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PART PG
GENERAL REQUIREMENTS FOR ALL METHODS OF CONSTRUCTION

GENERAL

PG-1 SCOPE

The requirements of Part PG apply to power boilers and high pressure, high-temperature water boilers and to parts and appurtenances thereto and shall be used in conjunction with the specific requirements in the applicable Parts of this Section that pertain to the methods of construction used.

PG-2 SERVICE LIMITATIONS

PG-2.1 The rules of this Section are applicable to the following services:

(a) boilers in which steam or other vapor is generated at a pressure of more than 15 psig (103 kPa);

(b) high-temperature water boilers intended for operation at pressures exceeding 160 psig (1 100 kPa) and/or temperatures exceeding 250°F (121°C).

PG-2.2 For services below those specified in PG-2.1 it is intended that rules of Section IV apply; however, boilers for such services may be constructed and stamped in accordance with this Section provided all applicable requirements are met.

PG-2.3 Coil-type hot water boilers where the water can flash into steam when released directly to the atmosphere through a manually operated nozzle may be exempted from the rules of this Section provided the following conditions are met.

(a) There is no drum, header, or other steam space.

(b) No steam is generated within the coil.

(c) Tubing outside diameter does not exceed 1 in. (25 mm).

(d) Pipe size does not exceed NPS $^{3}/_{4}$ (DN 20).

(e) Nominal water capacity does not exceed 6 gal (23 l).

(f) Water temperature does not exceed 350°F (177°C).

(g) Adequate safety relief valves and controls are provided.

PG-3 REFERENCED STANDARDS

Specific editions of standards referenced in this Section are shown in Appendix A-360.

MATERIALS

PG-5 GENERAL

PG-5.1 Material subject to stress due to pressure shall conform to one of the specifications given in Section II and shall be limited to those that are listed in the Tables of Section II, Part D, except as otherwise permitted in PG-8.2, PG-8.3, PG-10, and PG-11. Materials shall not be used at temperatures above those for which stress values are limited, for Section I construction, in the Tables of Section II, Part D. Specific additional requirements described in PG-5 through PG-13 shall be met as applicable.

PG-5.2 Material covered by specifications in Section II is not restricted as to the method of production unless so stated in the specification, and as long as the product complies with the requirements of the specification.

PG-5.3 If, in the development of the art of boiler construction, it is desired to use materials other than those herein described, data should be submitted to the Boiler and Pressure Vessel Committee in accordance with the requirements of Appendix 5 of Section II, Part D. Material not completely identified with any approved Code specifications may be used in the construction of boilers under the conditions outlined in PG-10.

PG-5.4 Size Limits and Tolerances A02

PG-5.4.1 Materials outside the limits of size or thickness given in the title or scope clause of any specification in Section II may be used if the material is in compliance with the other requirements of the specification, and no similar limitation is given in the rules for construction.

PG-5.4.2 Pipe having a tolerance of ±1% on either the OD or the ID, rather than the tolerance specified in the material specification, may be used,

provided the material complies with all other requirements of the specifications. When used under external pressure, such pipe shall be limited to a maximum of 24 in. (610 mm) in diameter. The pipe shall include the designation 1% OD or 1% ID, as appropriate, in any required documentation and marking of the material.

PG-5.5 The use of austenitic alloy steel is permitted for boiler pressure parts that are steam touched in normal operation. Except as specifically provided in PG-9.1.1, PG-12, and PEB-5.3, the use of such austenitic alloys for boiler pressure parts that are water wetted in normal service is prohibited.[1]

PG-6 PLATE

01 A03

PG-6.1 Steel plates for any part of a boiler subject to pressure, whether or not exposed to the fire or products of combustion, shall be of pressure vessel quality in accordance with one of the following specifications:

SA-202 Pressure Vessel Plates, Alloy Steel, Chromium-Manganese-Silicon
SA-204 Pressure Vessel Plates, Alloy Steel, Molybdenum
SA-240 (Type 405 only) Pressure Vessel Plates, Alloy Steel (Ferritic Stainless), Chromium
SA-285 Pressure Vessel Plates, Carbon Steel, Low- and Intermediate-Tensile Strength
SA-299 Pressure Vessel Plates, Carbon Steel, Manganese-Silicon
SA-302 Pressure Vessel Plates, Alloy Steel, Manganese-Molybdenum and Manganese-Molybdenum-Nickel
SA-387 Pressure Vessel Plates, Alloy Steel, Chromium-Molybdenum
SA-515 Pressure Vessel Plates, Carbon Steel, for Intermediate- and Higher-Temperature Service
SA-516 Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service
SA/AS 1548 Steel Plates for Pressure Equipment
SA/EN-10028-2 Flat Products Made of Steels for Pressure Purposes
SA/JIS G3118 Carbon Steel Plates for Pressure Vessels for Intermediate and Moderate Temperature Service

[1] Austenitic alloys are susceptible to intergranular corrosion and stress corrosion cracking when used in boiler applications in water wetted service. Factors that affect the sensitivity to these metallurgical phenomena are applied or residual stress and water chemistry. Susceptibility to attack is usually enhanced by using the material in a stressed condition with a concentration of corrosive agents (e.g., chlorides, caustic, or reduced sulfer species). For successful operation in water environments, residual and applied stresses must be minimized and careful attention must be paid to continuous control of water chemistry.

PG-7 FORGINGS

PG-7.1 Seamless steel drum forgings made in accordance with SA-266 for Carbon-Steel and SA-336 for Alloy Steel may be used for any part of a boiler for which pressure vessel quality is specified or permitted.

PG-7.2 Forged flanges, fittings, nozzles, valves, and other pressure parts of the boiler shall be of material that conforms to one of the forging specifications as listed in PG-9.

PG-7.3 Drums, shells, or domes may be of seamless drawn construction, with or without integral heads, provided the material conforms to the requirements of the Code for shell material.

PG-8 CASTINGS

PG-8.1 Except for the limited usage permitted by PG-8.2 and PG-8.3, cast material used in the construction of vessels and vessel parts shall conform to one of the specifications listed in PG-9 for which maximum allowable stress values are given in Tables 1A and 1B of Section II, Part D. The allowable stress values shall be multiplied by the applicable casting quality factor given in PG-25 for all cast materials except cast iron.

When cast iron is used as allowed in PG-11.1 for standard pressure parts, it shall conform to one of these standards:

ASME B16.1, Cast Iron Pipe Flanges and Flanged Fittings

ASME B16.4, Cast Iron Threaded Fittings

Material conforming to ASTM A 126 may be used subject to all requirements of the particular standard. Such usage is subject also to all the requirements for the use of cast iron given in PG-8.2 and other paragraphs of this Section.

PG-8.2 Cast Iron

PG-8.2.1 Cast iron shall not be used for nozzles or flanges attached directly to the boiler for any pressure or temperature.

PG-8.2.2 Cast iron as designated in SA-278, Gray Iron Castings for Pressure-Containing Parts for Temperatures up to 650°F (343°C) may be used for boiler and superheater connections under pressure, such as pipe fittings, water columns, valves and their bonnets, for pressures up to 250 psi (1 720 kPa), provided the steam temperature does not exceed 450°F (232°C).

PG-8.3 Cast Nodular Iron. Cast nodular iron as designated in SA-395 may be used for boiler and superheater connections under pressure, such as pipe fittings, water columns, and valves and their bonnets, for pressures not to exceed 350 psi (2 410 kPa), provided the steam temperature does not exceed 450°F (232°C).

PG-8.4 Nonferrous. Bronze castings shall conform to SB-61 and SB-62 and may be used only for the following:

PG-8.4.1 For flanges and flanged or threaded fittings complying with the pressure and temperature requirements of ANSI B16.15 or B16.24, except that such fittings shall not be used where steel or other material is specifically required. Threaded fittings shall not be used where flanged types are specified.

PG-8.4.2.1 For valves at allowable stress values not to exceed those given in Table 1B of Section II, Part D, with maximum allowable temperatures of 550°F (288°C) for SB-61 and 406°F (208°C) for SB-62.

PG-8.4.2.2 For parts of safety valves or safety relief valves subject to limitations of PG-67.7.

PG-9 PIPES, TUBES, AND PRESSURE CONTAINING PARTS

Pipes, tubes, and pressure containing parts used in boilers shall conform to one of the specifications listed in this paragraph for which maximum allowable stresses are given in Tables 1A and 1B of Section II, Part D. The stress values given in these tables include the applicable joint efficiency factor for welded pipes and tubes.

Open-hearth, electric furnace, or basic oxygen steel shall be used for boiler pressure parts exposed to the fire or products of combustion. When used for internal pressure, the material stress and dimensions shall meet the appropriate requirements of PG-27 and Part PW and be in accordance with the following:

01 A02 **PG-9.1** Boiler parts shall be of the following specifications only:

SA-53 Welded and Seamless Steel Pipe (excluding galvanized)
SA-105 Forgings, Carbon Steel, for Piping Components
SA-106 Seamless Carbon Steel Pipe for High-Temperature Service
SA-178 Electric-Resistance-Welded Carbon Steel Boiler Tubes
SA-181 Forged or Rolled Steel Pipe Flanges, Forged Fittings, and Valves and Parts for General Service
SA-182 Forged or Rolled Alloy-Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service (ferritic only)
SA-192 Seamless Carbon Steel Boiler Tubes for High Pressure Service
SA-209 Seamless Carbon-Molybdenum Alloy-Steel Boiler and Superheater Tubes
SA-210 Seamless Medium Carbon Steel Boiler and Superheater Tubes
SA-213 Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater and Heat Exchanger Tubes (ferritic only)
SA-216 Carbon Steel Castings Suitable for Fusion Welding for High-Temperature Service
SA-217 Alloy-Steel Castings for Pressure-Containing Parts Suitable for High-Temperature Service
SA-234 Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and Elevated Temperatures
SA-250 Electric-Resistance-Welded Ferritic Alloy-Steel Boiler and Superheater Tubes
SA-266 Carbon Steel Seamless Drum Forgings
SA-268 Seamless and Welded Ferritic Stainless Steel Tubing for General Service
SA-335 Seamless Ferritic Alloy Steel Pipe for High-Temperature Service
SA-336 Alloy Steel Seamless Drum Forgings (ferritic only)
SA-423 Seamless and Electric Welded Low Alloy Steel Tubes
SA-660 Centrifugally Cast Carbon Steel Pipe for High-Temperature Service
SA-731 Seamless, Welded Ferritic, and Martensitic Stainless Steel Pipe

PG-9.1.1 Boiler parts on once-through boilers shall be any of the specifications listed in PG-9.1 or any of the following[2]:

SB-407 Nickel-Iron-Chromium Alloy Seamless Pipe and Tube
SB-408 Nickel-Iron-Chromium Alloy Rod and Bar
SB-409 Nickel-Iron-Chromium Alloy Plate, Sheet, and Strip
SB-423 Nickel-Iron-Chromium-Molybdenum Seamless Pipe and Tube
SB-424 Nickel-Iron-Chromium-Molybdenum-Copper Alloy Plate, Sheet, and Strip
SB-425 Nickel-Iron-Chromium-Molybdenum-Copper Alloy Rod and Bar
SB-515 Welded Nickel-Iron-Chromium Alloy Tubes
SB-564 Nickel Alloy Forgings

01 A02 **PG-9.2** Superheater parts shall be of any one of the specifications listed in PG-9.1 or one of the following:

SA-182 Forged or Rolled Alloy-Steel Pipe Flanges, Forged Fittings, and Valves and Plates for High-Temperature Service
SA-213 Seamless Ferritic and Austenitic Alloy Steel Boiler, Superheater and Heat Exchanger Tubes

[2] The maximum recommended feedwater-dissolved solids concentration for once-through boilers is 0.050 ppm.

