attached. X-ray examination may be omitted.

(b) Domes and manhole frames attached to shells or heads of pressure vessels shall be designed in accordance with Par. U-59(g), with the additional requirement that the working stress in tension of rivets in manhole frames having a thickness of $^7/_8$ in. or less and of rivets in dome flanges shall not exceed 7200 psi.

**U-34 Rivet and Staybolt Holes.** All holes for rivets or staybolts in plates, butt straps, heads, braces, and lugs shall be drilled; or they may be punched at least $^1/_8$ in. less than full diameter for material not over $^5/_{16}$ in. in thickness and at least $^1/_4$ in. less than full diameter for material over $^5/_{16}$ in.




Dimensions of finished heads may be larger or $^1/_{10}$ smaller than those shown. Fillets under heads may be used but are not required.

FIG. U-2 ACCEPTABLE FORMS OF RIVET HEADS AFTER DRIVING
(For Additional Acceptable Forms See American Standards in Fig. UA-9)

Such holes shall not be punched in material more than $^5/_8$ in. in thickness.

For final drilling or reaming the holes to full diameter, the parts shall be firmly bolted in position by tack bolts.

The finished holes must be true, clean, and concentric.

**U-35** 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. U-2.

## DISHED HEADS

**U-36** (a) A head may be made from a single sheet, or built up of several pieces joined together. The thickness of a blank 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:

$$t = \frac{5PL}{6SE}$$

where $t$ = thickness of plate, inches,
$P$ = maximum allowable working pressure, pounds per square inch,
$L$ = radius to which the head is dished, measured on the concave side of the head, inches,
$S$ = maximum allowable working stress, as given in Tables U-2 or U-3, pounds per square inch,
$E$ = efficiency of weakest joint used in forming the head (exclusive of the joint to the shell);

for riveted joints = calculated riveted efficiency,
for fusion-welded joints = efficiency specified in Pars. U-68 and U-69. For Par. U-70 use the values of $SE$ given in the paragraph.
for seamless heads = 100 per cent (unity).

(b) The radius to which a head is dished shall be not greater than the outside diameter of the flanged portion of the head. Where two radii are used, the longer shall be taken as the value of $L$ in the formula.

(c) 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 $^1/_8$ 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. If more than one manhole is inserted in a head, the thickness of which is calculated by this rule, the minimum distance between the openings shall be not less than one fourth of the outside diameter of the head.

In a multipiece welded head if the center of such a flanged-in type manhole (over 6 in. in any dimension) is not closer to a welded joint than a distance equal to the maximum dimension of the manhole, the added thickness required shall be based on the required thickness for a seamless (one-piece) blank head. If the distance of the manhole from a welded joint is less than this, or if it crosses the weld, the added thickness shall be based on the required thickness for a welded blank head.

(d) Except as otherwise provided for in (c), (g), and (l), all openings which require reinforcement, placed in a head dished to a segment of a sphere, or in an ellipsoidal head, or in a full-hemispherical head, including all types of manholes except those of the integral flanged-in type, shall be reinforced in accordance with the rules n Par. U-59(g). In the application of those rules the opening shall be treated as though it were in a shell:

(1) Of the same outside diameter as the outside diameter of the flange of the head;
(2) Of the same material as that in the head and for the same working pressure.

The required thickness $t$ of the shell, indicated in Fig. U-9 and required in Par. U-59(g) for computing the amount of reinforcement required, shall be determined from the formula in Par. U-20, using $E = 0.90$ [this is the method specified in Par. U-59(g)], except that one half the computed value may be used for $t$ when the opening is in a full-hemispherical head. The actual thickness of the head shall be taken as the value of $m$ referred to in Fig. U-9 and Par. U-59(g).

When so reinforced, the thickness of such a head may be the same as for a blank unstayed dished head.

(e) Where the radius $L$ to which the head is dished is less than 80 per cent of the diameter of the shell, the thickness of a head with a flanged-in manhole opening shall be at least that found by making $L$ equal to 80 per cent of the diameter of the shell and with the added thickness for the manhole. This thickness shall be the minimum thickness of a head with a flanged-in manhole opening for any form of head.

(f) No head, except a full-hemispherical head, shall be of a lesser thickness than that required for a seamless shell of the same diameter. Dished heads with a reversed flange having pressure on the concave side of the dish may be used only when the requirements of Par. U-51 are met.

(g) A blank dished head of a semi-ellipsoidal form, in which half the minor axis or the depth of the head is at least equal to one quarter of the inside diameter of the head, shall be made at least as thick as the required thickness of a seamless shell of the same diameter. If a flanged-in manhole which meets the Code requirements is placed in an ellipsoidal head, the thickness of the head shall be the same as for a head dished to a segment of a sphere with a dish radius equal to 0.8 the diameter of the shell and with the added thickness for the manhole.

(h) 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.

(i) Unreinforced openings in heads shall be governed by the following rules:

(1) The edge of any unreinforced opening, excluding rivet holes, shall come no closer to the line bounding the spherical or ellipsoidal portion of the head around a manhole than the distance equal to the thickness of the head, and in no case except for water-gage connections shall it come within the part formed by the corner radius of a dished head.

(2) The maximum allowable diameter of any unreinforced opening in a head, except in a full-hemispherical head, shall not exceed that permitted by the rules in Par. U-59(a) for a shell:

(a) Of the same outside diameter as the outside diameter of the flange of the head;

(b) Of the same thickness as the actual thickness of the head;

(c) Of the same material as that in the head and for the same working pressure; but in no case shall the diameter of the opening exceed 8 in.

For unreinforced openings in full-hemispherical heads, the same rule shall apply, except that the value of $K$ used in Par. U-59(a) and the chart in Fig. U-8 shall be one half the value given by the formula therein.

(3) The minimum distance between the centers of any two unreinforced openings, rivet holes excepted, shall be determined by the following formula:

$$L = \frac{A + B}{2(1 - K)}$$

where $L$ = distance between the centers of the two openings measured on the surface of the head, inches,

$A$ and $B$ = diameters of the two openings, inches,
$K$ = same as defined in Par. U-59(a) for the equivalent shell described in (2).

(j) When the flange of an unstayed dished head is machined to make a close and accurate fit into or onto the shell, the thickness shall not be reduced to less than 90 per cent of that required for a blank head.

(k) The thickness of a blank unstayed full-hemispherical head with the pressure on the concave side shall be calculated by the following formula:

$$t = \frac{PL}{2SE}$$

where $t$ = minimum thickness of head, inches,
$P$ = maximum allowable working pressure, pounds per square inch,
$S$ = maximum allowable working stress, as given in Tables U-2 or U-3, pounds per square inch,
$L$ = radius to which the head is formed, measured on the concave side of the head, inches,
$E$ = efficiency of weakest joint used in forming the head, including the joint to the shell;

for riveted joints = calculated riveted efficiency,
for fusion-welded joints = efficiency specified in Pars. U-68, U-69, and U-70,
for seamless shells with integral heads = 100 per cent.

The above formula shall not be used when the required thickness $t$ of the head given by the formula exceeds 20 per cent of the inside radius.

Joints in full-hemispherical heads, including the joint to the shell, shall be governed by and meet all the requirements for longitudinal joints in cylindrical shells, except that in a butt-welded joint attaching a head to a shell the middle lines of the plate thicknesses need not be in alignment.

(l) If a flanged-in manhole which meets the Code requirements is placed in a full-hemispherical head, the thickness of the head shall be the same as for a head dished to a segment of a sphere [See (a)], with a dish radius equal to eight tenths the diameter of the shell and with the added thickness for the manhole as specified in (c).

**U-37** (a) When dished heads are of a thickness less than called for by Par. U-36, they shall be stayed as flat surfaces, no allowance being made in such staying for the holding power due to the spherical form unless all of the following conditions are met:

(1) They be at least two thirds as thick as called for by the rules for unstayed dished heads;

(2) They be at least $^7/_8$ in. in thickness;

(3) Through stays be used attached to the dished head by outside and inside nuts;

(4) 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 given in Par. U-40, using 70 for the value of $C$.

(b) If a dished head is formed with a flattened spot or surface, the diameter of the flat spot shall not exceed that allowable for flat heads as given by the formula in Par. U-39 using $C = 0.40$.

(c) Circular cast-iron blank spherically dished heads with bolting flanges (dished cover plates) for heads concave to pressure [Fig. U-3(a)] shall be calculated by the formula:

$$t = \frac{0.6\,PL}{S}$$

where $t$ = thickness of dished portion, inches,
$P$ = maximum allowable working pressure, pounds per square inch,
$L$ = radius to which head is dished measured on the concave side of the head, inches, but not to exceed the inside diameter of the shell to which the head is attached,
$S$ = maximum allowable working tensile stress, as given in Par. U-13(g)(3), pounds per square inch.

The plane of the bolting flange shall be at right angle to the axis of the head. The strength of the flanges shall be not less than that of the several American Standards for cast-iron fittings of the same diameters.

If of a semi-ellipsoidal form [Fig. U-3(b)] in which the inside depth of the head (one half of the minor axis of the ellipse) is not less than one quarter of the inside diameter of the shell to which the head is to be attached, the thickness of the head shall be at least that required for a cast-iron cylinder with that diameter.

Heads flatter than the foregoing limits shall be designed as flat plates.

The use of cast-iron heads shall be limited to the requirements of Par. U-13(g).

**(d)** A cast-iron dished head integral with the cast-iron shell [Fig. U-3(**c**)], when a segment of a sphere and subject to pressure on the concave side, shall be designed in accordance with (**c**) but must have a corner radius equal to at least 3 times the thickness of the head. If of semiellipsoidal shape, the provisions of (**c**) for heads of that shape shall apply.

If a cast-iron dished head is so placed as to be subject to pressure on the convex side and the dished portion is not supported by ribs or bracing, the allowable working pressure shall be limited to six tenths of that permitted when pressure is applied on the concave side.

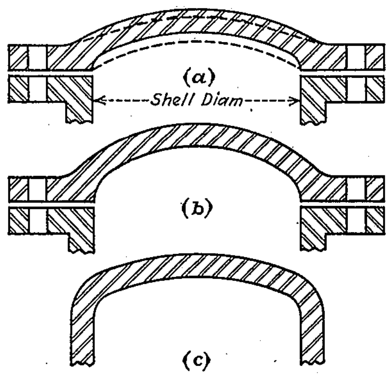


FIG. U-3 TYPICAL FORMS OF CAST IRON HEADS

**U-38** (**a**) 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, due to the process of forming, of the knuckle portion of any dished head, consisting of a segment of a sphere encircled by a part of a torus constituting the knuckle portion (torispherical), exceed 10 per cent of the thickness required by the formula in Par. U-36(**a**). Other types of heads shall have a thickness after forming of not less than that required by the applicable formula.

(**b**) 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 $1^1/_2$ in. in thickness. For plate exceeding $1^1/_2$ in., 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.

## FLAT HEADS

**U-39** (a) The minimum required thickness of unstayed flat heads, cover plates, blind flanges, etc. shall be calculated by the following formula:[1]

$$t = d\sqrt{\frac{CP}{S}}$$

where $t$ = minimum required thickness of plate, inches,

$d$ = diameter, or shortest span, measured as indicated in Fig. U-4, inches,

$P$ = maximum allowable working pressure, pounds per square inch,

$S$ = maximum allowable unit working stress, as given in Table U-2, pounds per square inch; for cast iron, $S$ = maximum bending stress as given in Par. U-13(g)(3), pounds per square inch,

$C$ = 0.162 for plates rigidly riveted or bolted to shells, flanges, or side plates, as shown in Fig. U-4(a); and for integral flat heads as shown in Fig. U-4(b) where dimension $d$ does not exceed 24 in., and the ratio of thickness of the head to dimension $d$ is at least equal to or greater than 0.05,

$C$ = 0.30 for flanged plates attached to vessels as shown in Fig. U-4(c) by means of circumferential lap joints riveted, fusion welded, or brazed and meeting

[1] This formula is designed to give safe results in so far as stress conditions are concerned. Greater thicknesses than indicated by this formula may be necessary in certain special cases. For example, in a bolted cover plate as shown in Fig. U-4(g) or (h), the deflection of the plate under pressure may relieve the pressure on the gasket sufficiently to result in leakage. A further tightening of the bolts will tend to correct this condition. Another example is that of a cover plate, as shown in Fig. U-4(g) or (h), bolted to the channel casting of a multiple-pass heat exchanger, where the cover plate makes the seal with the partitions in the channel casting separating the different passes. The deflection of the plate under bolt tension and/or pressure may be sufficient to break its contact with the partitions and short-circuit the various passes. A further tightening of the bolts will tend to aggravate this condition.

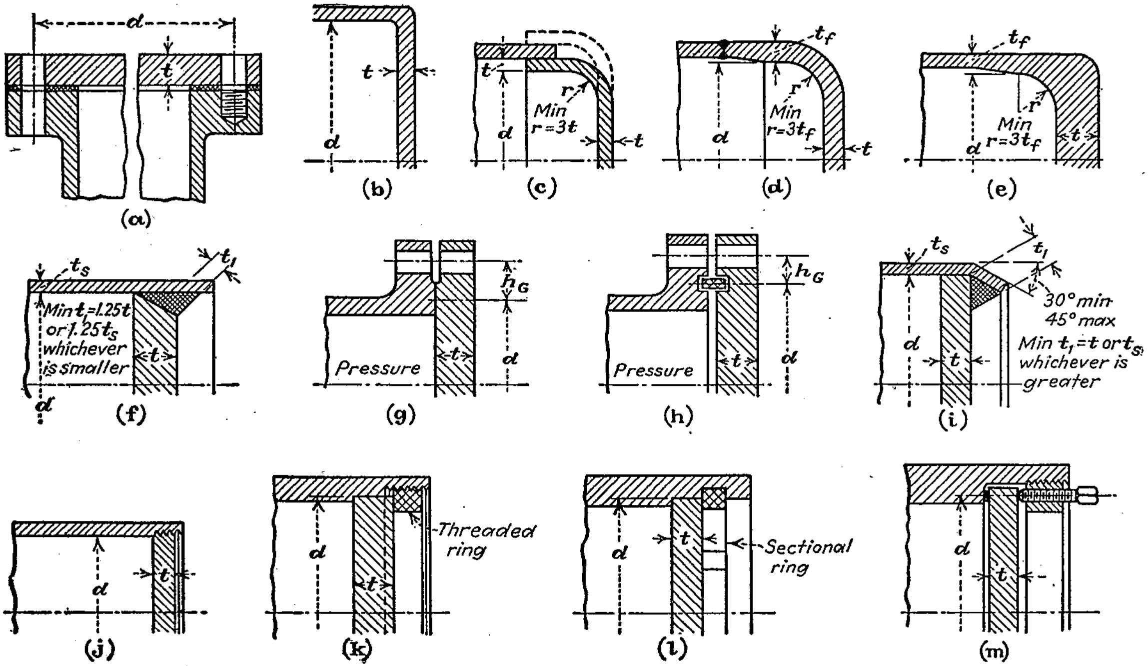



**Fig. U-4 Some Acceptable Types of Flat Heads and Covers**

Note: The above illustrations are diagrammatic only. Other designs that meet the requirements of Par. U-39 will be acceptable.

all the requirements therefor, and where the corner radius on the inside is not less than 3 times the thickness of the flange immediately adjacent thereto, and for flanged plates, with the same inside corner radius screwed over the ends of vessels, in which the design of the threaded joint against failure by shear, tension, or compression resulting from the end force due to pressure is based on a factor of safety of at least 5, and the threaded parts are at least as strong as the threads for standard piping of the same diameter. Seal welding may be used, if desired.

$C$ = 0.25 for heads forged integral with or butt welded to vessels as shown in Fig. U-4(d) and (e), where the corner radius on the inside is not less than 3 times the thickness of the flange immediately adjacent thereto, and where the welding meets all the requirements for circumferential joints given in Pars. U-67 to U-79, including those for stress-relieving and radiographic examination,

$C$ = 0.50 for plates fusion welded to the inside of vessels and otherwise meeting the requirements for the respective types of fusion-welded vessels, including stress-relieving when required for the vessel but omitting radiographic examination, and where the plate is welded for its entire thickness as shown in Fig. U-4(f) with a fillet weld having a throat not less than 1.25 times the thickness of shell or flat head, whichever is smaller,

$C = 0.30 + \frac{1.40 W h_G}{H d}$ for plates bolted to shells, flanges, or side plates, in such a manner that the setting of the bolts tends to dish the plate and where the pressure is on the same side of the plate as the bolting flange, as shown in Figs. U-4(g) and (h),

where $W$ = flange design bolt load, pounds,
$h_G$ = radial distance from the bolt circle diameter to the diameter $d$, inches,
$H$ = total hydrostatic end force on area bounded by the outside diameter of the gasket or contact surface, pounds,
$d$ = as defined above,

$C$ = 0.50 for plates having a dimension $d$ not exceeding 18 in. inserted into vessels and welded thereto as shown in Fig. U-4(i) and otherwise meeting the requirements for the respective types of fusion-welded vessels including stress-relieving when required for the vessel but omitting radiographic examination, and where the end of the vessels is crimped over to an angle not less than 30 deg nor more than 45 deg, the crimping is done cold only when this operation will not injure the metal, and the throat of the weld is not less than the thickness of the vessel wall or flat head, whichever is greater,

$C$ = 0.75 for plates screwed into the end of a vessel having an inside diameter $d$ not exceeding 12 in., as shown in Fig. U-4(j), or for heads having an integral flange screwed over the end of a vessel having an inside diameter $d$ not exceeding 12 in., and where the design of the threaded joint against failure by shear, tension, or compression resulting from the end force due to pressure is based on a factor of safety of at least 5, and the threaded parts are at least as strong as the threads for standard piping of the same diameter. Seal welding may be used, if desired.

$C$ = 0.30 for plates inserted into the ends of vessels and held in place by some suitable positive mechanical-locking arrangement such as shown in Fig. U-4(k) and (l), where all possible means of failure, either by shear, tension, or compression, due to the hydrostatic end force, are resisted with a factor of safety of 5. Seal welding may be used, if desired.

$C$ = 0.30 for plates held by set bolts in line with the gasket as shown in Fig. U-4(m), provided the design of all holding parts against failure by shear, tension, or compression resulting from the end force due to pressure, is based on a factor of safety of at least 5, and threaded joints, if any, are at least as strong as for standard piping of the same diameter.

(b) **Openings.** Unreinforced openings in unstayed flat heads shall be designed in accordance with the rules in Par. U-59(**a**), where $D = d$ and $K =$ [thickness required by formula given above in (**a**)] ÷ (actual thickness of flat plate).

Reinforced openings in unstayed flat heads, where the maximum diameter of the opening does not exceed 50 per cent of dimension $d$, shall be designed in accordance with the rules in Par. U-59(g), where $t$ is the thickness required by the formula given above in (a) except that the required cross section need be only 75 per cent of that specified in Par. U-59(g).

Where the maximum diameter of an opening exceeds 50 per cent of dimension $d$, the flat plate shall be designed as a flange in accordance with the Rules for Bolted Flanged Connections given in Pars. UA-18 to UA-24, inclusive.

(c) **Bolted Flanged Connections.** Bolted flanged connections shall be designed in accordance with Pars. UA-18 to UA-24, inclusive.

## BRACED AND STAYED SURFACES

**U-40** (a) 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:

$$P = C \times \frac{T^2}{p^2} \times \frac{S}{11{,}000}$$

where $P$ = maximum allowable working pressure, pounds per square inch,

$T$ = thickness of plate in sixteenths of an inch,

$S$ = maximum allowable unit working stress, pounds per square 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 $^7/_{16}$ in. in thickness with ends riveted over,

$C$ = 120 for stays screwed through plates over $^7/_{16}$ in. in thickness 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 Par. U-43),

$C$ = 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 $T$.

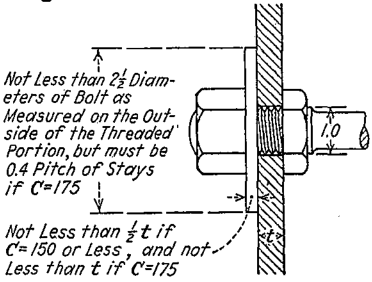



FIG. U-5 ACCEPTABLE PROPORTIONS FOR ENDS OF THROUGH STAYS

**(b)** If a flat plate not less than $^3/_8$ in. in thickness is strengthened with a securely riveted doubling plate covering the full area of the stayed surface and having a thickness of not less than $^2/_3\,T$, then the value of $T$ in the formula shall be three fourths of the combined thickness of the plate and doubling plate but not more than $1^1/_2$ times the thickness of the plate, and the value of $C$ given above may also be increased 15 per cent.

**(c)** 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.

**(d)** Acceptable proportions for the ends of through stays with washers are indicated in Fig. U-5.

**U-41 Staybolts.** **(a)** The ends of staybolts or stays screwed through the plate 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.

(b) Welded-in staybolts which need not be stress-relieved may be used in the construction of Pars. U-69 and U-70 vessels provided:

(1) The pressure does not exceed 150 psi;
(2) The thickness of plate does not exceed 3/4 in.;

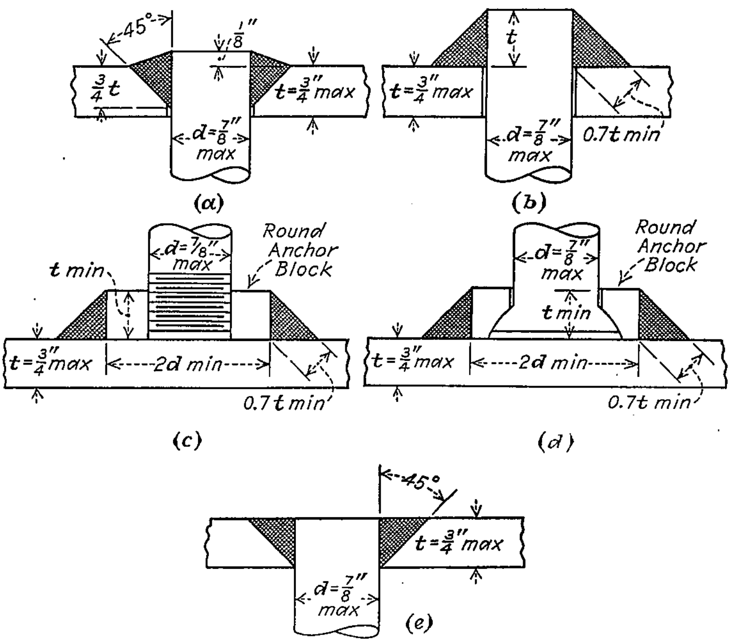



FIG. U-6 TYPICAL FORMS OF WELDED STAYBOLTS

(3) The diameter of the staybolt does not exceed 7/8 in.;
(4) The calculated shearing stress does not exceed 6000 psi, based on the throat dimension of the fillet weld;
(5) The arrangement used conforms to one of those illustrated in Fig. U-6;
(6) The provisions of Par. U-40 are followed using the constant for threaded staybolts;

(7) The inside welds are properly inspected before the attachment of the closing plates;

(8) The welding operators are qualified under the rules of Section IX of the Code.

(c) Welded stays, substantially as shown in Fig. U-7 and which need not be stress-relieved, may be used to stay jacketed unfired pressure vessels built in accordance with Par. U-69 provided:

(1) The pressure does not exceed 150 psi;

(2) The plates do not exceed $^1/_2$ in. in thickness;

(3) The throats of the welds do not exceed the plate thickness;

(4) The inside welds are properly inspected before the attachment of the closing plates;

(5) The stresses calculated on the throat dimension of the weld do not exceed 5600 psi;

(6) The maximum diameter or width of the hole in the plate does not exceed $1^1/_4$ in.;

(7) The welding operators are qualified under the rules of Section IX of the Code.

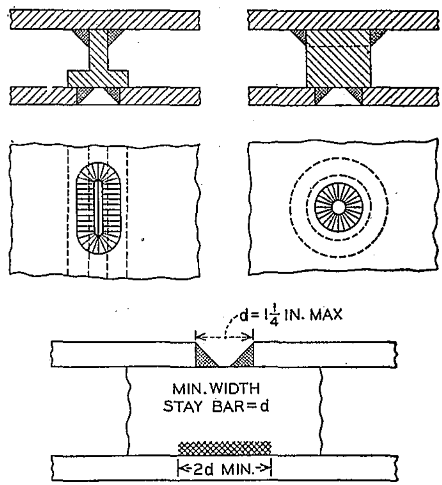



Fig. U-7 Use of Plug and Slot Welds for Staying Plates

**U-42 Structural Reinforcements.** (a) When channel or angle sections or other members are securely riveted to the heads for attaching through stays, the transverse stress on such members shall not exceed $1^1/_8$ times the maximum allowable unit working stress in 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 in conformity with that specified for staybolts.

(b) If the outstanding legs of the two members are fastened together so that 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 pressure vessel, 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.

**U-43** (a) The maximum spacing between centers of rivets attaching the crowfeet of braces to the braced surface shall be determined as in Par. U-40, using 135 for the value of *C*.

(b) 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 Par. U-40, using 175 for the value of *C*.

(c) 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 Par. U-40, 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.

(d) In applying these rules and those in Par. U-40 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.

**U-44** The formula in Par. U-40 was used in computing Table U-5 for steel plate stamped 55,000 psi. Where values for screwed stays with ends riveted over are required for con-

TABLE U-5 MAXIMUM ALLOWABLE PITCH OF SCREWED STAYBOLTS, ENDS RIVETED OVER

| Pressure, psi | Thickness of plate, in. | | | | | | |
|---|---|---|---|---|---|---|---|
| | 5/16 | 3/8 | 7/16 | 1/2 | 9/16 | 5/8 | 11/16 |
| | Maximum pitch of staybolts, in. | | | | | | |
| 100 | 5 1/4 | 6 3/8 | 7 3/8 | ... | ... | ... | ... |
| 110 | 5 | 6 | 7 | 8 3/8 | ... | ... | ... |
| 120 | 4 3/4 | 5 3/4 | 6 3/4 | 8 | ... | ... | ... |
| 125 | 4 3/4 | 5 5/8 | 6 5/8 | 7 3/4 | ... | ... | ... |
| 130 | 4 5/8 | 5 1/2 | 6 1/2 | 7 5/8 | ... | ... | ... |
| 140 | 4 1/2 | 5 3/8 | 6 1/4 | 7 3/8 | 8 3/8 | ... | ... |
| 150 | 4 1/4 | 5 1/8 | 6 | 7 1/8 | 8 | ... | ... |
| 160 | 4 1/8 | 5 | 5 7/8 | 6 7/8 | 7 3/4 | ... | ... |
| 170 | 4 | 4 7/8 | 5 5/8 | 6 3/4 | 7 1/2 | 8 3/8 | ... |
| 180 | ... | 4 3/4 | 5 1/2 | 6 1/2 | 7 3/8 | 8 1/8 | ... |
| 190 | ... | 4 5/8 | 5 3/8 | 6 3/8 | 7 1/8 | 7 7/8 | ... |
| 200 | ... | 4 1/2 | 5 1/4 | 6 1/8 | 7 | 7 3/4 | 8 1/2 |
| 225 | ... | 4 1/4 | 4 7/8 | 5 7/8 | 6 1/2 | 7 1/4 | 8 |
| 250 | ... | 4 | 4 5/8 | 5 1/2 | 6 1/4 | 6 7/8 | 7 5/8 |
| 300 | ... | ... | 4 1/4 | 5 | 5 5/8 | 6 1/4 | 7 |

ditions not given in Table U-5, they may be computed from the formula and used, provided the pitch does not exceed 8½ in. Where the staybolting of shells 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.

**U-45** 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.

**U-46** The minimum diameter of a screw stay (usually the root of the thread) shall be used.

**U-47** 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.

**U-48** Holes for screw stays shall be drilled full size or punched not to exceed ¼ in. less than full diameter of the hole

TABLE U-6 MAXIMUM ALLOWABLE STRESSES FOR STAYBOLTS AND STAYS OR BRACES

| Description of staybolts and stays or braces | Stresses, psi | |
|---|---|---|
| | For lengths between supports not exceeding 120 diameters[1] | For lengths between supports exceeding 120 diameters[1] |
| (*a*) Unwelded or flexible staybolts less than 20 diameters[1] long, screwed through plates with ends riveted over | 7,500 | .... |
| (*b*) Hollow steel staybolts less than 20 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 in. 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.

The reference to welded stays in Par. U-50(b) and to "welded stays or braces" in the above table refers to the method of fabrication by forge welding of the part itself and not to the attachment of the stays or braces to the sheets.

for plates over $^5/_{16}$ in. in thickness, and $^1/_8$ in. less than the full diameter of the hole for plates not exceeding $^5/_{16}$ in. in thickness, and then drilled or reamed to the full diameter. The holes shall be tapped fair and true with a full thread.

**U-49** The ends of steel stays upset for threading shall be thoroughly annealed.

**U-50** (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) 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 U-6.

## HYDROSTATIC DEFORMATION TEST

**U-51** Where no rules are given and it is impossible to calculate with a reasonable degree of accuracy the strength of a pressure vessel or any part thereof, a full-sized sample shall be built by the manufacturer and tested in accordance with the standard practice for making a hydrostatic test on a pressure part to determine the maximum allowable working pressure, as given in Pars. UA-1 to UA-11, or in such other manner as the Boiler Code Committee may prescribe.

## CALKING

**U-52** (a) The calking edges of plates, butt straps, and heads shall be beveled to an angle not sharper than 70 deg 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 $^1/_8$ in. Calking shall be done with a tool of such form that there is no danger of scoring or damaging the plate underneath the calking edge, or splitting the calked sheet.

(b) Fusion welding may be used to seal the calking edges of riveted joints and rivet heads of unfired pressure vessels, provided the plates do not exceed 0.30 per cent carbon and the thickness of the plate or head affected by the welding is at least $^1/_8$ in. more than that required for a seamless shell of the same diameter, the same working pressure, and the same grade of material. Such seal welding shall not be applied until after the vessel is made tight as evidenced by the regular hydrostatic pressure test prescribed in Par. U-64. Seal welding may be used on nozzles and their reinforcing plates under the same conditions. On unstayed dished heads, seal welding shall not be applied closer than $^1/_2$ in. to the point of tangency of the knuckle of the flange. Seal welding may be applied only when the weld metal is deposited in a single layer having a throat thickness of not less than $^3/_{16}$ in., nor more than $^5/_{16}$ in. The heat from welding shall not distort the plate or loosen the rivets in such a manner as to break the initial bond effected in the riveted joint. After seal welding, the vessel shall be resubjected to the prescribed hydrostatic test.

## MANHOLES AND HANDHOLES

**U-53** (a) All unfired pressure vessels for use with compressed air or subject to internal corrosion shall be provided with suitable manhole, handhole, or other inspection openings for examination and cleaning, except that such openings may be omitted from vessels containing compressed air when the actual service conditions or other material stored in them are such that the vessel is not subject to internal corrosion.

(b) An elliptical manhole shall be not less than 11 × 15 in., or 10 × 16 in. size. A circular manhole shall be not less than 15 in. in diameter.

(c) A handhole opening shall be not less than 2 × 3-in. size but it is recommended that it be as large as possible consistent with the size of the vessel and the location of the opening.

(d) All access and inspection openings in a shell or unstayed head shall be designed in accordance with the rules in Par. U-59.

(e) When a threaded inspection opening is to be used for inspection or cleaning purposes, it shall be not less than $1^1/_2$ in.

pipe size. The closing plug or cap shall be of a material suitable for the pressure and temperature conditions. Bronze shall not be used for temperatures over 450 F.

The thread shall be a standard tapered pipe thread except that a straight thread of equal strength may be used if other sealing surfaces to prevent leakage are provided.

**U-54** All vessels which require access or inspection openings shall be equipped as follows:

(a) All vessels less than 18 in. in diameter shall have at least two handholes or two plugged threaded inspection openings.

(b) All vessels 18 to 36 in., inclusive, in diameter shall have a manhole, or at least two handholes, or two plugged threaded inspection openings of not less than 2 in. pipe size.

(c) All vessels over 36 in. in diameter shall have a manhole except those whose shape or use make it impracticable, in which case they shall have at least two 4 × 6 in. handholes, or two handholes of equivalent area.

(d) When handholes or plugged openings are used for inspection openings in place of a manhole, where permitted, one handhole or one plugged opening shall be placed in each head or in the shell near each head.

(e) Removable heads or cover plates may be used in place of the required openings provided they are equal at least to the required size of the required inspection openings.

A single removable head or cover plate may be used in place of all other inspection openings if it is of such size and location that a general view of the interior may be obtained through the opening at least equal to that obtained through the inspection openings otherwise required.

(f) In special cases where vessels 16 in. or less in diameter are located so that inspections cannot be made without dismantling or removing the vessel, special openings need not be provided if the tapping for pipe connections properly located for inspection purposes is not less than $1^1/_2$ in. pipe size.

**U-55** A manhole or handhole reinforcing ring or frame, when used, shall be of rolled, forged, or cast steel, or cast iron, or nonferrous material, and shall comply with the requirements of Par. U-59(g).

*(Pars. U-56 and U-57 have been omitted)*

**U-58** Manhole and handhole cover plates and yokes shall be of rolled, forged, or cast steel, or cast iron, or nonferrous material.

The strength of all such parts together with the bolts and yokes, if any, shall be proportioned for the service for which they are used.

## NOZZLE OPENINGS

**U-59 Unreinforced Openings.** (a) The rules in this section, (b), (c), and (d) following, and the charts in Fig. U-8 apply only to shells in which there are tube holes or other plain unreinforced openings or which may be pierced with telltale holes without reducing the working pressure below that given by the rules in Par. P-180 of Section I of the Code, and they are further limited to shells 8 in. or more in diameter in which the shell thickness does not exceed one fifth the diameter, and in which the largest hole does not exceed six tenths of the diameter of the shell. Plain unreinforced holes, such as threaded openings tapped directly into the shell of the pressure vessel, drilled holes for the boiler-tube type of connection, and studded connections, shall not exceed the diameter given by the charts in Fig. U-8, nor shall they exceed a diameter of 8 in. in any case. The diameter of a threaded opening shall be taken as that at the root of the thread.

The definitions of the symbols shown in Fig. U-8 are as follows:

$d$ = maximum allowable diameter of openings, inches,
$D$ = outer diameter of the shell, inches,
$t$ = actual thickness of shell, inches,
$K = \frac{PD}{2St}$,
$P$ = working pressure, pounds per square inch,
$S$ = working stress, pounds per square inch, given in Table U-2.

When there is a series of unreinforced openings in a pressure vessel, the efficiency of the ligaments between openings shall be calculated by the rules given in Pars. P-192 and P-193 of Section I of the Code.

(b) **Threaded Connections.** All threaded connections 1 in. pipe size or over which conform to the American Pipe Thread Standard shall have not less than the number of full threads given in Table U-7. For smaller threaded connections there shall be at least four such threads. Other thread standards may be used provided the threaded thickness of the material conforms to Table U-7.

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

Where the maximum allowable working pressure exceeds 125 psi, threaded joints for nipple or pipe connections over 3 in. pipe size shall not be used either at the shell or terminating end of such connections. When threaded joints are used for other purposes such as inspection openings or end closures, the foregoing limitation of 3 in. pipe size shall not apply, but the details of such construction must meet the requirements of other sections of the Code where threaded joints are permitted.

Piping connected to the flanges of outlet nozzles on a pressure vessel, or for piping between pressure parts of a pressure vessel, may be attached by any of the following methods:

(1) By screwing into a tapped opening with a screwed fitting or valve at the other end;

(2) By screwing each end into tapped flanges, fittings, or valves with or without rolling or peening;

(3) By bolted joints including those of the Van Stone type;

(4) By expanding into grooved holes.

TABLE U-7 MINIMUM NUMBER OF PIPE THREADS FOR CONNECTIONS

| Size of pipe connection, in. | 1 and 1 1/4 | 1 1/2 and 2 | 2 1/2 to 4 inclusive | 4 1/2 to 6 inclusive | 7 and 8 | 9 and 10 | 12 |
|---|---|---|---|---|---|---|---|
| Number of threads per inch | 11 1/2 | 11 1/2 | 8 | 8 | 8 | 8 | 8 |
| Minimum number of threads required for connection | 4 | 5 | 7 | 8 | 10 | 12 | 13 |
| Minimum thickness or length required to give above number of threads, in. | 0.348 | 0.435 | 0.875 | 1 | 1.25 | 1.5 | 1.625 |

Any of these joints may be seal welded, if desired.

(c) **Expanded Connections.** A pipe or tube connection or forging may be attached by inserting through an opening and expanding into the shell, provided the diameter of such an

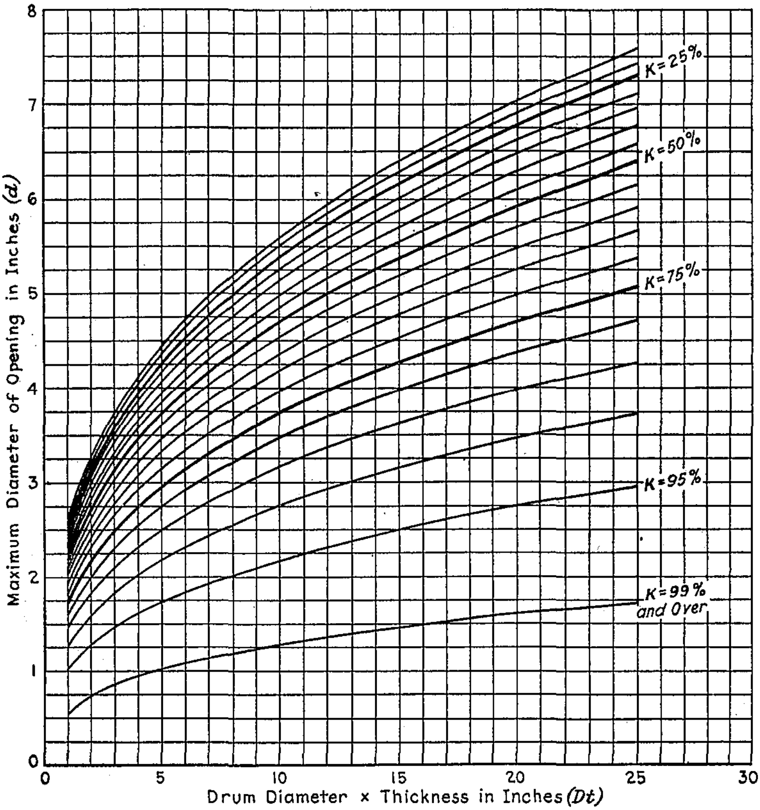



FIG. U-8 CHART SHOWING LIMITS OF SIZES OF UNREINFORCED OPENINGS IN CYLINDRICAL SHELLS

opening is not greater than that permitted for unreinforced circular openings in this section. Such connections shall be expanded and flared not less than $^1/_8$ in. over the diameter of the tube hole or they may be flared not less than $^1/_8$ in.,

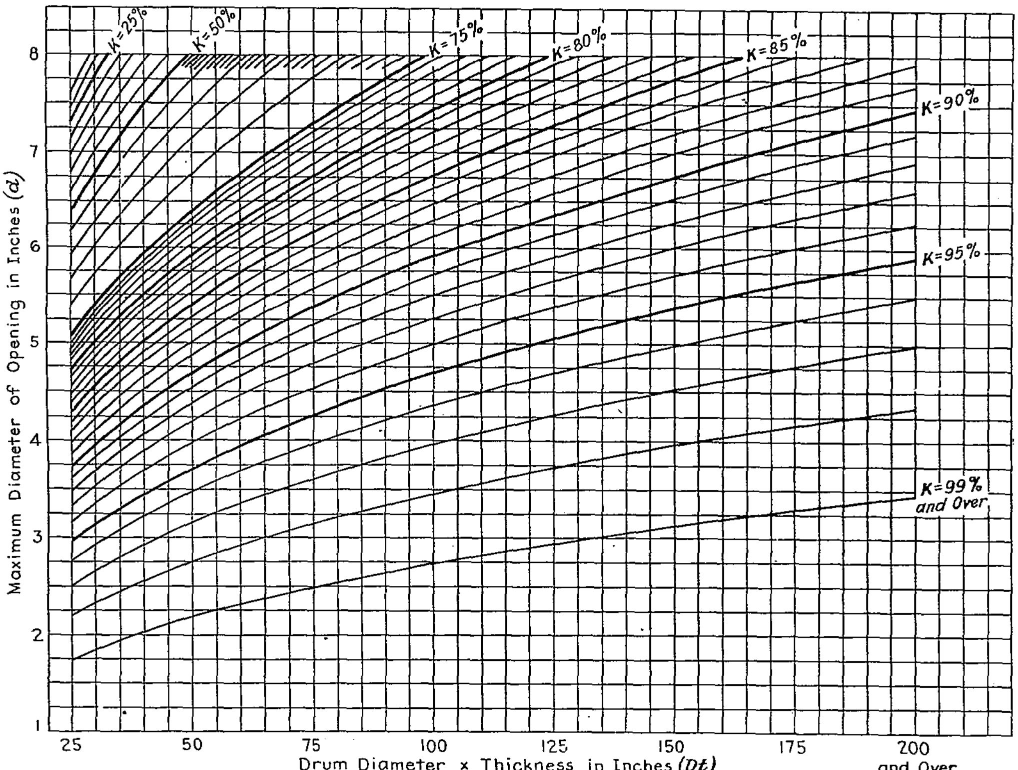



FIG. U-8 CHART SHOWING LIMITS OF SIZES OF UNREINFORCED OPENINGS IN CYLINDRICAL SHELLS (*Continued*) rolled, and beaded, or flared, rolled, and welded. Such tubes shall project through the shell not less than 1/4 in. nor more than 1/2 in. before flaring. Where such tubes enter at an angle, the maximum limit of 1/2 in. shall apply only at the point of least projection. The outside diameter of such a connection shall not exceed 6 in.

(d) **Studded Connections.** A studded connection with a flat surface machined on the shell for a gasket may be used for attaching flanged fittings provided the studs are engaged in the shell for a depth of at least the diameter of the stud used. The design and bolting of the flange shall be in accordance with Par. P-299 of Section I of the Code. Stud holes shall straddle the center line of the vessel. The equivalent diameter of the opening shall be that determined by the total length of shell removed, including stud holes, if any, on any line parallel to the longitudinal axis of the shell. The equivalent diameter shall not exceed the maximum allowable diameter of an unreinforced opening as given by the rules above, using in Fig. U-8 the minimum thickness of the shell resulting from the machining of the flat surface.

(e) **Reinforced Openings.** An opening in the shell of a pressure vessel with a diameter greater than the maximum unreinforced opening permitted by (a) shall be provided with reinforcement. Openings of the reinforced type shall consist of one or more reinforcing rings or flanges riveted, welded, or brazed to the shell and/or a tube or pipe extension or fitting welded to the shell and/or welded to or integral with the reinforcing flange. The thickness of each independent riveted reinforcing flange or ring shall be not less than given in Table U-8.

(f) The thickness of a tube or pipe extension welded to the

TABLE U-8 MINIMUM THICKNESS OF INDEPENDENT RIVETED REINFORCING RINGS OR FLANGES

| Thickness of shell plate, in. | Thickness of reinforcing ring or flange, in. |
|---|---|
| 1/8 | 1/8 |
| 3/16 | 3/16 |
| 1/4 to 11/32 | 1/4 |
| 3/8 to 13/32 | 5/16 |
| 7/16 to 15/32 | 3/8 |
| 1/2 to 9/16 | 7/16 |
| 5/8 to 3/4 | 1/2 |
| 7/8 | 5/8 |
| 1 | 11/16 |
| 1 1/8 to 2 | 3/4 |
| Over 2 | 1 |

shell and/or a reinforcing ring or flange shall be not less than that for standard-weight pipe of the same diameter and shall comply with Par. P-23 of Section I of the Code.

For nozzle fittings having a bolting flange and an integral flange for riveting, the thickness of the flange attached to the pressure vessel shall also be not less than the thickness of the neck of the fitting.

(g) All circular or elliptical openings of the reinforced type shall comply with the following requirements:

(1) On a line parallel to the longitudinal axis of the shell and passing approximately through the center of the opening and through the weakest section of a riveted reinforcing ring or flange (sectional views in Fig. U-9), the total cross section in the complete reinforced opening, including the shell and cross section of fusion welds if any, and deducting for rivet holes if any, within the limits defined below (defined by rectangle *ABCD* in the sectional views) shall be at least equal to the cross section (*EFGH* plus *JKLM*) obtained by multiplying the shell thickness $t$ required by Par. U-20, using $E = 0.90$, by twice the diameter $d$ of the opening, less 2 in. The above mentioned limits are:

(a) A distance on each side of the center line of the opening equal to the actual inside diameter $d$ of the opening in the shell in the finished construction (lines *AD* and *BC* in the sectional views).

(b) A distance on each side of the middle line of the actual thickness $m$ of the shell equal to 3 times such actual thickness, except that in no case shall the limits extend along the tubular portion of a connection beyond the surface *NP* of the shell, or of the reinforcement if any, more than $2^1/_2$ times the thickness $n$ of the tubular portion (lines *AB* and *DC* in the sectional views).

When there are two or more adjacent openings, the limits (defined by *AD* and *BC*) for the openings shall not be considered to overlap, and in no case shall any portion of a cross section be considered to apply to more than one opening. If the difference between thickness $t$ and actual thickness $m$ represents material added for corrosion, the reinforcement must be computed on the basis of thickness $t$ and no credit taken for the corrosion allowance.