SA-240 Stainless and Heat-Resisting Chromium and Chromium-Nickel Steel Plates, Sheet and Strip for Fusion-Welded Unfired Pressure Vessels
SA-249 Welded Austenitic Steel Boiler, Superheater, Heat Exchanger, and Condenser Tubes
SA-250 Electric-Resistance-Welded Ferritic Alloy-Steel Boiler and Superheater Tubes
SA-312 Seamless and Welded Austenitic Stainless Steel Pipe
SA-336 Alloy Steel Seamless Drum Forgings
SA-351 Ferritic and Austenitic Steel Castings for High-Temperature Service
SA-369 Ferritic Alloy Steel Forged and Bored Pipe for High-Temperature Service
SA-376 Seamless Austenitic Steel Pipe for High-Temperature Central-Station Service
SA-430 Austenitic Steel Forged and Bored Pipe for High-Temperature Service
SA-479 Stainless and Heat-Resisting Steel Bars and Shapes for Use in Boilers and Other Pressure Vessels
SA-731 Seamless, Welded Ferritic, and Martensitic Stainless Steel Pipe
SB-163 Seamless Nickel and Nickel Alloy Condenser and Heat Exchanger Tubes
SB-166 Nickel-Chromium Iron Alloys (UNS N06600, N06601, N06690, and N06045) and Nickel-Chromium-Cobalt-Molybdenum Alloy (UNS N06617) Rod, Bar, and Wire
SB-167 Nickel-Chromium Iron Alloys (UNS N06600, N06601, N06690, N06025, and N06045) Seamless Pipe and Tube
SB-168 Nickel-Chromium Iron Alloys (UNS N06600, N06601, N06690, N06026, and N06045) and Nickel-Chromium-Cobalt-Molybdenum Alloy (UNS N06617) Plate, Sheet, and Strip
SB-366 Factory-Made Wrought Nickel and Nickel Alloy Fittings
SB-407 Nickel-Iron-Chromium Alloy Seamless Pipe and Tube
SB-408 Nickel-Iron-Chromium Alloy Rod and Bar
SB-409 Nickel-Iron-Chromium Alloy Plate, Sheet, and Strip
SB-423 Nickel-Iron-Chromium-Molybdenum Seamless Pipe and Tube
SB-424 Nickel-Iron-Chromium-Molybdenum-Copper Alloy Plate, Sheet, and Strip
SB-425 Nickel-Iron-Chromium-Molybdenum-Copper Alloy Rod and Bar
SB-435 N06002, W06230, and R30556 Plate, Sheet, and Strip
SB-514 Welded Nickel-Iron-Chromium Alloy Pipe
SB-515 Welded Nickel-Iron-Chromium Alloy Tubes
SB-516 Welded Nickel-Chromium-Iron Alloy (UNS N06600), UNS N06025, and UNS N06045 Tubes
SB-517 Welded Nickel-Chromium-Iron Alloy (UNS N06600), UNS N06025, and UNS N06045 Pipe
SB-564 Nickel Alloy Forgings
SB-572 Nickel-Molybdenum-Chromium-Iron Alloy Rod
SB-619 Welded Nickel and Nickel-Cobalt Alloy Pipe
SB-622 Seamless Nickel and Nickel-Cobalt Alloy Pipe and Tube
SB-626 Welded Nickel and Nickel-Cobalt Alloy Tube

PG-9.3 Copper or copper alloy pipe or tubes shall not be used in the boiler proper for any service where the temperature exceeds 406°F (208°C). Copper and copper alloys shall be seamless, having a thickness not less than ANSI Schedule 40 standard pipe, and shall comply to one of the following specifications: SB-42, Seamless Copper Pipe, Standard Sizes; SB-43, Seamless Red Brass Pipe, Standard Sizes; SB-75, Seamless Copper Tube; or SB-111, Copper and Copper-Alloy Seamless Condenser Tubes and Ferrule Stock.

PG-9.4 Bimetallic tubes, having a core of an acceptable boiler and superheater material, and having an external cladding of another metal alloy, may be used provided the requirements of PG-27.2.1.5 are met for establishing minimum thickness of the core. The permissible variation in wall thickness tolerance of SA-450 or SB-163, as applicable, shall apply to the total wall thickness. The thickness and over and undertolerances of the cladding shall be included in the ordering information. Marking of the bimetallic tubular product shall meet the specification requirements of the core material, but shall also suitably identify the cladding alloy.

PG-9.5 ERW products shall be limited to a maximum thickness of $\frac{1}{2}$ in. (13 mm) for internal pressure applications. For external pressure applications, ERW products shall be limited to a maximum thickness of $\frac{1}{2}$ in. (13 mm) and a maximum size of NPS 24 (DN 600). The thickness and diameter limitations noted above shall be within tolerances stated by the product material specification. 01 A03

PG-10 MATERIAL IDENTIFIED WITH OR PRODUCED TO A SPECIFICATION NOT PERMITTED BY THIS SECTION, AND MATERIAL NOT FULLY IDENTIFIED

PG-10.1 Identified With Complete Certification From the Material Manufacturer. Material identified with a specification not permitted by this Section, or material procured to chemical composition requirements

and identified to a single production lot as required by a permitted specification may be accepted as satisfying the requirements of a specification permitted by this Section provided the conditions set forth in PG-10.1.1 or PG-10.1.2 are satisfied.

PG-10.1.1 Recertification by an organization other than the boiler or part manufacturer:

PG-10.1.1.1 All requirements, including but not limited to, melting method, melting practice, deoxidation, quality, and heat treatment, of the specification permitted by this Section, to which the material is to be recertified, have been demonstrated to have been met.

PG-10.1.1.2 A copy of the certification by the material manufacturer of the chemical analysis required by the permitted specification, with documentation showing the requirements to which the material was produced and purchased, and which demonstrates that there is no conflict with the requirements of the permitted specification, has been furnished to the boiler or part manufacturer.

PG-10.1.1.3 A certification that the material was manufactured and tested in accordance with the requirements of the specification to which the material is recertified, excluding the specific marking requirements, has been furnished to the boiler or part manufacturer, together with copies of all documents and test reports pertinent to the demonstration of conformance to the requirements of the permitted specification.

PG-10.1.1.4 The material, and the Certificate of Compliance or the Material Test Report have been identified with the designation of the specification to which the material is recertified and with the notation "Certified per PG-10."

PG-10.1.2 Recertification by the boiler or part manufacturer:

PG-10.1.2.1 A copy of the certification by the material manufacturer of the chemical analysis required by the permitted specification, with documentation showing the requirements to which the material was produced and purchased, which demonstrates that there is no conflict with the requirements of the permitted specification, is available to the Inspector.

PG-10.1.2.2 For applications in which the maximum allowable stresses are subject to a note of Table 1A of Section II, Part D, requiring the use of killed steel, documentation is available to the Inspector that establishes that the material is a killed steel.

PG-10.1.2.3 Documentation is available to the Inspector that demonstrates that the metallurgical structure, mechanical property, and hardness requirements of the permitted specification have been met.

PG-10.1.2.4 For material recertified to a permitted specification that requires a fine austenitic grain size or that requires that a fine grain practice be used during melting, documentation is available to the Inspector that demonstrates that the heat treatment requirements of the permitted specification have been met, or will be met during fabrication.

PG-10.1.2.5 The material has marking, acceptable to the Inspector, for identification to the documentation.

PG-10.1.2.6 When the conformance of the material with the permitted specification has been established, the material has been marked as required by the permitted specification.

PG-10.2 Material Identified to a Particular Production Lot as Required by a Specification Permitted by This Section but That Cannot Be Qualified Under PG-10.1. Any material identified to a particular production lot as required by a specification permitted by this Section, but for which the documentation required in PG-10.1 is not available, may be accepted as satisfying the requirements of the specification permitted by this Section provided that the conditions set forth below are satisfied.

PG-10.2.1 Recertification by an organization other than the boiler or part manufacturer — not permitted.

PG-10.2.2 Recertification by the boiler or part manufacturer.

PG-10.2.2.1 Chemical analyses are made on different pieces from the lot to establish a mean analysis which is to be accepted as representative of the lot. The pieces chosen for analyses shall be selected at random from the lot. The number of pieces selected shall be at least 10% of the number of pieces in the lot, but not less than three. For lots of three pieces or less, each piece shall be analyzed. Each individual analysis in the permitted specification and the mean for each element shall conform to the heat analysis limits of that specification. Analyses need to be made for only those elements required by the permitted specification. However, consideration should be given to making analyses for elements not specified in the specification but which would be deleterious if present in excessive amounts.

PG-10.2.2.2 Mechanical property tests are made in accordance with the requirements of the permitted specification and the results of the tests conform to the specified requirements.

PG-10.2.2.3 For applications in which the maximum allowable stresses are subject to a note of Table 1A of Section II, Part D, requiring the use of killed steel, documentation is available to the Inspector which establishes that the material is a killed steel.