No credit can be taken for the additional strength of ma-

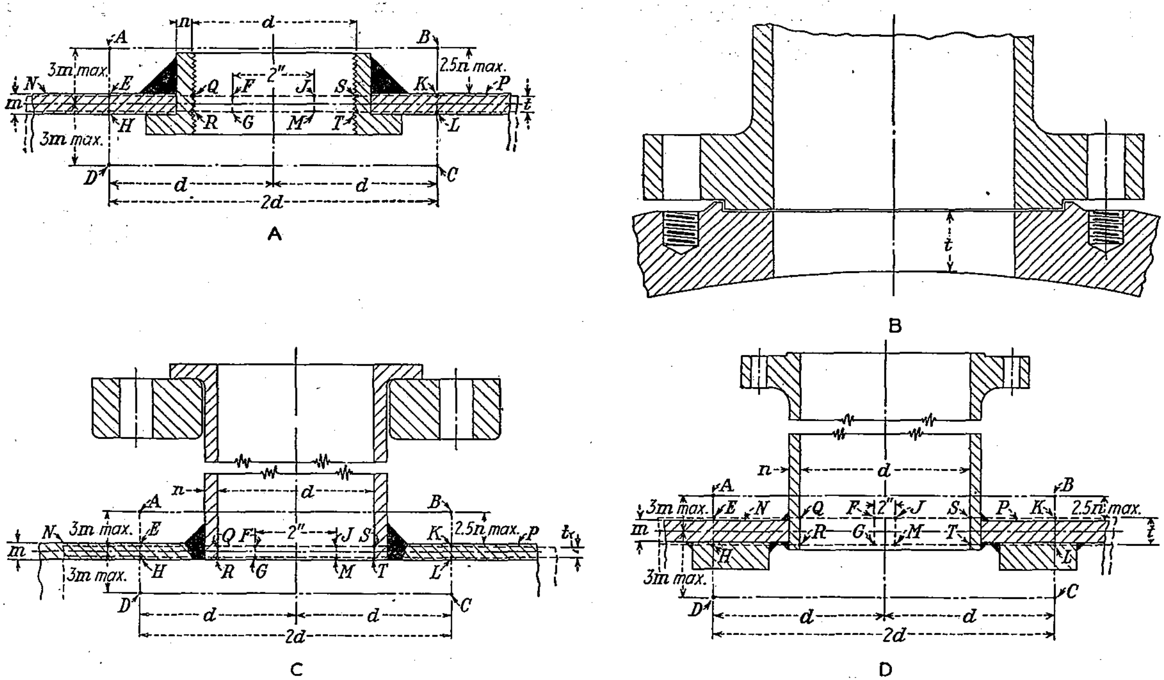



FIG. U-9 TYPES OF NOZZLE FITTINGS

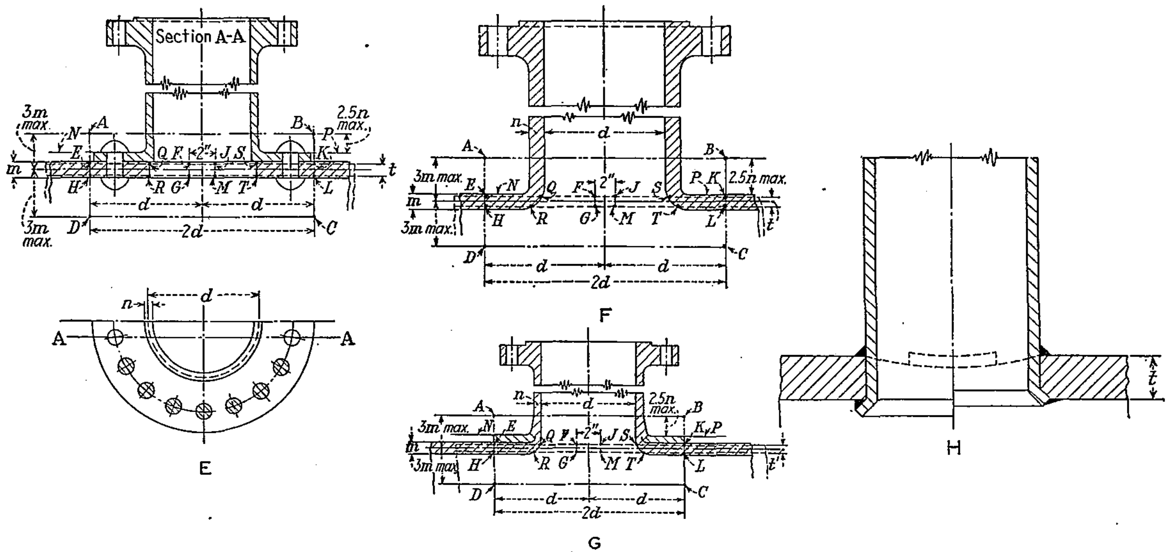



Fig. U-9 Types of Nozzle Fittings (*Continued*) terial having a higher tensile strength than that of the vessel wall to be reinforced.

(2) On either side of the line parallel to the longitudinal axis of the shell, as determined in (1), the strength of the attachment to the pressure vessel of each separate part entering into the fabrication of a reinforced opening shall be at least equal either to the tensile strength of the cross section of the reinforcing part within the above limits (within the rectangle *ABCD*), or to the tensile strength of a cross-sectional area (*QFGR* plus *JSTM*) determined by multiplying the shell thickness $t$ required by Par. U-20, using $E = 0.90$, by the diameter $d$, less 2 in. of the opening in the shell in the finished construction, whichever tensile strength is the smaller. For riveted construction the strength of attachment is the shearing strength of the rivets, and for fusion-welded construction it is the strength of the weld in shear or in tension, whichever is smaller.

(h) The unit working shear stress of a weld shall not exceed 0.8 times the allowable working stress in tension for the type of fusion-welded vessel for which the welding process is suitable. For fusion-welded connections, in addition to complying with the rules given above in (2), the following additional requirements shall be met:

(1) Where the thickness $t$ of the thinner of the two parts being joined is $^3/_4$ in. or less, the dimensions of the welds shall be not less than the requirements given by the formulas in Fig. U-10.

(2) Where the thickness $t$ is greater than $^3/_4$ in., the dimensions of the welds shall be not less than the requirements given in Fig. U-10 using a value of $^3/_4$ in. for $t$ in the formulas.

(i) **Riveted Connections.** Materials for riveted openings shall be of rolled, forged, or cast steel, or cast iron as herein provided. Cast-iron nozzles and fittings may be used if the pressure does not exceed 160 psi, and/or the temperature does not exceed 450 F. Riveted cast-iron fittings may be considered as reinforcement as permitted by this paragraph provided the thicknesses of the cast-iron parts are not less than $^5/_8$ in., and the total area of the cast-iron reinforcement is at least twice that required for steel.

(j) The strength of the rivets in tension in a flange frame or ring riveted to a vessel, based on the minimum tensile strength given in the specifications, shall be at least equal to that re-

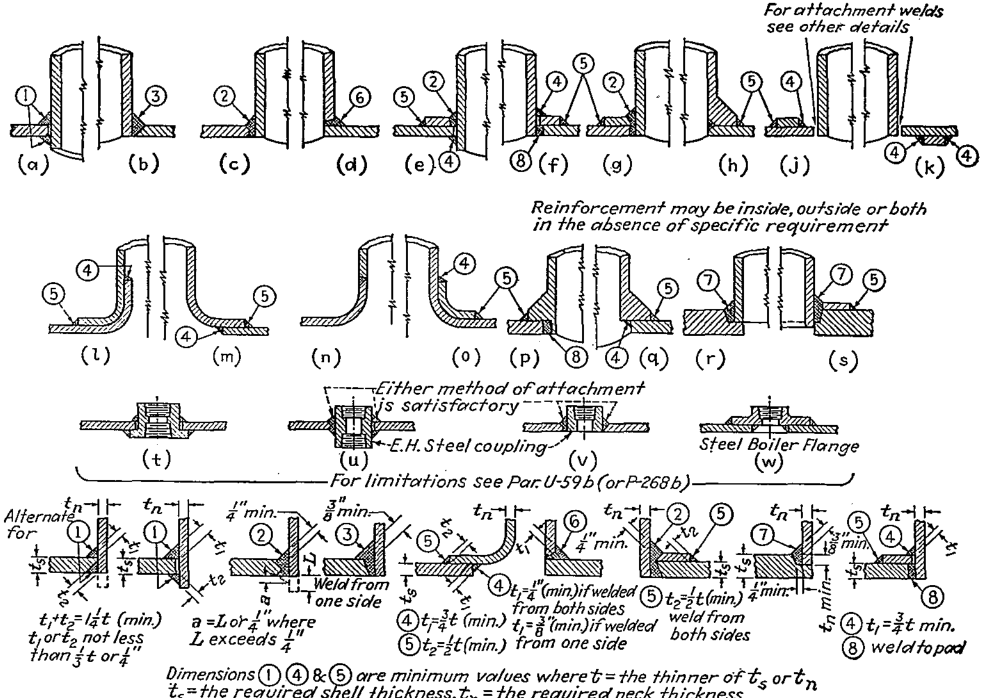



Fig. U-10 Some Acceptable Types of Fusion-Welded Nozzles and Other Connections to Shells or Drums

**Note: The above arrangements are illustrative only. Any other design that meets the requirements of Par. U-59(g) and (h) will be acceptable. Weld dimensions indicated are minimum values. For reinforced openings the strength of all welds should be checked to conform with Par. U-59(g) and (h).**

quired to resist the stress due to the maximum allowable working pressure with a factor of safety of five.

The tensile stress in the rivets due to the pressure shall be computed in the following ways:

(1) For outside calking the stress shall be equal to the area bounded by the outside calking multiplied by the maximum allowable working pressure.

(2) For inside calking (and with no outside calking) the stress shall be equal to the area bounded by the inside calking multiplied by the maximum allowable working pressure.

(k) The rivets attaching nozzles shall be so spaced as to avoid the possibility of the shell plate failing by tearing around through the rivet holes. This feature shall be checked by applying the rules given in Par. P-193(b) of Section I of the Code which bear on the strength where a series of holes is placed in a drum.

(l) Riveted domes shall also comply with the additional rules given in Par. U-33.

(m) Seal welding may be employed in accordance with the procedure in Par. U-52(b).

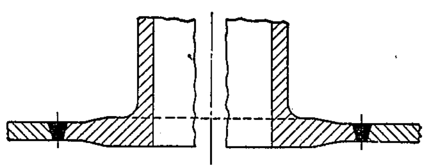


Fig. U-11 Inserted Type Nozzle

(n) **Forge - Welded Connections.** Forge-welded connections shall be of forged or rolled steel material, seamless tubing, or forge-welded pipe.

Forge-welded connections shall be attached by the methods shown in Fig. U-20.

All forge-welded connections shall be stress-relieved in accordance with the procedure given in Par. U-76.

(o) **Fusion-Welded Connections.** Materials for fusion-welded connections shall be in accordance with Par. U-71(b).

All welding for fusion-welded connections shall be equivalent to that required for the particular vessel to which the connection is attached.

Where a nozzle is attached to a Par. U-68 pressure vessel by a flange or saddle inserted in and butt-welded to the shell at the edge of the flange as shown in Fig. U-11, the weld so made shall be radiographed. Radiographic examination of other types of connections of nozzles to shells or drums may be omitted except as specifically required in other paragraphs of the Code.

The fusion welding of dome flanges shall also comply with additional rules given in Par. U-33.

(p) When vessels are built in accordance with Par. U-68, all connections after being attached by fusion welding shall be stress-relieved.

When vessels are built in accordance with Par. U-69 and are required to be stress-relieved, all connections and other attachments after being attached by fusion welding shall also be stress-relieved. When vessels are built in accordance with Par. U-69 and are not required to be stress-relieved, connections and other attachments after being attached by fusion welding need not be stress-relieved.

CAUTION: A welding procedure should be used which will prevent excessive locked-up stresses and warpage. A certain degree of preheating provided either by the welding itself or by other means may be necessary in some cases.

If a vessel as a whole is not required to be stress-relieved, but some parts, because of thickness if any welding is done on them, are required to be stress-relieved, the parts may be so treated before being attached to the vessel.

When vessels are built in accordance with Par. U-70, connections and other welded-on attachments need not be stress-relieved.

(q) When connections are attached by fusion welding to a forge-welded, riveted, brazed, or seamless vessel, the vessel shall be stamped "U-68," "U-69," or "U-70" as required by Par. U-66 and in accordance with the service limitations as to pressure, temperature, etc., as the case may be, and the requirements for welding and stress-relieving of fusion-welded connections as given in (o) and (p) above shall apply.

(r) Fusion-welded connections which require stress-relieving and which are attached to vessels whose seams are of riveted construction shall be fabricated and stress-relieved prior to the making up or attachment of the courses by riveting. If they do not require stress-relieving and are attached after riveting, the welds shall be located at a distance from the riveted seam at least equal to the diameter of the opening plus 4 times the plate thickness of the shell.

(s) Fig. U-10 illustrates some types of fusion-welded connections which are acceptable.

(t) **Brazing.** For threaded openings in pressure vessels where brazing is permitted, if the thickness of material in the vessel is not sufficient to give the number of threads specified in (a), the openings may be fabricated for a threaded connection by brazing to the shell a plate or a forged boss with inside flange, or any other type of connection described in this section may be used.

(u) Typical examples of the application of the above rules are presented in Pars. UA-12 to UA-17.

## GENERAL REQUIREMENTS

**U-60 Supports.** (a) All vessels must be so supported as to properly distribute the stresses due to the weight of the vessel and contents.

(b) Lugs or brackets when used to support a vessel shall be properly fitted to the surfaces to which they are attached. The shearing and crushing stresses on material used for attaching the lugs or brackets to the vessels shall not exceed 40 per cent of the maximum allowable working stresses given in Pars. U-15 and U-16.

**U-61** (a) In laying out and cutting the plates care must be taken to leave one of the stamps required in the specifications for material used, so located as to be plainly visible when the vessel is completed; or in case these are unavoidably cut out, the heat number, quality of plate, minimum tensile strength, and maker's name shall be accurately transferred, as to form, by the pressure-vessel manufacturer to a location where these stamps will be visible. The form of stampings shall be such that it can be readily distinguished from the plate maker's stamping.

(b) When plates less than $1/4$ in. in thickness are used, the manufacturer must mark each vessel in some permanent manner which will enable him to identify the heat from which the sheet in each tank has been rolled.

(c) When plates under $1/4$ in. are formed into heads 36 in. or less in diameter, the marking requirements of plate specifications may be stenciled in one place with the manufacturer's name and test identification number. The mill certification of the physical and chemical requirements of this material, in conjunction with the above modified marking requirements, shall be considered sufficient to properly identify these heads.

**U-62** (a) Vessels subject to corrosion must be so installed that there is sufficient access to all parts of the exterior and particularly to the manhole, handhole, or cover plates to permit proper inspection of the interior and exterior, except where the vessel is of such size and is so connected that it may readily be removed from its permanent location for inspection. In the case of vertical cylindrical vessels subject to corrosion, the bottom head, if dished, must have the pressure on the concave side to insure complete drainage.

(b) It is recommended that when the thickness of the plate is increased as provided for in Par. U-11, telltale holes be drilled to provide some positive indication when the thickness has been reduced to a dangerous degree. In cases where telltale holes are drilled they shall be $^1/_8$ in. to $^1/_4$ in. in diameter and shall be drilled to a depth of not less than 60 per cent of the thickness required for a seamless shell of like dimensions. These holes shall be drilled in the surface of the plate opposite to that subjected to such deterioration, the spacing of the holes to be not over 2 ft apart. If telltale holes are put in the walls of vessels under external pressure, their depth shall be at least that of the thickness of plate required for a pressure of 60 per cent of the working pressure.

**U-63** Every pressure vessel shall conform in all details with these rules, and when so constructed shall be stamped with the legend provided for in Par. U-66.

**U-64 Hydrostatic and Air Tests.** (a) Each vessel constructed under these rules shall be tested under hydrostatic pressure of not less than $1^1/_2$ times the maximum allowable working pressure, except that for enameled vessels including those of welded construction the test pressure shall be at least but need not exceed the maximum allowable working pressure, and except that other fusion-welded vessels shall be tested in accordance with Par. U-77.

(b) The maximum allowable working pressure as determined by the formula in Par. U-20 and used in determining the hydrostatic test pressures shall be that at normal atmospheric temperature and based on the actual dimensions and plate thicknesses required for the pressure and temperature that are to be stamped on the vessel.

(c) In case the vessel is not to be operated at temperatures over 650 F, the hydrostatic test pressures shall be based on the maximum allowable working pressure to be stamped on the vessel.

(d) In case the vessel is to be operated at temperatures exceeding 650 F, the hydrostatic test pressures shall be based on the maximum allowable pressure to be stamped on the vessel increased by the ratio of the allowable tensile stress at 650 F, for the material used and the corresponding allowable stress as given in Table U-2, interpolated, if necessary, for the maximum working temperature to be stamped on the vessel.

For example, a riveted vessel to be stamped 200 lb, 900 F, built of 55,000 lb steel (Specification SA-70, firebox):

| | | |
|---|---|---|
| Allowable stress, psi, at 650 F | = | 11,000 |
| Allowable stress, psi, at 900 F | = | 4,400 |
| Maximum allowable pressure, psi, at normal atmospheric temperature 200 × 11,000/4,400 | = | 500 |
| Hydrostatic test pressure, psi, 500 × 1½ | = | 750 |

(e) Gas storage vessels of riveted construction which are so constructed or installed as not to be capable of safely withstanding the weight of the large mass of water required to fill them for hydrostatic test may be tested by compressed air to a pressure of at least, but which need not exceed, the maximum allowable working pressure of the vessel, provided the allowable working pressure does not exceed 80 per cent of that which would be permitted if the vessel were subjected to the regular hydrostatic test pressure.

(f) Similar vessels of welded construction shall be subjected to a hammer test, if required, as prescribed in Par. U-77, except the vessels shall be empty and at atmospheric pressure, after which they shall be subjected to an air pressure not to exceed 2 psi, and while under this pressure the joints shall be examined for leaks by the application of soapsuds or equivalent means. Following this soap test, the vessels shall be subjected to an air pressure not less than 1¼ times the maximum allowable working pressure, after which the welded joints shall be re-examined for leaks by the application of soapsuds or equivalent means while the vessels are under an air pressure of not less than the maximum allowable working pressure.

(g) Vessels that are galvanized after fabrication may be hydrostatically tested after the galvanizing process.

**U-65 Inspection.** (a) Every pressure vessel constructed to conform with this section of the Code shall be inspected at least twice by a state inspector, a municipal inspector, or an inspector employed regularly by an insurance company. These inspectors shall have been qualified by a written examination under the rules of any state which has adopted this Code. In the case of a riveted vessel one inspection shall be made at the time of reaming rivet holes. In the case of a vessel fabricated in whole or in part by a welding process one internal inspection shall be made before final closure. A final inspection shall be made at the time of the hydrostatic test.

(b) A data sheet shall be filled out and signed by the manufacturer and the inspector. This data sheet, together with the stamping on the vessel, shall be a guarantee by the manufacturer that he has complied with all the requirements of this section of the Code. (A sample data report sheet appears as form U-1.) For vessels not inspected [See Par. U-1(a)] use form U-3.

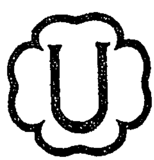


FIG. U-12 OFFICIAL SYMBOL FOR STAMP TO DENOTE THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS' STANDARD

(c) Those parts of a pressure vessel requiring Code inspection and which are furnished by other than the shop of the manufacturer responsible for the completed vessel shall be fabricated by a manufacturer in possession of a Code symbol stamp and shall be inspected by a qualified inspector. The data sheets, in triplicate, covering the part or parts, shall be executed by the manufacturer and the inspector in accordance with the Code requirements, and forwarded, in duplicate, to the manufacturer of the finished vessel. This partial data report, together with his own inspection, shall be the final inspector's authority to witness the application of a Code stamp to the vessel. The manufacturer who completes the vessel and the shop inspector making the final inspection shall be responsible for its meeting Code requirements. (A sample manufacturers' partial data report sheet appears as form U-2.)

**U-66 Stamping.** (a) Each such pressure vessel shall conform in every detail to these rules and shall be distinctly stamped in the presence of the inspector with the symbol as shown in Fig. U-12, the manufacturer's name, the manufacturer's serial number, the working pressure, and the year built, denoting that the vessel was constructed in accordance therewith. The maximum temperature corresponding with the maximum allowable working pressure shall also be stamped on the vessel.

(b) If the circumferential or longitudinal joint or joints of a vessel are brazed, forge welded, or resistance-welded, the vessel shall be stamped under the Code symbol with the letters "BRZ," "FGD," or "RES," as the case may be. Where a vessel is built by combination of types of construction as mentioned above or different types of fusion welding, the stamping on the vessel shall indicate the different classes.

(c) If the vessel is of fusion-welded construction or if it has welded pressure parts, it shall also be stamped with the number

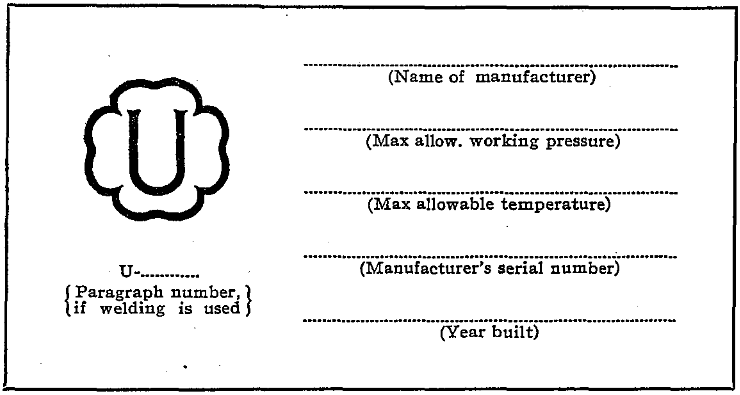



FIG. U-13 FORM OF STAMPING

of the paragraph under which the welding was done. These markings shall be legibly stamped with letters and figures at least $^5/_{16}$ in. high on some conspicuous portion of the vessel, near a manhole, if any, or handhole.

(d) Separate name plates may, and for vessels constructed of plate less than $^1/_4$ in. thick must be used on which the data required by this paragraph, excepting the Code symbol and serial number, may be etched, cast, or impressed. Such plates shall be brazed or otherwise irremovably attached to the vessel in a conspicuous location.

(e) The Code symbol and other required data not on the plate when made may be stamped on the plate prior to its being affixed to the vessel but the inspector shall see that the plate with the correct stamping is applied to the proper vessel, or the stamping may be grouped at one location and so arranged that the data for the separate parts can be properly identified. Removable pressure parts must be so stamped as to identify them with the vessel to which they pertain.

(f) The stamps shall be arranged substantially as shown in Fig. U-13.

(g) The height of the letters and figures shall be not less than $^5/_{32}$ in. Any arrangement of the required items may be followed except that the Code symbol must be on the left side of the plate.

(h) When an unfired pressure vessel unit consists of more than one pressure chamber operating at the same or different pressure, each such pressure chamber (vessel) which operates at a pressure above 15 psi shall be subject to the required inspections and hydrostatic tests. The part or pressure chamber tested shall be stamped so as to indicate that the stampings apply only to the chamber (vessel) tested, such as "jackets only," "stock space only," etc.

(i) The required hydrostatic tests shall be applied to each separate pressure chamber without pressure in the others. After passing the inspections and hydrostatic tests, each pressure chamber shall be stamped and a data sheet made out for each as required for a single vessel by Pars. U-65 and U-66.

(j) After obtaining the stamp to be used when vessels are to be constructed to conform with this section of the A.S.M.E. Boiler Construction Code, a state inspector, or a municipal inspector of any state or municipality that has adopted the Code, or an inspector employed regularly by an insurance company and who is qualified under the rules of such states or municipalities to inspect such vessels is to be notified than an inspection is to be made, and he shall inspect such vessels during construction and after completion.

(k) The stamping shall not be covered permanently with insulating or other material.

(l) Permission to use the symbol designated in the foregoing paragraph will be granted by The American Society of Mechanical Engineers to any manufacturer complying with the provisions of this Code who will agree upon forms issued by the Society that any vessel to which the symbol is applied will be constructed in full accordance with Code requirements and that he will not misuse or allow others to use the stamp by which the symbol is applied.

(m) All steel stamps for applying the symbol shall be purchased from the Society.

## RULES FOR THE FUSION PROCESS OF WELDING

**U-67** (a) Pressure vessels may be fabricated by means of fusion welding provided the construction is in accordance with the requirements for material and design of the rules for fusion welding as required in this Code.

(b) Except as specifically provided elsewhere in the Code, the welding procedure and welding operator qualifications for strength welding shall comply with the requirements of Section IX.

(c) The tests conducted by one manufacturer shall not qualify a welding operator to do work for any other manufacturer. No production work shall be undertaken until both the procedure and the operator have been qualified.

(d) **Definitions.** The following definitions cover the application of fusion-welding processes:

(1) FUSION WELDING. A process of welding metals in the molten, or molten and vaporous, state without the application of mechanical pressure or blows.

(2) FILLET WELD. A fusion weld of approximately triangular cross section, the throat of which lies in a plane disposed approximately 45 deg with respect to the surface of the parts joined.

(3) THROAT. The minimum thickness of a weld along a straight line passing through the bottom of the cross-sectional space provided to contain a fusion weld.

(4) DOUBLE-WELDED BUTT JOINT. A joint formed by the fusion of two abutting edges with a filler metal added from both sides of the joint and with reinforcement on both sides.

(5) SINGLE-WELDED BUTT JOINT. A joint formed by the fusion of two abutting edges with all the filler metal added from one side of the joint with a reinforcement on the side from which the filler metal is added.

NOTE: A joint with filler metal added from only one side is considered equivalent to a double-welded butt joint when and if means are provided for accomplishing complete penetration and reinforcement on both sides of the joint.

**U-68** Vessels covered by this Code may be used for any purpose when constructed in accordance with the rules given in this paragraph subject to the further modifications given in Par. U-141(b), as these may apply.

The joint efficiency $E$ to be used in applying the rules in Par. U-20 shall be taken as 90 per cent.

The welding shall meet the following test requirements:

**(a) Test Plates.** A test plate of the dimensions shown in Fig. U-15 from steel of the same specifications and thickness as the shell plates prepared for welding may be attached to the shell plate being welded, as in Fig. U-14, on one end of one longitudinal joint of each drum so that the edges to be welded in the test plate are a continuation of and duplication of the corresponding edges of the longitudinal joint. In this case the weld metal shall be deposited in the test plates continuously with the weld metal deposited in the longitudinal joint. The

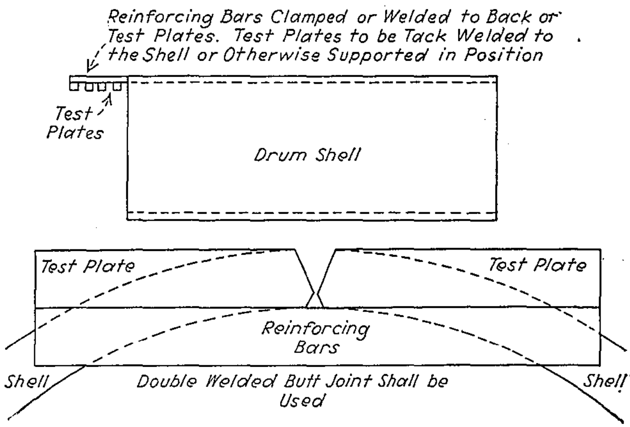



FIG. U-14 METHOD OF FORMING LONGITUDINAL TEST PLATES

plates for test samples may be taken from any part of one or more plates of the same lot of material that is used in the fabrication of welded vessels and without reference to the direction of the mill rolling. As an alternate method, a detached test plate may be welded as provided for in (b).

(b) When a test plate is welded for the longitudinal joints, none need be furnished for circumferential joints or nozzles in the same drum, providing the welding process, procedure, and technique are the same. Where a drum has only circumferential joints a test plate of the same material as the shell shall be welded in the same way as the joints in question.

When a drum has neither longitudinal nor circumferential joints, no test plate need be furnished for nozzles if the welding process and welding operator are qualified under Section IX of the Code.

**(c)** When there are several vessels being welded in succession or at any one time the plate thicknesses of which fall within a range of 1/4 in., each 200 ft of longitudinal and circumferential seams may be considered as the equivalent of one vessel and only the test plates required by **(a)** and **(b)** need

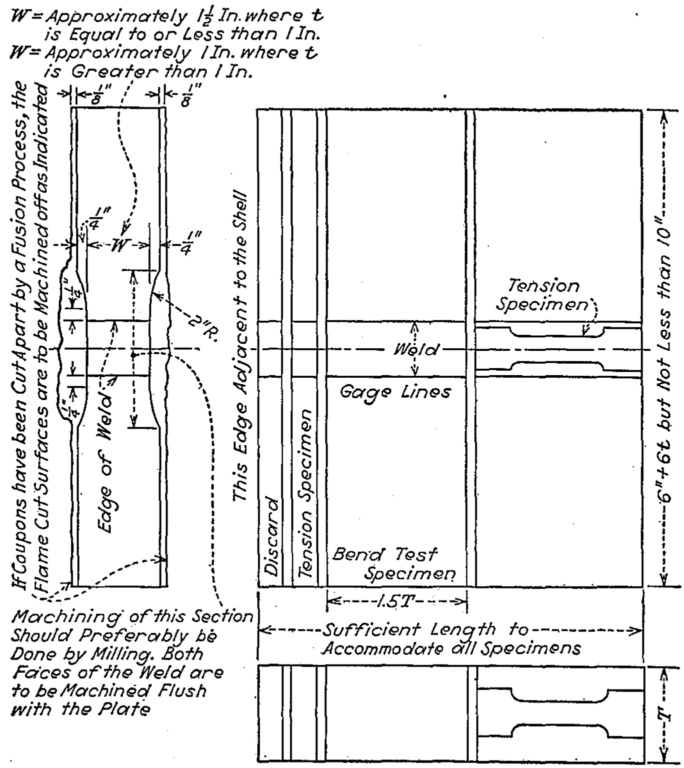



FIG. U-15 TEST SPECIMEN FROM LONGITUDINAL WELDED TEST PLATES

be made, provided they are welded in the same way as the joints in question. The test plates shall be so supported that warping due to welding shall not throw the finished test plate out of line by an angle of over 5 deg.

Where the welding has warped the test plates they shall be straightened before being stress-relieved. The test plates shall be subjected to the same stress-relieving operation as required by Par. U-76. At no time shall the test plates be heated to a temperature higher than that used for stress-relieving the vessel.

**(d) Test Specimens.** The coupons for tension and bend test shall be removed as shown in Fig. U-15 and be of the dimensions shown in Figs. U-15 and U-16.

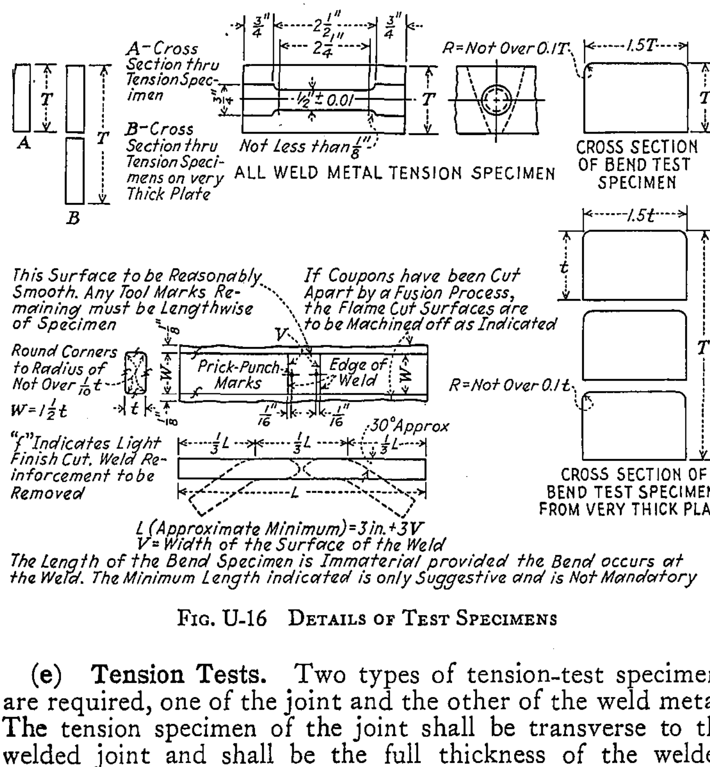



Fig. U-16 Details of Test Specimens

**(e) Tension Tests.** Two types of tension-test specimens are required, one of the joint and the other of the weld metal. The tension specimen of the joint shall be transverse to the welded joint and shall be the full thickness of the welded plate after the outer and inner surfaces of the weld have been machined to a plane surface flush with the plate. When the capacity of the available testing machine does not permit testing a specimen of the full thickness of the welded plate, the specimen may be cut with a thin saw into as many portions of the thickness as necessary, each of which shall meet the requirements.

The tensile strength of the joint specimen in Fig. U-15 shall be not less than the minimum of the specified tensile range of the plate used. (The tension test of the joint specimen as specified herein is intended as a test of the welded joint and not of the plate. If the specimen breaks in the plate and the weld shows no sign of weakness, the test may be accepted as meeting the requirements even though the stress at which failure occurs is less than the minimum of the specified range.)

The tension-test specimen of the weld metal shall be taken entirely from the deposited weld metal and shall meet the following requirements:

Tensile strength = at least that of the minimum of the range of the plate which is welded;

Elongation, minimum = 20 per cent in 2 in.

For plate thicknesses less than $^5/_8$ in., the all-weld-metal tension test may be omitted.

(f) **Bend Tests.** The bend-test specimen shall be transverse to the welded joint of the full thickness of the plate and shall be of rectangular cross section with the width $1^1/_2$ times the thickness of the specimen. When the capacity of the available testing machine does not permit testing a specimen of the full thickness of the welded plate, the specimen may be cut with a thin saw into as many portions of the thickness as necessary, each of which shall meet the requirements. The inside and outside surfaces of the weld shall be machined to a plane surface flush with the plate. The edges of this surface shall be rounded to a radius not over 10 per cent of the thickness of the plate. The specimen shall be bent cold under free bending conditions until the least elongation measured within or across approximately the entire weld on the outside fibers of the bend-test specimen is 30 per cent.

When a crack is observed in the convex surface of the specimen between the edges the specimen shall be considered to have failed and the test shall be stopped. Cracks at the corners of the specimen shall not be considered as a failure. The appearance of small defects in the convex surface shall not be considered as a failure if the greatest dimension does not exceed $^1/_{16}$ in.

(g) **Retests.** Should any of the tests fail to meet the requirements by more than 10 per cent, no retests shall be allowed except that in the case of failure of the free-bend test specimen due to permissible defects, free-bend specimen retests may be allowed at the discretion of the inspector.

Should any of the tests fail to meet the requirements by 10 per cent or less, retests shall be allowed. A second test plate shall be welded by the same operator who welded the plate which failed to meet the test requirements. The retest shall be made on specimens cut from the second plate.

The retests shall comply with the requirements. For either of the tension retests, two specimens shall be cut from the second test plate, and both of these shall meet the requirements.

When there is more than one specimen of the same type and when one or more of the group specimens fail to meet the requirements by 10 per cent or less, the retest shall be made on an entire group of specimens, which shall meet the requirements.

If the percentage of elongation of any tension test specimen is less than that specified and any part of the fracture is more than $^3/_4$ in. from the center of the gage length of the 2 in. specimen, or is outside of the middle third of the gage length of the full-size specimen as indicated by the scribe scratches marked on the specimen before testing, a retest shall be allowed.

(h) **Nondestructive Tests.** (1) All longitudinal and circumferential fusion-welded butt joints shall be radiographically examined throughout their length except:

(a) As specifically exempted in other paragraphs of the Code;

(b) Circumferential welded butt joints of manholes and sumps not exceeding 10 in. nominal pipe size or $1^1/_8$ in. wall thickness (Note: This provision applies to the fabrication and not to the method of attachment which is otherwise provided for);

(c) Vessels or nozzles made of pipe material not exceeding 10 in. nominal pipe size or $1^1/_8$ in. wall thickness, having only circumferential welded butt joints.

(2) All welded joints to be radiographed shall be prepared as follows: The weld reinforcements on both the inside and outside shall be ground, chipped and ground, or suitably machined to remove the irregularities of the weld surface so that it merges smoothly into the plate surface. The finished surface of the reinforcement may have a crown of approximately uniform amount not to exceed the following:

| Plate Thickness, In. | Thickness of Reinforcement, In. |
|---|---|
| Up to $^1/_2$, incl. | $^1/_{16}$, maximum |
| Over $^1/_2$ to 1, incl. | $^1/_{16}$ to $^3/_{32}$ |
| Over 1 thick | $^3/_{32}$ to $^1/_8$ |

Single-welded butt joints made the equivalent of double-welded butt joints, in accordance with Par. U-73(a), may be radiographed without removal of backing strip, provided the backing strip image will not interfere with the interpretation of resultant radiographs.

(3) The films obtained by the use of X rays shall be known as "exographs," and those obtained by the use of gamma rays as "gammagraphs." Both types of films shall be generally termed "radiographs."

(4) The weld shall be radiographed with a technique which will determine quantitatively the size of defects with thicknesses equal to and greater than 2 per cent of the thickness of the base metal. As a check on the radiographic technique, suitable thickness gages or penetrameters shall be employed as follows:

(a) To determine whether the radiographic technique employed is detecting defects of a thickness equal to and greater than 2 per cent of the thickness of the base material, thickness gages or penetrameters of the following type shall be placed on the side of the plate nearest the source of radiation and used as directed.

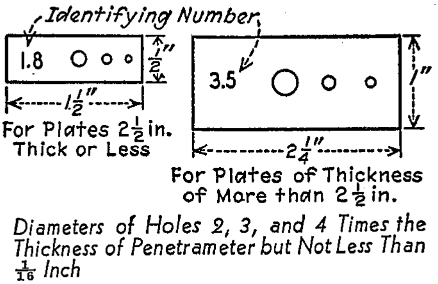



FIG. U-17 DIMENSIONS OF PENETRAMETERS

(b) The material of the penetrameter shall be substantially the same as that of the plate under examination.

(c) The thickness of the penetrameter shall be not more than 2 per cent of the thickness of the plate.

(d) In each penetrameter there shall be three holes of diameters equal, respectively, to two, three, and four times the penetrameter thickness, but in no case less than $^1/_{16}$ in., except when gamma rays are used as a source of radiation, the minimum hole need not be less than $^3/_{32}$ in. The smallest hole must be distinguishable on the radiograph.

(e) Each penetrameter shall carry an identifying number representing, to two significant figures, the minimum thickness of plate for which it may be used.

(f) The images of these identifying numbers shall appear clearly on the radiograph.

(g) For plates up to and including $2^1/_2$ in. in thickness, each penetrameter shall be $1^1/_2$ in. long and $^1/_2$ in. wide. For plates thicker than $2^1/_2$ in., each penetrameter shall be $2^1/_4$ in. long and 1 in. wide, as shown in Fig. U-17.

(h) Two penetrameters shall be used for each exposure, one at each end of the exposed length, parallel and adjacent to the weld seam with the small holes at the outer ends.

(5) The film during exposure shall be as close to the surface of the weld as is practicable. The distance of the film from the surface of the weld on the side opposite the source of radiation shall, if possible, be not greater than 1 in. With the film not more than 1 in. from the weld surface the minimum distance between the source of radiation and the back of the weld shall be as follows:

| Plate thickness, in. | Minimum distance from source of radiation to back of weld, in. |
|---|---|
| Up to 1 | 14 |
| 1 to 2 | 21 |
| 2 to 3 | 28 |
| 3 to 4 | 36 |
| 4 to 5 | 38 |

(6) There should also be a plain indication on each film showing the job number, the drum, and seam, as well as the manufacturer's identification symbol or name.

(7) If it is necessary to expose the film at a distance greater than 1 in. from the weld, the following ratio of

$$\frac{\text{Distance from source of radiation to weld surface toward radiation}}{\text{Distance from weld surface toward radiation to film}}$$

shall be at least 7 to 1. When a grid of the Buckey type is employed to reduce scattered radiation, the above ratio may be reduced to five. These conditions are imposed so as to limit the allowable distortion and magnification of any defects in the welded seam.

(8) However, when the X-ray tube is operated at a voltage of 1000 kv or more and the Buckey grid is used on plates 3 in. or more in thickness, the foregoing specification on technique may be modified to suit the requirements.

(9) All radiographs shall be free from excessive mechanical

processing defects which would interfere with proper interpretation of the radiograph.

(10) Identification markers, the images of which will appear on the film, shall be placed adjacent to the weld and their location accurately and permanently stamped near the weld on the outside surface of the drum or shell, so that a defect appearing on the radiograph may be accurately located in the actual weld.

(11) The radiographs shall be submitted to the inspector. If the inspector requests, the following data shall be submitted with the radiographs:

(1) The thickness of the base metal;
(2) The distance of the film from the surface of the weld;
(3) The distance of the film from the source of radiation.

(12) The acceptability of welds examined by radiography shall be judged by comparing the radiographs with a standard set of radiographs, reproductions of which may be obtained by purchase from the Boiler Code Committee. In general the standards of judgment shall be:

(a) Welds in which the radiographs show elongated slag inclusions or cavities exceeding the permissible limits or lack of fusion shall be unacceptable if the length of any such imperfection is greater than $^1/_3T$, where $T$ is the thickness of the weld. If the lengths of such imperfections are less than $^1/_3T$ and are separated from each other by at least $6L$ of acceptable weld metal, where $L$ is the length of the longest imperfection, the weld shall be judged acceptable if the sum of the lengths of such imperfections is not more than $T$ in a weld length of $12T$.

(b) Welds in which the radiographs show any type of crack shall be unacceptable.

(c) Welds in which the radiographs show porosity shall be judged as acceptable or unacceptable by comparison with the standard set of radiographs.

(d) A complete set of radiographs for each job shall be retained by the manufacturer and kept on file for a period of at least ten years.

(13) When radiographing a circumferential pipe joint by placing a radium capsule inside the pipe, the penetrameters may be placed on the film side of the circumferential joint pro-

vided the manufacturer satisfies the inspector that the technique followed in doing the work is known to be adequate.[1]

(14) When the radium capsule is placed on the axis of the joint and the complete circumference radiographed with a single exposure, four penetrameters uniformly spaced shall be employed.

(i) All vessels constructed under the requirements of this paragraph shall be stress-relieved in accordance with Par. U-76.

(j) Vessels constructed in accordance with this paragraph shall be stamped "U-68" as required by Par. U-66.

(k) The manufacturer shall be responsible for the quality of the welding done by his organization and shall conduct tests of welding operators to determine their ability to produce welds of the required quality.

The manufacturer shall satisfy the inspector that all the welding operators employed on a pressure vessel or pressure part of a unit have previously made test plates which comply with the requirements of the Code. Such test plates shall have been made within a period of six months, except that when the welding operator is regularly employed on production work embracing the same process and type of welding the tests may be effective for one year.

It is the duty of the inspector to satisfy himself that only welding operators who are proved competent by these test plates are used to weld any pressure part and that all welding complies with Code requirements.

The inspector has the right at any time to call for and witness the making of test plates described in this paragraph by any welding operator and to observe the physical tests of them. For such qualification tests, the thickness of the test plate shall be approximately the thickness of the plate or parts on which the welding operator is to work except that it need not exceed $1^1/_2$ in.

[1] NOTE: A suggested method or proving the adequacy of the radium capsule method of radiography is as follows:

A preliminary radiograph should be made with a piece of pipe with penetrameters on both the inside and outside. The diameter of the pipe employed in making this proof radiograph should be substantially the same as that of the job in hand, and its wall thickness the practical equivalent of the over-all thickness of the joint to be radiographed, including both backing ring and reinforcement if these are present in the joint to be examined. The radium capsule employed in making this proof radiograph, together with all other items of technique such as the location of the capsule and the time of the exposure, should be the same as employed on the actual job. Each penetrameter should be provided with a marker which will show up clearly on the film and which will indicate the side of the joint on which it is located: *F* for the film side, and *R* for the radiation side.

When more than one welding operator is employed on a pressure vessel, the required test plates for the individual vessels shall be made by the welding operator designated by the inspector.

**U-69** (a) All vessels covered by this Code when constructed in accordance with the rules of this paragraph, and when the plate thickness of the shells and of the heads fabricated of more than one piece do not exceed $1^1/_2$ in. at the joint, may be used for any purpose and under any operating conditions except:

(1) To contain lethal[1] substances, either gases or liquids;
(2) For operating pressures exceeding 600 psi.

The limit of plate thickness does not apply to heads formed of a single plate. The pressure limitation does not apply to vessels operating under hydrostatic pressure at atmospheric temperatures.

(b) The joint efficiency $E$ to be used in applying the rules in Par. U-20 shall be taken as 80 per cent.

(c) The qualification of the welding procedures and the welding operators shall comply with the requirements of Section IX of the Code, except:

(1) A welding operator who has been regularly qualified and engaged in welding Par. U-68 vessels is qualified thereby to weld Par. U-69 vessels provided the same procedure and position are employed as those for which the operator has been qualified;

(2) As may be otherwise provided.

(d) Each manufacturer or contractor shall be responsible for the quality of the welding done by his organization and shall conduct tests not only of the welding process to determine its suitability to insure welds which will meet the required tests, but also of the welding operators to determine their ability to properly apply the procedure.

Each welding operator shall be assigned by the manufacturer

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[1] By "lethal substances" are meant poisonous gases or liquids of such a nature that a very small amount of the gas or vapor of the liquid mixed or unmixed with air when breathed is dangerous to life. For purposes of this Code, this class includes substances of this nature which are stored under pressure or may generate a pressure if stored in a closed vessel. Some such substances are hydrocyanic acid, carbonyl chloride, cyanogen, mustard gas, and xylyl bromide. For the purposes of this Code ammonia, chlorine, natural or manufactured gas, propane, or butane are not considered as lethal substances, but it is the intention of the Committee that their storage should not be permitted in pressure vessels built in accordance with Par. U-70.

an identifying number, letter, or symbol, which shall be stamped on all vessels adjacent to and at intervals of not more than 3 ft along the welds which he makes either by hand or by machine, or a permanent record may be kept by the manufacturer of the welding operators employed on each joint, which shall be available to the inspector, and in such case the stamping may be omitted.