PG-10.2.2.4 When the requirements of the permitted specification include metallurgical structure requirements (i.e., fine austenitic grain size), tests are made and the results are sufficient to establish that those requirements of the specification have been met.

PG-10.2.2.5 When the requirements of the permitted specification include heat treatment, the material is heat treated in accordance with those requirements, either prior to or during fabrication.

PG-10.2.2.6 When the conformance of the material with the permitted specification has been established, the material has been marked as required by the permitted specification.

PG-10.3 Material Not Fully Identified. Material which cannot be qualified under the provisions of either PG-10.1 or PG-10.2, such as material not fully identified as required by the permitted specification or as unidentified material, may be accepted as satisfying the requirements of a specification permitted by this Section provided that the conditions set forth below are satisfied.

PG-10.3.1 Qualification by an organization other than the boiler or part manufacturer — not permitted.

PG-10.3.2 Qualification by the boiler or part manufacturer:

PG-10.3.2.1 Each piece is tested to show that it meets the chemical composition for product analysis and the mechanical properties requirements of the permitted specification. Chemical analyses need only be made for those elements required by the permitted specification. However, consideration shall be given to making analyses for elements not specified in the specification but which would be deleterious if present in excessive amounts. For plates, when the direction of final rolling is not known, both a transverse and a longitudinal tension test specimen shall be taken from each sampling location designated in the permitted specification. The results of both tests shall conform to the minimum requirements of the specification, but the tensile strength of only one of the two specimens need conform to the maximum requirement.

PG-10.3.2.2 The provisions of PG-10.2.2.3, PG-10.2.2.4, and PG-10.2.2.5 are met.

PG-10.3.2.3 When the identity of the material with the permitted specification has been established in accordance with PG-10.3.2.1 and PG-10.3.2.2, each piece (or bundle, etc., if permitted in the specification) is marked with a marking giving the permitted specification number and grade, type, or class as applicable and a serial number identifying the particular lot of material. A suitable report, clearly marked as being a "Report on Tests of Nonidentified Material," shall be completed and certified by the boiler or part manufacturer. This report, when accepted by the Inspector, shall constitute authority to use the material in lieu of material procured to the requirements of the permitted specification.

PG-11 MISCELLANEOUS PRESSURE PARTS

Prefabricated or preformed pressure parts for boilers which are subject to allowable working stresses due to internal or external pressure in the boiler and which are furnished by other than the shop of the Manufacturer responsible for the completed boiler shall conform to all applicable requirements of the Code for the completed boiler, including inspection in the shop of the parts manufacturer and the furnishing of Manufacturer's Partial Data Reports as provided for in PG-112.2.4 except as permitted in PG-11.1, PG-11.2, and PG-11.3.

PG-11.1 Cast, Forged, Rolled, or Die Formed Standard Pressure Parts

PG-11.1.1 Pressure parts such as pipe fittings, valves, flanges, nozzles, welding necks, welding caps, manhole frames and covers, and casings of pumps that are part of a boiler circulating system that are wholly formed by casting, forging, rolling, or die forming shall not require inspection, mill test reports, or Partial Data Reports. Standard pressure parts that comply with some ASME Standard[3] shall be made of materials permitted by this Section or of materials specifically listed in an ASME product standard listed elsewhere in this Section but not of materials specifically prohibited or beyond use limitations listed in this Section. Standard pressure

[3] These are pressure parts that comply with some ASME product standard accepted by reference in PG-42. The ASME product standard establishes the basis for the pressure–temperature rating and marking.

parts that comply with a manufacturer's standard[4,5] shall be made of materials permitted by this Section. Such parts shall be marked with the name or trademark of the parts manufacturer and such other markings as are required by the standard. Such markings shall be considered as the parts manufacturer's certification that the product complies with the material specifications and standards indicated and is suitable for service at the rating indicated. The intent of the paragraph will have been met if, in lieu of the detailed marking on the part itself, the parts described herein have been marked in any permanent or temporary manner that will serve to identify the part with the parts manufacturer's written listing of the particular items and such listings are available for examination by the Inspector.

PG-11.1.2 Parts of small size falling within this category for which it is difficult or impossible to obtain identified material or that may be stocked and for which mill test reports or certificates cannot be economically obtained and are not customarily furnished, and that do not appreciably affect the safety of the vessel, may be used for relatively unimportant part or parts stressed to not more than 50% of the stress value permitted by this Section, and listed in Tables 1A and 1B of Section II, Part D, provided they are suitable for the purpose intended and meet the approval of the Inspector. The Manufacturer of the completed vessel shall satisfy himself that the part is suitable for the design conditions specified for the completed vessel.

PG-11.2 Cast, Forged, Rolled, or Die Formed Nonstandard Pressure Parts. Pressure parts such as shells, heads, removable and access opening cover plates, that are wholly formed by casting, forging, rolling, or die forming, may be supplied basically as materials. All such parts shall be made of materials permitted under this Section, and the manufacturer of the part shall furnish mill test reports or other acceptable evidence to that effect. Such parts shall be marked with the name or trademark of the parts manufacturer and with such other markings as will serve to identify the particular parts with accompanying material identification. The Manufacturer of the completed boiler shall satisfy himself that the part is suitable for the design conditions specified for the completed boiler.

PG-11.3 Welded Standard Pressure Parts for Use Other Than the Shell of a Vessel.[6] Pressure parts such as welded standard pipe fittings, caps, valves, and flanges that are fabricated by one of the welding processes recognized by this Section shall not require inspection, mill test reports, or Manufacturers' Partial Data Reports provided.[7]

PG-11.3.1 Standard pressure parts that comply with some ASME product standard[4] shall be made of materials permitted by this Section or of materials specifically listed in an ASME product standard accepted and listed elsewhere in this Section but not of materials specifically prohibited or beyond use limitations listed in this Section. Standard pressure parts that comply with a manufacturer's standard[4,5] shall be made of materials permitted by this Section.

PG-11.3.2 Welding for pressure parts that comply with a manufacturer's standard[4,5] shall comply with the requirements of PW-26 through PW-39. Welding for pressure parts that comply with some ASME product standard[3] shall comply with the requirements of PW-26 through PW-39 or, as a minimum, may comply with the welding requirements of SA-234. Markings where applicable, or certification by the parts manufacturer where markings are not applicable shall be accepted as evidence of compliance with the above welding requirements. Such parts shall be marked as required by PG-11.1.1.

PG-11.3.3 If radiographic examination or heat treatment is required by the applicable rules of this Section, it may be performed either in the plant of the parts manufacturer or in the plant of the Manufacturer of the completed vessel.

If the radiographic examination is done under the control of the parts manufacturer, the completed radiographs, properly identified, with a radiographic inspection report, shall be forwarded to the vessel manufacturer and shall be available to the Authorized Inspector.

PG-11.3.4 If heat treatment is performed at the plant of the parts manufacturer, certification by the parts manufacturer that such treatment was performed shall be accepted as evidence of compliance with applicable Code paragraphs. This certification shall be available to the Authorized Inspector. The Manufacturer of the completed vessel shall satisfy himself that the

[4] These are pressure parts that comply with a parts manufacturer's standard that defines the pressure–temperature rating marked on the part and described in the parts manufacturer's literature. The Manufacturer of the completed vessel shall satisfy himself that the part is suitable for the design conditions of the completed vessel.

[5] Pressure parts may be in accordance with an ASME product standard not covered by footnote 4, but such parts shall satisfy the requirements applicable to a parts manufacturer's standard and footnote 6.

[6] Fusion welded pipe, with added filler metal, for use as the shell of the vessel shall be subject to the same requirements as a shell fabricated from plate, including inspection at the point of manufacture and Manufacturers' Partial Data Reports.

[7] For requirements for welded water columns, see PW-42.

part is suitable for the design conditions specified for the completed vessel.

PG-12 GAGE GLASS BODY AND CONNECTOR MATERIALS

Gage glass body and connector materials shall comply with a Manufacturer's standard that defines the pressure–temperature rating marked on the unit. The materials used may include austenitic stainless steel.

PG-13 STAYS

Threaded stays shall be of steel complying with SA-36 or SA-675.

Seamless steel tubes for threaded stays shall comply with SA-192 or SA-210.

Staybolts, stays, through-rods, or stays with ends for attachment by fusion welding shall comply with SA-36 or SA-675.

DESIGN

PG-16 GENERAL

PG-16.1 The design of power boilers, high-temperature water boilers, and other pressure parts included within the scope of these rules shall conform to the general design requirements in the following paragraphs and in addition to the specific requirements for design given in the applicable Parts of this Section that pertain to the methods of construction used.

PG-16.2 When the pressure parts of a forced-flow steam generator with no fixed steam and waterline are designed for different pressure levels as permitted in PG-21.2, the owner shall provide or cause to be provided a boiler pressure system design diagram, certified by a Professional Engineer experienced in the mechanical design of power plants, which supplies the following information.

PG-16.2.1 The relative location of the various pressure parts within the scope of Section I, with respect to the path of water-steam flow.

PG-16.2.2 A line showing the expected maximum sustained pressure as described in PG-21.2, indicating the expected variation in pressure along the path of water-steam flow.

PG-16.2.3 The maximum allowable working pressure of the various pressure parts.

PG-16.2.4 The location and set pressure of the overpressure protection devices.

Copy of this diagram shall be attached to the Master Data Report per PG-113.

PG-16.3 Minimum Thicknesses. The minimum thickness of any boiler plate under pressure shall be $\frac{1}{4}$ in. (6 mm) except for electric boilers constructed under the rules of Part PEB. The minimum thickness of plates to which stays may be applied in other than cylindrical outer shell plates shall be $\frac{5}{16}$ (8 mm) in. When pipe over NPS 5 (DN 125) is used in lieu of plate for the shell of cylindrical components under pressure, its minimum wall shall be $\frac{1}{4}$ in. (6 mm).

PG-16.4 Undertolerance on Plates. Plate material that is not more than 0.01 in. (0.3 mm) 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. (0.3 mm) thinner than ordered.

PG-16.5 Undertolerance on Pipe and Tubes. Pipe or tube material shall not be ordered thinner than that calculated from the applicable formula of this Section. The ordered material shall include provision for the allowed manufacturing undertolerance as given in Section II in the applicable pipe or tube specification.