The manufacturer shall maintain a permanent record of the welding operators employed by him, showing the date and result of the tests and the identification mark assigned to each. These records shall be certified to by the manufacturer and accessible to the inspector. An authorized inspector shall have the right at any time to call for and witness tests of the welding process or of the ability of any welding operator.

U-70 (a) All vessels covered by this Code, when constructed in accordance with the rules of this paragraph, may be used for the storage of gases or liquids, except lethal[1] gases or liquids, at temperatures not materially exceeding their boiling temperature at atmospheric pressure, and at pressures not to exceed 200 psi, and/or not to exceed a temperature of 250 F. The plate thickness of shells and of heads fabricated of more than one piece shall be limited to $^5/_8$ in. The limitation of plate thickness does not apply to heads formed of a single plate. The maximum allowable working pressure of the vessel shall be calculated on the basis of a maximum unit joint working stress (*SE*) in pounds per square inch as follows:

| | |
|---|---|
| Double-welded butt joints for all joints | 8000 |
| Single-welded butt joints for girth or head joints | 6500 |
| Double full-fillet lap welds for girth joints only | 7000 |
| Plug or intermittent welds for girth or head joints | 5600 |

(b) For single-welded butt joints and for double full-fillet welds for longitudinal joints, the maximum unit joint working stress (*SE*) shall be as follows: For material of thickness of less than $^1/_4$ in., 5600 psi; for material of thickness of $^1/_4$ to $^3/_8$ in., 7000 psi.

(c) Lap joints as provided for in Par. U-73(a) shall not be used in the construction of vessels for the storage of gases of any

[1] By "lethal substances" are meant poisonous gases or liquids of such a nature that a very small amount of the gas or vapor of the liquid mixed or unmixed with air when breathed is dangerous to life. For purposes of this Code, this class includes substances of this nature which are stored under pressure or may generate a pressure if stored in a closed vessel. Some such substances are hydrocyanic acid, carbonyl chloride, cyanogen, mustard gas, and xylyl bromide. For the purposes of this code ammonia, chlorine, natural or manufactured gas, propane, or butane are not considered as lethal substances, but it is the intention of the Committee that their storage should not be permitted in pressure vessels built in accordance with Par. U-70.

kind at pressures in excess of 100 psi, nor for the storage of any liquid at a temperature exceeding its boiling point at atmospheric pressure.

(d) The qualification of the welding procedures and the welding operators shall comply with the requirements of Section IX of the Code, except:

(1) A welding operator who has been regularly qualified and engaged in welding Pars. U-68 or U-69 vessels is qualified thereby to weld Par. U-70 vessels provided the same procedure and position are employed as those for which the operator has been qualified;

(2) As may be otherwise provided.

(e) Each manufacturer or contractor shall be responsible for the quality of the welding done by his organization and shall conduct tests not only of the welding process to determine its suitability to insure welds which will meet the required tests, but also of the welding operators to determine their ability to properly apply the procedure.

Each welding operator shall be assigned by the manufacturer an identifying number, letter, or symbol, which shall be stamped on all vessels adjacent to and at intervals of not more than 3 ft along the welds which he makes either by hand or by machine, or a permanent record may be kept by the manufacturer of the welding operators employed on each joint, which shall be available to the inspector, and in such case the stamping may be omitted.

The manufacturer shall maintain a permanent record of the welding operators employed by him, showing the date and result of the tests and the identification mark assigned to each. These records shall be certified to by the manufacturer and accessible to the inspector. An authorized inspector shall have the right at any time to call for and witness tests of the welding procedure or of the ability of any welding operator.

**U-71 Material.** (a) Ferrous materials used in the fabrication of any fusion-welded drum, shell, or parts, covered by this Code, shall conform to Specifications S-4, SA-7 (bar stock only), SA-27, SA-30, SA-31, SA-53, SA-70, SA-72, SA-83, SA-84, SA-89, SA-105, SA-106, SA-129, SA-135, SA-157, SA-158, SA-178, SA-181, SA-182, SA-192, SA-201, SA-202 Grade A, SA-203, SA-204, SA-206, SA-209, SA-210, SA-212, SA-213, SA-216, SA-217, SA-225, SA-240, *SA-249* Grades T8, T18, T19,

* Materials complying with these specifications to be used only under the conditions set forth in Case No. 897.

and T20, and SA-250. The carbon content in all such materials shall not exceed 0.35 per cent.

(**b**) Material for manhole frames, nozzles, and other pressure connections which are to be joined to the shell or heads by fusion welding shall, when forged, rolled, or cast, comply with the specifications given for forgings, plates, or castings, respectively, as to chemical and physical properties and be of good weldable quality. Small parts of cast, rolled, or forged steel of good weldable quality may be used as provided for in Par. U-12(**c**).

(**c**) If, in the development of the art of welding, it is desired to use materials other than those herein described, data should be submitted to the Boiler Code Committee in accordance with Pars. UA-71 to UA-81.

**U-72 Preparation for Welding.** (**a**) The plates may be cut to size and shape by machining or shearing, or by flame cutting if the carbon content does not exceed 0.35 per cent. If shaped by flame cutting, the edges must be uniform and smooth and must be freed of all loose scale and slag accumulations before welding. The discoloration which may remain on the flame-cut surface is not considered to be detrimental oxidation. The plates or sheets to be joined shall be accurately cut to size and formed. In all cases the forming, if done cold, shall be by pressure and not by blows, including the edges of the plates forming longitudinal joints of cylindrical vessels. Carbon steel plates, conforming to the specifications in the Code, which are to be subsequently stress-relieved, may be formed by blows providing this is done while that portion of the plate is at a forging temperature and that such forming does not objectionably deface the plate.

(**b**) Particular care should be taken in the layout of joints in which fillet welds are to be used so as to make possible the fusion of the weld metal at the bottom of the fillet. Great care must also be exercised in the deposition of the weld metal so as to secure satisfactory penetration.

(**c**) If the thickness of the flange of a head to be attached to a cylindrical shell by a butt joint exceeds the shell thickness by more than 25 per cent (maximum $^1/_4$ in.), the flange thickness shall be reduced at the abutting edges either on the inside or the outside, or both, as shown in Fig U-18(**a**).

(**d**) The edges of the plates at the joints shall not have an offset from each other at any point in excess of one quarter of the plate thickness at the joint, with a maximum permissible offset of 1/8 in. for longitudinal joints and 1/4 in. for girth joints.

(e) In all cases where plates of unequal thicknesses are abutted, the edge of the thicker plate shall be reduced in some manner so that it is approximately the same thickness as the other plate.

In longitudinal shell joints the middle lines of the plate thicknesses shall be in alignment, within the fabricating tolerances specified in (d) above.

(f) Except where specific details are permitted in other paragraphs, the design of welded vessels shall be such, that if

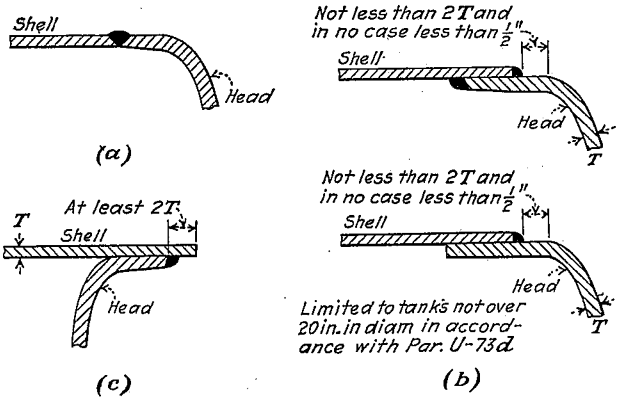



Fig. U-18 Welded Head Attachments

bending stresses are brought directly upon a welded joint, the design shall be analyzed to keep the maximum stress within the allowable limits, and complete weld penetration through the thickness of the joined plates shall be obtained, with added fillet welds where necessary to reduce stress concentration. Corner joints with fillet welds only shall not be used unless the plates forming the corner are properly supported independently of such welds.

(g) Bars, jacks, clamps, or other appropriate tools may be used to hold the edges to be welded in line. The edges of butt joints shall be so held that they will not overlap during welding. Where fillet welds are used, the lapped plates shall fit closely and be kept together during welding.

(h) The surfaces of the sheets or plates to be welded shall be cleaned thoroughly of all scale, rust, oil, or grease for a distance of not less than $^1/_2$ in. from the welding edge. Grease or oil may be removed with gasoline, lye, or the equivalent. A steel-wire scratch brush may be used for removing light rust or scale, but for heavy scale, slag, and the like, a grinder, chisel, air hammer, or other suitable tool shall be used to obtain clean and bright metal. When it is necessary to deposit metal over a previously welded surface, any scale or slag therefrom shall be removed by a roughing tool, a chisel, an air chipping hammer, or other suitable means to prevent inclusion of impurities in the weld metal.

(i) The dimensions and shape of the edges to be joined shall be such as to allow thorough fusion and complete penetration.

(j) For double-welded butt joints the reverse sides shall be chipped, ground, or melted out so as to secure a clean surface of the originally deposited weld prior to the application of the first bead of welding on the second side. Such chipping, grinding, or melting out shall be done in a manner that will insure proper fusion of the weld metal. These requirements are not intended to apply to any process of welding by which proper fusion and penetration are otherwise obtained and no impurities remain at the base of the weld.

(k) If the welding is stopped for any reason, extra care shall be taken in restarting to get full penetration to the bottom of the joint and thorough fusion between the weld metal and the plates, and to the weld metal previously deposited.

(l) Where single-welded butt joints are used, particular care shall be taken in aligning and separating the edges to be joined so that complete penetration and fusion at the bottom of the joint will be assured.

**U-73 Joints.** (a) LONGITUDINAL. Longitudinal joints on vessels covered by Pars. U-68 and U-69 shall be of the double-welded butt type and a reinforcement of at least $^1/_{16}$ in. shall be built up on each face of the weld, except that for plates $^1/_4$ in. or less in thickness the reinforcements need not exceed 25 per cent of the plate thickness.

The reinforcement on either or both faces of the weld may be removed, but if not removed there shall be no valley, groove, or other change in contour along the edge or upon the surface of the weld that, in the opinion of the inspector, would be objectionable.[1]

[1] If the reinforcement is built up so as to form a ridge with a valley or depression at the edge of the weld next to the plate, the result is a notch which causes concentration of stress and reduces the strength of the joint.

When a butt-welded joint is made the equivalent of a double-welded joint (See note in Par. U-67) by using a backing strip and adding filler metal on one side only, the requirement for reinforcement applies only to the side opposite the backing strip. The backing strip may be allowed to remain or it may be removed.

The longitudinal joints of vessels covered by Par. U-70 may be of the butt-welded type for thicknesses of $^5/_8$ in. or less, or of the double-welded lap type for thicknesses of $^3/_8$ in. or less, or of the single-welded butt type for thicknesses of $^1/_4$ in. or less. If of the lap type the throat dimension of each of the welds shall be no less than $^5/_8T$, where $T$ represents the thickness of the plate. Both edges of the lap shall be welded and the surface overlap shall be not less than $4T$. The reinforcement for a single-welded butt joint shall be not less than $^1/_{16}$ in. The reinforcement may be machined off, if so desired.

(b) Except for Par. U-68 vessels, where vessels are made up of two or more courses with welded longitudinal joints, the joints of adjacent courses shall be separated by a distance of at least 5 times the thickness of the thicker plate.

(c) CIRCUMFERENTIAL. Circumferential and other joints of vessels uniting the plates of the shell, or other pressure parts, except as provided for in Par. U-59, covered by Par. U-68 shall be of the double-welded butt type. Circumferential and other joints of vessels uniting the plates of the shell, or other pressure parts, except as provided for in Par. U-59, covered by Par. U-69 shall be of the double-welded butt type, except for thicknesses of $^5/_8$ in. or less, in which case they may be of the single-welded butt type. Circumferential and other joints of vessels uniting the plates of the shell, or other pressure parts, except as provided for in Par. U-59, covered by Par. U-70 may be of the butt or lap type. The details of all of these joints shall conform to the requirements of longitudinal joints given in (a).

(d) Dished heads concave to the pressure when used on vessels covered by Par. U-70 may be inserted with a driving fit and fillet welded inside and outside, except that for vessels 20 in. in diameter or less the heads may be welded on the outside only. The welds shall be located on the flange of the head at a distance not less than twice the thickness of the head from the point of tangency of the knuckle and not less than $^1/_2$ in.

(e) Heads concave to the pressure and/or plate edges at girth joints to be attached by butt joints shall be aligned so that the deviations are not more than permitted by the limitations of Par. U-72, but if greater, correction shall be made by re-forming the shell or head, whichever is out of true, until the errors are within the limits specified. The edges of head and girth joints shall be kept separated at the point of welding enough to insure thorough penetration of the weld metal.

(f) Flat heads may be welded into any pressure vessel under the rules given in Par. U-39(**a**).

**U-74 Holes.** Unreinforced holes may be machine-cut through welded seams that have been stress-relieved and radiographed. The joint efficiency as well as the ligament efficiency shall be considered in calculating the thickness.

Tubes may be rolled and expanded in such unreinforced holes, or such holes may be threaded, provided that in the portion of the welded joint in which the holes are cut the following additional requirements are met:

(**1**) The welds have been examined by the magnetic powder method on both sides and found to be satisfactory;

(**2**) The weld shall contain no slag inclusion or defect longer than $0.15T$ (where $T$ is the thickness of the weld), but in no case greater than $^3/_8$ in.

If either item (1) or (2) is not complied with, the unreinforced holes for threaded connections or for rolled or expanded tubes may not be placed closer than $^1/_4$ in. to the edge of the fused metal, and no deduction need be made in the maximum allowable working pressure computed for the same tube layout without a circumferential weld.

**U-75 Dished Heads.** Dished heads convex to the pressure shall have a flange not less than $1^1/_2$ in. long except where the thickness is $^3/_8$ in. or under, in which case the flange need not be more than 4 times the thickness of the head. When heads are inserted into the shell, it shall be with a driving fit and welded as shown in Fig. U-18.

Dished heads concave to the pressure shall have a length of flange not less than 1 in. for shells not over 24 in. in diameter. For vessels over 24 in. in diameter, this length shall be not less than $1^1/_2$ in.

**U-76 Stress-Relieving.** (**a**) All fusion-welded vessels constructed in accordance with Par. U-68 shall be stress-relieved.

(**b**) Unless otherwise limited by the provisions of Par. U-13(**c**), vessels constructed in accordance with Par. U-69 shall be stress-relieved where the thickness exceeds $1^1/_4$ in., or where the diameter is less than that determined by the formula $d = 120t - 50$, where $d$ is the inside diameter in inches and $t$ the shell thickness in inches. Vessels having a wall thickness less than 0.58 in. need not be stress-relieved regardless of diameter.

(c) Where stress-relieving is required it shall be done by heating uniformly to at least 1100 F, and up to 1200 F, or higher, if this can be done without distortion. Different temperatures may be used to obtain proper stress-relieving when required by the characteristics of the material. The structure or parts of the structure shall be brought slowly up to the specified temperature and held at that temperature for a period of time proportioned on the basis of at least one hour per inch of thickness and shall be allowed to cool slowly in a still atmosphere.

(d) All connections attached by fusion welding shall be stress-relieved on vessels requiring stress relief and as required by Par. U-59(p), (q), and (r).

All heavy attachments, such as supporting lugs, attached by fusion welding shall be stress-relieved when welded to vessels for which stress-relieving as a whole is required.

Attachments, including nonpressure parts, the failure of which would not affect the safety of the vessel, need not be stress-relieved after welding them to stress-relieved vessels provided the strength of the shell is computed with the tack welds considered the equivalent of holes drilled through the shell of the following diameters:

(1) For material containing more than 0.35 per cent carbon, such as that used in forged seamless steel shells, the diameter of the equivalent holes shall be taken as twice the maximum dimension of the weld, but in no case shall a weld exceed 1 in. in length;

(2) For material containing not to exceed 0.35 per cent carbon, the diameter of the equivalent holes, in a vessel for which stress relief as a whole is required, shall be taken as the maximum dimension of the weld plus $^1/_2$ in., but in no case shall a weld exceed 3 in. in length;

(3) The efficiency of the ligaments between any two of the welds (considered on the basis of equivalent holes) shall be not less than the required efficiency for ligaments or longitudinal joint of the shell.

When nonpressure parts are attached by fusion welding to pressure parts of carbon steel containing not more than 0.35

per cent carbon, or of carbon molybdenum steel containing not more than 0.20 per cent carbon, no deductions need be made on account of welds having a throat thickness not exceeding $^1/_4$ in., if the welds are not over 3 in. in length and have a center-to-center distance not less than twice this length. This rule also applies to continuous welds longer than 3 in., if the weld metal is deposited intermittently in sections not over 3 in. long, with center-to-center distances not less than twice this length, and if these welds are peened and the intervening spaces then welded and peened.

When nonpressure parts are attached by fusion welding and the drums and parts are subsequently heat-treated or stress-relieved in accordance with the provisions of this paragraph, no deductions need be made on account of the welds.

(e) The structure shall be stress-relieved by any of the following methods:

(1) Heating the complete vessel as a unit;

(2) Heating a complete section of the vessel (head or course) containing the part or parts to be stress-relieved before attachment to other sections of the vessel;

(3) In cases where the vessel is stress-relieved in sections, stress-relieving the final girth joints by heating uniformly a circumferential band having a minimum width of 6 times the plate thickness on each side of the welded seam in such a manner that the entire band shall be brought up to the temperature and held for the time specified above for stress-relieving.

(4) Nozzles or other welded attachments for which stress relief is required may be locally stress-relieved by heating a circumferential band around the entire vessel with the connection at the middle of the band, the band width to be at least 12 times the shell thickness wider than the attachment, in such a manner that the entire band shall be brought up to the temperature and held for the time specified above for stress-relieving.

(5) In the case of welded joints in piping and tubing, the width of the heated circumferential band shall be at least three times the width of the widest part of the welding groove but in no case less than twice the width of the weld reinforcement.

**U-77 Hydrostatic and Hammer Tests.** (a) Fusion-welded pressure vessels which have been both stress-relieved and radiographed need not be subjected to the hammer test, but shall be hydrostatically tested to not less than twice the maximum allowable working pressure for a sufficient time to permit an inspection of all joints and connections.

(b) Vessels built in accordance with the requirements of Pars. U-69 and U-70, 12 ft or less in diameter and/or 20 ft or less in vertical height, the welded joints of which are not stress-relieved and radiographed, shall be subjected to a hydrostatic test pressure of $1^1/_2$ times the maximum allowable working pressure, and while subject to this pressure all butt-welded joints that are not supported by other means, and all welded joints if such a test is feasible, shall be given a thorough hammer or impact test. This impact test shall consist of striking the plate at 6 in. intervals on both sides of the welded joint and for the full length of all welded joints. The weight of the hammer in pounds shall approximately equal the thickness of the shell in tenths of an inch, but not to exceed 10 lb, and the plates shall be struck with a sharp swinging blow. The edges of the hammer shall be rounded so as to prevent defacing the plates. This hammer test shall be applied to vessels over 12 ft in diameter and/or 20 ft or more in vertical height while they are empty.

Following the hammer test, the vessels shall be hydrostatically tested to not less than twice the maximum allowable working pressure, for a sufficient length of time to permit an inspection of all joints and connections.

(c) On other pressure parts the hydrostatic pressure shall be maintained at not less than $1^1/_2$ times the maximum allowable working pressure a sufficient length of time to permit complete inspection. The hydrostatic test pressure of the completed unit shall not exceed that prescribed in Par. U-64.

(d) Enameled vessels of welded construction need not be hammer tested nor need they comply with the hydrostatic tests prescribed in this paragraph, but shall be tested in accordance with the provisions of Par. U-64.

(e) Vessels which cannot safely be filled with water shall be given a pneumatic test as prescribed in Par. U-64(f).

(f) The maximum allowable working pressure as determined by the formula in Par. U-20 and used in determining the hydrostatic test pressures shall be that at normal atmospheric temperature and based on the actual dimensions and plate thicknesses required for the pressure and temperature that are to be stamped on the vessel.

**In case the vessel is not to be operated at temperatures over 650 F, the hydrostatic test pressures shall be based on the**

maximum allowable working pressure to be stamped on the vessel.

In case the vessel is to be operated at temperatures exceeding 650 F, the hydrostatic test pressures shall be based on the maximum allowable pressure to be stamped on the vessel, increased by the ratio of the allowable tensile stress at 650 F for the material used and the corresponding allowable stress as given in Table U-2, interpolated, if necessary, for the maximum working temperature to be stamped on the vessel.

For example, the vessel to be stamped 200 lb, 900 F, built of 55,000 lb steel. (Specification SA-70, firebox):

| | | |
|---|---|---|
| Allowable stress, psi, at 650 F | = | 11,000 |
| Allowable stress, psi, at 900 F | = | 4,400 |
| Maximum allowable pressure, psi, at normal atmospheric temperature $200 \times 11{,}000/4{,}400$ | = | 500 |
| Hydrostatic pressure, psi, during hammer test $500 \times 1^1/_2$ | = | 750 |
| Hydrostatic pressure, psi, following hammer test $500 \times 2$ | = | 1,000 |

(g) Pinholes, cracks, or other defects shall be repaired only by chipping, machining, or burning out the defect and rewelding. For gas welding the metal around the defects shall be preheated to a dull red for a distance of at least 4 in. all around. Any preheating means may be used, such as a flange fire, gas or oil burner, or a welding torch. The preheating shall be done slowly so the heat will get well back into the plate and expand it thoroughly. For metallic arc welding preheating or reheating is not required.

(h) Vessels requiring stress-relieving shall be stress-relieved after any welding repairs have been made.

(i) After repairs have been made the vessel shall again be tested in the regular way, and if it passes the test the inspector shall accept it. If it does not pass the test the inspector can order supplementary repairs, or, if in his judgment the vessel is not suitable for service, he may permanently reject it.

**U-78 Inspection.** (a) In the case of vessels built in accordance with Par. U-68 the manufacturer shall submit the vessel for inspection at such stages as may be designated by the inspector.

(b) For vessels built in accordance with Par. U-69 the first inspection shall be made during the welding of the longitudinal joint. At this time the inspector shall inspect the plate material and the fit-up of the work and observe the workmen to see that only welding operators who have passed the test requirements are employed on the work of welding.

(c) A second inspection shall be made during the welding of the circumferential joints. At this time the inspector shall check any new material being used which may not have been examined at the time of the first inspection, also the fit-up of the vessel at this stage of construction, and again observe the welding operators to see that only welding operators who have passed the test requirements are employed.

(d) For vessels built in accordance with Par. U-70 one inspection shall be made during the welding of the longitudinal joint. If there is no longitudinal joint the inspection shall be made during the welding of a circumferential or a head joint. At this time the inspector shall check the plate material and the fit-up of the work and observe the workmen to see that only welding operators who have passed the test requirements are employed.

(e) Every pressure vessel covered by this Code shall also be inspected at the time of hydrostatic-pressure and hammer tests.

(f) The manufacturer shall certify that the welding on the vessel has been done only by welding operators who have passed the test requirements and that the same material and technique used in making the tests were employed in fabricating the vessel.

(g) In the case of vessels built in accordance with Par. U-69 or U-70 the plate thickness of which is over $^1/_4$ in., the manufacturer may, if he so desires or if requested by the purchaser, remove one or more specimens from the welded joints for examination for soundness. The specimens shall be such as to provide a full cross section of the welded joint and may be removed by trepanning a round plug or by any equivalent method. For lap joints specimens need be taken from the outer edge only. At least one specimen shall be taken from each vessel except that when there are a number of similar vessels, each having less than a total of 50 ft of welded longitudinal and circumferential joints, built at the same time and under the same specifications, a specimen for each 50 ft or fraction thereof will suffice; from a vessel having more than 50 ft of welded joints two specimens shall be taken; and from a vessel having more than 100 ft of welded joints, three specimens shall be taken. If more than one method of welding is used or if more than one operator does the welding, at least one specimen shall be taken for each method and for each operator.

The authorized inspector shall designate the points from which the specimens are to be taken.

Cylindrical specimens or those not having a plane surface shall be sectioned across the welds to obtain plane surfaces which shall include the full width of the weld. The plane surfaces shall be polished to a bright, smooth condition which may be accomplished by filing or grinding and polishing with emery cloth and should be completed with the use of emery cloth of grade 00. The specimen shall then be etched by any method or solution which will reveal the defects without unduly exaggerating or enlarging them (See Par. UA-85).

As respects soundness, defects are defined as gas pockets, slag inclusion, lack of fusion, and cracks. Defects in specimens, other than cracks or lack of fusion, shall be permissible:

(1) When there is slag inclusion between layers, substantially parallel with the plate surface and which is not more than one half the width of the weld metal.

(2) When there is slag inclusion across the thickness of the plate not more than 10 per cent of the thickness of the thinner plate.

(3) When there are gas pockets that do not exceed $^1/_{16}$ in. in greatest dimension and when there are no more than six gas pockets of this maximum size per square inch of the weld metal or where the combined areas of a greater number of pockets do not exceed 0.02 sq in. per square inch of weld metal.

When a specimen shows defects that are not permissible, two additional specimens may be cut from the same operator's work, at intervals to be determined by the inspector, on each side of the defective specimen. If the additional specimens are found to be not acceptable then more may be cut at intervals to be determined by the inspector until the limit of the defective welding has been definitely established; or the manufacturer may radiograph adjacent joint lengths; or he may cut out and replace all the welding done by that operator without cutting out additional samples.

If more than one of the additional specimens or the radiographic film shows objectionable defects the vessels shall be rejected or the welds may be chipped or melted out from one or both sides of the joint as required and be rewelded. The removal of only that portion of the joint shown to be defective need be required. All replacement welds in joints shall be checked by repeating the original test procedure.

Holes in plates formed by trepanning plug specimens shall be filled by the insertion and welding in of special filler plugs of which acceptable types are shown in Fig. U-19. Type (*a*) is adapted to welding from both sides and should be used wherever that method is practicable, and types (*b*) or (*c*) when access is possible only from one side. The diameter of the filler plug shall be such as to make a snug fit in the hole to be filled. Each layer of weld metal as deposited shall be thoroughly peened to reduce residual stresses. The 1/4 in. hole in the center of the plug shown in Fig. U-19 may be closed by any reasonable method.

Where gas welding is employed, the area surrounding the plugs shall be preheated prior to its welding.

If specimens are removed by other than the trepanning process the openings shall be closed as directed by the inspector.

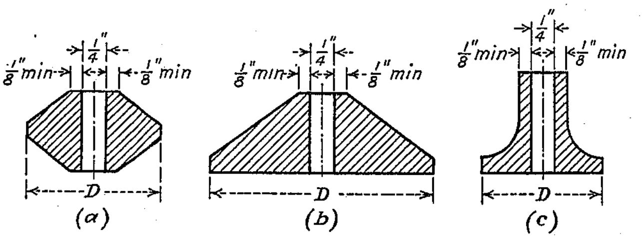



FIG. U-19 SOME ACCEPTABLE TYPES OF FILLER PLUGS FOR CLOSING TREPANNED HOLES

Local radiographic examination may be substituted for the removal of specimens. The inspector shall designate the places to be radiographed.

**U-79** The cylinder or barrel of a drum or shell shall be circular at any section within a limit of 1 per cent of the mean diameter, based on the difference between the maximum and minimum mean diameters at any section, and if necessary to meet this requirement shall be reheated, rerolled, or re-formed. To determine the difference in diameters, measurements may be made on the inside or the outside, and when the cylinder or barrel is made of plates of unequal thicknesses, the measurements shall be corrected for plate thicknesses as they may apply, to determine the diameters at the middle line of the plate thickness.

## RULES FOR FORGE WELDING

**U-80** The plate for any part of a forge-welded vessel on which welding is done shall be of forge-welding quality in accordance with Specification SA-89.

**U-81** The minimum thickness of any shell plate shall be $^1/_4$ in., but the thickness of shell plate shall be not less than the inside diameter of the vessel divided by 200.

**U-82** When properly welded by the forging process the strength of a joint may be calculated on a maximum unit working stress of $SE$ = 8000 psi (See Par. U-20).

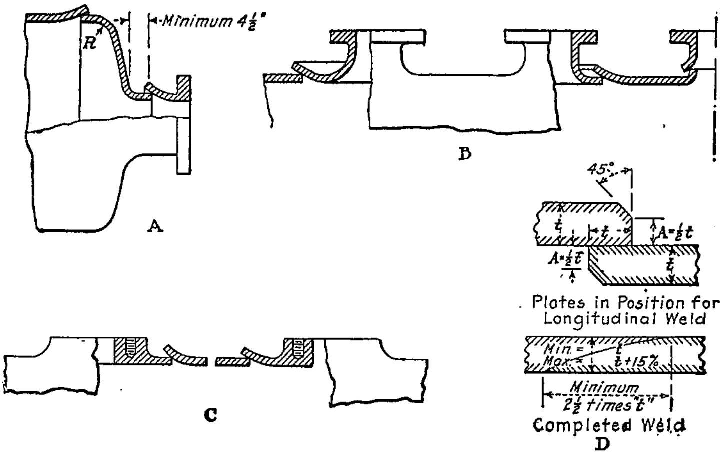



Fig. U-20 Methods of Forge Welding

**U-83 Corner Radius of Dished Heads.** The corner radius of a dished head measured on the concave side of the head shall be not less than 6 per cent of the inside diameter of the head (See $R$, Fig. U-20A).

**U-84** For flanged heads dished concave to pressure the depth of flange measured from a point tangent to the radius of the head to the end of the flange shall be not less than 5 in. For heads dished convex to pressure the depth of flange so measured need not be more than $2^1/_2$ in.

**U-85 Heating.** The heating agent shall be suitably prepared water gas or other heating medium by which equivalent or superior results will be obtained and shall be applied to both sides of the section and adjacent surfaces, and precaution shall be taken to see that the flame is of a character that will minimize the possibility of burning or oxidizing the metal and that it be free from all impurities which would tend to introduce foreign elements into the steel. The temperature of the flame for heating the surfaces shall be under constant and close control.

**U-86 Welding.** (a) The edges that are to be welded together shall be lapped a distance at least equal to the thickness of the plate to be welded. All plates $^7/_8$ in. in thickness and under shall be welded without scarfing; plates more than $^7/_8$ in. in thickness, if desired by the manufacturer, may be scarfed, the scarf to start at least one half the thickness of the plate from the side next to the weld. When the material has been brought to the proper welding temperature, it shall be placed between an anvil and a hammer, or between rolls, or mandrel and roll, or between mandrels, and the plates welded together by a pressure applied by the hammer, rolls, or mandrels, which will actually displace the material while the welding action is occurring. The metal in and adjacent to the weld shall not be worked at what is termed the critical blue-heat temperature of the steel, that is, between about 400 and 800 F.

(b) The thickness of the weld for all longitudinal and circumferential seams or special welds (See Fig. U-20D) shall be as follows: minimum = $t$; maximum = $t$ plus 15 per cent.

(c) The contact line of a completed forge weld shall be equal to at least $2^1/_2$ times the thickness of the plate ($t$) as shown in Fig. U-20D.

**U-87 Stress-Relieving.** (a) After welding, the vessel or cylinder shall be heated uniformly and the temperature increased slowly to at least 1100 F and held at that temperature for a time at least proportional to one hour per inch of thickness and shall be allowed to cool slowly in still air. The structure shall be stress-relieved in accordance with the procedure given in Par. U-76.

(b) If the vessel is not sufficiently rigid to retain its shape at the above temperature, the heating shall take place at 1000 F for a time at least proportional to three hours per inch of thickness. If any vessel has been distorted or deformed, it must be re-formed and then annealed, or re-formed at a proper annealing temperature. In a finished cylindrical shell the variation in diameter shall not exceed 1 per cent of the mean outside diameter when measured at any section. When a straight edge two diameters long is laid longitudinally on the outside of a shell, it shall be possible to so set the straight edge that no part of the edge will come farther than 1 per cent of the mean outside diameter from the outer surfaces of the shell.

**U-88** Openings for pipe connections to vessels having forged joints may be made by inserting pipe couplings, not exceeding 3 in. pipe size, or similar devices, in the shell or heads and securing them by fusion welding, without necessitating the application of the paragraph number indicating welded construction as required by Par. U-66. The welding shall be done by operators who are qualified to weld vessels under the provisions of Par. U-69.

(*Par. U-89 has been omitted*)

**U-90** All dished heads may be attached to the shell by forge welding as shown in Fig. U-20A, or by riveting. (Note corner radius *R* referred to in Par. U-83.)

## RULES FOR BRAZING

**U-91 Material.** Steel plates for the shells of brazed vessels shall be made by the open-hearth process and the thickness shall not exceed $^3/_8$ in., except with the variation permitted by Par. 12 of Specification SA-70 plus 0.01 in. when the longitudinal seam is of the lap-joint type, nor 1 in. plus 0.02 in. when the longitudinal joint is of the double-strap butt-joint type. The material used in the fabrication of brazed vessels shall conform to any of the specifications mentioned in Par. U-71.

**U-92** When the safety of the structure does not depend upon the riveting in the joints, rivet holes may be punched full size.

**U-93** Openings for pipe connections to vessels having brazed joints may be made by inserting pipe couplings, not exceeding 3 in. pipe size, or similar devices, into or on the shell or heads and securing them by fusion welding without necessitating the application of the paragraph number indicating welded construction as required by Par. U-66. The welding shall comply with the requirements for Par. U-69 vessels.

The welding shall be done by operators who are qualified to weld vessels under the provisions of Par. U-69.

**U-94** When properly brazed the strength of a joint may be calculated on a maximum unit working stress of $SE$ = 90 per cent of the maximum allowable working stresses shown in Table U-2 for the materials provided for in Par. U-71.

**U-95** A longitudinal lap joint shall have the edges of the plate lapped a distance of not less than 8 times the thickness of the shell plate. For double-strap butt-joint construction, the total amount of lap of the inner and outer straps shall be equal to at least 16 times the thickness of the shell plate, one half of which shall be on each side of the abutting edges. The width of these straps shall not differ more than 25 per cent of the width of the wider one. The laps shall be held closely in position substantially metal to metal by stitch riveting or other sufficient means. The brazing shall be done by placing the flux and brazing material on one side of the joint and applying heat until this material comes entirely through the lap and shows uniformly along the seam on the other side. Sufficient flux must be used to cause the brazing material to so appear promptly after reaching the brazing temperature. The brazing material used shall be such as to give a joint which has a shearing strength of at least 10,000 psi.

When the brazed joint does not extend the full length of the sheet, the unbrazed edges may be welded, provided the length of the weld is not greater than $4t$ ($t$ = thickness of shell plate) from the edge of the flange of the head. When so constructed the vessel need not be stamped with the paragraph number as provided in Par. U-66.

**U-96 Head and Girth Joints.** Heads shall be inserted into the shells with a tight drive or shrink fit and shall be thoroughly brazed in approximately the same manner as the longitudinal seam for a depth or distance from the end of the shell equal to at least 4 times the thickness of the shell metal. When a vessel is fabricated with more than one course in the shell, the girth joint may be of either the lap or butt type. If of the latter type, the circumference of the abutting courses shall not differ by more than 0.20 per cent, and either inside or outside sleeves shall be used. In either case the lap over the end of each course shall be at least 4 times the shell thickness.

*(Pars. U-97 to U-109, Rules for Enameled Vessels, have been omitted)*

## RULES FOR ELECTRIC-RESISTANCE BUTT WELDING

**U-110** The plate for any part of a vessel to be welded by electric-resistance butt welding shall be of a quality in accordance with Specification SA-89.

**U-111** Where the entire area is welded simultaneously, without the introduction of extraneous metal, the maximum allowable unit working stress shall be 8000 psi. The finished weld shall be annealed preferably before removing from the welding machine.

**U-112** Where the weld is made progressively and continuously over its entire length, the thickness of plate shall not exceed 0.15 in., and the offset of the edges, after welding, shall not exceed 60 per cent of the thickness of the plate. The maximum allowable unit working stress shall be 8000 psi.

Prior to the welding operation by this method, the edges of the plate and the electrical-contact area shall be cleaned so as to free those surfaces from scale, oxide, or grease.

**U-113** For temperatures higher than 700 F, the working stress allowable on electric-resistance-welded joints shall be reduced in proportion to the scale of reductions given in Table U-3.

**U-114** Vessels, the joints of which are made by electric-resistance butt welding, shall be tested in accordance with Par. U-77.

## RULES FOR VESSELS SUBJECTED TO EXTERNAL PRESSURE

*These rules do not apply to vessels used in petroleum processing. They may not be used for determination of thickness of walls of tubes that are to be expanded, rolled, or screwed into tube sheets.*

**U-120 Cylindrical Vessels Subjected to External Pressure.** The rules for this class of vessels shall apply only to cylindrical vessels of the three types (either with or without stiffening rings) illustrated in Fig. U-21, when constructed of steel complying with one of the following specifications:

| | |
|---|---|
| S-4 | Specifications for Seamless Steel Drum Forgings |
| SA-30 | Specifications for Boiler and Firebox Steel for Locomotives |
| SA-53 | Specifications for Welded and Seamless Steel Pipe |
| SA 70 | Specifications for Carbon-Steel Plates for Stationary Boilers and Other Pressure Vessels |

SA-83 Specifications for Lap-Welded and Seamless Steel and Lap-Welded Iron Boiler Tubes
SA-89 Specifications for Steel Plates of Flange and Firebox Qualities for Forge Welding
SA-106 Specifications for Lap-Welded and Seamless Steel Pipe for High-Temperature Service
SA-129 Specifications for Open-Hearth Iron Plates of Flange Quality
SA-135 Specifications for Electric-Resistance-Welded Steel Pipe
SA-178 Specifications for Electric-Resistance-Welded Steel and Open-Hearth Iron Boiler Tubes
SA-201 Specifications for Carbon-Silicon-Steel Plates of Ordinary Tensile Ranges for Fusion-Welded Boilers and Other Pressure Vessels

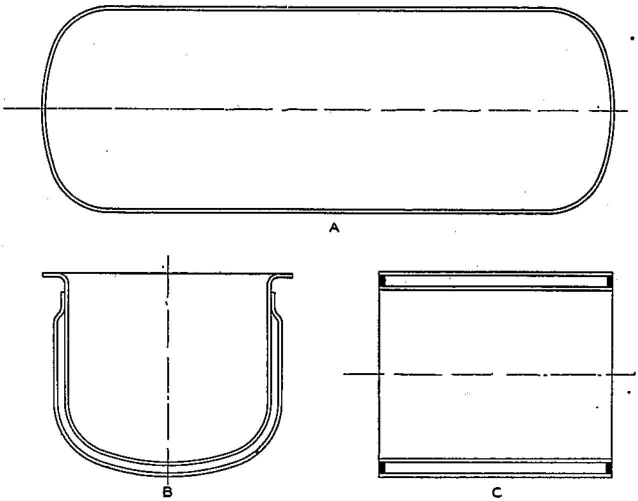



FIG. U-21 THREE TYPICAL FORMS OF UNFIRED CYLINDRICAL VESSELS SUBJECTED TO EXTERNAL PRESSURE

SA-202 Specifications for Chrome-Manganese-Silicon (CMS) Alloy-Steel Plates for Boilers and Other Pressure Vessels
SA-203 Specifications for Low-Carbon-Nickel Steel Plates for Boilers and Other Pressure Vessels
SA-204 Specifications for Molybdenum-Steel Plates for Boilers and Other Pressure Vessels
SA-209 Specifications for Seamless Carbon-Molybdenum Alloy-Steel Boiler and Superheater Tubes
SA-210 Specifications for Medium-Carbon Seamless Steel Boiler and Superheater Tubes
SA-212 Specifications for High-Tensile Strength Carbon-Silicon-Steel Plates for Boilers and Other Pressure Vessels (Plates $4^1/_2$ In. and Under in Thickness)

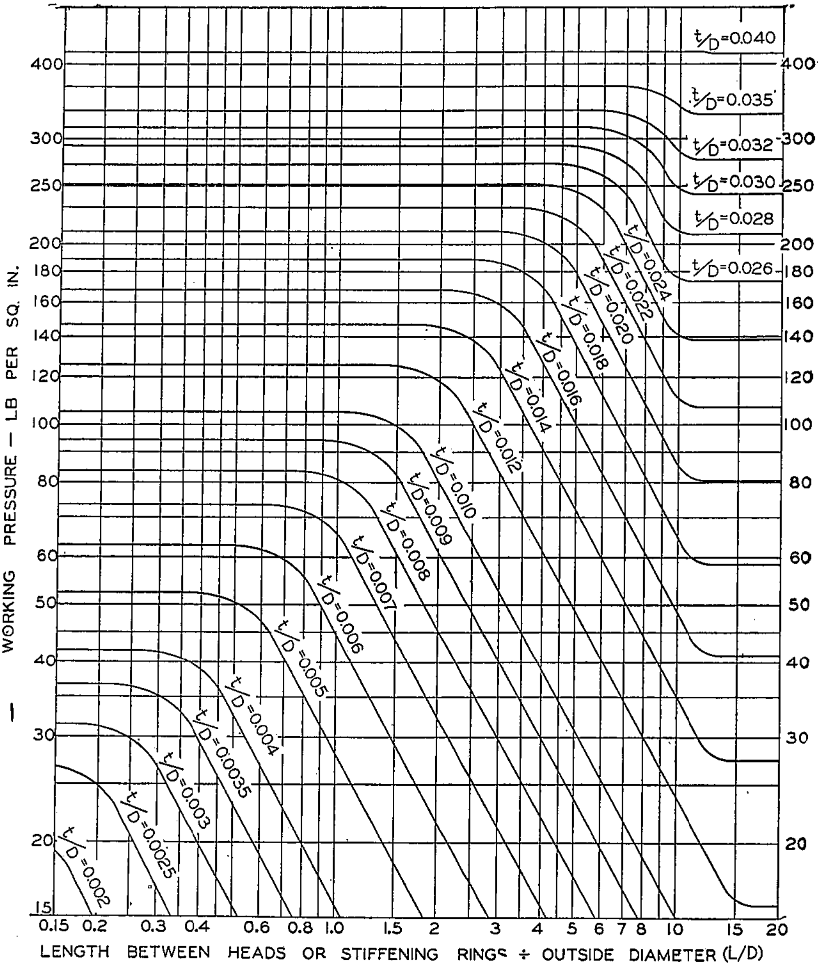



FIG. U-22 CHART FOR DETERMINING SHELL THICKNESS OF UNFIRED CYLINDRICAL VESSELS SUBJECTED TO EXTERNAL PRESSURE WHEN CONSTRUCTED OF STEEL COMPLYING WITH SPECIFICATIONS S-4, SA-53, SA-70, SA-83, SA-89, SA-129

SA-225 Specifications for Manganese-Vanadium Steel Plates for Boilers and Other Pressure Vessels
SA-250 Specifications for Electric-Resistance-Welded Carbon-Molybdenum Alloy-Steel Boiler and Superheater Tubes

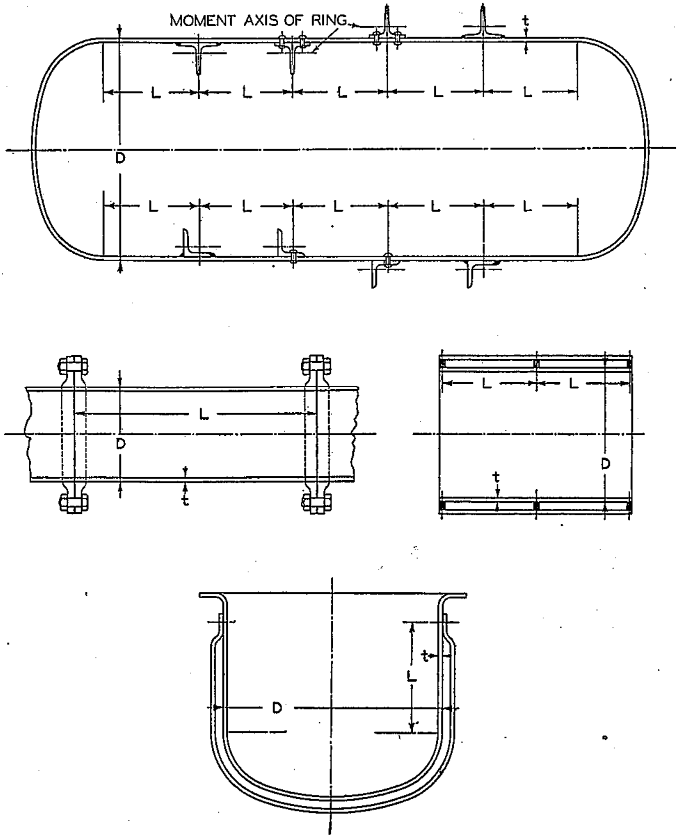



FIG. U-23 DIAGRAMMATIC REPRESENTATION OF VARIABLES FOR DESIGN OF UNFIRED CYLINDRICAL VESSELS SUBJECTED TO EXTERNAL PRESSURE

or of cast steel complying with Specification SA-27 Grade B, and when operated at pressures not in excess of 500 psi, and temperatures not in excess of 650 F. Corrugated shells subjected to external pressure may be used in unfired pressure vessels in accordance with Par. P-243 of Section I of the Code.

**U-121** Working pressure shall be the safe operating pressure which shall be the maximum possible difference in pressure between the outside and inside of the vessel at any time and shall be one fifth the collapsing pressure.

**U-122 Shell Thickness.** The minimum required thickness of the shell plate shall be determined from the chart as shown in Fig. U-22.

In this diagram the abscissas are $L/D$, the ordinates are working pressures, and the curves represent different values of $t/D$, where, as shown in Fig. U-23,

$L$ = length of vessel between centers of head seams or between centers of circumferential stiffeners, inches,
$D$ = outside diameter, inches,
$t$ = minimum required thickness of shell plate, inches.

**U-123** In no case shall the external working pressure for which the vessel is designed be taken as less than 15 psi (corresponding to a collapsing pressure of 75 psi).