PG-17 FABRICATION BY A COMBINATION OF METHODS

A boiler and parts thereof may be designed and fabricated by a combination of the methods of fabrication given in this Section, provided the rules applying to the respective methods of fabrication are followed and the boiler is limited to the service permitted by the method of fabrication having the most restrictive requirements.

PG-18 HYDROSTATIC DEFORMATION TEST

Where no rules are given and it is impossible to calculate with a reasonable degree of accuracy the strength of a boiler structure or any part thereof, a full-sized sample shall be built by the Manufacturer and tested in accordance with the Standard Practice for Making a Hydrostatic Test on a Boiler Pressure Part to Determine the Maximum Allowable Working Pressure, given in A-22 or in such other manner as the Committee may prescribe.

TABLE PG-19 POST COLD-FORMING STRAIN LIMITS AND HEAT-TREATMENT REQUIREMENTS A03

Grade	UNS Number	Limitations in Lower Temperature Range for Design Temperature Exceeding °F	Exceeding °C	But Less Than or Equal to °F	But Less Than or Equal to °C	And Forming Strains Exceeding	Limitations in Higher Temperature Range For Design Temperature Exceeding °F	Exceeding °C	And Forming Strains Exceeding	Minimum Heat-Treatment Temperature When Design Temperature and Forming Strain Limits are Exceeded [Notes (1) and (2)] °F	°C
304	S30400	1,075	(579)	1,250	(676)	20%	1,250	(676)	10%	1,900	(1 038)
304H	S30409	1,075	(579)	1,250	(676)	20%	1,250	(676)	10%	1,900	(1 038)
304N	S30451	1,075	(579)	1,250	(676)	15%	1,250	(676)	10%	1,900	(1 038)
309S	S30908	1,075	(579)	1,250	(676)	20%	1,250	(676)	10%	2,000	(1 093)
310H	S31009	1,075	(579)	1,250	(676)	20%	1,250	(676)	10%	2,000	(1 093)
310S	S31008	1,075	(579)	1,250	(676)	20%	1,250	(676)	10%	2,000	(1 093)
316	S31600	1,075	(579)	1,250	(676)	20%	1,250	(676)	10%	1,900	(1 038)
316H	S31609	1,075	(579)	1,250	(676)	20%	1,250	(676)	10%	1,900	(1 038)
316N	S31651	1,075	(579)	1,250	(676)	15%	1,250	(676)	10%	1,900	(1 038)
321	S32100	1,000	(538)	1,250	(676)	15% [Note (3)]	1,250	(676)	10%	1,900	(1 038)
321H	S32109	1,000	(538)	1,250	(676)	15% [Note (3)]	1,250	(676)	10%	2,000	(1 093)
347	S34700	1,000	(538)	1,250	(676)	15%	1,250	(676)	10%	1,900	(1 038)
347H	S34709	1,000	(538)	1,250	(676)	15%	1,250	(676)	10%	2,000	(1 093)
348	S34800	1,000	(538)	1,250	(676)	15%	1,250	(676)	10%	1,900	(1 038)
348H	S34809	1,000	(538)	1,250	(676)	15%	1,250	(676)	10%	2,000	(1 093)
800	N08800	1,100	(593)	1,250	(676)	15%	1,250	(676)	10%	1,800	(982)
800H	N08810	1,100	(593)	1,250	(676)	15%	1,250	(676)	10%	2,050	(1 121)

GENERAL NOTE: The limits shown are for cylinders formed from plates, spherical or dished heads formed from plate, and tube and pipe bends. For flares, swages, and upsets, the forming strain limits shall be half those tabulated in this Table. When the forming strains cannot be calculated as shown in PG-19, the forming strain limits shall be half those tabulated in this Table (see PG-19.1).

NOTES:

(1) Rate of cooling from heat-treatment temperature not subject to specific control limits.

(2) While minimum heat-treatment temperatures are specified, it is recommended that the heat-treatment temperature range be limited to 150°F (83°C) above that minimum [250°F (139°C) temperature range for 347, 347H, 348, and 348H].

(3) For simple bends of tubes or pipes whose outside diameter is less than 3.5 in., this limit is 20%.

01 A03 PG-19 COLD FORMING OF AUSTENITIC MATERIALS[8]

The cold formed areas of pressure-retaining components manufactured of austenitic alloys shall be heat treated for twenty minutes per inch of thickness or for ten minutes, whichever is greater, at the temperatures given in Table PG-19 under the following conditions:

(a) The finishing-forming temperature is below the minimum heat-treating temperature given in Table PG-19; and

(b) The design metal temperature and the forming strains exceed the limits shown in Table PG-19.

Forming strains shall be calculated as follows:

(a) Cylinders formed from plate:

$$\%Strain = \frac{50t}{R_f}\left(1 - \frac{R_f}{R_o}\right)$$

(b) Spherical or dished heads formed from plate:

$$\%Strain = \frac{75t}{R_f}\left(1 - \frac{R_f}{R_o}\right)$$

(c) Tube and pipe bends:

$$\%Strain = \frac{100r}{R}$$

01 [8] See Section II, Part D, Appendix 6, para. 6-460, for background on the rules in PG-19.

(d) Tube or pipe flares, swages, or upsets (see Fig. PG-19); the larger of either the O.D. or I.D. hoop strain, the axial strain, or the radial strain. The absolute value of the largest strain is to be used as the basis for evaluation.

O.D. hoop strain:

$$\%Strain = \frac{(D - D_f)}{D}100$$

I.D. hoop strain:

$$\%Strain = \frac{(d - d_f)}{d}100$$

Axial strain:

$$\%Strain = \frac{(L - L_f)}{L}100$$

Radial strain:

$$\%Strain = \frac{(t - t_f)}{t}100$$

where

D = original O.D. of the pipe or tube
D_f = O.D. of the pipe or tube after forming
d = original I.D. of the pipe or tube
d_f = I.D. of the pipe or tube after forming
L = original length of the "constant volume process zone" for the tube or pipe in flaring, swaging, or upsetting forming operations
L_f = final length of the "constant volume process zone" for the tube or pipe in flaring, swaging, or upsetting forming operations
R = nominal bending radius to centerline of pipe or tube
R_f = mean radius after forming
R_o = original mean radius (equal to infinity for a flat plate)
r = nominal outside radius of pipe or tube
t = nominal thickness of the plate, pipe, or tube before forming
t_f = nominal thickness of the cylindrical portion after forming
V = volume of the cylindrical process zone prior to forming; $V = (\pi/4)(D^2 - d^2)$
V = V_f, i.e., forming is a constant volume process
V_f = volume of the cylindrical process zone after forming; $V_f = (\pi/4)(D_f^2 - d_f^2)$

PG-19.1 When the forming strains cannot be calculated as shown in PG-19, the manufacturer shall have the responsibility to determine the maximum forming strain. In such instances, the forming limits for flares, swages, or upsets in Table PG-19 shall apply.

PG-21 MAXIMUM ALLOWABLE WORKING PRESSURE

The maximum allowable working pressure is the pressure determined by employing the allowable stress values, design rules, and dimensions designated in this Section.

Whenever the term maximum allowable working pressure is used in this Section of the Code, it refers to gage pressure, or the pressure above atmosphere in pounds per square inch.

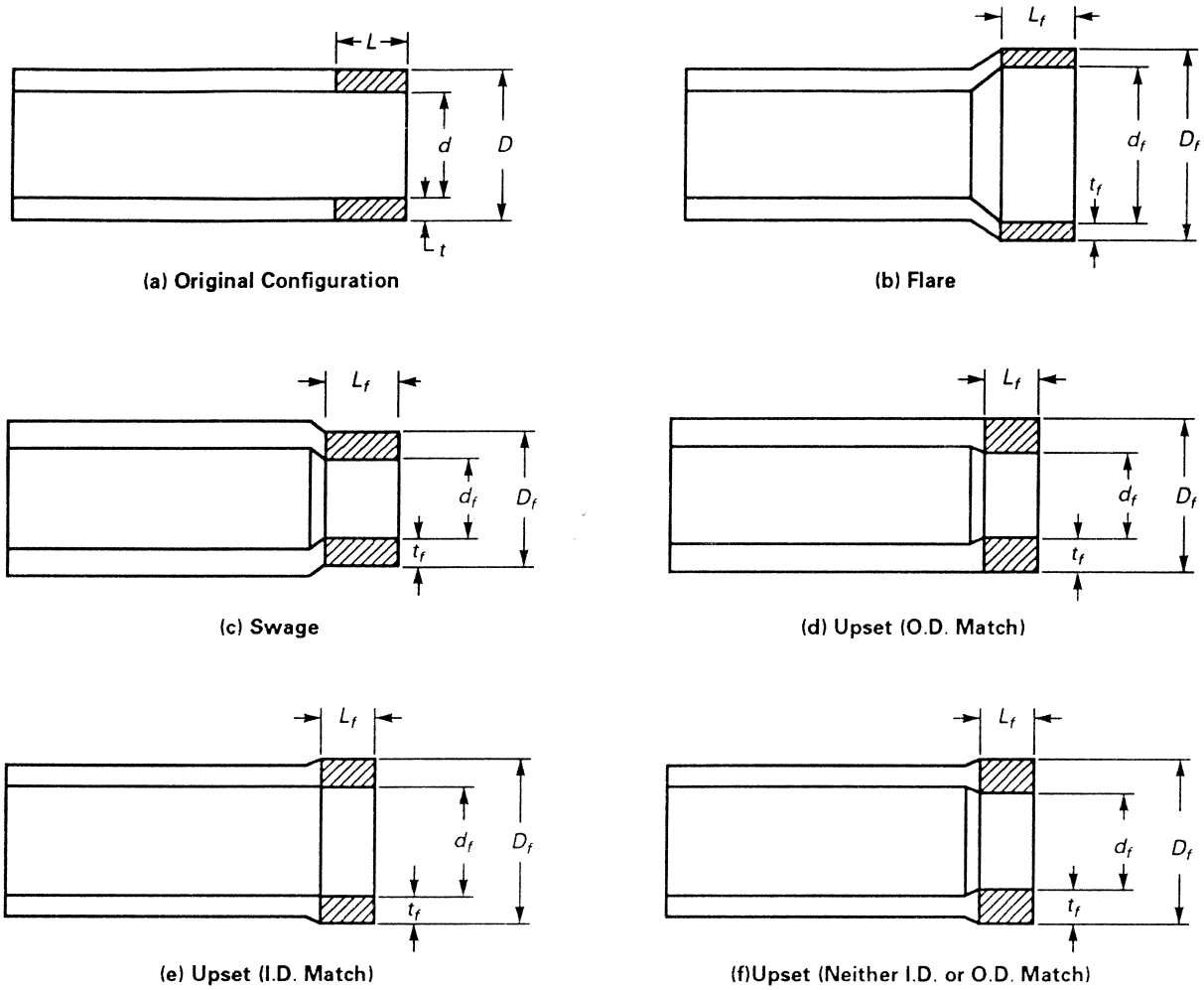
PG-21.1 No boiler, except a forced-flow steam generator with no fixed steam and water line that meets the special provisions of PG-67, shall be operated at a pressure higher than the maximum allowable working pressure except when the safety valve or safety relief valve or valves are discharging, at which time the maximum allowable working pressure shall not be exceeded by more than 6%.