**U-124 Instructions for Use of Chart.** To use the chart in Fig. U-22, the value of $L/D$ is computed and, with the given working pressure, the corresponding value of $t/D$ is read off. With this value of $t/D$, the required thickness $t$ is found. When a vessel has an $L/D$ ratio greater than 20, the same $t/D$ ratio shall be used as for a vessel having an $L/D$ ratio of 20.

**Example.** Given: Pressure vessel 12 ft long between heads, 96 in. outside diameter, external working pressure 15 psi.

Required: Thickness, $t$.

Solution: $L = 12 \times 12 = 144$ in. $D = 96$ in. $L/D = 144/96 = 1.5$.

From Fig. U-22, for a working pressure of 15 psi and an $L/D$ ratio of 1.5, the ratio $t/D$ is found to be 0.0046. Therefore: $t = 0.0046 \times D = 0.0046 \times 96 = 0.44$ in.

**U-125 Out-of-Roundness.** The out-of-roundness, $e$, or difference between the maximum and minimum diameters in any plane perpendicular to the longitudinal axis of the vessel expressed as a fraction of the shell thickness, shall not exceed that given by the chart in Fig. U-24, except that on vessels having longitudinal joints of lap construction, the difference between the maximum and minimum diameters may be as great as that given by the chart in Fig. U-24, plus the thickness of the plate (See also Par. U-136). Measurements shall be taken on the completed vessel in a sufficient number of planes to in-

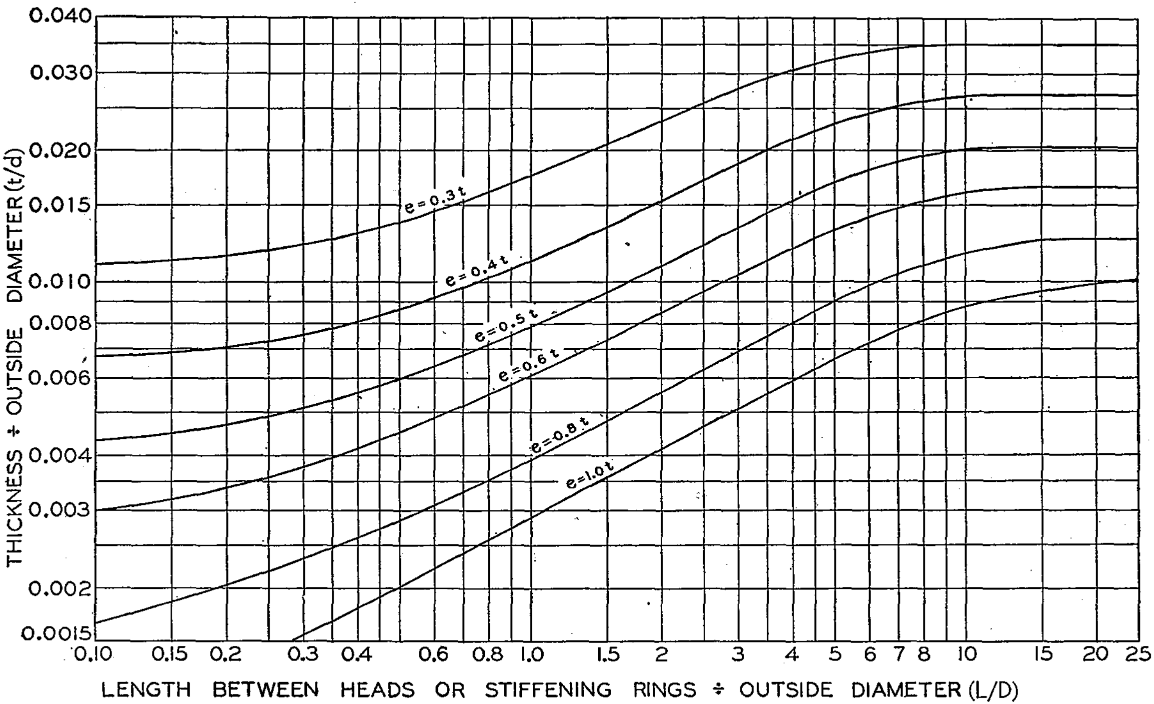



**Fig. U-24 Allowable Difference in Maximum and Minimum Diameters for Unfired Cylindrical Vessels Subjected to External Pressure**

(Maximum Diameter — Minimum Diameter = *e*.)

sure that the entire surface of the shell meets the requirements.

The maximum "out-of-roundness" allowed shall be determined from the actual thickness of the vessel minus the thickness, if any, added for a corrosion allowance.

**Example.** Given: Pressure vessel considered in previous example.

Required: Maximum out-of-roundness permitted.

Solution: From Fig. U-24, for a $t/D$ ratio of 0.0046 and an $L/D$ ratio of 1.5, $e$ is found to be 0.81 $t$.

This means that the difference between the maximum diameter $D_{max}$ and the minimum diameter $D_{min}$ (See Fig. U-25) in any plane perpendicular to the longitudinal axis of the vessel shall not exceed 0.81 of the shell thickness.

**U-126 Stiffening Rings.** Circumferential stiffening rings composed of bars or structural shapes secured to the shell of the vessel may be used, in which case the distance $L$ may be considered as the length measured parallel to the axis of the vessel between the centers of adjacent stiffening rings, provided the moment of inertia of the rings is not less than that obtained from the chart in Fig. U-26.

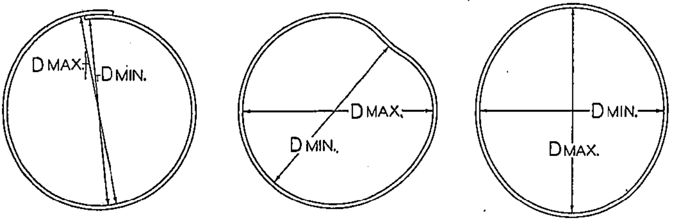



FIG. U-25 EXAMPLES OF VARIATION FROM CIRCULAR FORM IN UNFIRED CYLINDRICAL VESSELS SUBJECTED TO EXTERNAL PRESSURE

**U-127** Stiffening rings shall extend completely around the circumference of the vessel. Any joints between the ends or sections of such rings as shown at $C$, $D$, $F$, and $G$ in Fig. U-27, and any connections between adjacent portions of a stiffening ring lying inside and outside the shell as shown at $H$ in Fig. U-27, shall be so made that the full stiffness of the ring is maintained.

**U-128** Stiffening rings placed on the inside of a vessel may be arranged as shown at $A$ and $B$ in Fig. U-27, provided the moment of inertia required by Fig. U-26 is maintained within the sections indicated. The moment of inertia of each section shall be taken about its own neutral axis. However, any gap in that portion of a stiffening ring supporting the

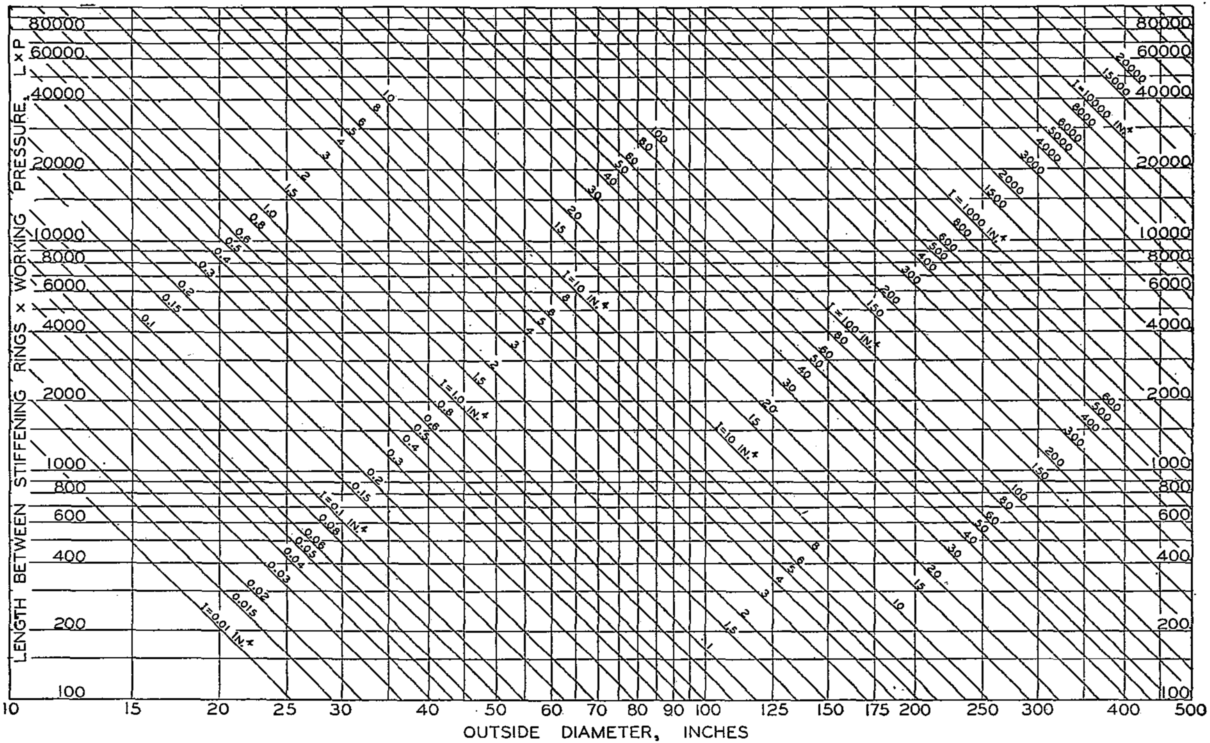



**Fig. U-26 Required Moment of Inertia of Stiffening Rings for Unfired Cylindrical Vessels Subjected to External Pressure**

shell, as shown at *A* and *E* in Fig. U-27, shall not exceed the length of arc given in Fig. U-28 unless additional reinforcement is provided as shown at *H* in Fig. U-27.

**Example.** Given: Pressure vessel 50 ft long, 200 in. outside diameter, working pressure 40 psi; to be stiffened by circumferential rings.

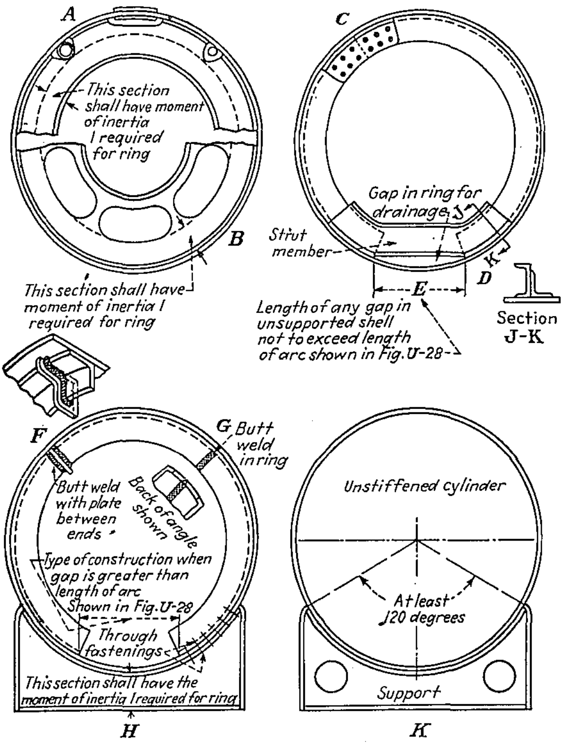



FIG. U-27 VARIOUS ARRANGEMENTS OF STIFFENING RINGS FOR UNFIRED CYLINDRICAL VESSELS SUBJECTED TO EXTERNAL PRESSURE

Required: Thickness *t*, best frame spacing *L*, proportions of stiffening rings, and allowable out-of-roundness.

Solution: If it is desired to use a minimum plate thickness (which will usually be the most economical design), the vessel must be designed with the lowest permissible $t/D$ ratio for the working pressure of 40 psi. From the chart in Fig. U-22 it will be found that this $t/D$ ratio is 0.0038, and the corre-

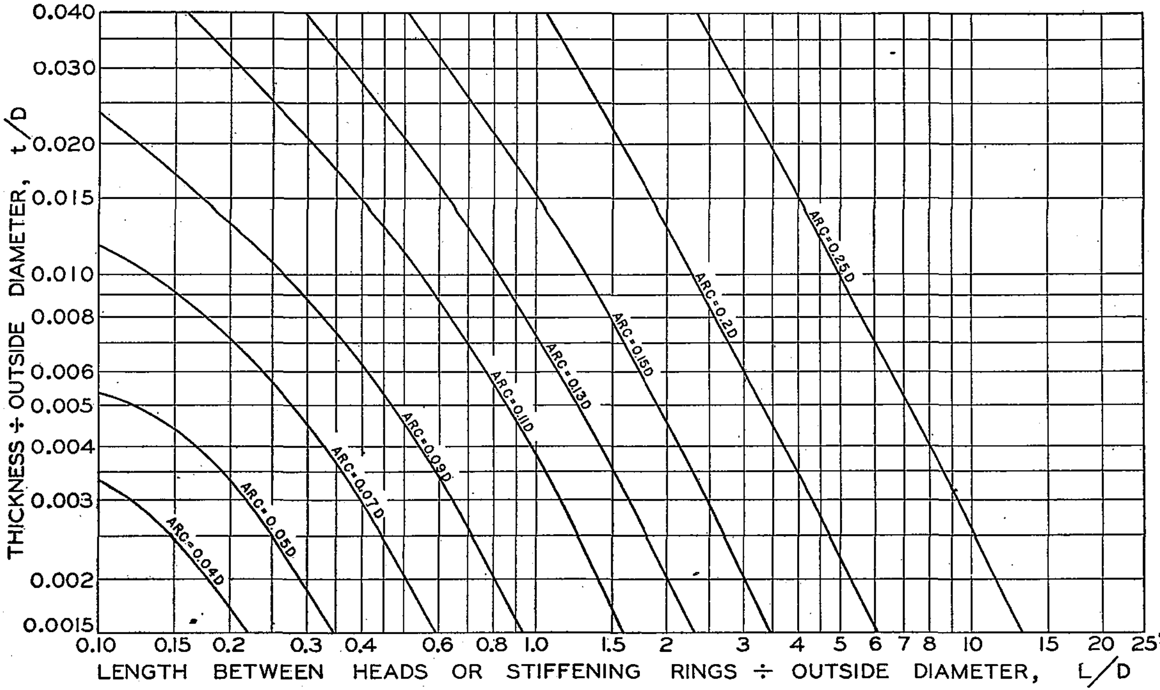



FIG. U-28 MAXIMUM ARC OF SHELL LEFT UNSUPPORTED BECAUSE OF GAP IN STIFFENING RING OF UNFIRED CYLINDRICAL VESSELS SUBJECTED TO EXTERNAL PRESSURE sponding maximum $L/D$ ratio is 0.25. Then, $t = 0.0038 \times D = 0.0038 \times 200 = 0.76$ in., and $L = 0.25 \times D = 0.25 \times 200 = 50$ in. It should be noted that any further reduction of the $L/D$ ratio below 0.25 does not lower the $t/D$ ratio. Therefore, a spacing of stiffening rings at 0.25 $D$ or 50 in. is the smallest that can be used to advantage.

The moment of inertia of the stiffening ring is obtained from Fig. U-26. For $L \times P = 50 \times 40 = 2000$, and a diameter $D$ of 200 in., $I$ is found to be 96 in.$^4$ A 9-in., 30-lb I-beam is shown in standard handbooks to have a moment of inertia $I$ about the neutral axis perpendicular to the web, of 101.4 in.$^4$ Such a beam is satisfactory. Stiffening rings must be placed every 50 in. along the vessel, and the shell plate must be not less than 0.76 in. in thickness.

The maximum out-of-roundness permitted is obtained from Fig. U-24. For a $t/D$ ratio of 0.0038 and an $L/D$ ratio of 0.25, $e$ is found to be $0.6t$. That is, the difference between the maximum diameter $D_{max}$ and the minimum diameter $D_{min}$ in any plane perpendicular to the axis of the vessel shall not exceed $0.6 \times 0.76 = 0.46$ in. (approximately).

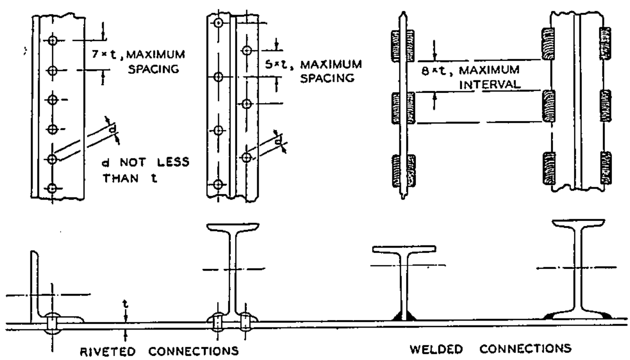



Fig. U-29 Some Acceptable Methods of Attaching Stiffening Rings to Shells of Unfired Cylindrical Vessels Subjected to External Pressure

**U-129** Particular attention is called to the fact that any arrangement of the structure which does not permit uniform radial contraction of the shell will weaken the vessel. Internal radial stays or supports for any purpose shall not bear against the shell of the vessel except through the medium of a substantially continuous ring.

**U-130 Attachment of Stiffening Rings to Shell.** Stiffening rings, if used, may be placed on the inside or outside of a vessel and they may be attached to the shell by riveting or welding. If the rings are outside and are riveted, the nominal diameter of the rivets shall be not less than the thickness of the shell plate and the center-to-center distance of the rivet holes shall not exceed that shown in Fig. U-29.

**U-131** If the rings are outside and are welded, the total length of the welding on either side of the stiffening ring shall be not less than one half the outside circumference of the vessel. The arrangement and spacing of such welds, if of the intermittent type, shall be in accordance with Fig. U-29.

**U-132** Stiffening rings placed on the inside of a vessel shall be in adequate contact with the shell and sufficiently secured to the shell to hold them in their proper position under any normal condition of operation.

**U-133** All welding for attachment of stiffening rings shall comply with the requirements of the Code for the type of vessel in question.

**U-134 Supports.** The supports for a vessel shall be such that no concentrated loads are imposed which would cause deformation of the vessel in service exceeding the limits of out-of-roundness permitted by these rules.

NOTE: Attention is called to the objection of supporting vessels through the medium of legs or brackets, the arrangement of which may cause concentrated loads to be imposed on the shell. Vertical vessels should be supported through a substantial ring secured to the shell. Horizontal vessels, unless supported at or close to the ends (heads) or at stiffening rings, should be supported through the medium of substantial members extending over at least one third of the circumference, as shown at *K* in Fig. U-27.

Attention is called also to the danger of imposing highly concentrated loads by the improper support of one vessel on another or by the hanging or supporting of heavy weights directly on the shell of the vessel.

**U-135 Heads.** The design of the heads shall comply with the requirements for dished or flat heads as given in Pars. U-36 and U-39. Attention is called to the allowable pressure on a dished head when the pressure is on the convex side.

**U-136 Longitudinal Joints.** Longitudinal joints may be of any type permitted by these rules, except that if a lap joint is used, either riveted, welded, or brazed, the allowable working pressure shall be 50 per cent of that computed by the rules given herein. Longitudinal joints, if riveted, shall have an efficiency of 50 per cent or greater and in no case less than

$$\frac{PD}{S2t}$$

where $P$ = working pressure, pounds per square inch,
$D$ = outside diameter, inches,
$S$ = working stress, pounds per square inch, given in Table U-2,
$t$ = minimum required thickness of shell plate, inches.

**U-137 Circumferential Joints.** Circumferential joints may be of any type permitted by these rules. The strength of riveted circumferential joints shall be sufficient, considering all methods of failure, to resist the total longitudinal force acting on the joint with a factor of safety of 5.

**U-138 Nozzle Openings.** Unreinforced openings in the shell shall conform to the requirements of Par. U-59(a) where

$$K = \frac{\text{thickness required by Fig. U-22}}{\text{actual thickness of shell}}$$

Reinforced openings in the shell shall conform to the requirements of Par. U-59(e) where $t$ is thickness required by Fig. U-22.

## RULES FOR CONTAINERS FOR GASES AND LIQUIDS AT TEMPERATURES OF —20 F AND BELOW

*These rules cover containers for noncorrosive gases and liquids which have no deleterious effect on the steel of the vessel, which containers may be used for the liquefaction or gasification of solid carbon dioxide. They do not apply to vessels designed for atmospheric or higher temperatures, nor do they apply to vessels in which thermal stresses imposed by the conditions of operation will be an important factor.*

**U-140 Special Seamless Containers.** (a) These containers shall not be used under conditions where there is danger of having holes made in the shell.

The material shall conform to Specification SA-53 with the following additional minimum requirements as to tensile properties:

| Min Tensile Strength, Psi | Elongation in 2 In., Per Cent |
|---|---|
| 62,000 | 25 |
| 75,000 | 22½ |
| 90,000 | 18 |

(b) In addition to complying with the test requirements in (a), specimens for each impact test shall be cut from one container selected, after heat-treatment, from each 100 containers or each heat, or each heat-treating batch, whichever is the smaller, and shall meet the impact tests as described in Par. U-142. Each impact test shall be the average of three specimens.

(c) **Design.** The containers shall consist of a seamless vessel in which there are no holes except as herein provided. The end or head to which any attachments are made shall be thicker than the shell portion. Two acceptable forms for solid carbon-dioxide containers for use with removable cover plates to provide filling openings and discharge gas openings which shall not exceed $^3/_4$ in. standard pipe size are shown in Fig. U-30. The thickness of the vessel shall be gradually in-

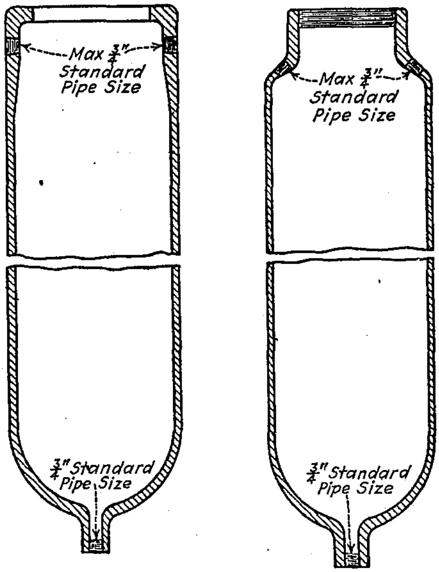



FIG. U-30 TYPICAL SECTIONS OF CONTAINERS FOR LIQUEFACTION OF SOLID CARBON DIOXIDE

creased near the head in order to avoid stress concentrations, and any openings shall be placed in the thickened part at or near the head at a point where the calculated stress before piercing is not more than one half the maximum allowable stress.

The containers shall otherwise be designed in accordance with all provisions of the other requirements of this Code using the formula in Par. U-20, except that the maximum $S$ factor shall not exceed:

| | Psi |
|---|---|
| For 62,000 lb Grade B steel | 15,500 |
| For 75,000 lb Grade C steel | 18,750 |
| For 90,000 lb Grade D steel | 22,500 |

There shall not be any welding on seamless containers.

**U-141 Other Containers.** (a) Containers fabricated other than as specified in Par. U-140 shall conform with the requirements given elsewhere in this Code, as they may apply, provided that specimens cut from one container selected from each batch of 100 containers or less shall meet the impact tests as described in Par. U-142. Each impact test shall be the average of three specimens.

(b) If of welded construction, containers shall be fabricated in accordance with the requirements of Par. U-68 and in addition, impact tests on the base metal and welds shall meet the requirements of Par. U-142. The number of such impact tests shall be the same as the number of tensile tests required for material and size under Par. U-68.

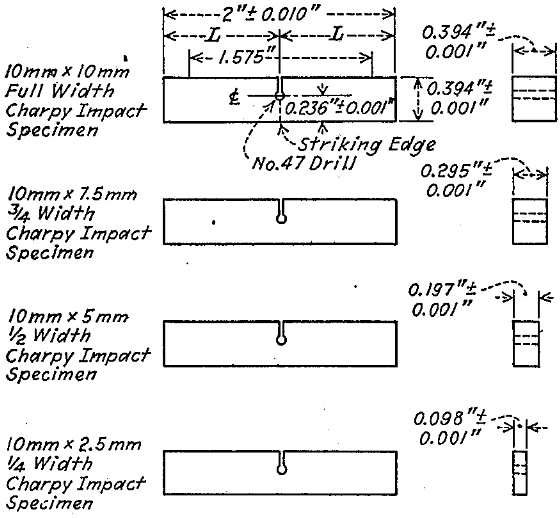
**U-142 Impact Properties and Tests.** (a) TEMPERATURE. Impact tests shall be run at the lowest temperature to which containers may be subjected during the operating cycle. The specimens shall be uniformly cooled by subjecting them to the test temperature for at least 30 minutes and the handling tongs shall be cooled similarly. The tests shall be made within 8 seconds after removal from the cooling medium.

(b) TESTS AND TEST SPECIMENS. Charpy-type impact tests are preferred. However, where this type of machine is not available the Izod test may be substituted. The standard 10 mm × 10 mm specimen shall be used where the thickness is $^{7}/_{16}$ in. or greater, and for thinner material a similar specimen shall be used except that the dimension along the axis of the notch shall be reduced from 10 mm to the largest possible of 7.5 mm, 5 mm, or 2.5 mm.

(c) DETAILS OF CHARPY TEST. Charpy tests shall be made on a standard Charpy machine using a keyhole or equivalent notch specimen as shown in Fig. U-31. The impact properties shall conform to the following:

| CHARPY IMPACT SPECIMENS, KEYHOLE OR EQUIVALENT NOTCH | MIN IMPACT VALUE, FT-LB AT MIN OPERATING TEMPERATURES |
|---|---|
| 10 mm × 10 mm | 15 |
| 10 mm × 7.5 mm | 12.5 |
| 10 mm × 5 mm | 10 |
| 10 mm × 2.5 mm | 5 |

(d) DETAILS OF IZOD TEST. Izod tests shall be made on a




EQUIVALENT NOTCH SPECIMENS

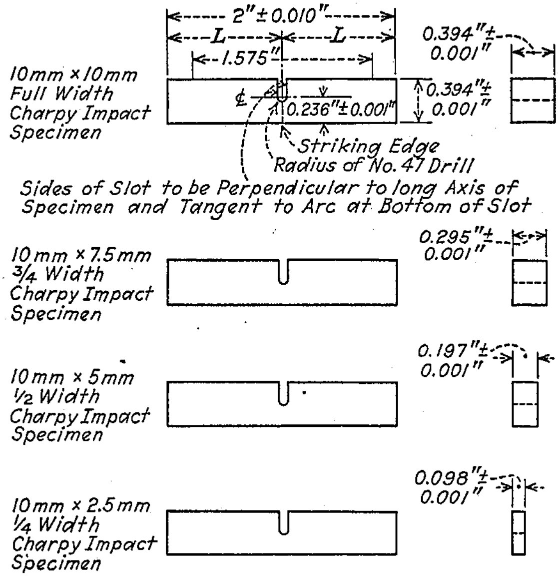



FIG. U-31 CHARPY IMPACT TEST SPECIMENS

standard Izod machine using a V-notch specimen as shown in Fig. U-33. The impact properties shall conform to the following:

| Izod Impact Specimens, V-Notch | Min Impact Value, Ft-Lb at Min Operating Temperatures |
|---|---|
| 10 mm × 10 mm | 18 |
| 10 mm × 7.5 mm | 15 |
| 10 mm × 5 mm | 10 |
| 10 mm × 2.5 mm | 4 |

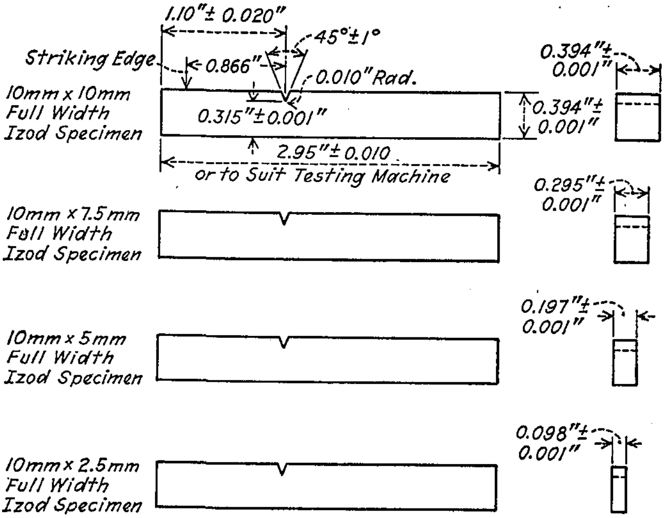



Fig. U-32 Izod Impact Test Specimens

(e) Number of Impact Tests Required. The number of specimens to be tested shall be as provided in Par. U-141, and each impact test shall consist of three specimens, each of which shall meet the minimum requirements. Where an erratic result indicates a defective specimen or other unusual condition, a retest will be allowed.

(f) Location and Heat-Treatment of Test Bars. The length of the impact bar shall be taken parallel to the direction of the expected maximum stress for both seamless and welded containers. The required test bars are to be taken from the ends of a seamless container before the shell is thickened for closure, and for the welded containers they shall be taken from the test plates required for each container under Par. U-68. In the case of a welded container one set of impact bars shall be taken across the weld with the notch in the weld metal and one set shall be similarly taken but with the notch in the adjacent metal in the heat-affected zone. All tests are to be run on bars heat-treated in equivalent section and in exactly the same manner as are the containers, and bars shall be heat-treated before machining. The procedure for producing such bars shall be similar to that used for making the member.

**U-143 Safety Devices.** The safety relief device or devices shall comply with the requirements of Par. U-2, and Pars. U-3 to U-10 shall not apply.

**U-144 Stamping.** The stamping required by Par. U-66 shall be applied at some thickened or reinforced portion of the vessel.

# APPENDIX

*Explanatory of the Code and containing matter which is not mandatory unless specifically referred to in the rules of the Code.*

## TABLE UA-1 STEEL PIPE FLANGES AND FLANGED FITTINGS
### FACING DIMENSIONS FOR 150-, 300-, 400-, 600-, 900-, 1500-, AND 2500-LB FLANGES
The following table is taken from ASA B16e–1939

| Nominal pipe size, in. | Outside diameter[3] | | | ID of large and small tongue,[3,5] in. | Outside diameter[3] | | | ID of large and small groove[3,5] in. |
|---|---|---|---|---|---|---|---|---|
| | Raised face, lapped large male, and large tongue,[5] in. | Small male,[4,5] in. | Small tongue,[5] in. | | Large female and large groove,[5] in. | Small female,[4,5] in. | Small groove,[5] in. | |
| | R | S | T | U | W | X | Y | Z |
| 1/2 | 1 3/8 | 23/32 | 1 3/8 | 1 | 1 7/16 | 25/32 | 1 7/16 | 15/16 |
| 3/4 | 1 11/16 | 15/16 | 1 11/16 | 1 5/16 | 1 3/4 | 1 | 1 3/4 | 1 1/4 |
| 1 | 2 | 1 3/16 | 1 7/8 | 1 1/2 | 2 1/16 | 1 1/4 | 1 15/16 | 1 7/16 |
| 1 1/4 | 2 1/2 | 1 1/2 | 2 1/4 | 1 7/8 | 2 9/16 | 1 9/16 | 2 5/16 | 1 13/16 |
| 1 1/2 | 2 7/8 | 1 3/4 | 2 1/2 | 2 1/8 | 2 15/16 | 1 13/16 | 2 9/16 | 2 1/16 |
| 2 | 3 5/8 | 2 1/4 | 3 1/4 | 2 7/8 | 3 11/16 | 2 5/16 | 3 5/16 | 2 13/16 |
| 2 1/2 | 4 1/8 | 2 11/16 | 3 3/4 | 3 3/8 | 4 3/16 | 2 3/4 | 3 13/16 | 3 5/16 |
| 3 | 5 | 3 5/16 | 4 5/8 | 4 1/4 | 5 1/16 | 3 3/8 | 4 11/16 | 4 3/16 |
| 3 1/2 | 5 1/2 | 3 13/16 | 5 1/8 | 4 3/4 | 5 9/16 | 3 7/8 | 5 3/16 | 4 11/16 |
| 4 | 6 3/16 | 4 5/16 | 5 11/16 | 5 3/16 | 6 1/4 | 4 3/8 | 5 3/4 | 5 1/8 |
| 5 | 7 5/16 | 5 3/8 | 6 13/16 | 6 5/16 | 7 3/8 | 5 7/16 | 6 7/8 | 6 1/4 |
| 6 | 8 1/2 | 6 3/8 | 8 | 7 1/2 | 8 9/16 | 6 7/16 | 8 1/16 | 7 7/16 |
| 8 | 10 5/8 | 8 3/8 | 10 | 9 3/8 | 10 11/16 | 8 7/16 | 10 1/16 | 9 5/16 |
| 10 | 12 3/4 | 10 1/2 | 12 | 11 1/4 | 12 13/16 | 10 9/16 | 12 1/16 | 11 3/16 |
| 12 | 15 | 12 1/2 | 14 1/4 | 13 1/2 | 15 1/16 | 12 9/16 | 14 5/16 | 13 7/16 |
| 14 OD | 16 1/4 | 13 3/4 | 15 1/2 | 14 3/4 | 16 5/16 | 13 13/16 | 15 9/16 | 14 11/16 |
| 16 OD | 18 1/2 | 15 3/4 | 17 5/8 | 16 3/4 | 18 9/16 | 15 13/16 | 17 11/16 | 16 11/16 |
| 18 OD | 21 | 17 3/4 | 20 1/8 | 19 1/4 | 21 1/16 | 17 13/16 | 20 3/16 | 19 3/16 |
| 20 OD | 23 | 19 3/4 | 22 | 21 | 23 1/16 | 19 13/16 | 22 1/16 | 20 15/16 |
| 24 OD | 27 1/4 | 23 3/4 | 26 1/4 | 25 1/4 | 27 5/16 | 23 13/16 | 26 5/16 | 25 3/16 |

Height, raised face, 150 and 300 lb stds.[1]........1/16 in.
Height, raised face, large and small male and tongue, 400, 600, 900, 1500, and 2500 lb stds.[2]........1/4 in.
Depth of groove or female........3/16 in.

[1] Regular facing for 150- and 300-lb steel flanged fittings and companion flange standards is a 1/16-in. raised face included in the minimum flange thickness dimensions given in Table UA-2. A 1/16-in. raised face may be supplied also on the 400-, 600-, 900-, 1500-, and 2500-lb flange standards, but it must be added to the minimum flange thickness.

[2] Regular facing for 400-, 600-, 900-, 1500-, and 2500-lb flange standards is a 1/4-in. raised face, not included in minimum flange thickness dimensions.

[3] A tolerance of plus or minus 0.016 in. (1/64 in.) is allowed on the inside and outside diameters of all facings.

[4] For small male and female joints care should be taken in the use of these dimensions to insure that pipe used is thick enough to permit sufficient bearing surface to prevent the crushing of the gasket. The dimensions apply particularly on lines where the joint is made on the end of pipe. Screwed companion flanges for small male and female joints are furnished with plain face and are threaded with American Standard Locknut Thread.

[5] Gaskets for male-female and tongue-groove joints shall cover the bottom of the recess with minimum clearances taking into account the tolerances prescribed in Note 3.

The bolting and nut material called for by the American Standard shall be used.

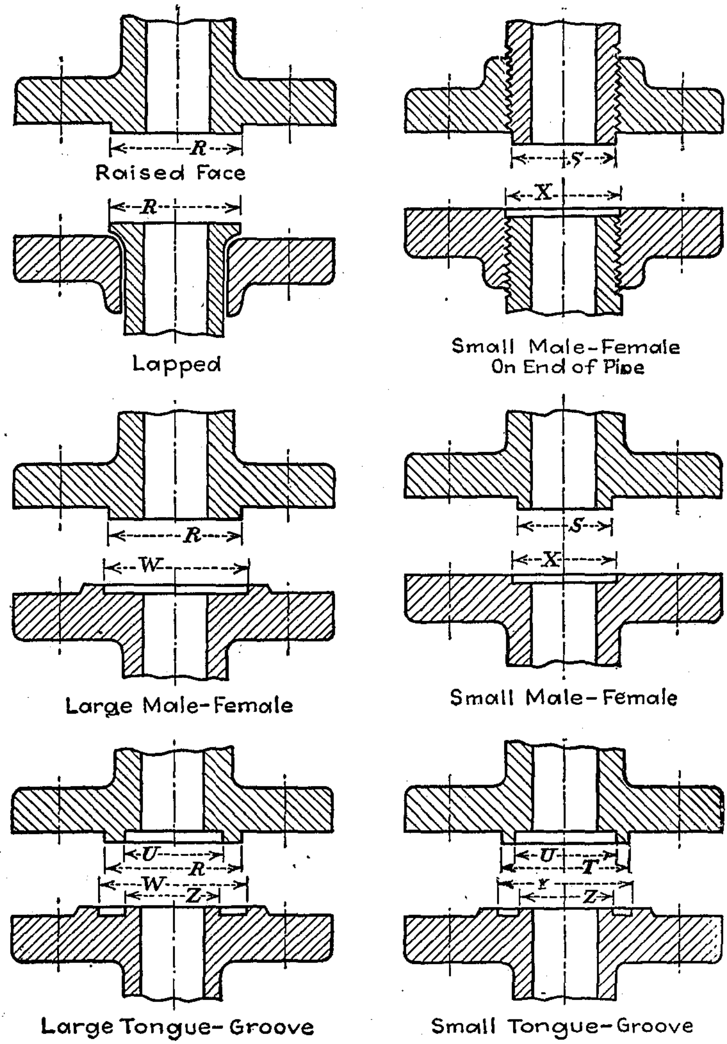



FIG. UA-1 TYPICAL FACINGS (FOR DIMENSIONS SEE TABLE UA-1)

# TABLE UA-2 STEEL PIPE FLANGES AND FLANGED FITTINGS

## DIMENSIONS OF FLANGES FOR PRIMARY SERVICE PRESSURE RATING

The following table is taken from ASA B16e–1939

| Nominal pipe size, in. | 150 lb | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Flanges | | | | | | Fittings | | Welding Neck Flanges | | | |
| | Outside diam of flange, in. | Thickness of flange | | Diam of bolt circle, in. | Number of bolts | Size of bolts, in. | Metal thickness of fitting, min, in. | Face-to-face dimension of length of tee, in. | Diam of hub | Hub diam beginning of chamfer[4,5,6] | Length through hub[1] | Inside diam of pipe schedule 40[5,6] |
| | | Loose flanges, min,[1] in. | Flanged fittings, min,[3] in. | | | | | | | | | |
| | O | Q | | | | | | | X | H | Y | J |
| 1/2 | 3 1/2 | 7/16 | ... | 2 3/8 | 4 | 1/2 | .. | ... | 1 3/16 | 0.84 | 1 7/8 | 0.62* |
| 3/4 | 3 7/8 | 1/2 | ... | 2 3/4 | 4 | 1/2 | .. | ... | 1 1/2 | 1.05 | 2 1/16 | 0.82* |
| 1 | 4 1/4 | 9/16 | 7/16 | 3 1/8 | 4 | 1/2 | 1/4 | 7 | 1 15/16 | 1.32 | 2 3/16 | 1.05* |
| 1 1/4 | 4 5/8 | 5/8 | 1/2 | 3 1/2 | 4 | 1/2 | 1/4 | 7 1/2 | 2 5/16 | 1.66 | 2 1/4 | 1.38* |
| 1 1/2 | 5 | 11/16 | 9/16 | 3 7/8 | 4 | 1/2 | 1/4 | 8 | 2 9/16 | 1.90 | 2 7/16 | 1.61* |
| 2 | 6 | 3/4 | 5/8 | 4 3/4 | 4 | 5/8 | 1/4 | 9 | 3 1/16 | 2.38 | 2 1/2 | 2.07* |
| 2 1/2 | 7 | 7/8 | 11/16 | 5 1/2 | 4 | 5/8 | 1/4 | 10 | 3 9/16 | 2.88 | 2 3/4 | 2.47* |
| 3 | 7 1/2 | 15/16 | 3/4 | 6 | 4 | 5/8 | 1/4 | 11 | 4 1/4 | 3.50 | 2 3/4 | 3.07* |
| 3 1/2 | 8 1/2 | 15/16 | 13/16 | 7 | 8 | 5/8 | 1/4 | 12 | 4 13/16 | 4.00 | 2 13/16 | 3.55* |
| 4 | 9 | 15/16 | 15/16 | 7 1/2 | 8 | 5/8 | 1/4 | 13 | 5 5/16 | 4.50 | 3 | 4.03* |
| 5 | 10 | 15/16 | 15/16 | 8 1/2 | 8 | 3/4 | 9/32 | 15 | 6 7/16 | 5.56 | 3 1/2 | 5.05* |
| 6 | 11 | 1 | 1 | 9 1/2 | 8 | 3/4 | 9/32 | 16 | 7 9/16 | 6.63 | 3 1/2 | 6.07* |
| 8 | 13 1/2 | 1 1/8 | 1 1/8 | 11 3/4 | 8 | 3/4 | [illegible]/16 | 18 | 9 11/16 | 8.63 | 4 | 7.98* |
| 10 | 16 | 1 3/16 | 1 3/16 | 14 1/4 | 12 | 7/8 | 11/32 | 22 | 12 | 10.75 | 4 | 10.02* |
| 12 | 19 | 1 1/4 | 1 1/4 | 17 | 12 | 7/8 | 3/8 | 24 | 14 3/8 | 12.75 | 4 1/2 | ... |
| 14 OD | 21 | 1 3/8 | 1 3/8 | 18 3/4 | 12 | 1 | 13/32 | 28 | 15 3/4 | 14.00 | 5 | To be specified by purchaser |
| 16 OD | 23 1/2 | 1 7/16 | 1 7/16 | 21 1/4 | 16 | 1 | 7/16 | 30 | 18 | 16.00 | 5 | |
| 18 OD | 25 | 1 9/16 | 1 9/16 | 22 3/4 | 16 | 1 1/8 | 15/32 | 33 | 19 7/8 | 18.00 | 5 1/2 | |
| 20 OD | 27 1/2 | 1 11/16 | 1 11/16 | 25 | 20 | 1 1/8 | 1/2 | 36 | 22 | 20.00 | 5 11/16 | |
| 24 OD | 32 | 1 7/8 | 1 7/8 | 29 1/2 | 20 | 1 1/4 | 9/16 | 44 | 26 1/8 | 24.00 | 6 | |

[1] The raised face of 1/16 in. is included in "thickness of flange minimum" and in "length through hub."
[2] The raised face of 1/4 in. is not included in "thickness of flange minimum" nor in "length through hub" or in "thread length."
[3] A raised face of 1/16 in. is provided on the flange of each opening of these fittings and is included in (*a*) "thickness of flange, minimum," (*b*) "center to contact surface," and (*c*) "contact surface to contact surface" dimensions.
[4] The outside surface of the welding end of the hub shall be straight or tapered at not more than 6 deg.
[5] Dimensions H and J correspond to the outside and inside diameters of pipe as given in ASA B36.10–1935, Schedule 40.
[6] See Par. 21, Tolerance for Welding Neck Flanges, in the Introductory Notes of the ASA B16e–1939.
* These diameters are identical with the diameters of what was formerly designated as "Standard Weight Pipe" of the corresponding sizes.

The thickness of flange minimum dimensions for these loose flanges, sizes 3 1/2 in. and smaller, are slightly heavier than for the flanges on the fittings which are reinforced by being cast integral with the body of the fitting.

TABLE UA-2 (*Continued*)

| Nominal pipe size, in. | Flanges: Outside diam of flange, in. O | Flanges: Thickness of flange, min,[1] in. | Flanges: Diam of bolt circle, in. Q | Flanges: Number of bolts | Flanges: Size of bolts, in. | Fittings: Metal thickness of fitting, min, in. | Fittings: Face-to-face dimension of length of tee, in. | Welding Neck Flanges: Diam of hub X | Welding Neck Flanges: Hub diam beginning of chamfer[4,5,7] H | Welding Neck Flanges: Length through hub[1] Y | Welding Neck Flanges: Inside diam of pipe, schedule 40[5,6,7] J | Welding Neck Flanges: Inside diam of pipe, schedule 80[5,6,7] J |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 300 lb | | | | | | | | | | | |
| 1/2 | 3 3/4 | 9/16 | 2 5/8 | 4 | 1/2 | ... | ... | 1 1/2 | 0.84 | 2 1/16 | 0.62* | 0.55† |
| 3/4 | 4 5/8 | 5/8 | 3 1/4 | 4 | 5/8 | ... | ... | 1 7/8 | 1.05 | 2 1/4 | 0.82* | 0.74† |
| 1 | 4 7/8 | 11/16 | 3 1/2 | 4 | 5/8 | 1/4 | 8 | 2 1/8 | 1.32 | 2 7/16 | 1.05* | 0.96† |
| 1 1/4 | 5 1/4 | 3/4 | 3 7/8 | 4 | 5/8 | 1/4 | 8 1/2 | 2 1/2 | 1.66 | 2 9/16 | 1.38* | 1.28† |
| 1 1/2 | 6 1/8 | 13/16 | 4 1/2 | 4 | 3/4 | 1/4 | 9 | 2 3/4 | 1.90 | 2 11/16 | 1.61* | 1.50† |
| 2 | 6 1/2 | 7/8 | 5 | 8 | 5/8 | 1/4 | 10 | 3 5/16 | 2.38 | 2 3/4 | 2.07* | 1.94† |
| 2 1/2 | 7 1/2 | 1 | 5 7/8 | 8 | 3/4 | 1/4 | 11 | 3 15/16 | 2.88 | 3 | 2.47* | 2.32† |
| 3 | 8 1/4 | 1 1/8 | 6 5/8 | 8 | 3/4 | 9/32 | 12 | 4 5/8 | 3.50 | 3 1/8 | 3.07* | 2.90† |
| 3 1/2 | 9 | 1 3/16 | 7 1/4 | 8 | 3/4 | 9/32 | 13 | 5 1/4 | 4.00 | 3 3/16 | 3.55* | 3.36† |
| 4 | 10 | 1 1/4 | 7 7/8 | 8 | 3/4 | 5/16 | 14 | 5 3/4 | 4.50 | 3 3/8 | 4.03* | 3.83† |
| 5 | 11 | 1 3/8 | 9 1/4 | 8 | 3/4 | 3/8 | 16 | 7 | 5.56 | 3 7/8 | 5.05* | 4.81† |
| 6 | 12 1/2 | 1 7/16 | 10 5/8 | 12 | 3/4 | 3/8 | 17 | 8 1/8 | 6.63 | 3 7/8 | 6.07* | 5.76† |
| 8 | 15 | 1 5/8 | 13 | 12 | 7/8 | 7/16 | 20 | 10 1/4 | 8.63 | 4 3/8 | 7.98* | 7.63† |
| 10 | 17 1/2 | 1 7/8 | 15 1/4 | 16 | 1 | 1/2 | 23 | 12 5/8 | 10.75 | 4 5/8 | 10.02* | .... |
| 12 | 20 1/2 | 2 | 17 3/4 | 16 | 1 1/8 | 9/16 | 26 | 14 3/4 | 12.75 | 5 1/8 | .... | .... |
| 14 OD | 23 | 2 1/8 | 20 1/4 | 20 | 1 1/8 | 5/8 | 30 | 16 3/4 | 14.00 | 5 5/8 | To be specified by purchaser | To be specified by purchaser |
| 16 OD | 25 1/2 | 2 1/4 | 22 1/2 | 20 | 1 1/4 | 11/16 | 33 | 19 | 16.00 | 5 3/4 | | |
| 18 OD | 28 | 2 3/8 | 24 3/4 | 24 | 1 1/4 | 3/4 | 36 | 21 | 18.00 | 6 1/4 | | |
| 20 OD | 30 1/2 | 2 1/2 | 27 | 24 | 1 1/4 | 13/16 | 39 | 23 1/8 | 20.00 | 6 3/8 | | |
| 24 OD | 36 | 2 3/4 | 32 | 24 | 1 1/2 | 15/16 | 45 | 27 5/8 | 24.00 | 6 5/8 | | |

[4] This outside surface of the welding end of the hub shall be straight or tapered at not more than 6 deg.
[5] Dimensions H and J correspond to the outside and inside diameters of pipe as given in ASA B36.10–1935, Schedules 40 and 80. Purchaser's order must specify which of these two inside diameters is desired.
[6] See Par. 21, Tolerance for Welding Neck Flanges, in the Introductory Notes.
[7] These flanges are regularly bored to match inside diameter of Schedule 40 pipe, but are bored to Schedule 80 pipe when so ordered.
* These diameters are identical with the diameters of what was formerly designated as "Standard Weight Pipe" of the corresponding sizes.
† These diameters are identical with the diameters of what was formerly designated as "Extra Strong Pipe" of the corresponding sizes.

TABLE UA-2 (*Continued*)

| Nominal pipe size, in. | 400 lb — Flanges: Outside diam of flange, in. O | Flanges: Thickness of flange, min,[1] in. Q | Flanges: Diam of bolt circle, in. | Flanges: Number of bolts | Flanges: Size of bolts, in. | Fittings: Metal thickness of fitting, min, in. | Fittings: Face-to-face dimension of length of tee, in. | Welding Neck Flanges: Diam of hub X | Welding Neck Flanges: Hub diam beginning of chamfer[4,5,7] H | Welding Neck Flanges: Length through hub[1] Y | Welding Neck Flanges: Inside diam of pipe, schedule 40[5,6,7] J | Welding Neck Flanges: Inside diam of pipe, schedule 80[5,6,7] J |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| * 1/2 | 3 3/4 | 9/16 | 2 5/8 | 4 | 1/2 | 1/4 | 6 1/2 | 1 1/2 | 0.84 | 2 1/16 | 0.62** | 0.55† |
| * 3/4 | 4 5/8 | 5/8 | 3 1/4 | 4 | 5/8 | 1/4 | 7 1/2 | 1 7/8 | 1.05 | 2 1/4 | 0.82** | 0.74† |
| *1 | 4 7/8 | 11/16 | 3 1/2 | 4 | 5/8 | 1/4 | 8 1/2 | 2 1/8 | 1.32 | 2 7/16 | 1.05** | 0.96† |
| *1 1/4 | 5 1/4 | 13/16 | 3 7/8 | 4 | 5/8 | 1/4 | 9 | 2 1/2 | 1.66 | 2 5/8 | 1.38** | 1.28† |
| *1 1/2 | 6 1/8 | 7/8 | 4 1/2 | 4 | 3/4 | 1/4 | 9 1/2 | 2 3/4 | 1.90 | 2 3/4 | 1.61** | 1.50† |
| *2 | 6 1/2 | 1 | 5 | 8 | 5/8 | 5/16 | 11 1/2 | 3 5/16 | 2.38 | 2 7/8 | 2.07** | 1.94† |
| *2 1/2 | 7 1/2 | 1 1/8 | 5 7/8 | 8 | 3/4 | 3/8 | 13 | 3 15/16 | 2.88 | 3 1/8 | 2.47** | 2.32† |
| *3 | 8 1/4 | 1 1/4 | 6 5/8 | 8 | 3/4 | 3/8 | 14 | 4 5/8 | 3.50 | 3 1/4 | 3.07** | 2.90† |
| *3 1/2 | 9 | 1 3/8 | 7 1/4 | 8 | 7/8 | 7/16 | 15 | 5 1/4 | 4.00 | 3 3/8 | 3.55** | 3.36† |
| 4 | 10 | 1 3/8 | 7 7/8 | 8 | 7/8 | 3/8 | 16 | 5 3/4 | 4.50 | 3 1/2 | 4.03** | 3.83† |
| 5 | 11 | 1 1/2 | 9 1/4 | 8 | 7/8 | 7/16 | 18 | 7 | 5.56 | 4 | 5.05** | 4.81† |
| 6 | 12 1/2 | 1 5/8 | 10 5/8 | 12 | 7/8 | 7/16 | 19 1/2 | 8 1/8 | 6.63 | 4 1/16 | 6.07** | 5.76† |
| 8 | 15 | 1 7/8 | 13 | 12 | 1 | 9/16 | 23 1/2 | 10 1/4 | 8.63 | 4 5/8 | 7.98** | 7.63† |
| 10 | 17 1/2 | 2 1/8 | 15 1/4 | 16 | 1 1/8 | 11/16 | 26 1/2 | 12 5/8 | 10.75 | 4 7/8 | 10.02** | ... |
| 12 | 20 1/2 | 2 1/4 | 17 3/4 | 16 | 1 1/4 | 3/4 | 30 | 14 3/4 | 12.75 | 5 3/8 | ... | ... |
| 14 OD | 23 | 2 3/8 | 20 1/4 | 20 | 1 1/4 | 13/16 | 32 1/2 | 16 3/4 | 14.00 | 5 7/8 | To be specified by purchaser | To be specified by purchaser |
| 16 OD | 25 1/2 | 2 1/2 | 22 1/2 | 20 | 1 3/8 | 7/8 | 35 1/2 | 19 | 16.00 | 6 | | |
| 18 OD | 28 | 2 5/8 | 24 3/4 | 24 | 1 3/8 | 15/16 | 38 1/2 | 21 | 18.00 | 6 1/2 | | |
| 20 OD | 30 1/2 | 2 3/4 | 27 | 24 | 1 1/2 | 1 1/16 | 41 1/2 | 23 1/8 | 20.00 | 6 5/8 | | |
| 24 OD | 36 | 3 | 32 | 24 | 1 3/4 | 1 3/16 | 48 1/2 | 27 5/8 | 24.00 | 6 7/8 | | |

* The dimensions given and the marking for sizes 1/2 to 3 1/2 in., inclusive, are identical with those of the 600 lb flanges.
** These diameters are identical with the diameters of what was formerly designated as "Standard Weight Pipe" of the corresponding sizes.

TABLE UA-2 (*Continued*)

| Nominal pipe size, in. | 600 lb | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Flanges | | | | | Fittings | | Welding Neck Flanges | | | |
| | Outside diam of flange, in. O | Thickness of flange, min,[2] in. Q | Diam of bolt circle, in. | Number of bolts, in. | Size of bolts, in. | Metal thickness of fitting min, in. | Face-to-face dimension of length of tee, in. | Diam of hub X | Hub diam of beginning of chamfer[4,5,6] H | Length through hub[1] Y | Inside diam of pipe[6] J |
| 1/2 | 3 3/4 | 9/16 | 2 5/8 | 4 | 1/2 | 1/4 | 6 1/2 | 1 1/2 | 0.84 | 2 1/16 | |
| 3/4 | 4 5/8 | 5/8 | 3 1/4 | 4 | 5/8 | 1/4 | 7 1/2 | 1 7/8 | 1.05 | 2 1/4 | |
| 1 | 4 7/8 | 11/16 | 3 1/2 | 4 | 5/8 | 1/4 | 8 1/2 | 2 1/8 | 1.32 | 2 7/16 | |
| 1 1/4 | 5 1/4 | 13/16 | 3 7/8 | 4 | 5/8 | 1/4 | 9 | 2 1/2 | 1.66 | 2 5/8 | |
| 1 1/2 | 6 1/8 | 7/8 | 4 1/2 | 4 | 3/4 | 1/4 | 9 1/2 | 2 3/4 | 1.90 | 2 3/4 | |
| 2 | 6 1/2 | 1 | 5 | 8 | 5/8 | 5/16 | 11 1/2 | 3 5/16 | 2.38 | 2 7/8 | To be specifie by purchase |
| 2 1/2 | 7 1/2 | 1 1/8 | 5 7/8 | 8 | 3/4 | 3/8 | 13 | 3 15/16 | 2.88 | 3 1/8 | |
| 3 | 8 1/4 | 1 1/4 | 6 5/8 | 8 | 3/4 | 3/8 | 14 | 4 5/8 | 3.50 | 3 1/4 | |
| 3 1/2 | 9 | 1 3/8 | 7 1/4 | 8 | 7/8 | 7/16 | 15 | 5 1/4 | 4.00 | 3 3/8 | |
| 4 | 10 3/4 | 1 1/2 | 8 1/2 | 8 | 7/8 | 1/2 | 17 | 6 | 4.50 | 4 | |
| 5 | 13 | 1 3/4 | 10 1/2 | 8 | 1 | 9/16 | 20 | 7 7/16 | 5.56 | 4 1/2 | |
| 6 | 14 | 1 7/8 | 11 1/2 | 12 | 1 | 5/8 | 22 | 8 3/4 | 6.63 | 4 5/8 | |
| 8 | 16 1/2 | 2 3/16 | 13 3/4 | 12 | 1 1/8 | 3/4 | 26 | 10 3/4 | 8.63 | 5 1/4 | |
| 10 | 20 | 2 1/2 | 17 | 16 | 1 1/4 | 7/8 | 31 | 13 1/2 | 10.75 | 6 | |
| 12 | 22 | 2 5/8 | 19 1/4 | 20 | 1 1/4 | 1 | 33 | 15 3/4 | 12.75 | 6 1/4 | |
| 14 OD | 23 3/4 | 2 3/4 | 20 3/4 | 20 | 1 3/8 | 1 1/8 | 35 | 17 | 14.00 | 6 1/2 | |
| 16 OD | 27 | 3 | 23 3/4 | 20 | 1 1/2 | 1 1/4 | 39 | 19 1/2 | 16.00 | 7 | |
| 18 OD | 29 1/4 | 3 1/4 | 25 3/4 | 20 | 1 5/8 | 1 3/8 | 43 | 21 1/2 | 18.00 | 7 1/4 | |
| 20 OD | 32 | 3 1/2 | 28 1/2 | 24 | 1 5/8 | 1 1/2 | 47 | 24 | 20.00 | 7 1/2 | |
| 24 OD | 37 | 4 | 33 | 24 | 1 7/8 | 1 3/4 | 55 | 28 1/4 | 24.00 | 8 | |

TABLE UA-2 (*Continued*)

| Nominal pipe size, in. | Flanges: Outside diam of flange, in. O | Flanges: Thickness of flange, min,[2] in. Q | Flanges: Diam of bolt circle, in. | Flanges: Number of bolts, in. | Flanges: Size of bolts, in. | Fittings: Metal thickness of fitting min, in. | Fittings: Face-to-face dimension of length of tee, in. | Welding Neck Flanges: Diam of hub X | Welding Neck Flanges: Hub diam of beginning of chamfer[4,5,6] H | Welding Neck Flanges: Length through hub[1] Y | Welding Neck Flanges: Inside diam of pipe[6] J |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 900 lb | | | | | | | | | | | |
| * 1/2 | 4 3/4 | 7/8 | 3 1/4 | 4 | 3/4 | 5/16 | 8 1/2 | 1 1/2 | 0.84 | 2 3/8 | |
| * 3/4 | 5 1/8 | 1 | 3 1/2 | 4 | 3/4 | 5/16 | 9 | 1 3/4 | 1.05 | 2 3/4 | |
| *1 | 5 7/8 | 1 1/8 | 4 | 4 | 7/8 | 3/8 | 10 | 2 1/16 | 1.32 | 2 7/8 | |
| *1 1/4 | 6 1/4 | 1 1/8 | 4 3/8 | 4 | 7/8 | 3/8 | 11 | 2 1/2 | 1.66 | 2 7/8 | |
| *1 1/2 | 7 | 1 1/4 | 4 7/8 | 4 | 1 | 7/16 | 12 | 2 3/4 | 1.90 | 3 1/4 | |
| *2 | 8 1/2 | 1 1/2 | 6 1/2 | 8 | 7/8 | 9/16 | 14 1/2 | 4 1/8 | 2.38 | 4 | |
| *2 1/2 | 9 5/8 | 1 5/8 | 7 1/2 | 8 | 1 | 11/16 | 16 1/2 | 4 7/8 | 2.88 | 4 1/8 | |
| 3 | 9 1/2 | 1 1/2 | 7 1/2 | 8 | 7/8 | 1/2 | 15 | 5 | 3.50 | 4 | To be specified by purchaser |
| 4 | 11 1/2 | 1 3/4 | 9 1/4 | 8 | 1 1/8 | 5/8 | 18 | 6 1/4 | 4.50 | 4 1/2 | |
| 5 | 13 3/4 | 2 | 11 | 8 | 1 1/4 | 3/4 | 22 | 7 1/2 | 5.56 | 5 | |
| 6 | 15 | 2 3/16 | 12 1/2 | 12 | 1 1/8 | 13/16 | 24 | 9 1/4 | 6.63 | 5 1/2 | |
| 8 | 18 1/2 | 2 1/2 | 15 1/2 | 12 | 1 3/8 | 1 1/16 | 29 | 11 3/4 | 8.63 | 6 3/8 | |
| 10 | 21 1/2 | 2 3/4 | 18 1/2 | 16 | 1 3/8 | 1 1/4 | 33 | 14 1/2 | 10.75 | 7 1/4 | |
| 12 | 24 | 3 1/8 | 21 | 20 | 1 3/8 | 1 7/16 | 38 | 16 1/2 | 12.75 | 7 7/8 | |
| 14 OD | 25 1/4 | 3 3/8 | 22 | 20 | 1 1/2 | 1 9/16 | 40 1/2 | 17 3/4 | 14.00 | 8 3/8 | |
| 16 OD | 27 3/4 | 3 1/2 | 24 1/4 | 20 | 1 5/8 | 1 13/16 | 44 1/2 | 20 | 16.00 | 8 1/2 | |
| 18 OD | 31 | 4 | 27 | 20 | 1 7/8 | 2 | 48 | 22 1/4 | 18.00 | 9 | |
| 20 OD | 33 3/4 | 4 1/4 | 29 1/2 | 20 | 2 | 2 1/4 | 52 | 24 1/2 | 20.00 | 9 3/4 | |
| 24 OD | 41 | 5 1/2 | 35 1/2 | 20 | 2 1/2 | 2 5/8 | 61 | 29 1/2 | 24.00 | 11 1/2 | |

* The dimensions given and the marking for sizes 1/2 to 2 1/2 in., inclusive, are identical with those of the 1500 lb flanges.

**TABLE UA-2** *(Continued)*

| Nominal pipe size, in. | 1500 lb | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Flanges | | | | | Fittings | | Welding Neck Flanges | | | |
| | Outside diam of flange, in. | Thickness of flange, min,[2] in. | Diam of bolt circle, in. | Number of bolts, in. | Size of bolts, in. | Metal thickness of fitting min, in. | Face-to-face dimension of length of tee, in. | Diam of hub X | Hub diam of beginning of chamfer[4,5,6] H | Length through hub[1] Y | Inside diam of pipe[6] J |
| 1/2 | 4 3/4 | 7/8 | 3 1/4 | 4 | 3/4 | 5/16 | 8 1/2 | 1 1/2 | 0.84 | 2 3/8 | |
| 3/4 | 5 1/8 | 1 | 3 1/2 | 4 | 3/4 | 5/16 | 9 | 1 3/4 | 1.05 | 2 3/4 | |
| 1 | 5 7/8 | 1 1/8 | 4 | 4 | 7/8 | 3/8 | 10 | 2 1/16 | 1.32 | 2 7/8 | |
| 1 1/4 | 6 1/4 | 1 1/8 | 4 3/8 | 4 | 7/8 | 3/8 | 11 | 2 1/2 | 1.66 | 2 7/8 | |
| 1 1/2 | 7 | 1 1/4 | 4 7/8 | 4 | 1 | 7/16 | 12 | 2 3/4 | 1.90 | 3 1/4 | |
| 2 | 8 1/2 | 1 1/2 | 6 1/2 | 8 | 7/8 | 9/16 | 14 1/2 | 4 1/8 | 2.38 | 4 | |
| 2 1/2 | 9 5/8 | 1 5/8 | 7 1/2 | 8 | 1 | 11/16 | 16 1/2 | 4 7/8 | 2.88 | 4 1/8 | |
| 3 | 10 1/2 | 1 7/8 | 8 | 8 | 1 1/8 | 3/4 | 18 1/2 | 5 1/4 | 3.50 | 4 5/8 | |
| 4 | 12 1/4 | 2 1/8 | 9 1/2 | 8 | 1 1/4 | 1 | 21 1/2 | 6 3/8 | 4.50 | 4 7/8 | To be specified by purchas |
| 5 | 14 3/4 | 2 7/8 | 11 1/2 | 8 | 1 1/2 | 1 1/8 | 26 1/2 | 7 3/4 | 5.56 | 6 1/8 | |
| 6 | 15 1/2 | 3 1/4 | 12 1/2 | 12 | 1 3/8 | 1 5/16 | 27 3/4 | 9 | 6.63 | 6 3/4 | |
| 8 | 19 | 3 5/8 | 15 1/2 | 12 | 1 5/8 | 1 5/8 | 32 3/4 | 11 1/2 | 8.63 | 8 3/8 | |
| 10 | 23 | 4 1/4 | 19 | 12 | 1 7/8 | 2 | 39 | 14 1/2 | 10.75 | 10 | |
| 12 | 26 1/2 | 4 7/8 | 22 1/2 | 16 | 2 | 2 5/16 | 44 1/2 | 17 3/4 | 12.75 | 11 1/8 | |
| 14 OD | 29 1/2 | 5 1/4 | 25 | 16 | 2 1/4 | 2 1/2 | 49 1/2 | 19 1/2 | 14.00 | 11 3/4 | |
| 16 OD | 32 1/2 | 5 3/4 | 27 3/4 | 16 | 2 1/2 | 2 7/8 | 54 1/2 | 21 3/4 | 16.00 | 12 1/4 | |
| 18 OD | 36 | 6 3/8 | 30 1/2 | 16 | 2 3/4 | 3 1/4 | 60 1/2 | 23 1/2 | 18.00 | 12 7/8 | |
| 20 OD | 38 3/4 | 7 | 32 3/4 | 16 | 3 | 3 5/8 | 65 1/2 | 25 1/4 | 20.00 | 14 | |
| 24 OD | 46 | 8 | 39 | 16 | 3 1/2 | 4 1/4 | 76 1/2 | 30 | 24.00 | 16 | |

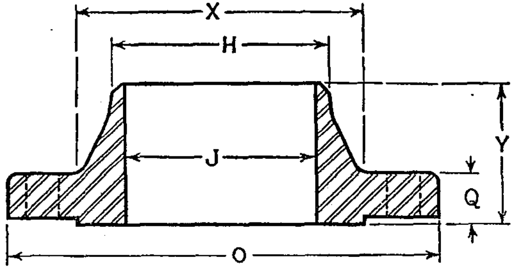



TABLE UA-2 (*Continued*)

| Nominal pipe size, in. | 2500 lb | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Flanges | | | | | Fittings | | Welding Neck Flanges | | | |
| | Outside diam of flange, in. | Thickness of flange,[2] min, in. | Diam of bolt circle, in. | Number of bolts, in. | Size of bolts, in. | Metal thickness of fitting min, in. | Face-to-face dimension of length of tee, in. | Diam of hub X | Hub diam of beginning of chamfer[4,5,6] H | Length through hub[1] Y | Inside diam of pipe[6] J |
| 1/2 | 5 1/4 | 1 3/16 | 3 1/2 | 4 | 3/4 | 3/8 | 10 3/8 | 1 11/16 | 0.84 | 2 7/8 | To be specified by purchaser |
| 3/4 | 5 1/2 | 1 1/4 | 3 3/4 | 4 | 3/4 | 7/16 | 10 3/4 | 2 | 1.05 | 3 1/8 | |
| 1 | 6 1/4 | 1 3/8 | 4 1/4 | 4 | 7/8 | 1/2 | 12 1/8 | 2 1/4 | 1.32 | 3 1/2 | |
| 1 1/4 | 7 1/4 | 1 1/2 | 5 1/8 | 4 | 1 | 5/8 | 13 3/4 | 2 7/8 | 1.66 | 3 3/4 | |
| 1 1/2 | 8 | 1 3/4 | 5 3/4 | 4 | 1 1/8 | 11/16 | 15 1/8 | 3 1/8 | 1.90 | 4 3/8 | |
| 2 | 9 1/4 | 2 | 6 3/4 | 8 | 1 | 13/16 | 17 3/4 | 3 3/4 | 2.38 | 5 | |
| 2 1/2 | 10 1/2 | 2 1/4 | 7 3/4 | 8 | 1 1/8 | 1 | 20 | 4 1/2 | 2.88 | 5 5/8 | |
| 3 | 12 | 2 5/8 | 9 | 8 | 1 1/4 | 1 3/16 | 22 3/4 | 5 1/4 | 3.50 | 6 5/8 | |
| 4 | 14 | 3 | 10 3/4 | 8 | 1 1/2 | 1 7/16 | 26 1/2 | 6 1/2 | 4.50 | 7 1/2 | |
| 5 | 16 1/2 | 3 5/8 | 12 3/4 | 8 | 1 3/4 | 1 13/16 | 31 1/4 | 8 | 5.56 | 9 | |
| 6 | 19 | 4 1/4 | 14 1/2 | 8 | 2 | 2 1/16 | 36 | 9 1/4 | 6.63 | 10 3/4 | |
| 8 | 21 3/4 | 5 | 17 1/4 | 12 | 2 | 2 5/8 | 40 1/4 | 12 | 8.63 | 12 1/2 | |
| 10 | 26 1/2 | 6 1/2 | 21 1/4 | 12 | 2 1/2 | 3 1/4 | 50 | 14 3/4 | 10.75 | 16 1/2 | |
| 12 | 30 | 7 1/4 | 24 3/8 | 12 | 2 3/4 | 3 13/16 | 56 | 17 3/8 | 12.75 | 18 1/4 | |

## TABLE UA-3 CAST-IRON PIPE FLANGES AND FLANGED FITTINGS

### DIMENSIONS OF 125-LB CAST-IRON FLANGES

The following table is taken from ASA B16a–1939

| Nominal pipe size, in. | Diameter of flange, in. | Thickness of flange, min,[2] in. | Diameter of bolt circle, in. | Number of bolts[1] | Diameter of bolts, in. | Diameter of drilled bolt holes,[1] in. | Wall thickness min, in. | Face-to-face dimension of length of tee, in. |
|---|---|---|---|---|---|---|---|---|
| 1 | 4 1/4 | 7/16 | 3 1/8 | 4 | 1/2 | 5/8 | 5/16 | 7 |
| 1 1/4 | 4 5/8 | 1/2 | 3 1/2 | 4 | 1/2 | 5/8 | 5/16 | 7 1/2 |
| 1 1/2 | 5 | 9/16 | 3 7/8 | 4 | 1/2 | 5/8 | 5/16 | 8 |
| 2 | 6 | 5/8 | 4 3/4 | 4 | 5/8 | 3/4 | 5/16 | 9 |
| 2 1/2 | 7 | 11/16 | 5 1/2 | 4 | 5/8 | 3/4 | 5/16 | 10 |
| 3 | 7 1/2 | 3/4 | 6 | 4 | 5/8 | 3/4 | 3/8 | 11 |
| 3 1/2 | 8 1/2 | 13/16 | 7 | 8 | 5/8 | 3/4 | 7/16 | 12 |
| 4 | 9 | 15/16 | 7 1/2 | 8 | 5/8 | 3/4 | 1/2 | 13 |
| 5 | 10 | 15/16 | 8 1/2 | 8 | 3/4 | 7/8 | 1/2 | 15 |
| 6 | 11 | 1 | 9 1/2 | 8 | 3/4 | 7/8 | 9/16 | 16 |
| 8 | 13 1/2 | 1 1/8 | 11 3/4 | 8 | 3/4 | 7/8 | 5/8 | 18 |
| 10 | 16 | 1 3/16 | 14 1/4 | 12 | 7/8 | 1 | 3/4 | 22 |
| 12 | 19 | 1 1/4 | 17 | 12 | 7/8 | 1 | 13/16 | 24 |

NOTE: For maximum saturated steam service pressures of 125 psi (gage), sizes 1 to 5 in., inclusive, apply; for 100 psi, sizes 6 to 12 in., inclusive, apply.

[1] NOTE: Drilling templates are in multiples of 4, so that fittings may be made to face in any quarter, and bolt holes straddle the center line. For bolts smaller than 1 3/4 in., the bolt holes shall be drilled 1/8 in. larger in diameter than the nominal diameter of the bolt. Holes for bolts 1 3/4 in. and larger shall be drilled 1/4 in. larger than nominal diameter of bolts.

[2] NOTE: All 125-lb cast-iron standard flanges have plain faces.

## TABLE UA-4 CAST-IRON FLANGED FITTINGS
## DIMENSIONS OF 250-LB CAST-IRON FLANGES

The following table is taken from ASA B16b-1928

| Nominal pipe size, in. | Outside diameter of flange, in. | Thickness of flange, min[2,4] in. | Diameter of raised face, in. | Diameter of bolt circle, in. | Number of bolts[1] | Diameter of bolts, in. | Diameter of drilled boltholes,[1] in. | Total effective area bolt metal, in. | Stress, lb per sq in. bolt metal,[3] in. | Metal thickness of body, min in. | Face-to-face dimension of length of tee, in. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 4 7/8 | 11/16 | 2 11/16 | 3 1/2 | 4 | 5/8 | 3/4 | 0.808 | 970 | 1/2 | 8 |
| 1 1/4 | 5 1/4 | 3/4 | 3 1/16 | 3 7/8 | 4 | 5/8 | 3/4 | 0.808 | 1520 | 1/2 | 8 1/2 |
| 1 1/2 | 6 1/8 | 13/16 | 3 9/16 | 4 1/2 | 4 | 3/4 | 7/8 | 1.208 | 1345 | 1/2 | 9 |
| 2 | 6 1/2 | 7/8 | 4 3/16 | 5 | 8 | 5/8 | 3/4 | 1.616 | 1595 | 1/2 | 10 |
| 2 1/2 | 7 1/2 | 1 | 4 15/16 | 5 7/8 | 8 | 3/4 | 7/8 | 2.416 | 2090 | 9/16 | 11 |
| 3 | 8 1/4 | 1 1/8 | 5 11/16 | 6 5/8 | 8 | 3/4 | 7/8 | 2.416 | 2030 | 9/16 | 12 |
| 3 1/2 | 9 | 1 3/16 | 6 5/16 | 7 1/4 | 8 | 3/4 | 7/8 | 2.416 | 2460 | 9/16 | 13 |
| 4 | 10 | 1 1/4 | 6 15/16 | 7 7/8 | 8 | 3/4 | 7/8 | 2.416 | 3120 | 5/8 | 14 |
| 5 | 11 | 1 3/8 | 8 5/16 | 9 1/4 | 8 | 3/4 | 7/8 | 2.416 | 4385 | 11/16 | 16 |
| 6 | 12 1/2 | 1 7/16 | 9 11/16 | 10 5/8 | 12 | 3/4 | 7/8 | 3.624 | 3915 | 3/4 | 17 |
| 8 | 15 | 1 5/8 | 11 15/16 | 13 | 12 | 7/8 | 1 | 5.04 | 4400 | 13/16 | 20 |
| 10 | 17 1/2 | 1 7/8 | 14 1/16 | 15 1/4 | 16 | 1 | 1 1/8 | 8.80 | 3625 | 15/16 | 23 |
| 12 | 20 1/2 | 2 | 16 7/16 | 17 3/4 | 16 | 1 1/8 | 1 1/4 | 11.10 | 3975 | 1 | 26 |
| 14 OD | 23 | 2 1/8 | 18 15/16 | 20 1/4 | 20 | 1 1/8 | 1 1/4 | 13.88 | 3735 | 1 1/8 | 30 |
| 16 OD | 25 1/2 | 2 1/4 | 21 1/16 | 22 1/2 | 20 | 1 1/4 | 1 3/8 | 17.86 | 2255 | 1 1/4 | 33 |
| 18 OD | 28 | 2 3/8 | 23 5/16 | 24 3/4 | 24 | 1 1/4 | 1 3/8 | 21.43 | 4505 | 1 3/8 | 36 |
| 20 OD | 30 1/2 | 2 1/2 | 25 9/16 | 27 | 24 | 1 1/4 | 1 3/8 | 21.43 | 4845 | 1 1/2 | 39 |
| 24 OD | 36 | 2 3/4 | 30 5/16 | 32 | 24 | 1 1/2 | 1 5/8 | 31.06 | 4500 | 1 5/8 | 45 |
| 30 OD | 43 | 3 | 37 3/16 | 39 1/4 | 28 | 1 3/4 | 2 | 48.89 | 5590 | 2 | 55 |
| 36 OD | 50 | 3 3/8 | 43 11/16 | 46 | 32 | 2 | 2 1/4 | 73.70 | 5355 | ... | .. |
| 42 OD | 57 | 3 11/16 | 50 7/16 | 52 3/4 | 36 | 2 | 2 1/4 | 82.90 | 5945 | ... | .. |
| 48 OD | 65 | 4 | 58 7/16 | 60 3/4 | 40 | 2 | 2 1/4 | 92.08 | 7315 | ... | .. |

[1] NOTE: Drilling templates are in multiples of 4, so that fittings may be made to face in any quarter, and bolt holes straddle the center line. For bolts smaller than 1 3/4 in., the bolt holes shall be drilled 1/8 in. larger in diameter than the nominal size of the bolts. Holes for bolts 1 3/4 in. and larger shall be drilled 1/4 in. larger than nominal diameter of bolts.

[2] NOTE: All 250-lb cast-iron standard flanges have a 1/16-in. raised face. This raised face is included in the face-to-face, center-to-face; and the minimum thicknesses of flange dimensions.

[3] NOTE: The stress shown is that of internal pressure only assumed to act on a circular area equal in diameter to the outside diameter of the raised face.

[4] NOTE: For tongue-groove and male-female facings the dimensions given in Table UA-1 are recommended.

TABLE UA-5 SERVICE PRESSURE RATINGS FOR STEEL PIPE FLANGES AND FLANGED FITTINGS

The following tables are taken from ASA B16e–1939

| | | Carbon steel flanges and flanged fittings at temperatures 850 F and below with standard facings (other than ring joints) | | | | | | | Carbon steel flanges and flanged fittings at temperatures 850 F and below with ring-joint facings | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fluid | Primary service pressure ratings | 150 | 300 | 400 | 600 | 900 | 1500 | 2500 | 150 | 300 | 400 | 600 | 900 | 1500 | 2500 |
| | Maximum hydrostatic shell test pressures[1] | 350 | 750 | 1000 | 1500 | 2000 | 3500 | 6000 | 350 | 750 | 1000 | 1500 | 2000 | 3500 | 6000 |
| | Service temperatures, deg F | Maximum, nonshock, service pressure ratings at temperatures from 100 to 850 F | | | | | | | Maximum, nonshock, service pressure ratings at temperatures from 100 to 850 F | | | | | | |
| Water Steam | 100 | 230 | 500 | 670 | 1000 | 1500 | 2500 | 4170 | 275 | 600 | 800 | 1200 | 1800 | 3000 | 5000 |
| | 150 | 220 | 480 | 640 | 960 | 1440 | 2400 | 4000 | 255 | 575 | 765 | 1150 | 1725 | 2875 | 4790 |
| | 200 | 210 | 465 | 620 | 930 | 1395 | 2325 | 3875 | 240 | 550 | 730 | 1100 | 1650 | 2750 | 4580 |
| | 250 | 200 | 450 | 600 | 900 | 1350 | 2250 | 3750 | 225 | 525 | 700 | 1050 | 1575 | 2625 | 4375 |
| | 300 | 190 | 435 | 580 | 870 | 1305 | 2175 | 3625 | 210 | 500 | 670 | 1000 | 1500 | 2500 | 4170 |
| | 350 | 180 | 420 | 560 | 840 | 1260 | 2100 | 3500 | 195 | 475 | 635 | 950 | 1425 | 2375 | 3960 |
| | 400 | 170 | 405 | 540 | 810 | 1215 | 2025 | 3375 | 180 | 450 | 600 | 900 | 1350 | 2250 | 3750 |
| | 450 | 160 | 390 | 520 | 780 | 1170 | 1950 | 3250 | 165 | 425 | 565 | 850 | 1275 | 2125 | 3540 |
| | 500 | 150* | 375 | 500 | 750 | 1125 | 1875 | 3125 | 150* | 400 | 530 | 800 | 1200 | 2000 | 3330 |
| | 550 | 140 | 360 | 480 | 720 | 1080 | 1800 | 3000 | 140 | 380 | 505 | 760 | 1140 | 1900 | 3165 |
| | 600 | 130 | 345 | 460 | 690 | 1035 | 1725 | 2875 | 130 | 360 | 480 | 720 | 1080 | 1800 | 3000 |
| | 650 | 120 | 330 | 440 | 660 | 990 | 1650 | 2750 | 120 | 340 | 450 | 680 | 1020 | 1700 | 2830 |
| | 700 | 110 | 315 | 420 | 630 | 945 | 1575 | 2625 | 110 | 320 | 425 | 640 | 960 | 1600 | 2665* |
| | 750 | 100 | 300* | 400* | 600* | 900* | 1500* | 2500* | 100 | 300* | 400* | 600* | 900* | 1500* | 2500 |
| | 800 | 85 | 250 | 335 | 500 | 750 | 1250 | 2085 | 85 | 250 | 335 | 500 | 750 | 1250 | 2085 |
| | 850 | 70 | 200 | 270 | 400 | 600 | 1000 | 1670 | 70 | 200 | 270 | 400 | 600 | 1000 | 1670 |

All pressures are in pounds per square inch (gage).

[1] All tests shall be made with water at a temperature not to exceed 125 F.

* Primary service pressure rating.

TABLE UA-5 (*Continued*)

| Fluid | Primary service pressure ratings | Carbon-molybdenum and equivalent alloy steels at temperatures 1000 F and below with standard facings (Other than ring joints) 300 | 400 | 600 | 900 | 1500 | 2500 | Carbon-molybdenum and equivalent alloy steels at temperatures 1000 F and below with ring joints 300 | 400 | 600 | 900 | 1500 | 2500 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Maximum hydrostatic shell test pressures[1] | 900 | 1200 | 1800 | 2400 | 4200 | 7200 | 900 | 1200 | 1800 | 2400 | 4200 | 7200 |
| | Service temperatures, deg F | Maximum, nonshock, service pressure ratings at temperatures from 100 to 1000 F | | | | | | Maximum, nonshock, service pressure ratings at temperatures from 100 to 1000 F | | | | | |
| Water<br>Steam<br>Oil | 100 | 600 | 800 | 1200 | 1800 | 3000 | 5000 | 720 | 960 | 1440 | 2160 | 3600 | 6000 |
| | 150 | 590 | 775 | 1180 | 1770 | 2950 | 4905 | 700 | 925 | 1400 | 2100 | 3500 | 5825 |
| | 200 | 580 | 750 | 1160 | 1740 | 2900 | 4810 | 675 | 900 | 1350 | 2025 | 3375 | 5625 |
| | 250 | 560 | 725 | 1120 | 1680 | 2800 | 4645 | 650 | 875 | 1300 | 1950 | 3250 | 5425 |
| | 300 | 540 | 700 | 1080 | 1620 | 2700 | 4480 | 625 | 825 | 1250 | 1875 | 3125 | 5200 |
| | 350 | 520 | 675 | 1040 | 1560 | 2600 | 4315 | 600 | 800 | 1200 | 1800 | 3000 | 5000 |
| | 400 | 500 | 650 | 1000 | 1500 | 2500 | 4150 | 575 | 775 | 1150 | 1725 | 2875 | 4800 |
| | 450 | 480 | 625 | 960 | 1440 | 2400 | 3985 | 550 | 725 | 1100 | 1650 | 2750 | 4575 |
| | 500 | 460 | 600 | 920 | 1380 | 2300 | 3820 | 525 | 700 | 1050 | 1575 | 2625 | 4375 |
| | 550 | 440 | 575 | 880 | 1320 | 2200 | 3655 | 500 | 675 | 1000 | 1500 | 2500 | 4175 |
| | 600 | 420 | 550 | 840 | 1260 | 2100 | 3490 | 475 | 625 | 950 | 1425 | 2375 | 3950 |
| | 650 | 400 | 525 | 800 | 1200 | 2000 | 3325 | 450 | 600 | 900 | 1350 | 2250 | 3750 |
| | 700 | 380 | 500 | 760 | 1140 | 1900 | 3160 | 425 | 575 | 850 | 1275 | 2125 | 3550 |
| | 750 | 360 | 475 | 720 | 1080 | 1800 | 2995 | 400 | 525 | 800 | 1200 | 2000 | 3325 |
| | 800 | 340 | 450 | 680 | 1020 | 1700 | 2830 | 375 | 500 | 750 | 1125 | 1875 | 3125 |
| | 850 | 320 | 425 | 640 | 960 | 1600 | 2665 | 350 | 475 | 700 | 1050 | 1750 | 2925 |
| | 900 | 300* | 400* | 600* | 900* | 1500* | 2500* | 325 | 425 | 650 | 975 | 1625 | 2700 |
| | 950 | 265 | 350 | 530 | 795 | 1325 | 2205 | 300* | 400* | 600* | 900* | 1500* | 2500* |
| | 1000 | 190 | 250 | 380 | 570 | 950 | 1580 | 200 | 275 | 400 | 600 | 1000 | 1675 |

All pressures are in pounds per square inch (gage).

Carbon-molybdenum alloy steel, castings Grade C-1, and forgings Grade F-1 (A.S.T.M. Specifications A 157-36 and A 182-36) serve as the fundamental basis for alloy steel ratings. Other alloys with superior qualities may be given appropriate ratings. For temperatures above 950 F, Grades C-1 and F-1 for steam service should be given consideration as to scaling due to oxidation.

[1] All tests shall be made with water at a temperature not to exceed 125 F.

* Primary service pressure ratings.

TABLE UA-6 MINIMUM METAL THICKNESS OF BODIES OF CAST-IRON AND MALLEABLE-IRON SCREWED FITTINGS

The following table is taken from ASA B16d–1941, B16c–1939, and MSS SP-31–1931

| Nominal pipe size, in. | Body metal thickness, in. | | | |
|---|---|---|---|---|
| | Cast-iron screwed fittings | | Malleable-screwed fittings | |
| | 125 lb | 250 lb | 150 lb | 300 lb |
| 1/8 | ... | .. | 0.090 | .. |
| 1/4 | 0.110 | 0.18 | 0.095 | 0.14 |
| 3/8 | 0.120 | 0.18 | 0.100 | 0.15 |
| 1/2 | 0.130 | 0.20 | 0.105 | 0.16 |
| 3/4 | 0.155 | 0.23 | 0.120 | 0.18 |
| 1 | 0.170 | 0.28 | 0.134 | 0.20 |
| 1 1/4 | 0.185 | 0.33 | 0.145 | 0.22 |
| 1 1/2 | 0.200 | 0.35 | 0.155 | 0.24 |
| 2 | 0.220 | 0.39 | 0.173 | 0.26 |
| 2 1/2 | 0.240 | 0.43 | 0.210 | 0.31 |
| 3 | 0.260 | 0.48 | 0.231 | 0.35 |
| 3 1/2 | 0.280 | 0.52 | 0.248 | .. |
| 4 | 0.310 | 0.56 | 0.265 | .. |
| 5 | 0.380 | 0.66 | 0.300 | .. |
| 6 | 0.430 | 0.74 | 0.336 | .. |
| 8 | 0.550 | 0.90 | ... | .. |
| 10 | 0.690 | 1.08 | ... | .. |
| 12 | 0.800 | 1.24 | ... | .. |

All pressures are in pounds per square inch (gage).

## STANDARD PRACTICE FOR MAKING HYDROSTATIC TESTS ON A PRESSURE PART

**UA-1 Scope.** This method of test is applicable only to materials having a definite proportional or elastic limit such as most carbon and alloy steels. It is not applicable to materials with indefinite or indeterminate proportional limits such as cast iron and most nonferrous materials.[1] The principle upon which the test is based assumes that the most highly stressed point in the pressure part will be subjected to a permanent set when the stress at this location reaches the proportional or elastic limit of the material. Since the stress will be directly proportional to the hydrostatic pressure, the determination of the pressure which stresses the weakest point to the proportional limit will permit a calculation of the maximum allowable working pressure that will result in a safe working stress in accordance with Code requirements for the material from which the part is made at the maximum operating temperature.

**UA-2 Material.** The structure shall be made from material approved for its intended use by the A.S.M.E. Code.

**UA-3 Workmanship.** The dimensions and minimum thickness of the structure to be tested should not vary materially from those actually used. If possible, the structure to be tested should be selected at random from a quantity of such intended for use.

**UA-4 Preparation for Test.** It is necessary to test only the weakest point of the structure but several points should be checked to make certain that the weakest one is included. The less definite the location of the weakest point, the more points should be checked.

The movement of the reference points may be measured with reference to a fixed surface, or two reference points may be located on opposite sides of a symmetrical structure and the total deformation between those two points measured.

Indicating micrometer gages accurate to 0.001 in. are most suitable for measuring deformation of the structure at the reference points although any form of accurate micrometer may be used.

A hand test pump is satisfactory as a source of hydrostatic pressure. Either a test gage or a reliable gage which has been calibrated with a test gage should be attached to the structure.

The maximum hydrostatic pressure which must be provided for will vary from 2 to 3 times the expected maximum allowable working pressure for carbon steel structures.

The location of the weakest point of the structure may be determined by applying a thin coating of plaster of Paris or similar material, and noting where the surface coating starts to break off under hydrostatic test. The coating should be allowed to dry before the test is started.

**UA-5 Hydrostatic Test.** The first application of hydrostatic pressure need not be less than the expected maximum allowable working pressure. At least ten separate applications of pressure, in approximately equal increments, should be made between the initial test pressure and the final test pressure.

When each increment of pressure has been applied the valve between the pump and the structure should be closed and the pressure gage watched to see that the pressure is maintained and no leakage occurs. The total deformation at the reference points should be measured and recorded and the hydrostatic

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[1] For method of testing parts made from such materials, see Par. UA-11.

pressure recorded. The pressure should then be released and each point checked for any permanent deformation which should be recorded.

Only one application of each increment of pressure is necessary.

The pressure should be increased by substantially uniform increments and readings taken until the elastic limit of the structure has obviously been exceeded.

The pressure part shall not have been subjected to a pressure greater than the designed maximum allowable working pressure prior to making the proof hydrostatic test.

**UA-6 Physical Characteristics of Metal.** Determine the proportional limit of the material in accordance with A.S.T.M. Specification E8-42 Standard Method of Tension Testing of Metallic Materials. It is important that this be determined from a number of specimens cut from the part tested, after the test is completed, in order to insure that the average proportional limit of the material in the part tested is used to calculate the safe working pressure. The specimens should be cut from a location where the stress during the test, has not exceeded the proportional limit, so that the specimens will be representative of the material as tested. These specimens should not be cut with a gas torch as there is danger of changing the proportional limit of the material.

**UA-7 Plotting Curves.** A single cross-section sheet should be used for each reference point of the structure. A scale of 1 in. = 0.01 in. deformation, and a scale of at least 1 in. equals the approximate test pressure increments, has been found satisfactory. Plot two curves for each reference point, one showing total deformation under pressure and one showing permanent deformation when the pressure is removed.

**UA-8 Determining Proportional Limit of Pressure Part.** Locate the proportional limit on each curve of total deformation as the point at which the total deformation ceases to be proportional directly to the hydrostatic pressure. Draw a straight line that will pass through the average of the points that lie approximately in a straight line. The proportional limit will occur at the value of hydrostatic pressure where the average curve through the points deviates from this straight line.

In pressure parts such as headers, where a series of similar weak points occur, the average hydrostatic pressure corresponding to the proportional limits of the similar points may be used.

The proportional limit obtained from the curve of total deformation may be checked from the curve of permanent deformation by locating the point where the permanent deformation begins to increase regularly with further increases in pressure. Permanent deformations of a low order that occur prior to the point really corresponding to the proportional limit of the structure, resulting from the equalization of stresses and irregularities in the material, may be disregarded.

It should be made certain that the curves show the deformation of the structure and not slip or displacement of reference surfaces, gages, or the structure.