PG-21.2 In a forced-flow steam generator with no fixed steam and waterline it is permissible to design the pressure parts for different pressure levels along the path of water-steam flow. The maximum allowable working pressure of any part shall be not less than that required by the rules of Part PG for the expected maximum sustained conditions[9] of pressure and temperature to which that part is subjected except when one or more of the overpressure protection devices covered by PG-67.4 is in operation.

PG-22 LOADINGS

PG-22.1 Stresses due to hydrostatic head shall be taken into account in determining the minimum thick-

[9] "Expected maximum sustained conditions of pressure and temperature" are intended to be selected sufficiently in excess of any expected operating conditions (not necessarily continuous) to permit satisfactory boiler operation without operation of the overpressure protection devices.



GENERAL NOTE:
$V = V_f$

FIG. PG-19 COLD FORMING OPERATIONS FOR FLARING, SWAGING, AND UPSETTING OF TUBING
(The Above Illustrations Are Diagrammatic Only)

ness required unless noted otherwise. Additional stresses imposed by effects other than working pressure or static head that increase the average stress by more than 10% of the allowable working stress shall also be taken into account. These effects include the weight of the component and its contents, and the method of support.

PG-22.2 Loading on structural attachments — refer to PW-43.

PG-23 STRESS VALUES FOR CALCULATION FORMULAS

A03 **PG-23.1** The maximum allowable stress values in Tables 1A and 1B of Section II, Part D, are the unit stresses to be used in the formulas of this Section to calculate the minimum required thickness or the maximum allowable working pressure of the pressure part (see Appendix 1 of Section II, Part D).

PG-23.2 The yield strength values for use in PFT-51 may be found in Table Y-1 of Section II, Part D.

PG-25 QUALITY FACTORS FOR STEEL CASTINGS

A quality factor as specified below shall be applied to the allowable stresses for steel casting materials given in Table 1A of Section II, Part D.

PG-25.1 A factor not to exceed 80% shall be applied when a casting is inspected only in accordance with the minimum requirements of the specification for the material, except when the special methods of examination prescribed by the selected specification are followed, thus permitting the use of the applicable higher factor in this paragraph.

PG-25.2 A factor not to exceed 100% shall be applied when the casting meets the following requirements.

PG-25.2.1 All steel castings $4\frac{1}{2}$ in. (114 mm) nominal body thickness or less, other than steel flanges and fittings complying with ASME B16.5, and valves complying with ASME B16.34, shall be inspected as follows:

01 **PG-25.2.1.1** All critical areas, including the junctions of all gates, risers, and abrupt changes in section or direction and weld-end preparations, shall be radiographed in accordance with Article 2 of Section V, and the radiographs shall conform to the requirements of ASTM E 446, Standard Reference Radiographs for Steel Castings Up to 2 in. (51 mm) in Thickness, or ASTM E 186, Standard Reference Radiographs for Heavy Walled [2 in. to $4\frac{1}{2}$ in. (51 mm to 114 mm)] Steel Castings, depending upon the section thickness. The maximum acceptable severity level for 100% quality factor shall be:

For ASTM E 446 [castings up to 2 in. (51 mm) thickness]:

	Severity Level	
Imperfection Category	Up to and Including 1 in. (25 mm) Thick	Greater Than 1 in. (25 mm) Thick
A	1	2
B	2	3
C Types 1, 2, 3, and 4	1	3
D, E, F, and G	None acceptable	None acceptable

For ASTM E 186 [castings 2 in. to $4\frac{1}{2}$ in. (51 mm to 114 mm) thickness]:

Imperfection Category	Severity Level
A and B, Types 1 and 2 of C	2
Type 3 of C	3
D, E, and F	None acceptable

PG-25.2.1.2 All surfaces of each casting, including machined gasket seating surfaces, shall be examined after heat treatment by the magnetic particle method in accordance with PG-25.2.1.2.1 or by the liquid penetrant method in accordance with PG-25.2.1.2.2.

PG-25.2.1.2.1 The technique for magnetic particle examination shall be in accordance with Article 7 of Section V. Imperfections causing magnetic particle indications exceeding degree 1 of Type I, degree 2 of Type II, and degree 3 of Type III, and exceeding degree 1 of Types IV and V of ASTM E 125, Standard Reference Photographs for Magnetic Particle Indications on Ferrous Castings, are unacceptable.

PG-25.2.1.2.2 The technique for liquid penetrant examination shall be in accordance with Article 6 of Section V. Surface indications determined by liquid penetrant examination are unacceptable if they exceed the following:

(a) all cracks and hot tears;

(b) any group of more than six linear indications other than those in (a) in any rectangular area of $1\frac{1}{2}$ in. × 6 in. (38 mm × 152 mm) or less, or any circular area having a diameter of $3\frac{1}{2}$ in. (89 mm) or less, these areas being taken in the most unfavorable location relative to the indications being evaluated;

(c) other linear indications more than $^1/_4$ in. (6 mm) long for thicknesses up to $^3/_4$ in. (19 mm) inclusive, more than one-third of the thickness in length for thicknesses from $^3/_4$ in. to $2^1/_4$ in. (19 mm to 57 mm), and more than $^3/_4$ in. (19 mm) long for thicknesses over $2^1/_4$ in. (57 mm). (Aligned acceptable indications separated from one another by a distance equal to the length of the longer indication are acceptable.);

(d) all indications of nonlinear imperfections that have any dimension exceeding $^3/_{16}$ in. (4.8 mm).

PG-25.2.1.3 Where more than one casting of a particular design is produced, each of the first five castings shall be inspected as above. Where more than five castings are being produced, the examination shall be performed on the first five plus one additional casting to represent each five additional castings. If this additional casting proves to be unacceptable, each of the remaining castings in the group shall be inspected.

PG-25.2.1.4 Any indications in excess of the maximum permitted in PG-25.2.1.1 and PG-25.2.1.2 shall be cause for rejection unless the casting is repaired by welding after the base metal has been inspected to ensure that the imperfection has been removed or reduced to an acceptable size. The completed repair shall be subject to reinspection by the same method as was used in the original inspection and the repaired casting shall be postweld heat treated.

PG-25.2.1.5 All welding shall be performed using welding procedures qualified in accordance with Section IX. The procedure qualification shall be performed on test specimens of cast material of the same specification and subjected to the same heat treatment before and after welding as will be applied to the work. All welders and operators performing this welding shall also be qualified in accordance with Section IX.

PG-25.2.2 All steel castings having a body greater than $4^1/_2$ in. (114 mm) nominal thickness shall be inspected as follows:

PG-25.2.2.1 All surfaces of each casting, including machined gasket seating surfaces, shall be examined after heat treatment by the magnetic particle method in accordance with PG-25.2.1.2.1 or liquid penetrant method in accordance with PG-25.2.1.2.2.

01 **PG-25.2.2.2** All parts of castings shall be subjected to complete radiographic inspection in accordance with Article 2 of Section V, and the radiographs shall conform to the requirements of ASTM E 280, Standard Reference Radiographs for Heavy Walled [$4^1/_2$ in. to 12 in. (114 mm to 305 mm)] Steel Castings.

The maximum acceptable severity level for a 100% quality factor shall be:

Imperfection Category	Severity Level
A, B, and Types 1, 2, and 3 of C	2
D, E, and F	None acceptable

PG-25.2.2.3 Any indications in excess of the maximum permitted in PG-25.2.2.1 and PG-25.2.2.2 are unacceptable. The casting may be repaired by welding after the base metal has been magnetic particle or dye penetrant inspected to ensure that the imperfection has been removed or reduced to an acceptable size.

PG-25.2.2.4 All weld repairs of depth exceeding 1 in. (25 mm) or 20% of the section thickness, whichever is less, shall be inspected by radiography in accordance with PG-25.2.2.2 and by magnetic particle or dye penetrant inspection of the finished weld surface. All weld repairs of depth less than 20% of the section thickness, or 1 in. (25 mm), whichever is less, and all weld repairs of sections which cannot be effectively radiographed shall be examined by magnetic particle or dye penetrant inspection of the first layer, of each $^1/_4$ in. (6 mm) thickness of deposited weld metal and of the finished weld surface. Magnetic particle or dye penetrant testing of the finished weld surface shall be done after postweld heat treatment.

PG-25.2.2.5 When repair welding is done after heat treatment of the casting, the casting shall be postweld heat treated.

PG-25.2.2.6 All welding shall be performed using welding procedures qualified in accordance with Section IX. The procedure qualification shall be performed on test specimens of cast material of the same specification and subjected to the same heat treatment before and after welding as will be applied to the work. All welders and operators performing this welding shall also be qualified in accordance with Section IX.

PG-25.2.3 Identification and Marking. Each casting to which a quality factor greater than 80% is applied shall be marked with the name, trademark, or other traceable identification of the manufacturer and the casting identification, including the casting quality factor and material designation.

PG-25.2.4 Personnel performing radiographic, magnetic particle, or liquid penetrant examinations under this paragraph shall be qualified in accordance with

their employer's written practice. SNT-TC-1A[10] or CP-189 shall be used as a guideline for employers to establish their written practice for qualification and certification of their personnel.