**UA-9 Determining Maximum Allowable Working Pressure.** (a) Having determined the proportional limit of the weakest point of the structure, the corresponding maximum allowable working pressure may be determined by the formula:

$$P = \frac{HS}{E}$$

where $P$ = maximum allowable working pressure, pounds per square inch,

$H$ = hydrostatic pressure at the proportional limit of the pressure part, pounds per square inch,
$S$ = safe working stress permitted for the material at the maximum operating temperature as determined by Code requirements,
$E$ = average proportional limit of material, pounds per square inch.

(b) For carbon-steel material, complying with a Code specification and with a minimum tensile strength not over 62,000 psi, the proportional limit may be assumed to be two fifths of the average tensile strength of the specified range. Where no range is specified, the average tensile strength may be assumed as 5000 psi greater than the minimum. This will eliminate the necessity for cutting tensile specimens and determining the actual proportional limit. Under such conditions, the material in the pressure part tested should have had no appreciable cold working or other treatment that would tend to raise the proportional limit above the normal.

**UA-10 Retests.** A retest should be allowed on an additional structure if errors or irregularities are obvious in the results.

**UA-11 Testing Parts Made From Material Without Definite Proportional Limit.** Pressure parts made from cast iron or nonferrous materials without a well-defined proportional limit must be tested until failure occurs by rupture. The hydrostatic pressure at which rupture occurs must be determined. If excessive leakage occurs at rolled joints or at gasketed handhole fittings, they may be seal-welded for the test to permit test to destruction, provided the welding does not materially increase the strength of the part. No deflection measurements will be necessary. The average actual tensile strength of the material from which the part tested is made must be determined from test specimens cut from the part tested. If this is not practicable, the tensile strength must be assumed to be the maximum of the range given in the specification for the material.

The maximum allowable working pressure may be determined by the formula:

$$P = \frac{HS}{E}$$

where $P$ = maximum allowable working pressure, pounds per square inch,
$H$ = hydrostatic pressure at time of rupture, pounds per square inch,
$S$ = safe working stress permitted for the material at the maximum operating temperature as determined by Code requirements,
$E$ = average actual tensile strength from test specimens, or maximum of the range in specification, pounds per square inch.

It is possible that certain designs of pressure parts may result in concentrated stresses at critical points which may be relieved by yielding of the material at these points prior to rupture, so that failure may occur at some other point and not indicate the point of maximum stress at pressures below that causing rupture. There may be conditions which would make a test to destruction impracticable. Under such conditions a special test may be made from a carbon steel material of the same dimensions and thickness as used for the material in question. This special test part can then be tested in accordance with Pars. UA-1 to UA-10. The maximum allowable working pressure for the part made from the material in question would be determined by using the proper value of $S$ for the material in the formula in Par. UA-9. The value of $E$ used in the formula would be that for the carbon steel material from which the special test part is made.

## EXAMPLES OF METHODS OF COMPUTATION OF OPENINGS IN SHELLS

Applications of the rules in Par. U-59 are given in the following examples:

**UA-12** A pressure vessel for 275 psi working pressure has an inside diameter of 36 in. and is made of plate $^1/_2$ in. in thickness having a minimum ultimate tensile strength of 55,000 psi. Is it permissible to use a 2-in. pipe connection by tapping a hole for the pipe directly into the shell?

$$K = \frac{PD}{2St} = \frac{275 \times 37}{2 \times 11{,}000 \times 0.50} = 0.925 \text{ or } 92.5 \text{ per cent}$$

$$Dt = 37 \times 0.50 = 18.5$$

From the chart in Fig. U-8, the maximum allowable diameter of unreinforced opening is $d = 3.05$ in.

The 2 in. tapped hole has a diameter of 2.375 in. and according to Table U-7 requires at least 0.435 in. thickness for threads. Also, although the working pressure is above 125 psi, the size of the threaded connection is not greater than the maximum of 3 in. pipe size permitted when this pressure is exceeded. Therefore, the connection meets the requirements of the Code.

**UA-13** A special forging [such as shown in Fig. UA-2(a)] for a $3^1/_2$ in. pipe connection is inserted in a pressure vessel the working pressure of which is 100 psi. The length of thread is 2 in., the outside diameter of the portion projecting through the shell is $4^3/_4$ in., and the cross-sectional area of the forging is 2.25 sq in.

This construction complies with the rule that a threaded connection over 3 in. pipe size shall be used only for working pressures of 125 psi and under. The length of thread is sufficient, as indicated by Table U-7.

(a) **Seal Welded.** If seal welding only is applied to the forging, the opening is classed as an unreinforced hole having in this case a diameter of $4^3/_4$ in. The rules in Par. U-59(a) govern in this case. Assume the following data: Inside diameter at shell = 48 in.; thickness = $^1/_2$ in.; working pressure = 100 psi; material is Grade A of Specification SA-89 (45,000 psi minimum ultimate tensile strength).

$$K = \frac{PD}{2St} = \frac{100 \times 49}{2 \times 9000 \times 0.50} = 0.545 \text{ or } 54.5 \text{ per cent}$$

$$Dt = 49 \times 0.50 = 24.5$$

From Fig. U-8, $d = 6.15$ in.

The actual diameter is $4^3/_4$ in., and therefore this construction meets the requirements of the Code.

(b) **Strength Welded.** If the outside diameter of the neck of the forging (in this case $4^3/_4$ in.) is greater than $d$ as given by the charts in Fig. U-8, the welds must be strong enough to develop a minimum required amount of strength (strength welding). The rules in Par. U-59(e) to (h) govern in this case. Assume: Inside diameter, thickness, working pressure, and material of shell same as in (a); working temperature = 850 F; $S$ = 5700 psi (See Table U-2).

$$K = \frac{100 \times 49}{2 \times 5700 \times 0.50} = 0.86 \text{ or } 86 \text{ per cent}$$

$$Dt = 49 \times 0.50 = 24.5$$

From Fig. U-8, $d = 4.12$ in.

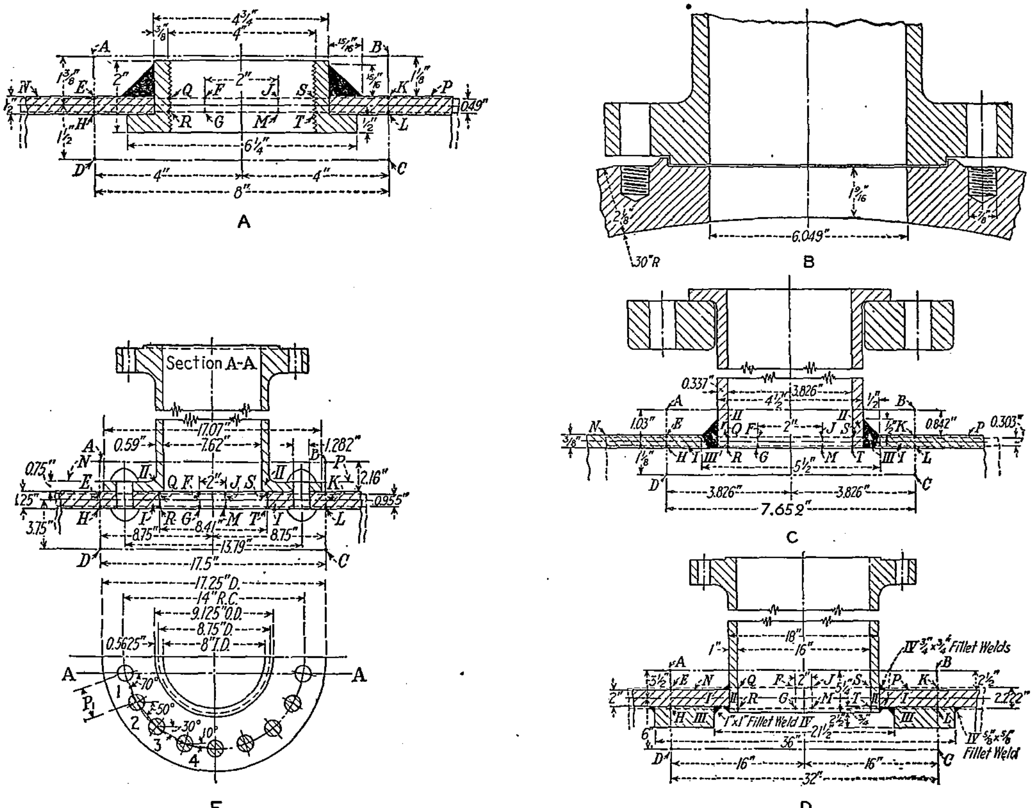



Fig. UA-2 Computations of Typical Nozzle Fittings

As the outside diameter of the neck of the forging (or hole in the shell) is $4^3/_4$ in., the forging must be strength welded to the shell and the design must comply with Par. U-59(e) to (h). Assume a fillet weld built in accordance with Par. U-68 on the outside with $^{15}/_{16}$ in. legs. The weld dimensions then comply with detail 3 of Fig. U-10. Since the forging is rigidly welded to the shell, the diameter of the opening is now 4 in., and the limits therefore are as shown in Fig. UA-2(a).

| | | |
|---|---|---|
| Cross section through shell | = 0.50 × (8 − 4.75) .......... = | 1.62 sq in. |
| Cross section through forging | = ($1^{15}/_{16}$ × 0.75) + (1.5 × 0.5).. = | 2.20 sq in. |
| Cross section through welds | = 2 × $^1/_2$ × 0.9375 × 0.9375... = | 0.88 sq in. |
| Total actual cross section.................................... | | 4.70 sq in. |

The required thickness when $E$ = 0.90 (See Par. U-20) is

$$t = \frac{PR}{SE} = \frac{100 \times 24}{5700 \times 0.90} = 0.468 \text{ in.}$$

Required cross section = area ($EFGH + JKLM$) = 0.468 × (8 − 2) = 2.810 sq in.

Therefore rule (1) of Par. U-59(g) has been complied with.

The fillet weld can fail in tension, around the circumference of the $4^3/_4$ in. diameter, or it can fail in shear around the circumference of the mean diameter of $5^{11}/_{16}$ in. The strength of that part of the weld on one side of the center line (on a semicircle) must be at least equal to that specified in rule (2) of Par. U-59(g), and (h). The allowable working stress of the weld in shear is 0.8 times the allowable working stress in tension.

Strength of weld in tension = 0.9375 × $^1/_2$ × (3.14 × 4.75) × (0.9 × 5700) = 35,900 lb

Strength of weld in shear = 0.9375 × $^1/_2$ × (3.14 × 5.6875) × (0.8 × × 0.9 5700) = 34,300 lb

The weld is weaker in shear

Strength of forging = 2.25 × 5700 = 12,800 lb

Strength of cross section represented by ($QFGR + JSTM$) = 0.468 × (4 − 2) × 5700 = 5330 lb.

Therefore rule (2) of Par. U-59(g), and Par. U-59(h) has been complied with

**UA-14** A studded connection such as shown in Fig. UA-2(b) is for 6-in. 400-lb American standard seamless pipe. The data for the shell are as follows: Inside diameter = 60 in.; thickness = $2^1/_8$ in.; working pressure = 325 psi; working temperature below 650 F; material Grade B of Specification SA-89. The flat for the raised face reduces the shell thickness to $1^9/_{16}$ in. at the edge of the opening.

$$K = \frac{325 \times 64.25}{2 \times 10{,}000 \times 1.5625} = 0.670 \text{ or 67 per cent}$$

$$Dt = 64.25 \times 1.5625 = 100.4$$

From Fig. U-8, $d$ = 8 in.

The actual equivalent diameter is the diameter of the hole in the shell plus the diameters of two stud holes, or 6.049 + (2 × 0.875) = 7.799 in. Therefore the connection meets the requirements of the Code.

**UA-15** A 4-in. extra-heavy pipe is welded into a fusion-welded pressure vessel built in accordance with Par. U-70 as shown in Fig. UA-2(c). The shell has an inside diameter of 30 in., a thickness of $^3/_8$ in., and a working pressure of 200 psi. The material is in accordance with Specification SA-70.

The weld, as shown in Fig. UA-2(c), complies with detail 4 of Fig. U-10.

| | | |
|---|---|---|
| Cross section I | = 0.375 × (7.652 − 4.50) ......... | = 1.181 sq in. |
| Cross section II | = 0.337 × 1.217 × 2 ............. | = 0.820 sq in. |
| Cross section III | = 2 × $^1/_2$ × 0.50 × 0.50 ......... | = 0.250 sq in. |
| **Total actual cross section** ........................ | | = **2.251 sq in.** |

The required thickness when $E$ = 0.90 is

$$t = \frac{200 \times 15}{11{,}000 \times 0.90} = 0.303 \text{ in.}$$

Required cross section = 0.303 × (7.652 − 2) = 1.71 sq in.

Therefore rule (1) of Par. U-59(g) has been complied with.

The weld can fail in tension by tearing around its circumference on a diameter of $5^1/_2$ in. Since single welding has been used, the allowable stress in tension is 7000 psi (See Par. U-70).

Strength of weld in tension = 0.375 × $^1/_2$ × 3.14 × 5.50 × 7000 = 22,700 lb.

The attachment of the nozzle can also fail by shearing through the weld and the nozzle neck (along the line $NP$ in Fig. UA-2(c)), around the circumference of the mean diameter of (5.50 + 3.826) × $^1/_2$ = 4.663 in. The allowable working stress of the weld in shear is 0.8 times the allowable working stress in tension

Strength of attachment in shear = (0.50 + 0.337) × $^1/_2$ × 3.14 × 4.663 × (0.8 × 7000) = 34,400 lb.

From the above, the construction is weaker in tension than in shear.

Strength of nozzle = (Area II) × $S$ = 0.820 × 11,000 = 9020 lb.

Strength of cross section represented by ($QFGR$ + $JSTM$) = 0.303 × (3.826 − 2) × 11,000 = 6090 lb.

Therefore rule (2) of Par. U-59(g) has been complied with.

**UA-16** A 16 in. welded circular nozzle-type manhole is located on a seamless shell (Class 1, Specification S-4), as shown in Fig. UA-2(d). The shell data are as follows: Inside diameter = 96 in.; thickness = 2 in.; working pressure = 500 psi; working temperature = 600 F. Welding suitable for vessels built in accordance with Par. U-68 is used.

The welds at the manhole neck comply with detail 1 and the welds on the reinforcing pad with details 5 and 6 of Fig. U-10.

| | | |
|---|---|---|
| Cross section I | = 2 × (32 − 18) ................. | = 28.00 sq in. |
| Cross section II | = 1.00 × 5.25 × 2 ............... | = 10.50 sq in. |
| Cross section III | = 2.5 × (32 − 21.5) ............. | = 26.25 sq in. |
| Cross section IV | = two $^3/_4$-in. fillets + one 1-in. fillet. | = 2.12 sq in. |
| **Total actual cross section** ........................ | | **66.87 sq in.** |

The required thickness when $E$ = 0.90 is

$$t = \frac{500 \times 48}{12{,}000 \times 0.90} = 2.222 \text{ in.}$$

Required cross section = 2.222 × (32 − 2) = 66.66 sq in.

Therefore the design meets the requirements of rule (1) of Par. U-59(g).

Welding of the manhole neck:

Strength of welds in tension = (2 × 0.75) × $^1/_2$ × 3.14 × 18 × (0.9 × 12,000) = 458,000 lb.

Strength of welds in shear = (2 × 0.75) × 1/2 × 3.14 × 18.75 × (0.8 × 0.9 × 12,000) = 381,000 lb.

The welds at the manhole neck are weaker in shear.

Strength of neck = (Area II) × $S$ = 10.50 × 12,000 = 126,000 lb.

Strength of cross section represented by ($QFGR + JSTM$) = 2.222 × (16 − 2) × 12,000 = 373,000 lb.

Therefore the welding of the neck meets the requirements of rule (2) of Par. U-59(g).

Welding of the reinforcing pad:

Strength of welds in tension = [(1.00 × 1/2 × 3.14 × 21.5) + (0.625 × 1/2 × 3.14 × 36)] × (0.9 × 12,000) = 746,000 lb.

Strength of welds in shear = [(1.00 × 1/2 × 3.14 × 20.5) + (0.625 × 1/2 × 3.14 × 36.625)] × (0.8 × 0.9 × 12,000) = 589,000 lb.

The welds at the reinforcing pad are weaker in shear.

Strength of reinforcing pad = 2.5 × (32 − 21.5) × 12,000 = 315,000 lb.

Strength of cross section represented by ($QFGR + JSTM$) = 373,000 lb, as above.

Therefore the welding of the reinforcing pad meets the requirements of rule (2) of Par. U-59(g).

The above design corresponds to type $H$ shown in Fig. U-10. For other types of construction employing reinforcing pads, such as types $F$, $G$, $J$, and others, the methods of calculation are similar to the above.

**UA-17** An 8 in. riveted nozzle is located on a pressure vessel as shown in Fig. UA-2(e). The shell data are as follows: Inside diameter = 54 in.; thickness = $1^1/_4$ in.; working pressure = 350 psi; working temperature = 440 F minimum tensile strength = 55,000 psi.

Assume the nozzle to be 8 in. inside diameter, the thickness of the nozzle neck to be $^9/_{16}$ in., the thickness of the riveting flange to be $^3/_4$ in., and the outside diameter of the riveting flange to be $17^1/_4$ in.

Assume also 18 $1^1/_4$ in. rivets on a 14 in. rivet circle with $1^9/_{32}$ in. rivet holes straddling the longitudinal center line through the nozzle; minimum tensile strength = 55,000 psi. The opening in the shell is $8^3/_4$ in. to provide space for calking.

The weakest section will be along a line parallel to the longitudinal axis passing through the centers of the two rivets nearest the center line of the nozzle as shown in Fig. UA-2(e).

The neck of the nozzle may be considered as reinforcement for a distance of $2^1/_2$ times its thickness measured from the back of the riveting flange. Therefore the distance of line $AB$ [See Fig. UA-2(e)] from the outside of the shell = (2.5 × 0.5625) + 0.75 = 2.16 in.

| | |
|---|---|
| Cross section I = 17.5 − (8.41 + 1.282 + 1.282) × 1.25.... = | 8.16 sq in. |
| Cross section II = (2.16 × 2 × 0.59) + [17.07 − (7.62 + 0.59 + 0.59 + 1.282 + 1.282)] × 0.75 = 2.55 + 4.28.................................. = | 6.83 sq in. |
| Total actual cross section.................................. = | 14.99 sq in. |

The required thickness when $E = 0.90$ is

$$t = \frac{350 \times 27}{11{,}000 \times 0.90} = 0.955 \text{ in.}$$

Required cross section = 0.955 × (17.5 − 2) = 14.81 sq in.

Therefore the design meets the requirements of rule (1) of Par. U-59(g).

Failure can occur by shearing of the rivets on one side of Section *AA*. The ultimate strength of the rivets in shear is 44,000 psi.

Area of rivets to one side of section = 0.7854 × 1.282 × 1.282 × 7 = 9.05 sq in.
Ultimate strength of rivets in shear = 9.05 × 44,000 = 398,000 lb.
Ultimate strength of nozzle = (Area II) × U.T.S. = 6.83 × 55,000 = 376,000 lb.
Ultimate strength of cross section represented by ($QFGR + JSTM$) = 0.955 × (8.41 − 2) × 55,000 = 336,000 lb.

Therefore the riveting meets the requirements of rule (2) of Par. U-59(**g**).
Failure can also occur by the internal pressure blowing the nozzle off the shell. The ultimate strength of the rivets in tension is 55,000 psi.
Total area of rivets = 0.7854 × 1.282 × 1.282 × 18 = 23.3 sq in.
Ultimate strength of rivets in tension = 23.3 × 55,000 = 1,282,000 lb.
Required strength due to internal pressure acting on $8^3/_4$ in. calking circle, with factor of safety of five = 0.7854 × 8.75 × 8.75 × 350 × 5 = 105,400 lb
If the riveting flange is calked also on the outside, then the required strength due to internal pressure acting on $17^1/_4$ in. calking circle, with factor of safety of five = 0.7854 × 17.25 × 17.25 × 350 × 5 = 410,000 lb.
Therefore the riveting meets the requirements of Par. U-59(**i**) and of rules (1) and (2) of Par. U-59(**j**).
The shell plate may fail by tearing around through the rivet holes. Checking by applying the rules in Par. P-193(**b**):

$$P_1 = 2 \times (\sin 10 \text{ deg}) \times 7 = 2.43 \text{ in.} \qquad \frac{P_1}{D} = \frac{2.43}{1.282} = 1.90$$

| Ligament | Θ | $P_L = P_1 \cos \Theta$ | E Fig. P-20 | $P_L \times E$ |
|---|---|---|---|---|
| 1 | 70° | 0.831 | 0.695 | 0.578 |
| 2 | 50° | 1.563 | 0.515 | 0.805 |
| 3 | 30° | 2.105 | 0.460 | 0.968 |
| 4 | 10° | 2.393 | 0.470 | 1.125 |
| | | | Total | 3.476 |
| | | | | × 2 = 6.95 in. |

Equivalent length removed from shell = (14 + 1.282) − 6.95 = 8.332 in.
Actual efficiency of shell (See Par. U-20):

$$E = \frac{PR}{St} = \frac{350 \times 27}{11{,}000 \times 1.25} = 68.7 \text{ per cent}$$

Efficiency using rule (1) of Par. P-193(**b**):

$$E = \frac{54 - 8.332}{54} = 84.5 \text{ per cent}$$

80 per cent of actual shell efficiency = 0.8 × 68.7 = 55.0 per cent.
Efficiency using rule (2) of Par. P-193(**b**):

$$E = \frac{27 - 8.332}{27} = 69.1 \text{ per cent}$$

Therefore the design meets the requirements of Par. P-193(**b**).

## RULES FOR BOLTED FLANGED CONNECTIONS

**UA-18 Scope.** (a) Bolted flanged connections, if of steel or cast iron, conforming to the several American Standards as given in Tables UA-1 and UA-2 for steel, and Tables UA-3 and UA-4 for cast iron, should be used for connections to external piping and may be used for other flanged connections. When used for external pipe connections such flanges, if of steel, shall not be used for pressure-temperature ratings exceeding those given in Table UA-5.

(b) Bolted flanged connections other than those meeting the requirements of (a) above shall be designed in accordance with the rules given in Pars. UA-19 to UA-24. These rules may be applied to flanges of any diameter, but are not intended for flanged connections having gaskets beyond or extending beyond the bolt circle. These rules shall not be construed to prohibit the use of flanges having gaskets beyond the bolt circle or other types of bolted closures, particularly those used for service at very high pressures, provided they are designed in accordance with good engineering practice.

**UA-19 Materials.** (a) Bolting material shall be made in accordance with the specifications for which allowable working stresses are given in Table U-2.

(b) Nuts and washers for bolts and studs shall be made in accordance with Specification SA-194. Nuts shall be semifinished, chamfered, and trimmed, of at least American Standard heavy dimensions as given in Table UA-7. The use of washers is optional, but when used, they shall be of forged or rolled materials.

(c) All bolts and studs shall have threads at least as strong as American Standard screw threads. The length of thread engagement shall be not less than the nominal thickness dimension of American Standard heavy nuts.

(d) It is recommended that bolts and studs be at least 1/2 in. in diameter

TABLE UA-7 AMERICAN STANDARD HEAVY NUTS
(Semi-Finished Hexagon)
The following table is taken from ASA B18.2–1933

| Diameter of bolt, D | | Width across flats, Maximum (basic) | | Width across flats, Min | Width across corners, min hex. | Thickness, heavy nut, Nom | Thickness, heavy nut, Max | Thickness, heavy nut, Min |
|---|---|---|---|---|---|---|---|---|
| 1/2 | 0.5000 | 7/8 | 0.8750 | 0.850 | 0.969 | 31/64 | 0.504 | 0.464 |
| 9/16 | 0.5625 | 15/16 | 0.9375 | 0.906 | 1.033 | 35/64 | 0.568 | 0.526 |
| 5/8 | 0.6250 | 1 1/16 | 1.0625 | 1.031 | 1.175 | 39/64 | 0.631 | 0.587 |
| 3/4 | 0.7500 | 1 1/4 | 1.2500 | 1.213 | 1.383 | 47/64 | 0.758 | 0.710 |
| 7/8 | 0.8750 | 1 7/16 | 1.4375 | 1.394 | 1.589 | 55/64 | 0.885 | 0.833 |
| 1 | 1.0000 | 1 5/8 | 1.6250 | 1.575 | 1.796 | 63/64 | 1.012 | 0.956 |
| 1 1/8 | 1.1250 | 1 13/16 | 1.8125 | 1.756 | 2.002 | 1 7/64 | 1.139 | 1.079 |
| 1 1/4 | 1.2500 | 2 | 2.0000 | 1.938 | 2.209 | 1 3/16 | 1.220 | 1.156 |
| 1 3/8 | 1.3750 | 2 3/16 | 2.1875 | 2.119 | 2.416 | 1 5/16 | 1.347 | 1.279 |
| 1 1/2 | 1.5000 | 2 3/8 | 2.3750 | 2.300 | 2.622 | 1 7/16 | 1.474 | 1.402 |
| 1 5/8 | 1.6250 | 2 9/16 | 2.5625 | 2.481 | 2.828 | 1 9/16 | 1.601 | 1.525 |
| 1 3/4 | 1.7500 | 2 3/4 | 2.7500 | 2.663 | 3.036 | 1 11/16 | 1.728 | 1.648 |
| 1 7/8 | 1.8750 | 2 15/16 | 2.9375 | 2.844 | 3.242 | 1 13/16 | 1.855 | 1.771 |
| 2 | 2.0000 | 3 1/8 | 3.1250 | 3.025 | 3.449 | 1 15/16 | 1.984 | 1.894 |
| 2 1/4 | 2.2500 | 3 1/2 | 3.5000 | 3.388 | 3.862 | 2 3/16 | 2.236 | 2.140 |
| 2 1/2 | 2.5000 | 3 7/8 | 3.8750 | 3.750 | 4.275 | 2 13/32 | 2.458 | 2.354 |
| 2 3/4 | 2.7500 | 4 1/4 | 4.2500 | 4.113 | 4.689 | 2 21/32 | 2.712 | 2.600 |
| 3 | 3.0000 | 4 5/8 | 4.6250 | 4.475 | 5.102 | 2 29/32 | 2.966 | 2.846 |
| 3 1/4 | 3.2500 | 5 | 5.0000 | 4.838 | 5.515 | 3 5/32 | 3.220 | 3.092 |
| 3 1/2 | 3.5000 | 5 3/8 | 5.3750 | 5.200 | 5.928 | 3 13/32 | 3.474 | 3.338 |
| 3 3/4 | 3.7500 | 5 3/4 | 5.7500 | 5.563 | 6.342 | 3 21/32 | 3.728 | 3.584 |
| 4 | 4.0000 | 6 1/8 | 6.1250 | 5.925 | 6.755 | 3 29/32 | 3.982 | 3.830 |

All dimensions given in inches.

## TABLE UA-8(a) GASKET MATERIALS AND CONTACT FACINGS

Gasket Factors (*m*) for Operating Conditions, Yield Point *y*

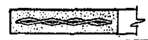
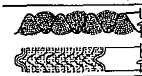
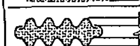
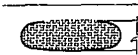
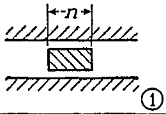
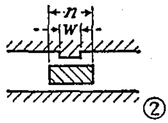
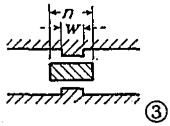
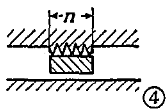
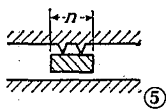
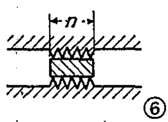
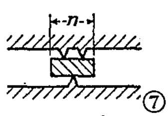
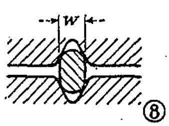
| | Gasket Material | | Gasket Factor *m* | Yield Point *y* | Sketch and Notes |
|---|---|---|---|---|---|
| (*a*) | Gum rubber sheet | | 0.50 | 500 | |
| (*b*) | Cloth-inserted soft rubber, or hard rubber sheet | | 0.75 | 750 | |
| (*c*) | Cloth-inserted hard rubber | | 1.00 | 1000 | |
| (*d*) | Vegetable fiber sheet (hemp or jute) | | 1.50 | 2000 | |
| (*e*) | Compressed asbestos, or asbestos composition | | 2.50 | 4500 | |
| (*f*) | Wire mesh reinforced asbestos | | 2.50 | 4500 |  |
| (*g*) | Corrugated metal, asbestos inserted, or spiral-wound metal, asbestos filled | | 2.50 | 4500 |  Facing ① Table 8(b) only |
| (*h*) | Corrugated metal jacket, asbestos filled | | 3.00 | 6000 |  Facing ① Table 8(b) only |
| (*j*) | Corrugated metal | (1) Copper | 3.00 | 6000 |  Facing ① Table 8(b) only |
| | | (2) Monel<br>(3) Iron<br>(4) Soft steel | 3.25 | 7000 | |
| (*k*) | Flat metal jacket, asbestos filled | (1) Aluminum<br>(2) Copper | 3.25 | 7000 |  |
| | | (3) Monel<br>(4) Iron<br>(5) Soft steel | 3.50 | 8000 |  |
| | | (6) 4–6% chrome<br>(7) 11–13% chrome<br>(8) KA2S<br>(9) Type 316 | 3.75 | 9000 |   |
| (*l*) | Solid metal | (1) Soft aluminum | 4.00 | 10000 | |
| | | (2) Soft copper<br>(3) Admiralty | 4.75 | 14000 | |
| | | (4) Iron<br>(5) Soft steel<br>(6) Monel | 5.50 | 18000 | |
| | | (7) 4–6% chrome<br>(8) 11–13% chrome | 6.00 | 21000 | |
| | | (9) KA2S<br>(10) Type 316 | 6.50 | 24500 | |

TABLE UA-8(b) (*Continued*)

| FACING SKETCH (Exaggerated) | EFFECTIVE GASKET YIELD WIDTH b |
|---|---|
|   | $\frac{n}{2}$ |
|   | $\frac{n+w}{4}$ |
|   | $\frac{n}{4}$ |
|   | $\frac{n}{3}$ |
|   | |
|   | $\frac{n}{4}$ |
|   | |
|   | $\frac{w}{8}$ |

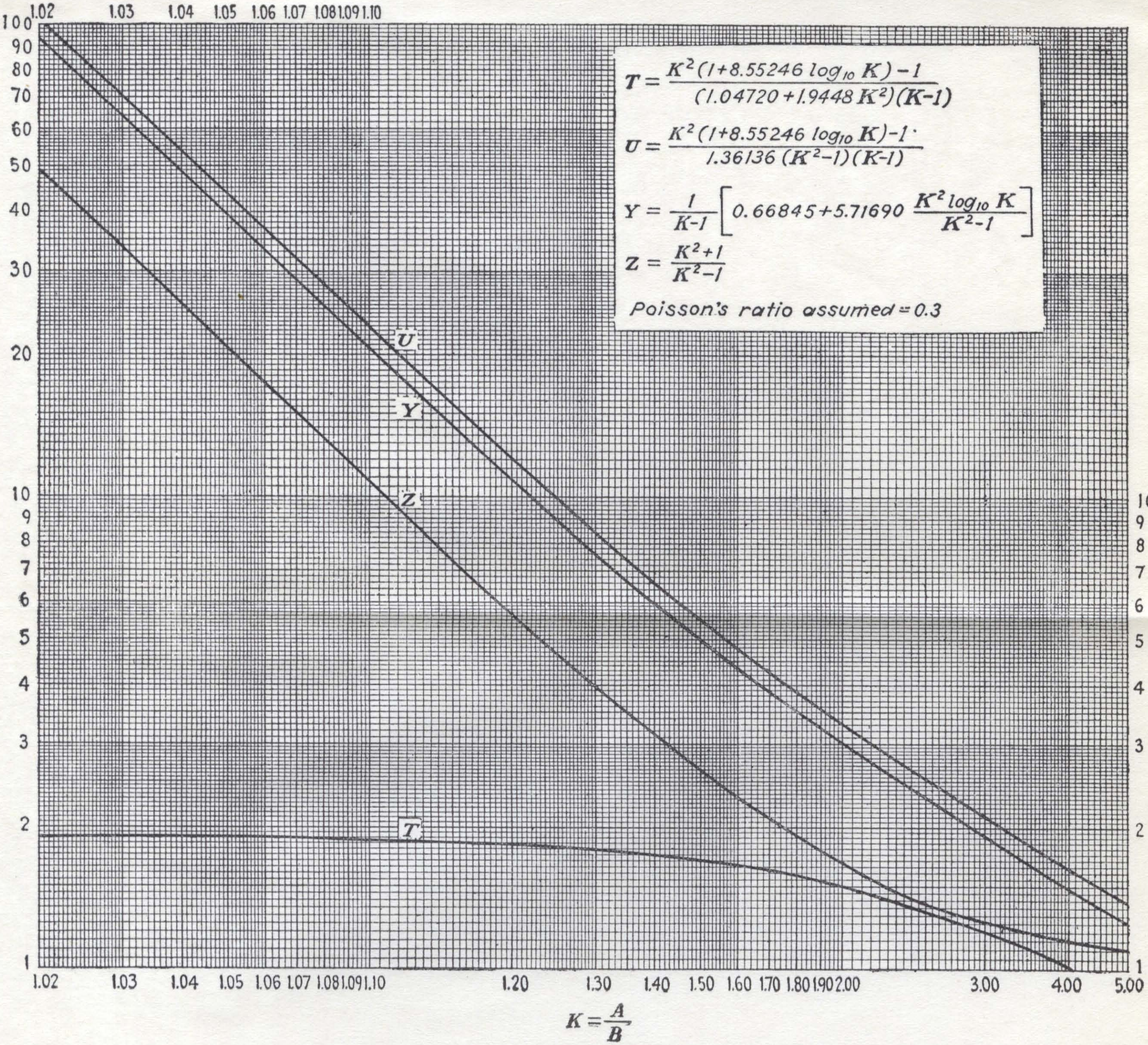



Fig. UA-5 Values of $T$, $U$, $Y$, and $Z$ (Terms Involving "$K$")

and if sizes 1/2 in. and smaller are used, precautions be taken to avoid overstressing.

(e) Flanges that are to be fusion welded shall be of good weldable quality and the carbon content of such material shall not exceed 0.35 per cent. Welded flanges shall comply with the stress-relieving requirements given in the Code.

(f) Flanges shall be made of rolled or forged steel, cast steel, or plate material, in accordance with the specifications in Section II of the Code for which allowable working stresses are given in Table U-2, except that hubbed flanges shall not be machine-cut from plate material. Flanges made in accordance with Specification SA-18 or SA-181 shall not be used when the flange thickness exceeds 3 in. Flanges may be fusion welded only when the material is listed as permissible for welding in Par. U-71(**a**).

UA-20 **Bolt Loads.** (**a**) MINIMUM REQUIRED BOLT LOAD $W_m$. The minimum bolt load in pounds shall be determined from the greater of the values obtained from formula (1) under maximum operating or working conditions and from formula (2) under atmospheric temperature conditions without consideration of internal pressure.

Operating or working conditions:

$$W_m = H + H_p = 0.785\, G^2 p + (2b \times 3.14\ Gmp) \quad \ldots\ldots\ldots [1]^1$$

Atmospheric temperature conditions without internal pressure:

$$W_m = H_y = 3.14\, bGyr \text{ (See note 2)} \quad \ldots\ldots\ldots [2]$$

Under the above requirements the minimum required bolt load $W_m$ in pounds will be at least sufficient:

Under maximum operating or working conditions, to resist the hydrostatic end force ($H$) in pounds exerted by the internal working pressure upon the area bounded by the mean diameter of gasket or joint contact surface and, in addition, maintain a predetermined compression load ($H_p$) on the gasket or joint-contact surface which, experience has shown, will be sufficient to assure a tight joint (See note 1).

Under atmospheric temperature conditions without the presence of internal pressure, to exert a load ($H_y$) to initially seat the gasket or joint-contact surfaces sufficiently to assure a tight joint (See notes 2 and 3).

(**b**) ACTUAL BOLT LOAD $W_a$. The actual bolt load, which shall be at least equal to the minimum required bolt load defined in (**a**) above, is the force in pounds available when the actual total bolt area is stressed to the maximum allowable working stress at the operating temperature (See note 4) and is determined in accordance with formula (3).

$$W_a = A_b \times S_b \quad \ldots\ldots\ldots [3]$$

(**c**) FLANGE DESIGN BOLT LOAD $W$. The bolt load used in the design of the flange shall be not less than the average of the minimum required bolt load $W_m$, defined in (**a**) above, formula (1) or (2), and the actual bolt load $W_a$, defined in (**b**) above, formula (3), or

$$W = \frac{W_m + W_a}{2} \text{ (See note 5)}$$

NOTE 1. Table UA-8 gives a list of many commonly used gasket materials and contact facings, with suggested values of $m$, $b$, and $y$ that have been proved satisfactory in actual service. These values are suggestive only and are not mandatory. Values that are too low may result in leakage at the joint, without affecting the safety of the design The primary proof that the values are adequate is the hydrostatic test.

[1] See Table UA-9 for definitions of all symbols.

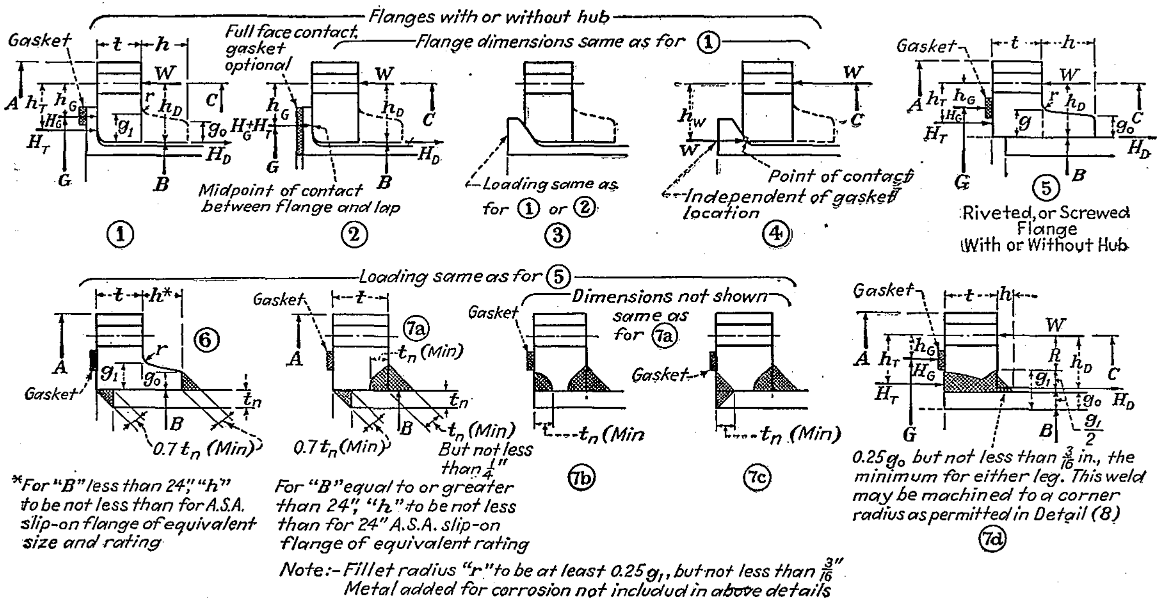



Fig. UA-3 Loose-Type Flanges

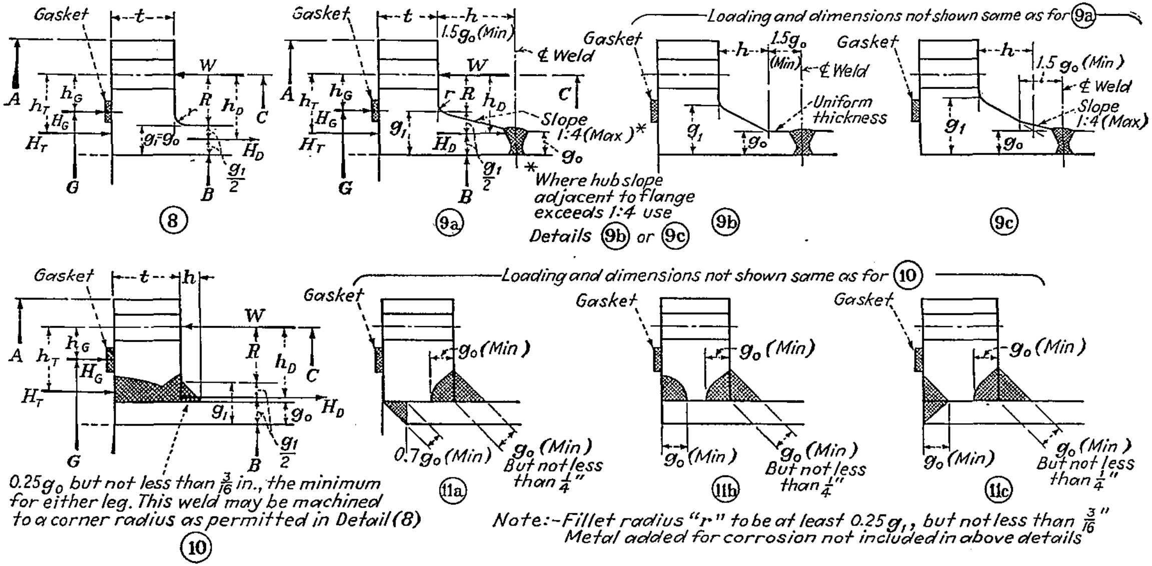



FIG. UA-4 INTEGRAL-TYPE FLANGES

NOTE 2. The value $r$ is inserted in order to allow direct comparison of the operating temperature loading and initial atmospheric temperature loading and thus makes use of the allowable operating temperature bolt stress only, in the remaining calculation.

NOTE 3. The need for providing sufficient bolt load to seat the gasket or joint-contact surfaces, in accordance with formula (2), will prevail on many low-pressure designs and in such cases where facings and materials requiring a high seating load are employed wherein the bolt load required for the operating conditions, formula (1), is insufficient to initially seat the joint. Similarly, on extremely high pressure designs where the bolt load is usually governed by the operating conditions, it may be necessary to assure sufficient gasket or joint contact area to avoid crushing under the initial tightening of the bolts.

NOTE 4. Ordinarily the bolting is selected to correspond with the minimum requirements of (a) above, with some unavoidable excess resulting from selecting the number of bolts, such as in multiples of four. In other cases, particularly on low-pressure designs, excess bolting is provided in order to maintain bolt spacings within reasonable limits to assure more uniform loading.

NOTE 5. This provides, in addition to the minimum requirements for safety, a margin against abuse from overbolting of 50 per cent of the excess above the required minimum. It is necessarily assumed that reasonable care will be taken in tightening the bolts, since any abuse from overpulling the bolts may affect the satisfactory operation of the unit or decrease the margin of safety.

Where additional safety against abuse is desired, or where it is necessary that the flange be suitable to withstand the full available bolt load, the flange may be designed on the basis of the actual bolt load $W_a$, as defined in (b) above.

**UA-21 Flange Types.** (a) For purposes of calculation, flanges are classified under two types as follows:

(1) Loose-type flanges, as shown in Fig. UA-3:

Sketches (1), (2), (3), (4), lap joint flange;
Sketch (5), riveted flange, or screwed flange with or without hub;
Sketch (6), slip-on welded hubbed flange;
Sketches (7a), (7b), (7c), (7d), slip-on welded ring where the following limits are not exceeded:

Working pressure, 300 psi; metal temperature, 700 F

$$g_o = {}^5/_8 \text{ in.} \quad B/g_o = 300$$

NOTE: At the option of the designer, the flanges shown in Figs. UA-3(6) and (7) may be designed on the assumption that they act as integral flanges and the stress calculations shall comply with the requirements of Pars. UA-23(a) and UA-24(1).

(2) Integral-type flanges, as shown in Fig. UA-4:

Sketch (8), flange integral with nozzle neck or vessel;
Sketches (9a), (9b), (9c), butt-welded hubbed flange;
Sketch (10), through-welded ring;
Sketches (11a), (11b), (11c), slip-on welded ring where any of the limitations given in (1) for sketches (7a), (7b), (7c), and (7d) are exceeded.

(b) All weld dimensions and other details as indicated shall conform at least to the dimensions as shown in Figs. UA-3 and UA-4.

For Par. U-68 vessels the requirements of Par. U-68(h) shall apply to the construction shown in Fig. UA-4(9). Otherwise radiographic examination of the welds in Figs. UA-3 and UA-4 may be omitted.