When personnel have been certified according to their employer's written practice based upon an edition of SNT-TC-1A or CP-189 earlier than that referenced in A-360, their certification shall be valid for performing nondestructive examination required by this Section until their next scheduled recertification. Any recertifications, reexaminations, or new examinations shall be performed to the employer's written practice based on the edition of SNT-TC-1A or CP-189 referenced in A-360.

PG-27 CYLINDRICAL COMPONENTS UNDER INTERNAL PRESSURE

PG-27.1 General. The formulas under this paragraph shall be used to determine the minimum required thickness or the maximum allowable working pressure of piping, tubes, drums, and headers in accordance with the appropriate dimensional categories as given in PG-27.2.1, PG-27.2.2, and PG-27.2.3 for temperatures not exceeding those given for the various materials listed in Tables 1A and 1B of Section II, Part D.

The calculated and ordered thickness of material must include the requirements of PG-16.2, PG-16.3, and PG-16.4. Stress calculations must include the loadings as defined in PG-22 unless the formula is noted otherwise.

When required by the provisions of this Code, allowance must be provided in material thickness for threading and minimum structural stability. (See PWT-9.2 and PG-27.4, Notes 3 and 5.)

PG-27.2 Formulas for Calculation

PG-27.2.1 Tubing — Up to and Including 5 in. (127 mm) Outside Diameter

$$t = \frac{PD}{2S + P} + 0.005D + e$$

$$P = S\left[\frac{2t - 0.01D - 2e}{D - (t - 0.005D - e)}\right]$$

See PG-27.4, Notes 2, 4, 8, and 10.

PG-27.2.1.1 For tubes of the materials listed in its title, Table PWT-10 may be used in lieu of the formula for determining the minimum wall thickness of tubes where expanded into drums or headers, provided the maximum mean wall temperature does not exceed 700°F (371°C).

PG-27.2.1.2 The wall thickness of the ends of tubes strength-welded to headers or drums need not be made greater than the run of the tube as determined by this formula.

PG-27.2.1.3 The wall thickness of the ends of tubes permitted to be attached by threading under the limitations of PWT-9.2 shall be not less than t as determined by this formula, plus $0.8/n$, where n equals the number of threads per inch.

PG-27.2.1.4 A tube in which a fusible plug is to be installed shall be not less than 0.22 in. (5.6 mm) in thickness at the plug in order to secure four full threads for the plug (see also A-20).

PG-27.2.1.5 Bimetallic tubes meeting the requirements of PG-9.4 shall use as an outside diameter D in the equation in PG-27.2.1 no less than the calculated outside diameter of the core material. The outside diameter of the core material shall be determined by subtracting the minimum thickness of the cladding from the outside diameter of the bimetallic tube, including the maximum plus tolerance. The minimum required thickness t shall apply only to the core material.

PG-27.2.2 Piping, Drums, and Headers. (Based on strength of weakest course)

$$t = \frac{PD}{2SE + 2yP} + C \quad \text{or} \quad \frac{PR}{SE - (1 - y)P} + C$$

$$P = \frac{2SE(t - C)}{D - 2y(t - C)} \quad \text{or} \quad \frac{SE(t - C)}{R + (1 - y)(t - C)}$$

See PG-27.4, Notes 1, 3, and 5 through 9.

PG-27.2.3 Thickness Greater Than One-Half the Inside Radius of the Component. The maximum allowable working pressure for parts of boilers of cylindrical cross section, designed for temperatures up to that of saturated steam at critical pressure [705.4°F (374.1°C)], shall be determined by the formulas in A-125.

PG-27.3 Symbols. Symbols used in the preceding formulas are defined as follows:

[10] SNT-TC-1A and CP-189 are published by the American Society for Nondestructive Testing, 1711 Arlingate Lane, PO Box 28518, Columbus, OH 43228-0518.

t = minimum required thickness, in. (mm) (see PG-27.4, Note 7)
P = maximum allowable working pressure, psi (kPa) (see PG-21)
D = outside diameter of cylinder, in. (mm)
R = inside radius of cylinder, in. (mm)
E = efficiency (see PG-27.4, Note 1)
S = maximum allowable stress value at the design temperature of the metal, as listed in the tables specified in PG-23, psi (see PG-27.4, Note 2)
C = minimum allowance for threading and structural stability, in. (see PG-27.4, Note 3)
e = thickness factor for expanded tube ends (see PG-27.4, Note 4)
y = temperature coefficient (see PG-27.4, Note 6)

PG-27.4 Notes. Notes referenced in the preceding formulas are as follows:

Note 1:
E = 1.00 for seamless or welded cylinders
= the efficiency from PG-52 or PG-53 for ligaments between openings

01 **Note 2:**
The temperature of the metal to be used in selecting the S value for tubes shall not be less than the maximum expected mean wall temperature, i.e., the sum of the outside and inside tube surface temperatures divided by 2. For tubes that do not absorb heat, the metal temperature may be taken as the temperature of the fluid within the tube but not less than the saturation temperature.

Note 3:
Any additive thickness represented by the general term C may be considered to be applied on the outside, the inside, or both. It is the responsibility of the designer using these formulas to make the appropriate selection of diameter or radius to correspond to the intended location and magnitude of this added thickness. The pressure- or stress-related terms in the formula should be evaluated using the diameter (or radius) and the remaining thickness which would exist if the "additive" thickness had not been applied or is imagined to have been entirely removed.

The values of C below do not include any allowance for corrosion and/or erosion, and additional thickness should be provided where they are expected. Likewise, this allowance for threading and minimum structural stability is not intended to provide for conditions of misapplied external loads or for mechanical abuse.

Type of Pipe	Value of C[b], in. (mm)
Threaded steel, or nonferrous pipe[a]	
$\frac{3}{4}$ in. (19 mm) nominal, and smaller	0.065 (1.65)
1 in. (25 mm) nominal and larger	Depth of thread h[c]
Plain end[d] steel, or nonferrous pipe	
$3\frac{1}{2}$ in. (89 mm), nominal and smaller	0.065 (1.65)
4 in. (102 mm), nominal and larger	0

(a) Steel or nonferrous pipe lighter than Schedule 40 of ASME B36.10M, Welded and Seamless Wrought Steel Pipe, shall not be threaded.

(b) The values of C stipulated above are such that the actual stress due to internal pressure in the wall of the pipe is no greater than the values of S given in Table 1A of Section II, Part D, as applicable in the formulas.

(c) The depth of thread h in in. may be determined from the formula $h = 0.8/n$, where n is the number of threads per inch or from the following:

n	h
8	0.100
$11\frac{1}{2}$	0.0696

(d) Plain-end pipe includes pipe jointed by flared compression couplings, lap (Van Stone) joints, and by welding, i.e., by any method that does not reduce the wall thickness of pipe at the joint.

Note 4:
e = 0.04 over a length at least equal to the length of the seat plus 1 in. (25 mm) for tubes expanded into tube seats, except
= 0 for tubes expanded into tube seats provided the thickness of the tube ends over a length of the seat plus 1 in. is not less than the following:
0.095 in. (2.41 mm) for tubes $1\frac{1}{4}$ in. (32 mm) O.D. and smaller
0.105 in. (2.67 mm) for tubes above $1\frac{1}{4}$ in. (32 mm) O.D. and up to 2 in. (51 mm) O.D., incl.
0.120 in. (3.05 mm) for tubes above 2 in. (51 mm) O.D. and up to 3 in. (76 mm) O.D., incl.
0.135 in. (3.43 mm) for tubes above 3 in. (76 mm) O.D. and up to 4 in. (102 mm) O.D., incl.
0.150 in. (3.81 mm) for tubes above 4 in. (102 mm) O.D. and up to 5 in. (127 mm) O.D., incl.
= 0 for tubes strength-welded to headers and drums

Note 5:
While the thickness given by the formula is theoretically ample to take care of both bursting pressure and material removed in threading, when steel pipe is threaded and used for steam pressures of 250 psi (1 720 kPa) and over, it shall be seamless and of a weight at least equal to Schedule 80 in order to furnish added mechanical strength.

01 A03 **Note 6:**

y = a coefficient having values as follows:

	Temperature, °F (°C)							
	900 (482) and below	950 (510)	1,000 (538)	1,050 (566)	1,100 (593)	1,150 (621)	1,200 (649)	1,250 (677) and above
Ferritic	0.4	0.5	0.7	0.7	0.7	0.7	0.7	0.7
Austenitic	0.4	0.4	0.4	0.4	0.5	0.7	0.7	0.7
Alloy 800	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.7
800H, 800HT	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.7
825	0.4	0.4	0.4	...	...	...	...	...
230 Alloy	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.7
N06045	0.4	0.4	0.4	0.4	0.5	0.7	0.7	0.7
Alloy 617	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.7

Values of y between temperatures listed may be determined by interpolation. For nonferrous materials, $y = 0.4$.

Note 7:

If pipe is ordered by its nominal wall thickness, as is customary in trade practice, the manufacturing tolerance on wall thickness must be taken into account. After the minimum pipe wall thickness t is determined by the formula, this minimum thickness shall be increased by an amount sufficient to provide the manufacturing tolerance allowed in the applicable pipe specification. The next heavier commercial wall thickness may then be selected from Standard thickness schedules as contained in ASME B36.10M. The manufacturing tolerances are given in the several pipe specifications listed in PG-9.

Note 8:

When computing the allowable pressure for a pipe of a definite minimum wall thickness, the value obtained by the formulas may be rounded out to the next higher unit of 10.

Note 9:

Inside backing strips, when used at longitudinal welded joints, shall be removed and the weld surface prepared for radiographic examination as required. Inside backing rings may remain at circumferential welded seams of cylinders provided such construction complies with requirements of PW-41.

Note 10:

The maximum allowable working pressure P need not include the hydrostatic head loading, PG-22, when used in this formula.

PG-28 WELDED ACCESS OR INSPECTION OPENINGS UNDER EXTERNAL PRESSURE

The maximum allowable working pressure for welded access or inspection openings, with inward projections subjected to external pressure (such as manhole or handhole rings with internal covers), may be determined in accordance with the rules of PG-27 when the following requirements are met. The length of the internal projection of the ring extending past the toe of the attachment weld on the ring, shall not exceed the thickness of the ring. The length past the toe of the weld is measured at the location of the shortest ring prjection into the vessel (see Fig. PG-28). For elliptical rings the value of D to be used in the procedures of PG-27 shall be determined in accordance with the following equation for elliptical rings:

$$D = a^2/b$$

where

a = outside major axis of the ellipse
b = outside minor axis of the ellipse

This provision does not apply to flanged in manholes covered by PG-29.3, PG-29.7, and PG-29.12.