**UA-22 Flange Moments.** The moments acting upon the flange and used in the calculation of flange stresses shall be determined as follows:

(a) LOOSE-TYPE FLANGES. (I) For loose-type flanges with or without a hub and having a gasket only partially covering the face of a lap on the end of the nozzle neck or vessel, as shown in sketches (1) and (3) of Fig. UA-3, and for loose-type flanges as shown in sketches (5), (6), (7a), (7b), (7c), and (7d) the total moment shall be determined as for integral type flanges in (b) be-

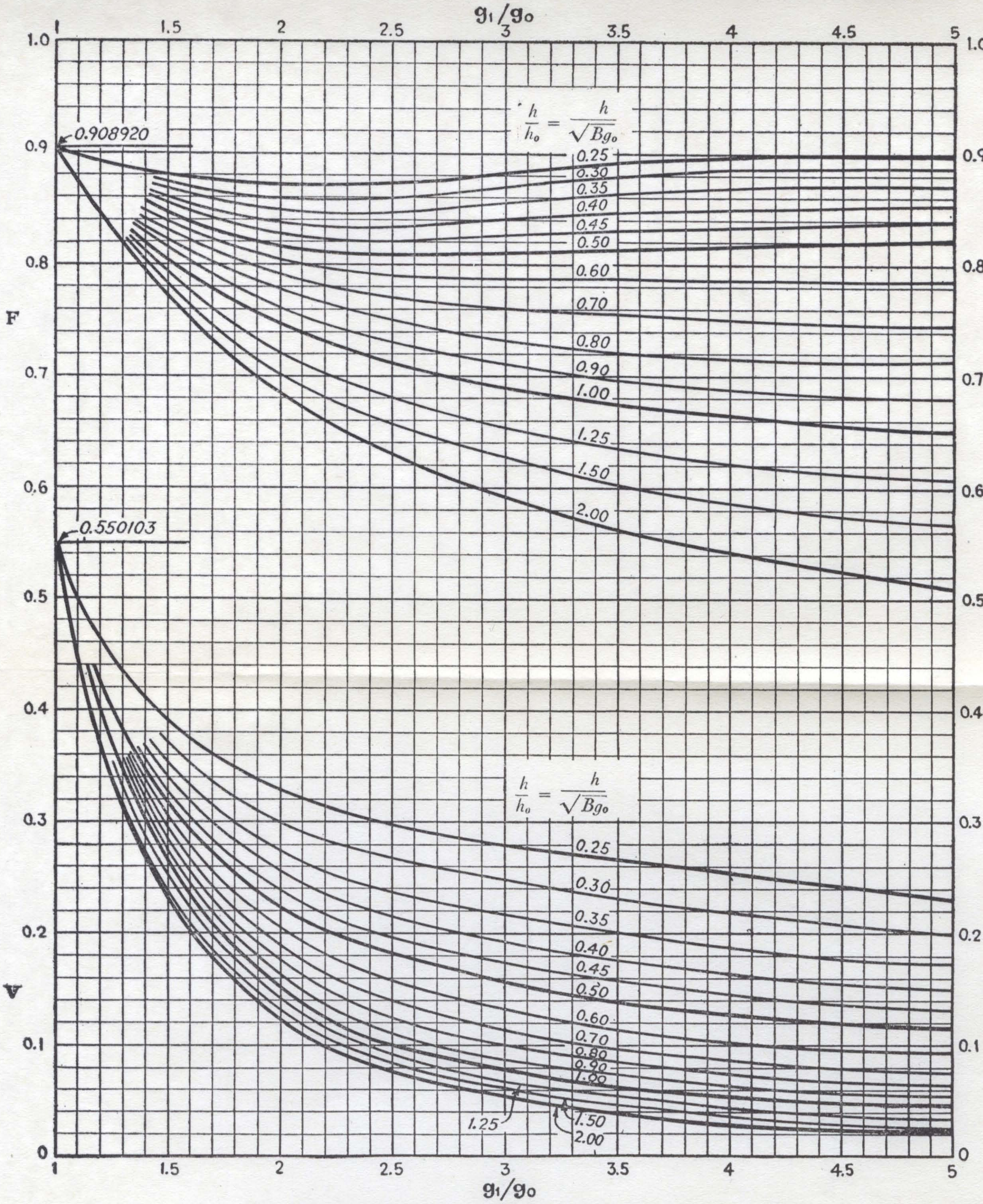



Fig. UA-6 Values of $F$ and $V$ (Integral Flange Factors) low, except that the force $H_D$ shall be considered to act at the inside diameter of the flange, in which case:

$$h_D = \frac{C - B}{2} \qquad h_T = \frac{h_D + h_G}{2}$$

(2) For loose-type flanges with or without a hub and having contact over the entire face of a lap on the end of the nozzle neck or vessel, with or without a gasket, as shown in sketches (2) and (3) of Fig. UA-3, the total moment shall be determined as for integral-type flanges in (b) below, except that the force $H_D$ shall be considered to act at the inside diameter of the flange, in which case:

$$h_D = \frac{C - B}{2} \quad h_G = h_T = \frac{C - G}{2}$$

(3) For loose-type flanges with or without a hub and having line contact between the flange and a lap on the end of the nozzle neck or vessel, as shown in sketch (4) of Fig. UA-3, the total moment shall be at least equal to the product of the design bolt load $W$ and lever arm $h_W$, or:

$$M_o = W \times h_W$$

(b) Integral-Type Flanges. For flanges classified in Par. UA-21(a) (2) as of the integral type (See Fig. UA-4), the total moment shall be at least equal to the sum of the moments acting upon the flange or:

| Flange loads | × | Lever arms | = | Moments |
|---|---|---|---|---|
| $H_D = 0.785B^2p$ | | $h_D = R + \frac{g_1}{2}$ | | $M_D = H_D \times h_D$ |
| $H_T = H - H_D$ | | $h_T = \frac{R + g_1 + h_G}{2}$ | | $M_T = H_T \times h_T$ |
| $H_G = W - H$ | | $h_G = \frac{C - G}{2}$ | | $M_G = H_G \times h_G$ |

and total moment $M_o = M_D + M_T + M_G$.

(c) No consideration shall be given to any possible reduction in lever arm due to cupping of the flanges or due to inward shifting of the line of action of the bolts as a result thereof.

**UA-23 Flange Design Stresses.** (a) The stresses in the flange as calculated from the formulas in Par. UA-24 shall not exceed the values indicated as follows (See note 6):

Longitudinal hub stress $S_H$ not greater than 1.5 $S_f$

Radial flange stress $S_R$ not greater than $S_f$

Tangential flange stress $S_T$ not greater than $S_f$

Also $\frac{S_H + S_R}{2}$ not greater than $S_f$ $\qquad$ $\frac{S_H + S_T}{2}$ not greater than $S_f$

(b) For hubbed flanges attached as shown in sketches (5) and (6) of Fig. UA-3, the nozzle neck or vessel shall not be considered to have any value as a hub.

(c) In the case of loose flanges with laps, as in sketches (1), (2), (3), and (4) of Fig. UA-3, where the gasket is so located that the lap is subjected to shear, the shearing stress shall not exceed 0.8 times the maximum allowable working stress $S_f$ for the material of the lap, as defined in Table UA-9. In the case of welded flanges, such as in sketches (6), (7a), (7b), (7c), and (7d) of Fig. UA-3, and sketches (10), (11a), (11b), and (11c) of Fig. UA-4, where the nozzle neck or vessel extends beyond the face of the flange to form the gasket or joint-contact surface, the shearing stress carried by the welds shall not exceed 0.8 times $S_f$. The shearing stress shall be calculated on the basis of $H_p$ or $H_y$ as defined in Table UA-9, whichever is greater. Similar cases where flange parts are subjected to shearing stress shall be governed by the same requirements.

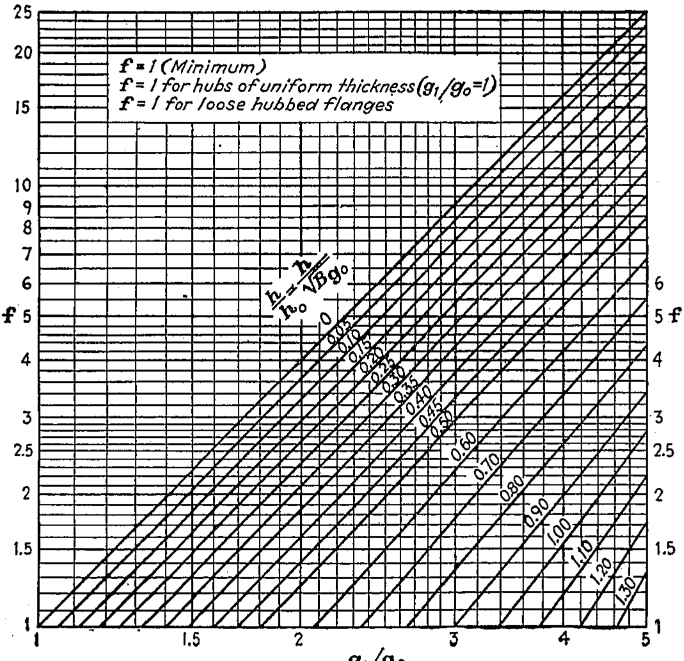



Fig. UA-8 Values of "$f$" (Hub Stress Correction Factor)

Note 6. These rules in their present form do not include any consideration of casting quality factors, weld metal efficiencies, and relative effectiveness of design details. The proper application of these factors is being studied by the Committee and, in view of the war emergency, is left for the consideration of the designer for the time being.

**UA-24 Calculation of Flange Stresses.** The stresses in the flange, determined in accordance with the following formulas, shall not exceed the values specified in Par. UA-23.

(1) For integral-type flanges and all hubbed flanges:

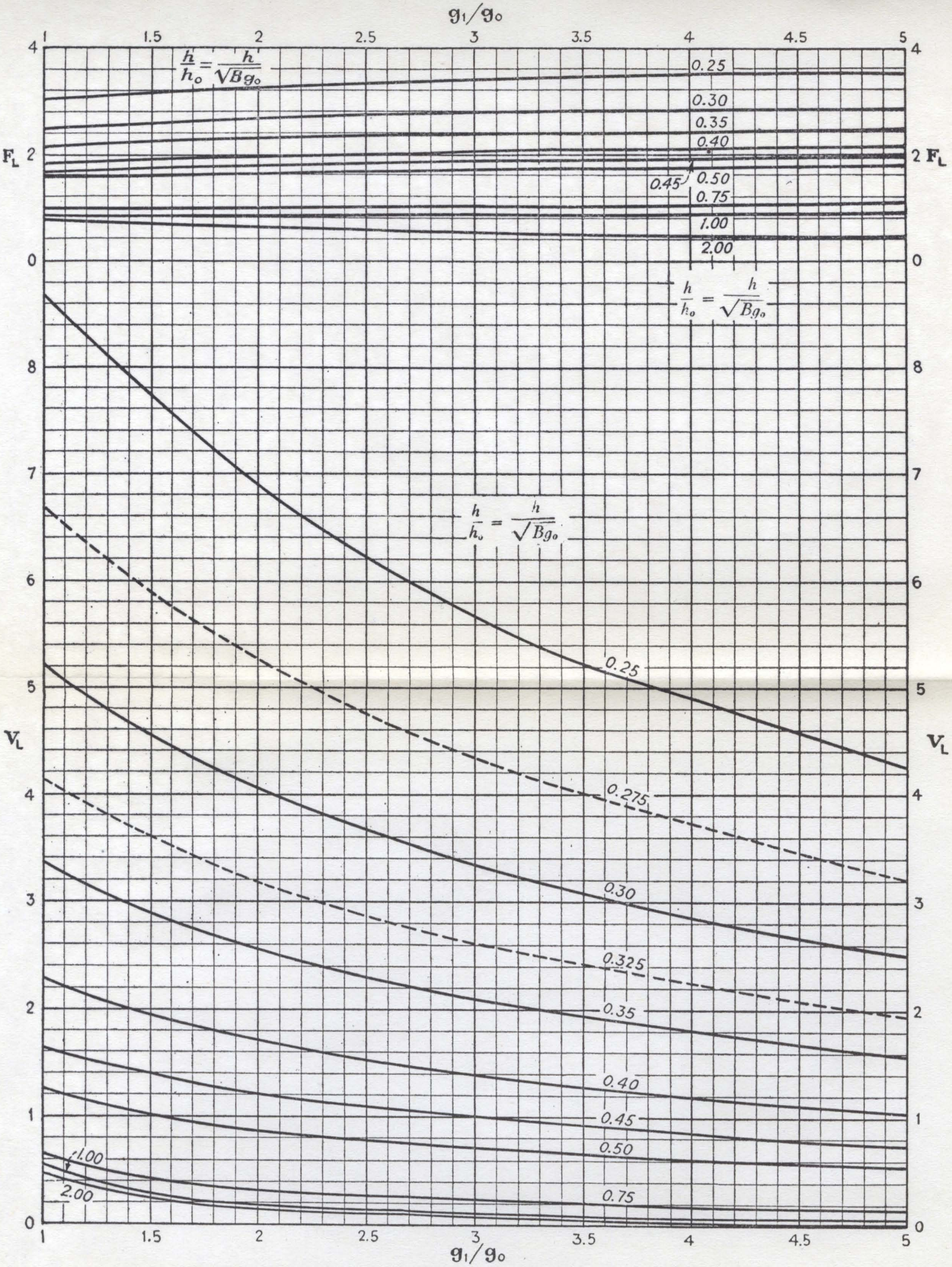



FIG. UA-7 VALUES OF $F_L$ AND $V_L$ (LOOSE HUB FLANGE FACTORS)

$$\text{Longitudinal hub stress } S_H = \frac{fM_o}{Lg_1^2B}$$

$$\text{Radial flange stress } S_R = \frac{(4/3\ te + 1)M_o}{Lt^2B}$$

$$\text{Tangential flange stress } S_T = \frac{YM_o}{t^2B} - ZS_R$$

(2) For ring flanges of the loose type:

$$S_T = \frac{YM_o}{t^2B} \quad S_R = o \quad S_H = o$$

TABLE UA-9 NOMENCLATURE AND VALUES
(See also Figs. UA-3 and UA-4)

$W_m$ = minimum required bolt load, pounds, Par. UA-20(a)
$W_a$ = actual or maximum available bolt load, pounds, Par. UA-20(b)
$W$ = flange design bolt load, pounds, Par. UA-20(c)
$H$ = total hydrostatic end force, pounds, = $0.785G^2p$, Par. UA-20(a)
$H_p$ = total joint-contact-surface compression load, pounds, Par. UA-20(a)
$H_y$ = total joint-contact-seating load, pounds, Par. UA-20(a)
$G$ = mean diameter of gasket or joint-contact surface, in., except as noted Fig. UA-3, sketch (2)
$p$ = maximum allowable working pressure, pounds per square inch
*$b$ = effective gasket or joint-contact-surface seating width, inches
*$2b$ = effective gasket or joint-contact-surface pressure width, inches
$n$ = possible contact width of gasket, inches (See Table UA-8)
$w$ = width of local concentration on gasket, inches (See Table UA-8)
*$m$ = unit contact compression factor
*$y$ = gasket or joint-contact-surface unit seating load, pounds per square inch
**$r$ = $S_b/S_a$, or ratio of maximum allowable bolt stress at operating temperature to maximum allowable bolt stress at atmospheric temperature
$S_b$ = maximum allowable bolt stress at operating temperature, pounds per square inch = 1.25 times the values given in Table U-2
$S_a$ = maximum allowable bolt stress at atmospheric temperature, pounds per square inch = 1.25 times the values give in Table U-2
$A_b$ = total cross-sectional area of bolts at root of thread or section of least diameter under stress, square inches
$A$ = outside diameter of flange, or where slotted bolt holes are used such as for swing bolts, the diameter to the bottom of the slots, inches
$B$ = inside diameter of flange, inches
When $B$ is less than 20 $g_1$, it will be optional for the designer to substitute $B_1$ for $B$ in the formula for longitudinal hub stress $S_H$, where:

$B_1 = B + g_1$ for loose-type hubbed flanges and for integral-type flanges when $f$ is less than 1 (below chart in Fig. UA-7)
$B_1 = B + g_o$ for integral-type flanges when $f$ is equal to or greater than 1

$C$ = bolt circle diameter, inches
$R$ = radial distance from bolt circle to point of intersection of hub and back of flange, inches (integral and hubbed flanges)

* See Note 1, Par. UA-20.
** See Note 2, Par. UA-20.

$g_1$ = thickness of hub at back of flange, inches
$g_o$ = thickness of hub at small end, inches
$M_o$ = total moment acting upon the flange
$K$ = $A/B$ or ratio of outside diameter of flange to inside diameter of flange
$T,U,Y,Z$ = terms involving factor $K$, obtain from Fig. UA-5
$F,V$ = factors for integral-type flanges, obtain from Fig. UA-6
$F_L,V_L$ = factors for loose-type hubbed flanges, obtain from Fig. UA-7
$f$ = hub stress correction factor (for integral flanges), obtain from Fig. UA-8 using values $\frac{g_1}{g_o}$ and $\frac{h}{h_o}$. For values below chart in Fig. UA-8, use $f = 1$
$h$ = hub length, inches
$h_o$ = $\sqrt{Bg_o}$, inches
$t$ = flange thickness, inches

$$L = \frac{te + 1}{T} + \frac{t^3}{d}$$

$$d = \frac{U}{V} h_o g_o^2 \text{ for integral-type flanges}$$

$$= \frac{U}{V_L} h_o g_o^2 \text{ for loose-type flanges}$$

$$e = \frac{F}{h_o} \text{ for integral-type flanges}$$

$$= \frac{F_L}{h_o} \text{ for loose-type flanges}$$

$S_f$ = for steel, maximum allowable working stress for flange material, or nozzle neck or vessel material, pounds per square inch = 1.25 times the values given in Table U-2
$S_H$ = longitudinal stress in hub, pounds per square inch
$S_R$ = radial stress in flange, pounds per square inch
$S_T$ = tangential stress in flange, pounds per square inch

## APPROVAL OF NEW MATERIALS UNDER THE A.S.M.E. BOILER CONSTRUCTION CODE

**UA-71** If possible, the material should be identified with an A.S.T.M. specification or tentative specification. If the material varies only slightly from an A.S.T.M. specification by the addition, say, of a small amount of alloying element, it should be stated that the material will comply with some specification except as noted and the exception should be stated not only as to chemical composition, but as to physical properties and test results.

**UA-72** If no A.S.T.M. specification can be applied, the following information should be given in the same form as used by the A.S.T.M.:

(1) Chemical composition, including for ferrous materials, carbon, manganese, phosphorus, sulphur, and silicon, together with alloying elements, if any.

(2) Tensile properties, over the temperature range of contemplated service. Where the vessels are to be stress-relieved or heat-treated, the tensile tests shall be made after the specimens are similarly treated.

In both (1) and (2) the range rather than an exact determination of the properties should be given within which it is commercially practicable to reproduce the material.

(3) Creep strength over any temperature range of contemplated service within which the phenomena of creep will lower the working strength of the material.

**UA-73** If any heat-treatment is required to produce the tensile properties, it should be stated.

**UA-74** The Brinell or Rockwell hardness should be given unless the information is well known for the material in question. This information is particularly advantageous if the hardness is higher than for the particular materials specified for boiler pressure parts.

**UA-75** If the material is to be used at low temperatures, below 0 F, the impact strength at these low temperatures should be given.

**UA-76** It is very important to know whether a new material is subject to critical conditions at temperatures within the range of use or fabrication. By "critical conditions" is meant a material change in brittleness, hardness, ductility, grain size, etc.

**UA-77** It should also be stated if the material is subject to age hardening or critical structural changes by a combination of physical and temperature conditions, such, for example, as the age hardening of certain aluminum alloys after cold working and subsequent heat-treatment. This is particularly important in conditions which might occur during fabrication that result in this critical condition.

**UA-78** Unless the material is well known and not unusual in its characteristics, the coefficient of thermal expansion over the range of temperature within which the material will be used should be given, particularly if there is any marked variation from that of ordinary carbon steel.

**UA-79** It should be stated whether the material is commercially available and can be purchased within the specified range of chemical and physical qualities. If the material is covered by patents so that it cannot be manufactured by anyone who wishes to use it without securing a license or paying royalties, it should be so stated.

**UA-80** If the material is to be welded, it should be stated whether any special procedure is required for electric, fusion, or gas welding and the amount of experience available for determining the weldability. It should be stated whether the material is subject to air hardening during welding. If special procedure must be followed in fusion welding the material, or if the vessel is stress-relieved or heat-treated after welding, the method should be specified, including the proper temperatures.

As a check on weldability, it is recommended that the tests described in Section IX of the Code be made, unless equivalent information is available.

**UA-81** Tests, results of which are submitted to the Boiler Code Committee, should be made upon the thickest plates contemplated, except as otherwise dictated by A.S.T.M. standards.

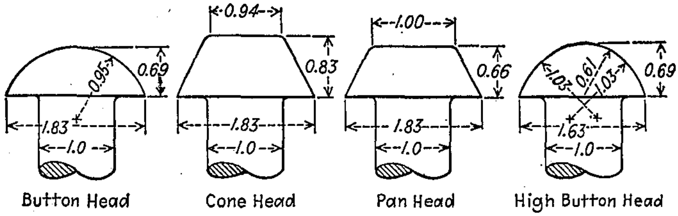



FIG. UA-9 ACCEPTABLE FORMS OF RIVET HEADS AFTER DRIVING—SUPPLEMENTAL TO FIG. U-1
(These Forms Are Taken From American Standard B18.4–1937)

## ETCH TESTS

**UA-85** Etching solutions adopted for carbon and low-alloy steels, together with their use, are suggested as follows:

HYDROCHLORIC ACID. Hydrochloric (muriatic) acid and water equal parts by volume. The solution should be kept at or near a boiling temperature during the etching process. The specimens are to be immersed in the solution for a sufficient period of time to reveal all lack of soundness that might exist at their cross-sectional surfaces.

AMMONIUM PERSULPHATE. One part of ammonium persulphate to nine parts of water by weight. The solution should be used at room temperature and should be applied by vigorously rubbing the surface to be etched with a piece of cotton saturated with the solution. The etching process should be continued until there is a clear definition of the structure in the weld.

IODINE AND POTASSIUM IODIDE. One part of powdered iodine (solid form), two parts of powdered potassium iodide, and ten parts of water, all by weight. The solution should be used at room temperature and brushed on the surface to be etched until there is a clear definition or outline of the weld.

NITRIC ACID. One part of nitric acid and three parts of water by volume. (Caution: Always pour the acid into the water. Nitric acid causes bad stains and severe burns.) The solution may be used at room temperature and applied to the surface to be etched with a glass stirring rod. The specimens may also be placed in a boiling solution of the acid but the work should be done in a well-ventilated room. The etching process should be continued for a sufficient period of time to reveal all lack of soundness that might exist at their cross-sectional surfaces.

To preserve the appearance of the etched specimens they should, after etching, be washed in clear water, the excess water removed, then immersed in ethyl alcohol, and dried. The etched surface may then be preserved by coating it with a thin clear lacquer.

## MAXIMUM WORKING PRESSURES—THICK SHELLS

**UA-100 Shells for Internal Pressure.** When the thickness of the shell exceeds one half of the inside radius, the maximum allowable working pressure on the cylindrical shell of a pressure vessel shall be determined by the following formulas:

$$P = SE\frac{Z-1}{Z+1} \quad \text{or} \quad t = (\sqrt{Z}-1)R = \left(\frac{\sqrt{Z}-1}{\sqrt{Z}}\right)R_o$$

where $P$ = maximum allowable working pressure, pounds per square inch,
$S$ = maximum allowable unit working stress, pounds per square inch taken from Tables U-2 and U-3,
$E$ = efficiency of longitudinal joints or of ligaments between openings:

for riveted joints = calculated riveted efficiency,
for fusion welded joints = efficiency specified in Pars. U-68 and U-69. For Par. U-70 use the values of $SE$ given in that paragraph.
for seamless shells = 100 per cent (unity),
for ligaments between openings, the efficiency shall be calculated by the rules given in Pars. P-192 and P-193 of the Code.

$$Z = \frac{SE+P}{SE-P} = \left(\frac{R+t}{R}\right)^2 = \left(\frac{R_o}{R}\right)^2$$

$t$ = minimum thickness of shell plates in weakest course, inches,
$R$ = inside radius of the weakest course of the shell, inches,
$R_o$ = outside radius of the weakest course of the shell, inches.

## FORM U-1 MANUFACTURERS' DATA REPORT FOR UNFIRED PRESSURE VESSELS

### As Required by the Provisions of the A.S.M.E. Code Rules

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

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

3. Type................................ (Horizontal or Vertical) Unfired Pressure Vessel No. (..............................................) (Mfrs.' serial, or A.S.M.E. No.) (................................) (State and State No.) Year built..................................

4. Have mill test reports been checked on all the plates entering this unfired pressure vessel..............................

Do the chemical and physical properties of all plates meet the requirements of the Code ........................................

5. SHELL OR DRUMS: No........................... Diameter (or width)...............ft................in. Length over all...............ft...............in. Height...............ft...............in.

6. STAMPS on shell plates.............................................. (Brand and lowest tensile strength) Rivets, stays and braces.............................................. (Iron or Steel)

7. SHELL PLATES (Outer)...............in. (Thickness) Butt straps...............in. (Thickness) Style of seams: Longitudinal.......................................Girth....................................... (Riveted, Forge Welded, Brazed, or Fusion Welded—Par. No.)

8. Diameter of rivet holes..............................in. Pitch of rivets..................×..................×.................. Efficiency of joint.........................................%

9. GIRTH JOINTS.............................. (Single or double riveted) Diameter rivet holes.....................in. Pitch of rivets..............................in. No. of courses..............................

10. INNER SHELL...............in. (Thickness) Style of seams: Longitudinal..........................Girth.......................... (Riveted, Forge Welded, Brazed, or Fusion Welded—Par. No.) Length of section or course...............ft...............in.

11. HEADS: flat or dished.........................in. (Thickness) Radius of dish.........................in. Side to pressure.............................................. (Concave or convex)

If removable, bolts used.................................. (Number and size) or method of fastening.............................................. (describe or sketch)

12.

| STAYS | No. | Size | Net Area | Welded or Weldless | Area to be Stayed | Maximum Allowable Working Pressure |
|---|---|---|---|---|---|---|
| (a) F. H. ........................ | | | | | | |
| (b) R. H. ........................ | | | | | | |
| (c) Through ........................ | | | | | | |

(d) Diagonal and Gusset Stays..............................................................................................

13. STAYBOLTS.......................... (Iron or Steel) If hollow.............................. (Size of hole) 14. Maximum pitch....................×.................... (Horizontal) (Vertical) Diameter.................... (Over the threads)in.

15. SAFETY VALVE outlets: No....................... Size..............................

16. FUSIBLE PLUG (if used): No....................... Diameter and material of filling.............................. Location..............................

17. OUTLETS: No....................... Size....................... Material of nozzle or reinforcement.............................. How attached.............................. (Riveted, welded, etc.)

18. DRAIN connection.......................in. (Size) HAND HOLES OR SIGHT HOLES.............................................. (Number, size and location)

19. MANHOLES: .................. (Number) .............................................. (Size and location of each) Reinforcement .............................................. (Riveted, welded, etc.)

20. Method of supporting vessel ........................................................................................................................

21. Bursting pressure..............................................psi Hydrostatic test..............................................lb

22. Constructed for pressure of..............................................psi Factor of safety..............................................

Remarks:........................................................................................................................
(Vessel to be used for air, gas, ammonia, etc.)

........................................................................................................................

We certify the above data to be correct and that all details of material and construction and workmanship on this unfired pressure vessel conform to the A.S.M.E. Code for Unfired Pressure Vessels.

Date..............................................19......... Signed.............................................................................. (Manufacturer) by..............................................................................

## CERTIFICATE OF SHOP INSPECTION

**Insurance Company's Serial Number.....................................**

**VESSEL MADE BY.................................................. at....................................................................................**

**I, the undersigned, holding a certificate of competency as an inspector of steam boilers in THE STATE OF**

**............................................., and employed by the ...................................................................................................**

**of.................................., inspected internally and externally, the vessel specified in this report, on.............................................**

**.........................................19 , and certify that the statements made on this report are correct, corresponding with the mill test reports of material as furnished by the builders, and measurements made of the vessel when completed; and that this vessel is constructed in accordance with the A.S.M.E. Code Rules for the Construction of Unfired Pressure Vessels.**

**.......................................................................................................................**

***Inspector for State or Boiler Insurance Company.***

# FORM U-2 MANUFACTURERS' PARTIAL DATA REPORT

## A Part of Boiler or Vessel Fabricated by One Manufacturer for Another Manufacturer

1. Manufactured by............................................................................
(Name and address of manufacturer of part)

(a) Manufactured for............................................................................
(Name and address of manufacturer of boiler or vessel)

2. Identification—Manufacturer's Serial No. of Part............................................................................

(a) Constructed According to Blueprint No..............................B.P. Prepared by..............................

(b) Description of Part Inspected............................................................................

3. If welded, what paragraphs of the Code (Pars. P-101 to P-114, inclusive, or Pars. U-68, U-69, or U-70) have been complied with? ..........

............................................................................

4. Remarks: ............................................................................

............................................................................

............................................................................

............................................................................

## CERTIFICATE OF SHOP INSPECTION

We certify the above data to be correct and that all details of material, construction, and workmanship of the object conform to A.S.M.E. Code requirements for parts............................................................

Date........................., 19........ Signed..............................................
*(Manufacturer)*

..............................................
*(Representative)*

.............................................. Commissions..............................................
*Inspector* *State or Natl. Board and No.*

5(a) Drums

| No. | Nominal diameter in. | Length Ft | Length In. | Shell plates Brand | Shell plates Material spec. no. | Shell plates Thickness | Shell plates Inside radius | Tube sheets Thickness | Tube sheets Inside radius | Tube hole ligament efficiency Longitudinal | Tube hole ligament efficiency Circumferential |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | | | |
| 2 | | | | | | | | | | | |
| 3 | | | | | | | | | | | |
| 4 | | | | | | | | | | | |
| 5 | | | | | | | | | | | |

| No. | Longitudinal joints No. & type* | Longitudinal joints Efficiency | Circum. joints No. & type | Circum. joints Efficiency | Heads Brand | Heads Material spec. no. | Heads Thickness | | Heads Type** | Heads Radius of dish | Heads Manholes No. | Heads Manholes Size | Hydrostatic test, lb |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | | |
| 3 | | | | | | | | | | | | | |
| 4 | | | | | | | | | | | | | |
| 5 | | | | | | | | | | | | | |

* Indicate if 1. Seamless; 2. Fusion welded; 3. Forge welded; 4. Riveted.

** Indicate if 1. Flat; 2. Dished; 3. Ellipsoidal; 4. Hemispherical.

5(b) Boiler Tubes

| Diameter | Thickness | Material specification no. |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |

(5c) Headers No. ........................................................................
(Box or sinuous; Mat. spec. no.; Thickness)

Heads or Ends.............................................. Hydro. Test-Lb..................
(Shape; Mat. spec. no.; Thickness)

5(d) Staybolts........................................................................
(Mat. spec. no.; Diameter; Size telltale; Net area)

Pitch......................... Net Area......................... Max. S.W.P.........
(Supported by one bolt)

5(e) Mud Drum........................................ Heads or Ends.............................. Hydro. Test-Lb.................
(For sect. header boilers. State size; Shape; Mat. spec. no.; Thickness) (Shape; Mat. spec. no.; Thickness)

6(a) Waterwall Headers — 6(b) Waterwall Tubes

| No. | Size and shape | Material spec. no. | Thickness | Heads or Ends Shape | Heads or Ends Thickness | Heads or Ends Material spec. no. | Hydro. test, lb | Diameter | Thickness | Material spec. no. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |

7(a) Economizer Headers — 7(b) Economizer Tubes

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |

8(a) Superheater Headers — 8(b) Superheater Tubes

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |

9(a) Other Parts (1)........................ (2)........................ (3)........................ — 9(b) Tubes for Other Parts

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| a | | | | | | | | | | |
| b | | | | | | | | | | |
| c | | | | | | | | | | |

10 Openings (1) Steam.............................................. (2) Safety valve..............................................
(No., size, and type of nozzles or outlets) (No., size, and type of nozzles or outlets)

(3) Blow off.............................................. (4) Feed..............................................
(No., size, and type of nozzles or outlets) (No., size, type, and location of connections)

11

| | | Bursting pressure weakest part | Maximum S.W.P. | Factor of safety | Shop hydro. test | Heating surface |
|---|---|---|---|---|---|---|
| a | Boiler | | | | | |
| b | Waterwall | | | | | |
| c | Economizer | | | | | |
| d | Superheater | | | | | |
| e | Other parts | | | | | |

Heating surface to be stamped on drum heads. This heating surface not to be used for determining minimum safety valve capacity.

| 12 Field hydro. test |
|---|
| |
| |
| |
| |
| |

## FORM U-3 (*FORMERLY U-$1^1/_2$*) MANUFACTURERS' CERTIFICATE COVERING NON-INSPECTED UNFIRED PRESSURE VESSELS

### As Required by the Provisions of the A.S.M.E. Code Rules

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

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

3. Type.................. (Horizontal or vertical) Unfired Pressure Vessel No. (........................) (Mfrs.' serial, or A.S.M.E. no.) (..................) (State and state no.) Year built.............

4. Have mill test reports been checked on all the plates entering this unfired pressure vessel........................................

Do the chemical and physical properties of all plates meet the requirements of the Code............................................

5. SHELL OR DRUMS: No........ Diameter (Or width)........ft........in. Length over-all........ft........in. Height........ft.........in.

6. STAMPS on shell plates........................ (Brand and lowest tensile strength) Rivets, stays and braces.................................. (Iron or steel)

7. SHELL PLATES (Outer)........in. (Thickness) Butt straps........in. (Thickness) Styles of seams: Longitudinal........................Girth................. (Riveted, forge welded, brazed, or fusion welded—type of)

8. Diameter of rivet holes.........in. Pitch of rivets........×........×.......Efficiency of joint...........................%

9. GIRTH JOINTS.................. (Single or double riveted) Diameter rivet holes........in. Pitch of rivets........in. No. of courses......................

10. INNER SHELL..........in. (Thickness) Style of seams; Longitudinal........Girth.......... (Riveted, forge welded, brazed, or fusion welded—type of) Length of section or course..........ft........in.

11. HEADS: Flat or dished............in. (Thickness) Radius of dish..........in. Side to pressure........................................ (Concave or convex)

If removable, bolts used................. (Number and size) or method of fastening.................................................... (Describe or sketch)

12. STAYBOLTS................ (Iron or Steel) If hollow................. (Size of hole) 13. Maximum pitch..........×.......... (Horizontal) (Vertical) Diameter............in. (Over the threads)

14. SAFETY VALVE outlets: No.............. Size..............

15. Have the welding operators and the welding procedure been qualified in accordance with Code requirements?......................

16. DRAIN connection..........in. (Size) HAND HOLES OR SIGHT HOLES.................................................... (Number, size, and location)

17. Bursting pressure..................................psi Hydrostatic test...................................................lb

18. Constructed for pressure of.......................psi Maximum stress in shell plate......................................psi

Remarks: ........................................................................................................
(Vessel to be used for air, gas, ammonia, etc.)

..................................................................................................................

We certify the above data to be correct and except for the omission of shop inspection that all details of material and construction and workmanship on this unfired pressure vessel conform to the A.S.M.E. Unfired Pressure Vessel Code.

Date...................19.... Signed.................................... (Manufacturer) by.................................

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# INDEX

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City.......................................State..........................

(over)

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# ADDENDA

TO

# A.S.M.E. BOILER CONSTRUCTION CODE

# UNFIRED PRESSURE VESSEL CODE

*Approved by Council, The American Society of Mechanical Engineers, August 25, 1944*

### *Foreword   Insert as the ninth paragraph*

Revisions and cases are permissible for constructions to be stamped with the A.S.M.E. Code symbol beginning with date of A.S.M.E. Council approval printed thereon. Unless specifically stated otherwise, Code revisions and cases become effective as minimum requirements six months thereafter, except for boilers or pressure vessels sold, constructed, or under construction, prior to the end of the six-month period. Manufacturers are cautioned that permission to use revisions and cases, if less restrictive than previous requirements, should be obtained from the proper authorities of the state or municipality in which installation is to be made unless such jurisdiction has, specifically or automatically, adopted such revisions and cases.

### *Par. U-2   Insert center heading above this paragraph to read: "Safety Devices"*

### *Par. U-2(a)   Revised*

(a) All pressure vessels shall be protected by adequate safety and relief valves together with such indicating and control devices as will insure safe operation except that, on vessels containing substances that may, for any reason, render a safety valve inoperative, or where a loss of valuable material by leakage should be avoided, or contamination of the atmosphere by leakage of noxious gases must be avoided, rupture disks may be used in lieu of safety valves. The safety valves or rupture disks, when used, shall be set to operate at not to exceed the maximum allowable working pressure stamped on the vessel and the relieving capacity shall be sufficient to prevent

***Par. U-2(a)*** *(Continued)*

a rise of pressure in the vessel of more than 10 per cent above the maximum allowable working pressure. All discharges shall be carried to a safe place. All protective devices shall be so constructed, located, and installed that they cannot readily be rendered inoperative.

***Par. U-3 Omit center heading above this paragraph which reads: "Safety Valves for Steam or Air."***

***Par. U-3 Add the following***

(c) Rupture disks may be used if they meet the requirements of Par. U-10(b) and the relief area is at least equal to the cross-sectional area of the connection thereto (See Note).

NOTE: It is common practice to keep the actual working pressure somewhat below the rupture disk bursting pressure which must not exceed the maximum allowable working pressure, in order to prevent its premature failure due to fatigue.

***Par. U-10 Renumber as Par. U-9 and insert the following new Par. U-10***

**U-10** (a) A rupture disk may be installed between a spring-loaded safety valve and the vessel provided:

(1) The valve is ample in capacity to meet the requirements of Par. U-2;

(2) The disk is designed to rupture at not more than the maximum allowable working pressure of the vessel;

(3) The opening provided through the disk, after breakage, is sufficient to permit a flow equal to the capacity of the attached valve and there is no chance of interference with the proper functioning of the safety valve;

(4) The connection between the disk and the safety valve is so arranged as to form a pocket in which any detached fragment of the disk will be retained, and this space is provided with a pressure gage, try cock, or free vent to indicate whether the rupture disk has leaked or burst.

(b) Every rupture disk shall have a specified temperature, bursting pressure, and lot number and shall be guaranteed by its manufacturer to burst within 5 per cent (plus or minus) of its specified bursting pressure.

The specified bursting pressure and temperature shall be determined by bursting two or more specimens from a lot of the same material, and of the same size as those to be used.

Every rupture disk shall have its specified bursting pressure, temperature, and lot number stamped upon the flange of

***Par. U-10*** (*Continued*)

the disk itself or upon a metal tab permanently attached thereto.

When a rupture disk is given a rated bursting pressure at a specified temperature, the increased bursting pressure at lower temperatures shall not exceed the proportional increased stress permitted at atmospheric temperature for the material of the vessel.

***Table U-2 Revise the following***

| Spec. no. | Grade | Spec. min tens. | 650 | 700 | 750 | 800 | 850 | 900 | 950 | 1000 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | For metal temperatures not exceeding deg F | | | | | | | |
| SA-30 | B | 48000 | 9600 | 9300 | 8750 | 7250 | 5900 | 4400 | 2600 | 1350 |
| SA-30 | A | 52000 | 10400 | 9900 | 9200 | 7700 | 6100 | 4400 | 2600 | 1350 |

***Table U-2 Add allowable stresses of 1400 and 900 psi at 1150 and 1200 F, respectively, for the following***

Specifications SA-213 Grade T13, SA-157 Grade C5B, SA-158 Grades P5a and P5c, SA-213 Grade T5, SA-182 Grade F5, SA-157 Grade C5A, SA-158 Grades P3a, P3b, and P11, SA-213 Grades T3, T11, T12, T14, and T16, SA-182 Grade F3

***Table U-2 Replace reference to "S-4" by "SA-266"***

***Table U-2 Delete references and values for "SA-176, Grades 1 and 2"***

***Table U-2 For "SA-240," add Grades A, B, and D, with allowable stresses for those now listed for "SA-176, Grade 2"***

***Table U-2 Add the following values***

| | Spec. SA-213 Grade T13 | Spec. SA-157 Grade C5B |
|---|---|---|
| Notes | ... | (7)(8) |
| Spec. min tensile, psi | 60000 | 90000 |
| Metal temperatures, F | | |
| —20 to 650 | 12000 | 15000 |
| 700 | 12000 | 15000 |
| 750 | 12000 | 15000 |
| 800 | 11800 | 14000 |
| 850 | 11000 | 12500 |
| 900 | 8800 | 8800 |
| 950 | 6000 | 6000 |
| 1000 | 4200 | 4200 |
| 1050 | 3000 | 3000 |
| 1100 | 2000 | 2000 |

***Table U-2 For Specification SA-157, add stresses for Grade C5A, to be identical with those now given for Grade C5, which latter grade has been dropped***

## *Par. U-39(a) Add the following*

$C$ = 0.50 for beveled plates having a diameter, $d$, not exceeding 18 in., inserted into shells, pipes, or headers, the ends of which are crimped over the bevel with the limitations shown in Fig. U-4($n$). The crimping shall be done when the entire circumference of the cylinder is uniformly heated to a temperature of at least 1300 F. For this construction the ratio $t_s/d$ shall be not less than the ratio $P/S$ nor less than 0.05.

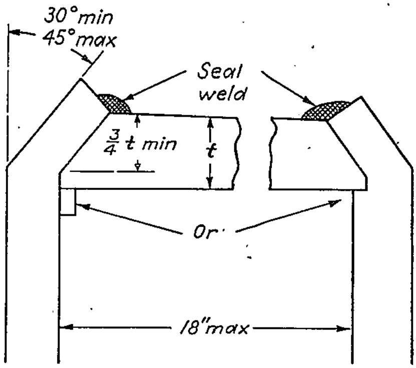


Fig. U-4 ($n$)

## *Fig. U-4(f) Add the following note*

*Note: $t_s$ may be taken as the required thickness of a seamless shell when computing $t_1$.*

## *Par. U-66(i) Add the following*

except that when all of the pressure chambers are:

(1) In a common cylindrical shell;
(2) Designed for the same maximum allowable working pressure and temperature;
(3) Required to have identical Code stamping.

A single report form may be used to record all of the required data and only one set of stampings need be applied to the vessel. Also when a combination of chambers, carrying different pressures but having common parts, make up a single unit the several chambers shall be properly stamped but a single data sheet, with the necessary additions, may be used.