PG-29 DISHED HEADS

PG-29.1 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:

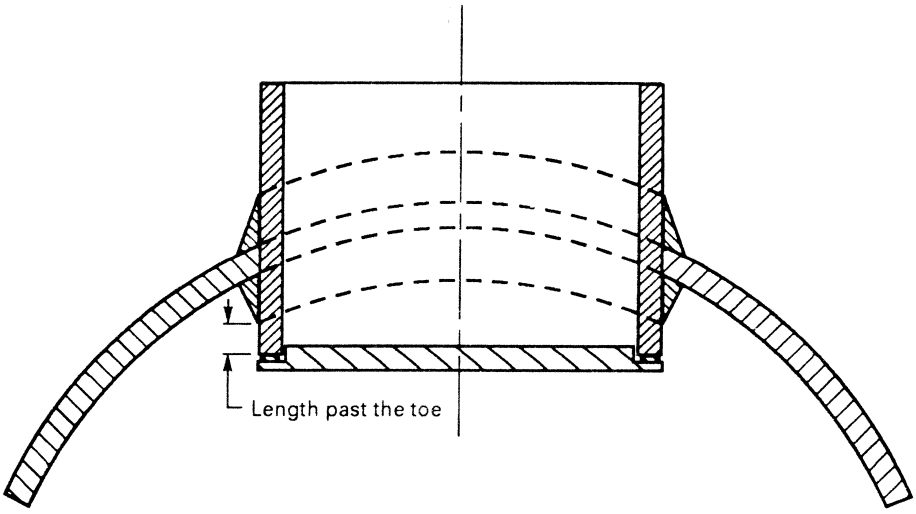
$$t = 5PL/4.8S$$

where

t = minimum thickness of head, in. (mm)
P = maximum allowable working pressure, psi (kPa) (hydrostatic head loading need not be included)
L = radius to which the head is dished, measured on the concave side of the head, in. (mm)
S = maximum allowable working stress, psi (kPa), using values given in Table 1A of Section II, Part D.

PG-29.2 The radius to which a head is dished shall be not greater than the outside diameter of flanged portion of the head. Where two radii are used the longer shall be taken as the value of L in the formula.

PG-29.3 When a head dished to a segment of a sphere has a flanged-in manhole or access opening that exceeds 6 in. (152 mm) in any dimension, the thickness shall be increased by not less than 15% of the required thickness for a blank head computed by the above formula, but in no case less than $\frac{1}{8}$ in. (3.2 mm) 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



GENERAL NOTE: For other acceptable weld configurations, see Fig. PW-16.1.

FIG. PG-28 MAXIMUM INTERNAL PROJECTION OF WELDED ACCESS OR INSPECTION OPENINGS

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.

PG-29.4 Except as otherwise provided for in PG-29.3, PG-29.7, and PG-29.12, 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 in PG-33.

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

PG-29.5 Where the radius L to which the head is dished is less than 80% 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% 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 and the maximum allowable working stress shall not exceed the values given in Table 1A of Section II, Part D.

PG-29.6 No head, except a full-hemispherical head, shall be of a lesser thickness than that required for a seamless shell of the same diameter.

PG-29.7 A blank head of a semiellipsoidal 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 as provided in PG-27.2.2. If a flanged-in manhole that 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 (see PG-29.1 and PG-29.5) with a dish radius equal to eight-tenths the diameter of the shell and with the added thickness for the manhole as specified in PG-29.3.

PG-29.8 When heads are made to an approximate ellipsoidal shape, the inner surface of such heads must lie outside and not inside of a true ellipse drawn with the major axis equal to the inside diameter of the head and one-half the minor axis equal to the depth of the head. The maximum variation from this true ellipse shall not exceed 0.0125 times the inside diameter of the head.

PG-29.9 Unstayed dished heads with the pressure on the convex side shall have a maximum allowable working pressure equal to 60% of that for heads of the same dimensions with the pressure on the concave side.

Head thicknesses obtained by using the formulas in PG-29.11 for hemispherical heads and PG-29.7 for

blank semiellipsoidal heads do not apply to heads with pressure on the convex side.

A02 PG-29.10 DELETED

A02 **PG-29.11** The thickness of a blank unstayed full-hemispherical head with the pressure on the concave side shall be calculated by the following formula:

$$t = \frac{PL}{2S - 0.2P}$$

where

t = minimum thickness of head, in. (mm)
P = maximum allowable working pressure, psi (kPa)
L = radius to which the head was formed, measured on the concave side of the head, in. (mm)
S = maximum allowable working stress, psi (kPa), using values given in Table 1A of Section II, Part D

The above formula shall not be used when the required thickness of the head given by this formula exceeds 35.6% of the inside radius, and instead, the following formula shall be used:

$$t = L(Y^{1/3} - 1)$$

where

$$Y = \frac{2(S + P)}{2S - P}$$

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 buttwelded joint attaching a head to a shell the middle lines of the plate thicknesses need not be in alignment.

PG-29.12 If a flanged-in manhole that 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 PG-29.1 and PG-29.5), with a dish radius equal to eight-tenths the diameter of the shell and with the added thickness for the manhole as specified in PG-29.3.

PG-29.13 The corner radius of an unstayed dished head measured on the concave side of the head shall be not less than three times the thickness of the material in the head; but in no case less than 6% 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% of the thickness required by the formula in PG-29.1. Other types of heads shall have a thickness after forming of not less than that required by the applicable formula.

PG-30 STAYED DISHED HEADS

PG-30.1 When dished heads are of a thickness less than called for by PG-29, 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:

PG-30.1.1 That they be at least two-thirds as thick as called for by the rules for unstayed dished heads.

PG-30.1.2 That they be at least $^{7}/_{8}$ in. (22 mm) in thickness.

PG-30.1.3 That through-stays be used attached to the dished head by outside and inside nuts.

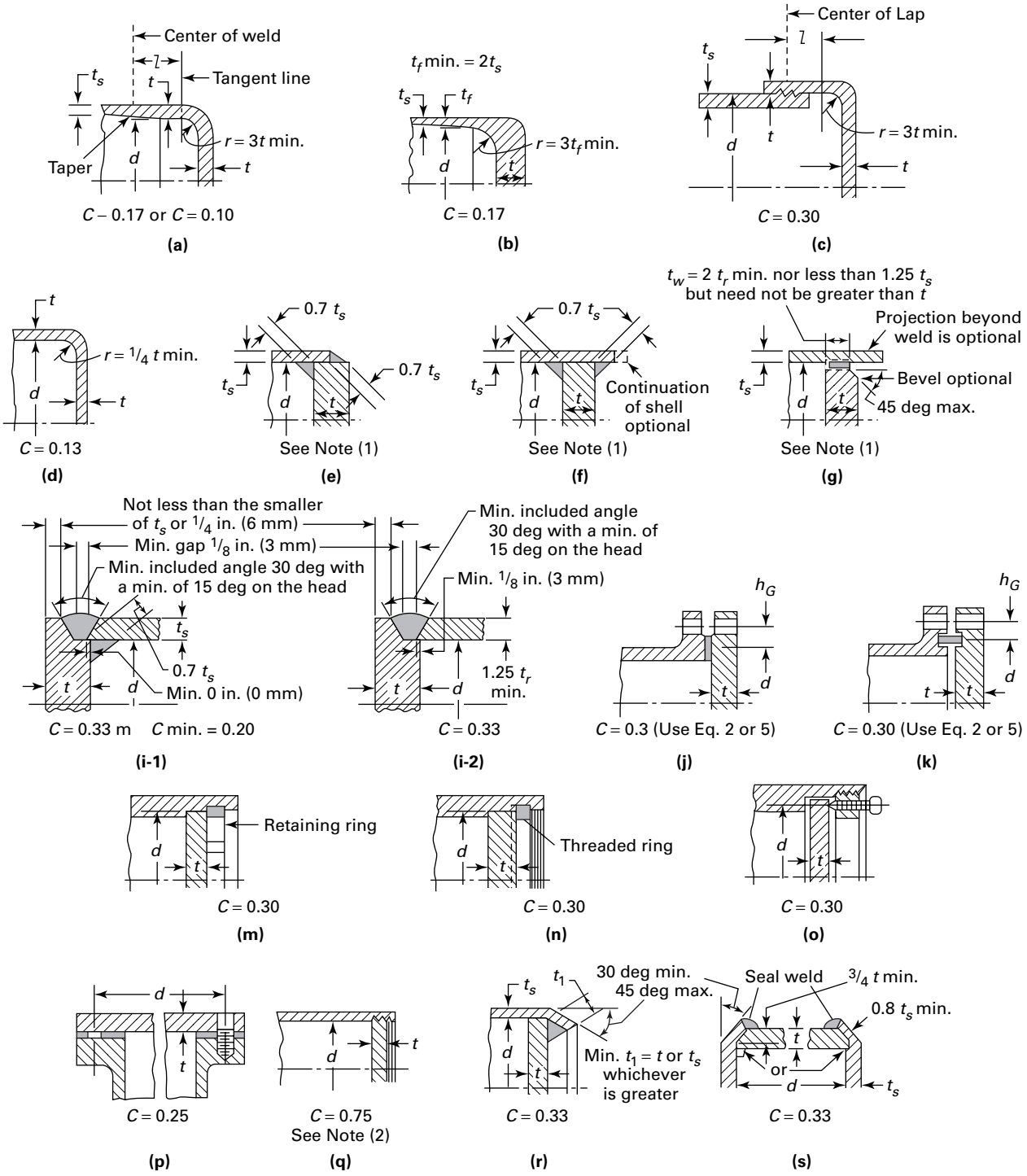
PG-30.1.4 That the maximum allowable working pressure shall not exceed that calculated by the rules for an unstayed dished head plus the pressure corresponding to the strength of the stays or braces secured by the formula for braced or stayed surfaces given in PG-46, using 1.3 for the value of C.

PG-30.2 If a dished head concave to pressure 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 PG-31, using $C = 0.25$.