TABLE U-3 MAXIMUM ALLOWABLE DESIGN STRESSES FOR NONFERROUS MATERIALS, POUNDS PER SQUARE INCH

| Material and spec. no. | Grade, type, or name | Condition | Notes | Spec. minimum tensile | For metal temperatures not exceeding deg F: Subzero to 150 | 250 | 300 | 350 | 400* | 450 | 500 | 550 | 600 | 700 | 800 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Aluminum** | | | | | | | | | | | | | | | |
| Plate, Sheet, or Strip | | | | | | | | | | | | | | | |
| SB-178 | Aluminum | Annealed | ... | 11000 | 2240 | 1680 | 1440 | 1280 | 1120 | ... | ... | ... | ... | ... | ... |
| SB-178 | Aluminum | As rolled | ... | 13000 | 2640 | 2080 | 1920 | 1600 | 1200 | ... | ... | ... | ... | ... | ... |
| SB-178 | Aluminum | 1/4 Hard | ... | 14000 | 2800 | 2240 | 2000 | 1680 | 1200 | ... | ... | ... | ... | ... | ... |
| **Aluminum Alloys** | | | | | | | | | | | | | | | |
| Plate, Sheet, or Strip | | | | | | | | | | | | | | | |
| SB-126 | Alum. Mang. | Annealed | ... | 14000 | 2800 | 2400 | 2100 | 1800 | 1600 | ... | ... | ... | ... | ... | ... |
| SB-126 | Alum. Mang. | As rolled | ... | 17000 | 3400 | 3000 | 2700 | 2400 | 2200 | ... | ... | ... | ... | ... | ... |
| SB-126 | Alum. Mang. | 1/4 Hard | ... | 17000 | 3400 | 3000 | 2700 | 2400 | 2200 | ... | ... | ... | ... | ... | ... |
| **Copper** | | | | | | | | | | | | | | | |
| Bars, | | | | | | | | | | | | | | | |
| SB-12 | ... | Annealed | ... | 30000 | 6000 | 5000 | 4750 | 4500 | 3000 | ... | ... | ... | ... | ... | ... |
| Pipe or tube | | | | | | | | | | | | | | | |
| SB-13 | ... | Annealed | (8) | 30000 | 6000 | 5000 | 4750 | 4500 | 3000 | ... | ... | ... | ... | ... | ... |
| SB-42 | ... | Annealed | (8) | 30000 | 6000 | 5000 | 4750 | 4500 | 3000 | ... | ... | ... | ... | ... | ... |
| SB-42 | ... | Light drawn | (8) | 36000 | 7200 | 6000 | 5000 | 4500 | 3000 | ... | ... | ... | ... | ... | ... |
| SB-42 | ... | Hard drawn | (8) | 50000 | 10000 | 9000 | 7000 | 5000 | 3000 | ... | ... | ... | ... | ... | ... |
| SB-75 | ... | Annealed | (8) | 30000 | 6000 | 5000 | 4750 | 4500 | 3000 | ... | ... | ... | ... | ... | ... |
| SB-75 | ... | Light drawn | ... | 36000 | 7200 | 6000 | 5000 | 4500 | 3000 | ... | ... | ... | ... | ... | ... |
| SB-75 | ... | Hard drawn | (8) | 50000 | 10000 | 9000 | 7000 | 5000 | 3000 | ... | ... | ... | ... | ... | ... |
| SB-111 | ... | Light drawn | (8) | 36000 | 7200 | 6000 | 5000 | 4500 | 3000 | ... | ... | ... | ... | ... | ... |
| SB-111 | ... | Hard drawn | (8) | 50000 | 10000 | 9000 | 7000 | 5000 | 3000 | ... | ... | ... | ... | ... | ... |
| **Plate** | | | | | | | | | | | | | | | |
| SB-11 | ... | Annealed | ... | 30000 | 6000 | 5000 | 4750 | 4500 | 3000 | ... | ... | ... | ... | ... | ... |
| **Copper Alloys** | | | | | | | | | | | | | | | |
| Rod or Shapes | | | | | | | | | | | | | | | |
| SB-98 | Copper Silicon A, C, D | Soft | (3), (5) | 52000 | 10400 | 10400 | 10400 | 5000 | ... | ... | ... | ... | ... | ... | ... |
| SB-98 | Copper Silicon A, C, D | 1/2 Hard | (3) | 70000 | 14000 | 14000 | 14000 | 10000 | ... | ... | ... | ... | ... | ... | ... |
| SB-98 | Copper Silicon B | Soft | (3) | 40000 | 8000 | 8000 | 7000 | 5000 | ... | ... | ... | ... | ... | ... | ... |
| SB-98 | Copper Silicon B | 1/2 Hard | (3) | 55000 | 11000 | 11000 | 10000 | 8000 | ... | ... | ... | ... | ... | ... | ... |
| Castings | | | | | | | | | | | | | | | |
| SB-61 | ... | ... | (4) | 34000 | 6800 | 6800 | 6500 | 6000 | 5500 | 5000 | 4000 | 3300 | ... | ... | ... |
| SB-62 | ... | ... | (4) | 30000 | 6000 | 5500 | 5000 | 4500 | 3500 | ... | ... | ... | ... | ... | ... |
| Pipe or Tube | | | | | | | | | | | | | | | |
| SB-43 | Muntz | Annealed | (8) | 50000 | 10000 | 9000 | 7000 | 2000 | 1500 | ... | ... | ... | ... | ... | ... |
| SB-43 | High Brass | Annealed | (8) | 45000 | 9000 | 9000 | 9000 | 6000 | 3000 | 1500 | 800 | ... | ... | ... | ... |
| SB-43 | Admiralty | Annealed | (8) | 45000 | 9000 | 9000 | 9000 | 6000 | 5500 | 4500 | 800 | ... | ... | ... | ... |
| SB-43 | Red Brass | Annealed | (8) | 40000 | 8000 | 8000 | 7000 | 6000 | 3000 | 1500 | 800 | ... | ... | ... | ... |
| SB-111 | Alum. Brass | Annealed | (8) | 45000 | 9000 | 9000 | 9000 | 6000 | 3000 | 1500 | 800 | ... | ... | ... | ... |
| SB-111 | Alum. Bronze | ... | (8) | 50000 | 10000 | 9000 | 9000 | 6500 | 3000 | 1500 | 800 | ... | ... | ... | ... |
| SB-111 | Muntz | Annealed | (8) | 50000 | 10000 | 9000 | 7000 | 2000 | 1500 | ... | ... | ... | ... | ... | ... |
| SB-111 | Admiralty | Annealed | (8) | 45000 | 9000 | 9000 | 9000 | 6000 | 5500 | 4500 | 800 | ... | ... | ... | ... |
| SB-111 | Red Brass | Annealed | (8) | 40000 | 8000 | 8000 | 7000 | 6000 | 3000 | 1500 | 800 | ... | ... | ... | ... |
| SB-111 | Copper Ni. 70–30 | Annealed | (8) | 55000 | 11000 | 11000 | 11000 | 11000 | 11000 | 11000 | 10000 | 10000 | 9000 | 8000 | ... |
| SB-111 | Copper Ni. 80–20 | Annealed | (8) | 50000 | 10000 | 10000 | 10000 | 10000 | 10000 | 10000 | 9500 | 8500 | 8000 | 7000 | ... |
| Plate or Sheet | | | | | | | | | | | | | | | |
| SB-96 | Copper Si. A, C | Annealed | (3) | 50000 | 10000 | 10000 | 10000 | 5000 | ... | ... | ... | ... | ... | ... | ... |
| SB-171 | Alum. Bronze | Annealed | ... | 90000 | 17000 | 10000 | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| SB-171 | Naval Brass | Annealed | ... | 50000 | 10000 | 10000 | 10000 | 6000 | 3000 | ... | ... | ... | ... | ... | ... |
| SB-171 | Muntz | Annealed | ... | 50000 | 10000 | 9000 | 7000 | 2000 | 1500 | ... | ... | ... | ... | ... | ... |
| SB-171 | Admiralty | Annealed | ... | 45000 | 9000 | 9000 | 9000 | 6000 | 5500 | 4500 | 800 | ... | ... | ... | ... |
| SB-171 | Copper Ni. 70–30 | Annealed | ... | 50000 | 10000 | 10000 | 10000 | 10000 | 10000 | 10000 | 9500 | 9000 | 8500 | 7500 | ... |
| **Nickel** | | | | | | | | | | | | | | | |
| Bar, Rod, or Shapes | | | | | | | | | | | | | | | |
| SB-160 | ... | Annealed | ... | 60000 | 12000 | 12000 | 12000 | 12000 | 12000 | 12000 | 12000 | ... | ... | ... | ... |
| SB-160 | ... | Hot rolled | (7) | 65000 | 13000 | 13000 | 13000 | 13000 | 13000 | 13000 | 13000 | ... | ... | ... | ... |
| Pipe or Tube | | | | | | | | | | | | | | | |
| SB-161 | ... | Annealed | ... | 60000 | 12000 | 12000 | 12000 | 12000 | 12000 | 12000 | 12000 | ... | ... | ... | ... |
| SB-161 | ... | As drawn | (1) | 80000 | 16000 | 16000 | 16000 | 16000 | 16000 | 16000 | 16000 | ... | ... | ... | ... |
| SB-163 | ... | Annealed | ... | 60000 | 12000 | 12000 | 12000 | 12000 | 12000 | 12000 | 12000 | ... | ... | ... | ... |
| SB-163 | ... | As drawn | (1) | 65000 | 13000 | 13000 | 13000 | 13000 | 13000 | 13000 | 13000 | ... | ... | ... | ... |
| Plate, Sheet, or Strip | | | | | | | | | | | | | | | |
| SB-162 | ... | Annealed | ... | 60000 | 12000 | 12000 | 12000 | 12000 | 12000 | 12000 | 12000 | ... | ... | ... | ... |
| SB-162 | ... | As rolled | (2) | 70000 | 14000 | 14000 | 14000 | 14000 | 14000 | 14000 | 14000 | ... | ... | ... | ... |
| **Nickel Alloys** | | | | | | | | | | | | | | | |
| Bars, Rods, or Shapes | | | | | | | | | | | | | | | |
| SB-164 | Ni. Copper A & B | Annealed | ... | 70000 | 14000 | 14000 | 14000 | 14000 | 14000 | 14000 | 14000 | 14000 | 14000 | 14000 | ... |
| SB-164 | Ni. Copper A | Hot rolled | ... | 80000 | 16000 | 16000 | 16000 | 16000 | 16000 | 16000 | 16000 | 16000 | 16000 | 16000 | ... |
| SB-164 | Ni. Copper B | Hot rolled | ... | 75000 | 15000 | 15000 | 15000 | 15000 | 15000 | 15000 | 15000 | 15000 | 15000 | 15000 | ... |
| SB-166 | Ni. Chrome Iron | Annealed | ... | 80000 | 16000 | 16000 | 16000 | 16000 | 16000 | 16000 | 16000 | 16000 | 16000 | 16000 | 16000 |
| SB-166 | Ni. Chrome Iron | Hot rolled | ... | 85000 | 17000 | 17000 | 17000 | 17000 | 17000 | 17000 | 17000 | 17000 | 17000 | 17000 | 17000 |
| Pipe or Tube | | | | | | | | | | | | | | | |
| SB-163 | Nickel-Copper | Annealed | ... | 65000 | 13000 | 13000 | 13000 | 13000 | 13000 | 13000 | 13000 | 13000 | 13000 | 13000 | ... |
| SB-165 | Nickel-Copper | Annealed | ... | 65000 | 13000 | 13000 | 13000 | 13000 | 13000 | 13000 | 13000 | 13000 | 13000 | 13000 | ... |
| SB-167 | Ni. Chrome Iron | Annealed | ... | 80000 | 16000 | 16000 | 16000 | 16000 | 16000 | 16000 | 16000 | 16000 | 16000 | 16000 | 16000 |
| Plate, Sheet, or Strip | | | | | | | | | | | | | | | |
| SB-127 | Nickel-Copper | Annealed | ... | 70000 | 14000 | 14000 | 14000 | 14000 | 14000 | 14000 | 14000 | 14000 | 14000 | 14000 | ... |
| SB-127 | Nickel-Copper | 1/4 Hard | ... | 78000 | 15600 | 15600 | 15600 | 15600 | 15600 | 15600 | 15600 | 15600 | 15600 | 15600 | ... |
| SB-127 | Nickel-Copper | As rolled | (2) | 80000 | 16000 | 16000 | 16000 | 16000 | 16000 | 16000 | 16000 | 16000 | 16000 | 16000 | ... |
| SB-168 | Ni. Chrome Iron | Annealed | ... | 80000 | 16000 | 16000 | 16000 | 16000 | 16000 | 16000 | 16000 | 16000 | 16000 | 16000 | 16000 |
| SB-168 | Ni. Chrome Iron | As rolled | (2) | 80000 | 16000 | 16000 | 16000 | 16000 | 16000 | 16000 | 16000 | 16000 | 16000 | 16000 | 16000 |

NOTES:

(1) As drawn, stress-equalized "condenser tubes."
(2) Hot rolled, as rolled.
(3) There is doubt concerning the suitability of this material when exposed to certain media, and/or high temperatures, particularly steam above 212 F. The user should satisfy himself that it is satisfactory for the service for which it is to be used.
(4) In the absence of evidence that the casting is of high quality throughout, values not in excess of 80 per cent of those given in the table shall be used. This is not intended to apply to valves and fittings made to recognized standards.
(5) Types "*A*" and "*C*," for hot headed bolts only.
(6) Types "*A*," "*C*," and "*D*" for machined bolts up to and including 1½ in. diameter.
(7) Also cold hexagon squares and flats.
(8) "Minimum tensile strength" not given in specification.

* For steam at 250 psi (406 F) the values given may be used.

***Par. U-68 Revised second section***

In applying the rules in Par. U-20, a welded joint efficiency of 95 per cent may be used, provided all weld reinforcement is removed substantially flush with the surface of the plate. Otherwise a joint efficiency not to exceed 90 per cent shall be used.

***Par. U-68(h)(12b) Revised***

(b) Welds in which the radiographs show any type of crack or zones of incomplete penetration shall be unacceptable.

***Par. U-72(e) Revised first section***

(e) In all cases where plate edges of unequal thicknesses are abutted, the edge of the thicker plate shall be trimmed to a smooth taper extending for a distance at least four times the offset between the abutting surfaces as shown in Fig. U-18¹/₈, so that the adjoining edges will be approximately the same thickness. The length of the required taper may include the width of the weld.

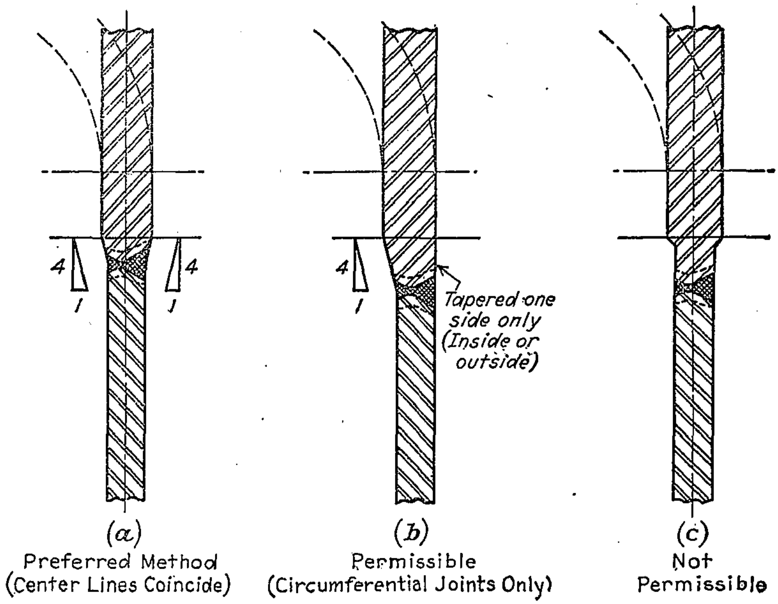


FIG. U-18¹/₈ BUTT WELDING OF PLATES OF UNEQUAL THICKNESS

### *Par. U-71(a) Revised*

(a) Ferrous materials used in the fabrication of any fusion-welded drum, shell, or parts covered by this Code shall conform to Specifications SA-7 (bar stock only), SA-27, SA-30, SA-31, SA-53, SA-70, SA-72, SA-83, SA-84, SA-89, SA-105, SA-106, SA-129, SA-135, SA-157, SA-158, SA-178, SA-181, SA-182, SA-192, SA-201, SA-202, Grade A, SA-203, SA-204, SA-206, SA-209, SA-210, SA-212, SA-213, SA-216, SA-217, SA-225, SA-240,* SA-249* Grades T8, T18, T19, and T20, SA-250, and SA-266. The carbon content in all such materials shall not exceed 0.35 per cent.

* Materials complying with these specifications to be used only under the conditions set forth in Case No. 897.

### *Par. U-76(c) Add the following to the last sentence*

to a temperature not exceeding 600 F.

### *Par. U-78(g) Insert the following as the second section*

The segments or plugs after removal shall be properly stamped or tagged for identification and, after etching, kept in proper containers, with a record of their place of removal as well as of the welding operator who performed the welding. A record shall be made by the inspector of all specimens with their identification marks on a developed shell-plate diagram. After the acceptance of the vessel, the specimens may be retained by the purchaser, if he so desires. Otherwise they may be discarded.

### *Par. U-78(g) Replace the present seventh section by the following*

Holes in welded joints left by the removal of trepanned plug specimens may be closed by any method approved by the authorized inspector. Some suggested methods for closing round plug openings by welding are as follows:

(1) Insert and weld in special plugs of which some acceptable types are shown in Fig. U-19. Type (*a*) is adapted to welding from both sides and should be used wherever that method is practicable, and types (*b*) or (*c*) when access is possible only from one side. The diameter of the filler plug shall be such as to make a snug fit in the hole to be filled. Each layer of weld metal as deposited shall be thoroughly peened to reduce residual stresses. The $^1/_4$-in. hole in the center of the plugs shown in Fig. U-19 may afterwards be

***Par. U-78(g)*** *(Continued)*

closed by any reasonable method. Plain plugs without a hole may be used.

(2) For joints where the thickness of the thinner plate at the joint is not greater than one third of the diameter of the hole, place a backing plate on the inside of the tank shell over the opening and fill the hole completely with weld metal applied from the outside of the shell. Rebuild fillet welds where cut.

(3) For joints where the thickness of the thinner plate at the joint is not less than one third, nor greater than two thirds the diameter of the hole, fill the hole completely with weld metal applied from both sides of the tank shell. Rebuild fillet welds where cut.

(4) For butt joints where the thickness of the thinner plate at the joint does not exceed $^7/_8$ in., chip a groove on one side of the plate each way along the seam from the hole. The groove at the opening shall have sufficient width to provide a taper to the bottom of the hole, and the length of the groove on each side of the opening is to have a slope of approximately 1 to 3. Use a backing plate on the side opposite which the chipping is done or a thin disk (not over $^1/_8$ in. thick) at the bottom of the hole and fill the groove and the hole with weld metal.

(5) For butt joints, and for plates of any thickness, chip a groove on both sides of the plate each way along the seam from the hole. The groove at the opening shall have sufficient width to provide a taper to the middle of the plate, and the length of the groove on each side of the opening is to have a slope of approximately 1 to 3. Place a thin disk (not over $^1/_8$ in. thick) in the hole at the middle of the plate and fill the grooves and the hole on both sides with weld metal.

The following is a suggested method for closing openings cut with a spherical saw: For butt-welded joints place a backing plate, where necessary, on the inside of the vessel shell over the opening. For lap-welded joints, a part of the parent plate remaining opposite the removed weld will usually serve as a backing plate. Fill the opening completely with the weld metal. Rebuild fillet welds where cut.

***Par. U-120 Replace reference to "S-4 Specifications for Seamless Steel Drum Forgings" by "SA-266 Specifications for Carbon-Steel Seamless Drum Forgings"***

## ALTERNATE RULES FOR UNFIRED PRESSURE VESSELS

Alternate rules for the construction of fusion-welded unfired pressure vessels are given in Pars. U-200 to U-210, inclusive, which permit liberalization of design stresses and welded joint efficiencies under certain restrictive construction rules which must be met in order to use the higher stress allowances. These rules apply only to seamless vessels and to fusion-welded vessels constructed under the provisions of Pars. U-68 and U-69, and to tubes for use in such vessels. Other applicable provisions of the Code, not specifically covered by these alternate rules, must be complied with in all respects.

**U-200** (a) Unfired pressure vessels constructed under the provisions of Par. U-68, and complying with other Code requirements except for the variations allowed in these alternate rules, shall be designated as Par. U-200 vessels.

(b) A welded joint efficiency of 95 per cent may be used.

(c) In the design of shells and heads, the maximum stresses in Table U-2 may be multiplied by 1.25 for use in the formulas of Par. U-20(a) and (b), U-36, U-39, and U-59.[1]

(d) The restrictive requirements of Pars. U-202 to U-207, inclusive, shall be complied with in all respects.

**U-201** (a) Unfired pressure vessels constructed under the provisions of Par. U-69, and complying with other Code requirements except for the variations allowed in these alternate rules, shall be designated as Par. U-201 vessels.

(b) A welded joint efficiency of 80 per cent may be used.

(c) In the design of shells and heads, the maximum design stresses of Table U-2 may be multiplied by 1.25 for use in the formulas of Pars. U-20(a) and (b), U-36, U-39, and U-59.[1]

(d) The restrictive requirements of Pars. U-202 to U-208, inclusive, shall be complied with in all respects.

**U-202** To the calculated thickness of shells, heads, and other pressure parts of steam, water, and air vessels shall be added a corrosion allowance of one sixth of the calculated thickness, or $^1/_{16}$ in., whichever is the smaller. Vessels in other corrosive services shall be provided with appropriate corrosion allowances.

**U-203** All weld reinforcement for Par. U-200 vessels shall be removed flush with the surface of the plate. For both Pars. U-200 and U-201 vessels, where plate edges of unequal thick-

[1] Pending investigation of stress concentrations around supports and openings of spheres, reference to the formula in Par. U-20(c), which would allow an increase in design stress, has been withheld.

***Par. U-203*** (*Continued*)

nesses are abutted, the edge of the thicker plate shall be trimmed to a smooth taper extending for a distance at least four times the offset between the abutting surfaces as shown in Fig. U-$18^1/_2$ so that the adjoining edges will be of approximately the same thickness.

The length of the required taper may include the width of the weld. All other joint details shall conform to the requirements of Par. U-72.

**U-204** Stresses due to hydrostatic head shall be taken into account in determining the thickness to be used, also the total of other stresses due to loads such as the weight of the vessel, water, and distances between vessel supports, if these stresses increase the average stress over substantial sections of the shell or head by more than 10 per cent.

**U-205** Large temperature differentials in heads or shells shall be avoided or the effect reduced by shields or other suitable means.

**U-206** (**a**) For heads, the increased design stresses authorized in Pars. U-200 and U-201 may be used only for flat heads and for hemispherical or ellipsoidal heads with pressure on the concave side.

(**b**) The following heads and other parts shall be designed using stresses as given in Table U-2 (without any multiplying factor) but may be used with shells constructed according to these alternate rules:

(**1**) Dished heads, other than hemispherical or ellipsoidal;
(**2**) All unstayed dished heads with pressure on the convex side;
(**3**) Ellipsoidal heads with flanged-in or other unreinforced manholes;
(**4**) All stays, braces, and parts requiring staying;
(**5**) Flanges.

**U-207** In determining the maximum size of an unreinforced opening under Par. U-59(**a**), the value of $K$ to be used in connection with the chart in Fig. U-8 shall be 1.1 times the value of $K$ computed by the formula of that paragraph for the part of the shell that contains the opening. When computing $K$ by the formula in Par. U-59(**a**), the pressure $P$ shall be that for which the vessel is designed, $S$ shall be 1.25 times the value from Table U-2, and $t$ shall be the actual full thickness of the

***Par. U-207*** (*Continued*)
shell at the location of the opening. Where $K$ so computed is unity or greater, the maximum size of unreinforced opening shall be 2 in.

**U-208** (**a**) Vessels constructed in accordance with Par. U-201 shall comply with the fusion welding requirements of Par. U-69; and in addition portions of the completed welded joints shall be examined either by spot-radiographing, by sectioning, or by a combination of both methods.

(**b**) Spot Radiographing. When the welded joint is to be examined by spot radiographing, the technique shall be that described in Par. U-68(**h**) and the radiograph shall comply with the standards specified in Par. U-68(**h**)(**12**) except as allowed under retests.

(**c**) Sectioning. When the welded joint is to be examined by sectioning, the specimens removed shall be such as to provide a full cross section of the welded joint and may be removed by trepanning a round hole or by any equivalent method.

Cylindrical specimens or those not having a plane surface shall be sectioned across the welds to obtain plane surfaces which shall include the full width of the weld. The plane surfaces shall be polished to a bright, smooth condition which may be accomplished by filing or grinding and polishing with emery cloth and should be completed with the use of emery cloth of grade 00. The specimen shall then be etched by any method or solution which will reveal the defects without unduly exaggerating or enlarging them (See Par. UA-85).

Sections removed from the welded joint shall show neither cracks nor lack of fusion. Gas pockets and slag inclusions shall be permissible only:

(**1**) When there is slag inclusion between layers, substantially parallel with the plate surface and which is not more than one half the width of the weld metal;

(**2**) When there is slag inclusion across the thickness of the plate not more than 10 per cent of the thickness of the thinner plate;

(**3**) When there are gas pockets that do not exceed $^{1}/_{16}$ in. in greatest dimension and when there are no more than six gas pockets of this maximum size per square inch of the weld metal or where the combined areas of a greater number of pockets do not exceed 0.02 sq in. per square inch of weld metal.

***Par. U-208*** (*Continued*)

Openings resulting from the removal of specimens may be closed by any method approved by the authorized inspector. Some acceptable methods for closing openings resulting from sectioning are given in Par. U-78(g).

(**d**) At least one spot shall be examined in each vessel except that when there are a number of similar vessels, each having less than 50 ft of welded longitudinal and circumferential joints, built at the same time and under the same specifications, one examined spot for each 50 ft or fraction thereof will suffice; two spots shall be examined in vessels having more than 50 ft of welded joints; and three spots shall be examined in vessels having more than 100 ft of welded joints. If more than one welding procedure is used or if more than one operator does the welding, at least one spot shall be examined for each procedure and for each operator.

The authorized inspector shall designate the spots on the welded joints to be examined.

(**e**) **Retests.** (**1**) RADIOGRAPHY. When a spot has been examined by radiography and the welding does not comply with the quality requirements referred to in (**b**), two additional radiographs shall be taken at locations indicated by the inspector. If either of the two additional radiographs fails to meet the standards described in (**2**), the full lengths of all the main seams shall be radiographed and all defects not permitted in (**2**) shall be chipped out, rewelded, and reradiographed.

Should the first spot radiograph fail to meet the minimum quality requirements described in (**2**), the full lengths of all the main seams shall be radiographed and all defects not permitted in (**2**) shall be chipped out, rewelded, and reradiographed.

(**2**) Welds in which radiographs show elongated slag inclusions, cavities, or lack of fusion, shall be unacceptable if the length of any such imperfection is greater than $^2/_3T$, where $T$ is the thickness of the thinner plate. If several imperfections within the above limitations exist in line, the welds shall be judged acceptable if the sum of the longest dimensions of all such imperfections is not more than $T$ in a length of $6T$, and if the defects are separated by at least $6L$ of acceptable weld metal, where $L$ is the length of the shortest imperfection. The maximum length of acceptable defect for any plate thickness shall be $^3/_4$ in. Any defect shorter than $^1/_4$ in. shall be acceptable for any plate thickness. The maximum permissible porosity shall be that prescribed for Par. U-68 vessels, except

# ADDENDA

## TO

# A.S.M.E. BOILER CONSTRUCTION CODE

# UNFIRED PRESSURE VESSEL CODE

***Approved by Council, The American Society of Mechanical Engineers, July 18, 1945***

***Par. U-41(b)(6) Revised***

(6) The provisions of Par. U-40 are followed using the following values of the constant (*C*):

*C* = 112 for plates 7/16 in. thick or less, for the detail shown in Fig. U-6(*a*), (*b*), and (*e*);
*C* = 120 for plates over 7/16 in. thick, for the detail shown in Fig. U-6(*a*), (*b*), and (*e*);
*C* = 135 for details shown in Fig. U-6(*c*) and (*d*).

***Par. U-41(c) Add the following as (8)***

(8) The maximum spacing of stays is determined by the formula in Par. U-40(*a*), using:

*C* = 112 if either plate is 7/16 in. thick or less;
*C* = 120 if both plates are more than 7/16 in. thick.

***Par. U-59(h)(1) Add "except as permitted otherwise in (3)"***

***Par. U-59(h) Add the following as (3)***

(3) The minimum size of attachment welds for threaded connections not exceeding 3 in. pipe size of which some acceptable designs are shown in Fig. U-10(*t*) to (*w*), inclusive, need not conform to the minimum values under this figure, but shall conform to Par. U-59(g).

***Par. U-59(o) Add the following***

When nozzles or couplings are attached to drums, shells, or headers of unfired pressure vessels as shown in Fig. U-10(*b*) and (*d*), and are welded from one side only, backing strips must be used except:

***Par. U-59(o)*** (*Continued*)

(**1**) When the wall thickness to which the nozzle or coupling is attached is not greater than $^3/_8$ in.;

(**2**) When the inside of the joint can be visually inspected so that the inspector may satisfy himself that complete penetration is obtained.

***Par. U-59(p) Revised first two sections***

(**p**) When vessels are built in accordance with Par. U-68, all connections after being attached by fusion welding shall be stress-relieved except as allowed otherwise in this paragraph.

When vessels are built in accordance with Par. U-69 and are required to be stress-relieved, all connections and other attachments after being attached by fusion welding shall also be stress-relieved except as allowed otherwise in this paragraph. When vessels are built in accordance with Par. U-69 and are not required to be stress-relieved, connections and other attachments after being attached by fusion welding need not be stress-relieved.

Fusion-welded connections may be added to a vessel after it has been stress-relieved, without requiring stress-relief provided:

(**1**) The diameter of the attachment opening in the vessel wall does not exceed that allowed for an unreinforced opening; or does not exceed 2 in., whichever is smaller;

(**2**) The inside and outside attachment welds do not exceed $^3/_8$ in. throat dimension.

This provision does not apply to those connections so placed as to form ligaments in the shell, the efficiency of which will affect the shell thickness. Such added connections shall be stress-relieved.

***Par. U-59(s) Add the following***

When end faces of nozzle or manhole necks are to remain unwelded in the completed vessel, these end faces shall not be cut by shearing unless at least $^1/_8$ in. of additional metal is removed by any method that will produce a smooth finish.

***Par. U-60(b) Revised***

(**b**) Lugs or brackets connected to a vessel used for support or piping connected to it shall be properly fitted to the surfaces to which they are attached. For lugs or brackets attached by riveting, the shearing and crushing stresses shall not exceed 40 per cent of the maximum allowable working stresses given in Pars. U-15 and U-16.

***Par. U-60 Add the following as (c)***

(c) External piping where connected to a pressure vessel should be installed so as not to overstress the vessel wall.

***Par. U-66 Revised***

**U-66 Stamping.** (a) The manufacturer shall stamp each pressure vessel constructed in compliance with the Code in the presence of the inspector, after the hydrostatic or permissible air test, in the shop of the manufacturer, except that:

(1) In cases where pressure parts cannot be completed and tested before shipment, proper stamping as called for in (f) shall be applied at the shop and the data sheets signed by the same or different inspectors who shall indicate the portions of the inspections made at the shop and in the field;

(2) In cases of field-erected vessels, the stamping shall be applied by the manufacturer in the presence of the inspector after the final pressure test.

The stamping on the vessel shall consist of the A.S.M.E. Code symbol (shown in Fig. U-12), the manufacturer's name, the manufacturer's serial number, the working pressure, and the year built, denoting that the vessel was constructed in accordance therewith. The maximum temperature corresponding with the maximum allowable working pressure shall also be stamped on the vessel.

(b) If the vessel is of fusion welded construction or if it has welded pressure parts, the number of the paragraph under which the welding was done shall be stamped under the Code symbol.

(c) If the circumferential or longitudinal joint or joints of a vessel are brazed, forge welded, or resistance welded, the letters "BRZ," "FGD," or "RES," as the case may be, shall be stamped under the Code symbol. When a vessel is built of a combination of types of construction as mentioned above, or different types of fusion welding, the stamping on the vessel shall indicate the various classes.

(d) The stamping on the vessel shall be arranged substantially as shown in Fig. U-13. These markings shall be legibly stamped on the vessel, except as provided in (e), with letters and figures at least $^5/_{16}$ in. high on the vessel near a manhole, if any, or handhole, or in some conspicuous place.

(e) For vessels constructed of plate less than $^1/_4$ in. thick, name plates bearing the official marking must be used, on which the data required by (d), excepting the Code symbol and serial

***Par. U-66*** *(Continued)*

number, may be etched, cast, or impressed. Name plates may be used on vessels constructed of plate 1/4 in. or more in thickness in lieu of stamping applied directly to the vessel. Such plates shall be brazed or otherwise irremovably attached to the vessel and located as described in (**d**). The letters and figures on a name plate, if used, shall be not less than 5/32 in. high.

The Code symbol and other required data not on the name plate when made must be stamped on these name plates. This stamping may be done prior to its being affixed to the vessel in which case the inspector shall see that the name plate with the correct stamping is applied to the proper vessel.

(**f**) When only a "part" of an unfired pressure vessel is supplied and the data are recorded on Manufacturers' Data Report Form U-2 (See Par. U-65**c**), unless otherwise specified, it shall be stamped with:

(1) A.S.M.E. Code symbol and underneath the symbol the word "part,"

(2) Name of manufacturer,

(3) Manufacturer's A.S.M.E. serial number of that "part,"

(4) Maximum allowable working pressure,

(5) Year built.

This does not apply to such parts as handhole covers, manhole covers, or their parts.

(**g**) On vessels having two or more separate parts or pressure chambers, the stamping may, under the conditions described in (**i**), be grouped in one location and so arranged that the data for the separate parts can be properly identified. Such pressure parts must be stamped sufficiently to identify them with the vessel or chamber of which they form a part.

(**h**) The required stamping shall not be covered permanently with insulating or other material.

(**i**) When an unfired pressure vessel unit consists of more than one pressure chamber operating at the same or different pressures, each such pressure chamber (vessel) which operates at a pressure above 15 psi shall be subject to the required inspections and hydrostatic tests. The part or pressure chamber tested shall be stamped so as to indicate that the stampings apply only to the chamber (vessel) tested such as "jackets only," "stock space only," etc.

***Par. U-66*** (*Continued*)

(j) Vessels built under the rules of Pars. U-140 to U-142 shall be stamped also with the lowest permissible temperature. If the required stamping is to be directly on the special seamless type of vessels, it shall be applied only to some thickened or reinforced portion of the vessel.

***Par. U-68(h)(2) Revised first sentence***

All welded joints to be radiographed shall be prepared as follows: The weld ripples or weld surface irregularities, on both the inside and outside, shall be removed by any suitable mechanical process, to a degree such that the resulting radiographic contrast due to any remaining irregularities cannot mask or be confused with that of any objectionable defect. Also the weld surface shall merge smoothly into the plate surface.

***Par. U-68(h)(12a) Revised***

(*a*) Welds in which the radiographs show elongated slag inclusions or cavities shall be unacceptable if the length of any such imperfection is greater than $^1/_3T$, where $T$ is the thickness of the thinner plate welded. If several imperfections within the above limitations exist in line, the welds shall be judged acceptable, if the sum of the longest dimensions of all such imperfections is not more than $T$ in a length of $12T$ and if the defects are separated by at least $6L$ of acceptable weld metal, where $L$ is the length of the longest imperfection. The maximum length of acceptable inclusion for any plate thickness shall be $^3/_4$ in. Any slag inclusion shorter than $^1/_4$ in. shall be acceptable for any plate thickness.

***Par. U-70 Add the following as (f)***

(f) Vessels assembled in the field shall not be built under the requirements of Par. U-70.

***Par. U-78(g) Revised items (1) and (2) of fifth section***

(1) When the width of any single slag inclusion between layers of weld metal substantially parallel with the plate surface is not greater than one half the width of the weld metal where the slag inclusion is located;

(2) When the total thickness of all of the slag inclusions in any plane at approximately right angles to the plate surface is not greater than 10 per cent of the thickness of the thinner plate.

## *Pars. U-140 to U-144 Revised*

NOTE: *This revision of requirements for vessels for low temperature service consists of a rearrangement of the material in the existing Code and a clarification of the requirements. There has been only minor change in the intent.*

*These rules cover the additional requirements for vessels intended for use at temperatures below −20 F in which region many of the materials acceptable for service at normal temperatures suffer such loss of impact resistance as to become unable to safely resist shock or sudden changes of stress or stresses at points of high-stress concentration. They cover vessels for use with any liquid or gas under the limitations of other sections of the Code.*

**U-140 Materials.** **(a)** Materials shall conform to the specifications given in Par. U-13, or in this paragraph. If the vessels are fabricated by fusion welding, the materials, if ferrous, shall conform to the specifications given in Par. U-71; if nonferrous, with Specification SB-96 or SB-98 for copper silicon alloys,* SB-127 for nickel-copper alloy,* SB-111 for cupro-nickel, SB-11, SB-13, SB-42, SB-75, or SB-111 for copper.*

**(b)** Seamless materials conforming to Specification SA-53, with the following additional requirements as to tensile properties, may be used for the manufacture of special seamless containers under the design limitations given in Par. U-141(**b**).

| Minimum Tensile Strength, Psi | Elongation in 2 In., Per Cent |
|---|---|
| 62,000 | 25 |
| 75,000 | 22 1/2 |
| 90,000 | 18 |

**(c)** All materials shall meet the impact test requirements of Par. U-142. If welded, the deposited weld metal and the heat affected zone shall also meet the impact test requirements of Par. U-142.

**U-141 Design** **(a)** The design and construction of vessels to operate at low temperature shall conform to the rules of this Code that are applicable to the type of fabrication used. If of welded construction, they shall conform to the requirements for welding given in Par. U-68 or U-69, or in Par. U-200 or U-201.

**(b)** Design stresses of one quarter the minimum tensile strengths specified in Par. U-140(**b**) for Specification SA-53 material may be used for special seamless containers, provided the following additional requirements are met:

* For welding of copper silicon alloys see Case No. 864, for nickel-copper alloy see Case No. 935, and for copper see Case No. 934.

***Par. U-141*** (*Continued*)

(**1**) The vessels are seamless with no holes except as herein provided;

(**2**) The end or head to which any attachments are made is thicker than the shell portion;

(**3**) The thickness of the vessel is gradually increased near the head to minimize stress concentrations;

(**4**) Outlet openings are not to exceed $^3/_4$ in. standard pipe size and are to be placed in the thickened part at or near the head at a point where the calculated stress, without holes, is not more than one half of the maximum allowable stress.

(**5**) No welding is utilized.

Two acceptable forms for the special containers covered by this paragraph are shown in Fig. U-30.

NOTE: *Considerable discussion has occurred in regard to Par. U-142. There are controversial opinions as to the suitability and applicability of impact tests in determining the safety in using a given material in a given design for a given set of operating conditions. The continuation of existing intent in this revision is not an implication that further revisions, particularly of Par. U-142, are not needed.*

**U-142 Impact Tests.** (**a**) Impact tests shall be run at the lowest temperature to which the vessel may be subjected during the operating cycle (an exception for dry ice converters is given in Case No. 845).

(**b**) **Number of Tests.** (**1**) For each pressure vessel, except as provided in (**4**), there shall be made one set of impact tests from each heat of material used for shell, heads, nozzles, or other pressure part in the assembly, except that no impact test is required for material to be used for nozzles, flanges, or covers having a thickness less than 0.098 in., or for material around openings that do not require reinforcement in accordance with Par. U-59. Certified reports of impact tests by the material producer will be acceptable evidence provided the material is not subjected to treatment during or following fabrication that will alter its impact resistance; if such treatment is subsequently applied to the material, the impact test must be made on specimens that are representative of the condition in which the material will be used. The length of the impact specimen shall, wherever possible, be taken parallel to the direction of the expected maximum stress. The required specimens for special seamless vessels may be taken from the end before the shell is thickened for closure.

***Par. U-142*** *(Continued)*

(**2**) Each set of impact tests shall consist of three specimens.

(**3**) In addition, if the vessels are of welded construction, test plates similar to those required by Par. U-68 shall be prepared for each vessel except as provided in (**4**). The test plate material shall be taken from one of the heats of material used in the vessel. One set of impact specimens shall be taken across the weld with the notch in the weld metal and one set shall be similarly taken with the notch in the adjacent metal in the heat-affected zone.

(**4**) For small vessels not exceeding the volume limitations defined by items (**1**) and (**2**) of Par. U-1(**a**), one set of specimens may represent all vessels from the same heat of material not in excess of 100 vessels or one heat-treatment furnace batch, whichever is smaller. In addition, when such vessels are welded, one test plate made from one of the heats of material used and two sets of impact specimens cut therefrom may represent the weld metal and the heat-affected zone metal respectively of one lot of 100 vessels or less, or of each heat-treatment furnace batch, whichever is smaller.

(**c**) **Temperatures of Tests.** Impact-test specimens shall be cooled to the temperature required for the test specified in (**a**) of this paragraph at which the vessel is to be operated. The specimens shall be uniformly cooled by subjecting them to the test temperature for at least 30 min and the handling tong shall be cooled similarly. The test shall be made within 8 sec after removal from the cooling medium.

(**d**) **Tests and Test Specimens.** Charpy-type impact tests are preferred. However, where this type of machine is not available, the Izod test may be substituted. The standard 10 mm × 10 mm specimen shall be used where the thickness is $^7/_{16}$ in. or greater and, for thinner material, a similar specimen shall be used, except that the dimension along the axis of the notch shall be reduced from 10 mm to the largest possible of 7.5 mm, 5 mm, or 2.5.

(**e**) **Details of Charpy Test.** Charpy tests shall be made on a standard Charpy machine using a keyhole or equivalent notch specimen as shown in Fig. U-31. The impact properties shall conform to the following:

| Charpy Impact Specimens, Keyhole or Equivalent Notch | Min Impact Value, Ft-Lb at Min Operating Temperatures |
|---|---|
| 10 mm × 10 mm | 15 |
| 10 mm × 7.5 mm | 12.5 |
| 10 mm × 5 mm | 10 |
| 10 mm × 2.5 mm | 5 |

***Par. U-142*** *(Continued)*

(f) **Details of Izod Test.** Izod tests shall be made on a standard Izod machine using a V-notch specimen as shown in Fig. U-32. The impact properties shall conform to the following:

| Izod Impact Specimens, V-Notch | Min Impact Value, Ft-Lb at Min Operating Temperatures |
|---|---|
| 10 mm × 10 mm | 18 |
| 10 mm × 7.5 mm | 15 |
| 10 mm × 5 mm | 10 |
| 10 mm × 2.5 mm | 4 |

(g) **Impact Test Results.** Each impact test specimen of the set shall meet the minimum requirements. When an erratic result is caused by a defective specimen, or there is uncertainty in test procedure, a retest will be allowed.

(h) **Heat-Treatment of Test Plates.** When the vessel is to be heat-treated, the test plates or samples from which the impact specimens are to be cut shall be heat-treated in the same manner as the vessels, before any machining.

***Par. U-143 Omit***

***Par. U-144 Omit***

***Par. U-204 Revised***

**U-204** Stresses due to hydrostatic head shall be taken into account in determining the minimum thickness of the shell or head. Additional stresses, imposed by effects other than working pressure and static head, which increase the average stress over substantial sections of the shell or head by more than 10 per cent of the allowable working stress shall be taken into account. These effects include the weight of the vessel and its contents, and method of support.

***Par. U-208*****(*****c*****)** ***Revised second section***

The specimens shall be ground or otherwise smoothed and then etched by any method or solution which will reveal the defects without unduly exaggerating or enlarging them (See Par. UA-85).

***Revised items (1) and (2) of third section***

(1) When the width of any single slag inclusion between layers of weld metal substantially parallel with the plate surface is not greater than one half the width of the weld metal where the slag inclusion is located;

***Par. U-208(c)*** (*Continued*)

(2) When the total thickness of all of the slag inclusions in any plane at approximately right angles to the plate surface is not greater than 10 per cent of the thickness of the thinner plate.

***Par. U-208(d) Add the following to the first section***

Any spot examined by this method may coincidentally represent one procedure, one operator, and one interval of 50 ft of joint length.

***Par. U-208(e)(2) Insert the following as the first sentence***

Welds in which the radiographs show any type of crack or zones of incomplete penetrations shall be unacceptable.

***Form U-1 Manufacturers' Data Report for Unfired Pressure Vessels. Revised item 20***

20. Nonpressure parts. (*a*) Supporting lugs, No.... Supporting skirts.... (*b*) Other nonpressure parts. Kind and number.... (*c*) Where and how attached................

***Table UA-3 Change title to read: "Dimensions of Class 125 Cast-Iron Flanges;" add the following to the note***

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For maximum water service pressures at or near the ordinary range of air temperature 175 psi (gage), sizes 1 to 2 in., inclusive, apply.

***Table UA-4 Revised***

TABLE UA-4 CAST-IRON FLANGED FITTINGS
DIMENSIONS OF CLASS 250 CAST-IRON FLANGES

**The following table is taken from ASA B16b–1944**

| Nominal pipe size, in. | Diameter of flange, in. | Thickness of flange, min,[2] in. | Diameter of raised face, in. | Diameter of bolt circle, in. | Diameter of bolt holes,[1] in. | Number of bolts[1] | Size of bolts, in. | Length of bolts,[4] in. | Wall[3] thickness of body, in. | Face-to-face dimension of length of tee, in. |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 4 7/8 | 11/16 | 2 11/16 | 3 1/2 | 3/4 | 4 | 5/8 | 2 1/2 | ... | .. |
| 1 1/4 | 5 1/4 | 3/4 | 3 1/16 | 3 7/8 | 3/4 | 4 | 5/8 | 2 1/2 | ... | .. |
| 1 1/2 | 6 1/8 | 13/16 | 3 9/16 | 4 1/2 | 7/8 | 4 | 3/4 | 2 3/4 | ... | .. |
| 2 | 6 1/2 | 7/8 | 4 3/16 | 5 | 3/4 | 8 | 5/8 | 2 3/4 | 7/16 | 10 |
| 2 1/2 | 7 1/2 | 1 | 4 15/16 | 5 7/8 | 7/8 | 8 | 3/4 | 3 1/4 | 1/2 | 11 |
| 3 | 8 1/4 | 1 1/8 | 5 11/16 | 6 5/8 | 7/8 | 8 | 3/4 | 3 1/2 | 9/16 | 12 |
| 3 1/2 | 9 | 1 3/16 | 6 5/16 | 7 1/4 | 7/8 | 8 | 3/4 | 3 1/2 | 9/16 | 13 |
| 4 | 10 | 1 1/4 | 6 15/16 | 7 7/8 | 7/8 | 8 | 3/4 | 3 3/4 | 5/8 | 14 |
| 5 | 11 | 1 3/8 | 8 5/16 | 9 1/4 | 7/8 | 8 | 3/4 | 4 | 11/16 | 16 |
| 6 | 12 1/2 | 1 7/16 | 9 11/16 | 10 5/8 | 7/8 | 12 | 3/4 | 4 | 3/4 | 17 |
| 8 | 15 | 1 5/8 | 11 15/16 | 13 | 1 | 12 | 7/8 | 4 1/2 | 13/16 | 20 |
| 10 | 17 1/2 | 1 7/8 | 14 1/16 | 15 1/4 | 1 1/8 | 16 | 1 | 5 1/4 | 15/16 | 23 |
| 12 | 20 1/2 | 2 | 16 7/16 | 17 3/4 | 1 1/4 | 16 | 1 1/8 | 5 1/2 | 1 | 26 |
| 14 OD | 23 | 2 1/8 | 18 15/16 | 20 1/4 | 1 1/4 | 20 | 1 1/8 | 6 | 1 1/8 | 30 |
| 16 OD | 25 1/2 | 2 1/4 | 21 1/16 | 22 1/2 | 1 3/8 | 20 | 1 1/4 | 6 1/4 | 1 1/4 | 33 |
| 18 OD | 28 | 2 3/8 | 23 5/16 | 24 3/4 | 1 3/8 | 24 | 1 1/4 | 6 1/2 | 1 3/8 | 36 |
| 20 OD | 30 1/2 | 2 1/2 | 25 9/16 | 27 | 1 3/8 | 24 | 1 1/4 | 6 3/4 | 1 1/2 | 39 |
| 24 OD | 36 | 2 3/4 | 30 1/4 | 32 | 1 11/16 | 24 | 1 1/2 | 7 3/4 | 1 5/8 | 45 |
| 30 OD | 43 | 3 | 37 3/16 | 39 1/4 | 2 | 28 | 1 3/4 | 8 1/2 | ... | .. |
| 36 OD | 50 | 3 3/8 | 43 11/16 | 46 | 2 1/4 | 32 | 2 | 9 1/2 | ... | .. |
| 42 OD | 57 | 3 11/16 | 50 7/16 | 52 3/4 | 2 1/4 | 36 | 2 | 10 1/4 | ... | .. |
| 48 OD | 65 | 4 | 58 7/16 | 60 3/4 | 2 1/4 | 40 | 2 | 10 3/4 | ... | .. |

NOTE: These flanges and fittings are rated as follows: For maximum saturated steam service pressures of 250 psi (gage), sizes 1 to 12 in., incl., 200 psi (gage), sizes 14 to 24 in., incl., 100 psi (gage), sizes 30 to 48 in., incl.; for maximum water service pressures at or near the ordinary range of air temperature, 400 psi (gage), sizes 1 to 12 in., incl., 300 psi (gage), sizes 14 to 48 in., incl.

[1] NOTE: Drilling templates are in multiples of 4, so that fittings may be made to face in any quarter, and bolt holes straddle the center line. For bolts smaller than 1 1/2 in., the bolt holes shall be drilled 1/8 in. larger in diameter than the nominal diameter of the bolt. Holes for bolts 1 1/2 in. shall be drilled 3/16 in. larger in diameter than the nominal diameter of the bolt. Holes for bolts 1 3/4 in. and larger shall be drilled 1/4 in. larger than nominal diameter of bolts.

[2] NOTE: All class 250 cast-iron standard flanges have a 1/16-in. raised face. This raised face is included in the face-to-face, center-to-face, and the minimum thicknesses of flange dimensions.

[3] Wall thickness at no point shall be less than 87 1/2 per cent of the dimensions given in the table.

[4] The bolting shall conform at least with the requirements of Par. 8 of ASA B16b–1944.