PG-31 UNSTAYED FLAT HEADS AND COVERS

PG-31.1 The minimum thickness of unstayed flat heads, cover plates, and blind flanges shall conform to the requirements given in this paragraph. These requirements apply to both circular and noncircular[11] heads and covers. Some acceptable types of flat heads and covers are shown in Fig. PG-31. In this figure, the dimensions of the welds are exclusive of extra metal required for corrosion allowance.

[11] Special consideration shall be given to the design of shells, nozzle necks, or flanges to which noncircular heads or covers are attached (see Preamble, second paragraph).



GENERAL NOTE: The above illustrations are diagrammatic only. Other designs that meet the requirements of PG-31 will be acceptable.

NOTES:

(1) For sketches (e), (f), and (g) circular covers, c = 0.33 *m*, c min. = 0.20; noncircular covers, c = 0.33.

(2) When pipe threads are used, see Table PG-39.

FIG. PG-31 SOME ACCEPTABLE TYPES OF UNSTAYED FLAT HEADS AND COVERS **A02**

A03 **PG-31.2** The notations used in this paragraph and in Fig. PG-31 are defined as follows:

C = a factor depending on the method of attachment of head and on the shell, pipe, or header dimensions, and other items as listed in PG-31.4 below, dimensionless. The factors for welded covers also include a factor of 0.667 that effectively increases the allowable stress for such constructions to 1.5S.

D = long span of noncircular heads or covers measured perpendicular to short span, in. (mm)

d = diameter, or short span, measured as indicated in Fig. PG-31, in. (mm)

h_g = gasket moment arm, equal to the radial distance from the center line of the bolts to the line of the gasket reaction, as shown in Fig. PG-31, sketches (j) and (k), in. (mm)

L = perimeter of noncircular bolted head measured along the centers of the bolt holes, in. (mm)

l = length of flange of flanged heads, measured from the tangent line of knuckle, as indicated in Fig. PG-31, sketches (a) and (c), in. (mm)

m = the ratio t_r/t_s, dimensionless

P = maximum allowable working pressure, psi (kPa)

r = inside corner radius on a head formed by flanging or forging, in. (mm)

S = maximum allowable stress value, psi (kPa), using values given in Table 1A of Section II, Part D

t = minimum required thickness of flat head or cover, in. (mm)

t_e = minimum distance from beveled end of drum, pipe, or headers, before welding, to outer face of head, as indicated in Fig. PG-31, sketch (i), in. (mm)

t_f = actual thickness of the flange on a forged head, at the large end, as indicated in Fig. PG-31, sketch (b), in. (mm)

t_h = actual thickness of flat head or cover, in. (mm)

t_r = thickness required for pressure of seamless shell, pipe, or header, in. (mm)

t_s = minimum specified thickness of shell, pipe, or header, in. (mm)

t_w = thickness through the weld joining the edge of a head to the inside of a drum, pipe, or header, as indicated in Fig. PG-31, sketch (g), in. (mm)

t_l = throat dimension of the closure weld, as indicated in Fig. PG-31, sketch (r), in. (mm)

W = total bolt load, lb (kN), as further defined in PG-31.3.2

Z = a factor for noncircular heads and covers that depends on the ratio of short span to long span, as given in PG-31.3, dimensionless

PG-31.3 The thickness of flat unstayed heads, covers, and blind flanges shall conform to one of the following three requirements.[12]

PG-31.3.1 Circular blind flanges of ferrous materials conforming to ANSI B16.5-1981 shall be acceptable for the diameters and pressure–temperature ratings in Table 2 of that Standard when of the types shown in Fig. PG-31, sketches (j) and (k).

PG-31.3.2 The minimum required thickness of flat unstayed circular heads, covers, and blind flanges shall be calculated by the following equation: A02

$$t = d\sqrt{CP/S} \quad (1)$$

except when the head, cover, or blind flange is attached by bolts causing an edge moment [Fig. PG-31, sketches (j) and (k)] in which case the thickness shall be calculated by the following equation:

$$t = d\sqrt{CP/S + 1.9Wh_g/Sd^3} \quad (2)$$

When using Formula (2) the thickness t shall be calculated for both design conditions and gasket seating, and the greater of the two values shall be used. For design conditions, the value of P shall be the maximum allowable working pressure, the value of S at design temperature shall be used, and W shall be the sum of the bolt loads required to resist the end pressure load and to maintain tightness of the gasket.[23] For gasket seating, P equals zero, the value of S at atmospheric

[12] The formulas provide safe construction as far as stress is concerned. Greater thicknesses may be necessary if deflection would cause leakage at threaded or gasketed joints.

[23] Equations for W may be found in any of several references, such as the following:

"Modern Flange Design," Bulletin 502, 7th Edition; G+W Taylor-Bonney Division, Southfield, Michigan.

Jawad, M. H. and Farr, J. R., Structural Analysis and Design of Process Equipment, Second Edition; John Wiley & Sons.

ASME BPVC, Section VIII, Division 1, "Rules for Construction of Pressure Vessels," Appendix 2, "Rules for Bolted Flange Connection with Risk Type Gaskets"; The American Society of Mechanical Engineers (ASME International), Three Park Avenue, New York, NY 10016; Order Dept.: 22 Law Drive, Box 2300, Fairfield, NJ 07007-2300.

temperature shall be used, and W shall be the average of the required bolt load and the load available from the bolt area actually used.

PG-31.3.3 Flat unstayed heads, covers, or blind flanges may be square, rectangular, elliptical, obround, segmental, or otherwise noncircular. Their required thickness shall be calculated by the following formula:

$$t = d\sqrt{ZCP/S} \tag{3}$$

where

$$Z = 3.4 - \frac{2.4d}{D} \tag{4}$$

with the limitation that Z need not be greater than $2\frac{1}{2}$.

Formula (3) does not apply to noncircular heads, covers, or blind flanges attached by bolts causing a bolt edge moment [Fig. PG-31, sketches (j) and (k)]. For noncircular heads of this type, the required thickness shall be calculated by the following formula:

$$t = d\sqrt{ZCP/S + 6Wh_g/SLd^2} \tag{5}$$

When using Formula (5), the thickness t shall be calculated in the same way as specified above for Formula (2).

A02 **PG-31.4** For the types of construction shown in Fig. PG-31, the minimum values of C to be used in Formulas (1), (2), (3) and (5) are:[13]

Fig. PG-31, sketch (a): $C = 0.17$ for flanged circular and noncircular heads forged integral with or buttwelded to the shell, pipe, or header, with an inside corner radius not less than three times the required head thickness, with no special requirement with regard to length of flange, and where the welding meets all the requirements for circumferential joints given in Part PW.

$C = 0.10$ for circular heads, where the flange length for heads of the above design is not less than

$$l = \left(1.1 - 0.8\frac{t_s^2}{t_h^2}\right)\sqrt{dt_h} \tag{6}$$

When $C = 0.10$ is used, the slope of the tapered sections shall be no greater than 1:3.

Fig. PG-31, sketch (b): $C = 0.17$ for circular and noncircular heads forged integral with or buttwelded to the shell, pipe, or header, where the corner radius on the inside is not less than three times the thickness of the flange and where the welding meets all the requirements for circumferential joints given in Part PW.

Fig. PG-31, sketch (c): $C = 0.30$ for circular flanged plates screwed over the end of the shell, pipe, or header, with inside corner radius not less than $3t$, 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 4, 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.

Fig. PG-31, sketch (d): $C = 0.13$ for integral flat circular heads when the dimension d does not exceed 24 in., the ratio of thickness of the head to the dimension d is not less than 0.05 nor greater than 0.25, the head thickness t_h is not less than the shell thickness t_s, the inside corner radius is not less than $0.25t$, and the construction is obtained by special techniques of upsetting and spinning the end of the shell, pipe, or header, such as are employed in closing header ends.

Fig. PG-31, sketches (e), (f), and (g): $C = 0.33m$ but not less than 0.20 for circular plates welded to the inside of a drum, pipe, or header, and otherwise meeting the requirements for the respective types of welded boiler drums, including postweld heat treatment when required for the drum, but omitting radiographic examination. If a value of m less than 1 is used in calculating t, the shell thickness t_s shall be maintained along a distance inwardly from the inside face of the head equal to at least $2\sqrt{dt_s}$. The throat thickness of the fillet welds in sketches (e) and (f) shall be at least 0.7 t_s. The size of the weld t_w in sketch (g) shall be not less than two times the required thickness of a seamless shell nor less than 1.25 times the nominal shell thickness but need not be greater than the head thickness; the weld shall be deposited in a welding groove with the root of the weld at the inner face of the head as shown in the figure.

$C = 0.33$ for noncircular plates, welded to the inside of a drum, pipe, or header, and otherwise meeting the requirements for the respective types of welded boiler drums, including postweld heat treatment when required for the drum, but omitting radiographic examination. The throat thickness of the fillet welds in sketches (e) and (f) shall be at least $0.7t_s$. The size of the weld t_w in sketch (g) shall be not less than two times the required thickness of a seamless shell nor less than 1.25 times the nominal shell thickness but need not be greater than the head thickness; the weld shall be deposited in a welding groove with the root of the weld at the inner face of the head as shown in the figure.

[13] Radiographic examination is not required for any of the weld joints shown in Fig. PG-31, sketches (e), (f), (g), (i), (r), and (s).

Fig. PG-31, sketch (i): $C = 0.33m$ but not less than 0.20 for circular plates welded to the end of the drum, pipe, or header, when an inside weld with minimum throat thickness of $0.7t_s$ is used. The width at the bottom of the welding groove shall be not less than $\frac{1}{8}$ in. (3 mm) and the exposed edge not less than t_s or $\frac{1}{4}$ in. (6 mm), whichever is smaller. The inside fillet weld may be omitted, providing t_s is not less than $1.25t_r$ and the factor C is taken as 0.33.

Fig. PG-31, sketches (j) and (k): $C = 0.3$ for circular and noncircular heads and covers bolted to the shell, flange, or side plate as indicated in the figures. Note that Eq. (2) or (5) shall be used because of the extra moment applied to the cover by the bolting. When the cover plate is grooved for a peripheral gasket, as shown in sketch (k) the net cover plate thickness under the groove or between the groove and the outer edge of the cover plate shall be not less than

$$d\sqrt{1.9Wh_g/Sd^3}$$

for circular heads and covers, not less than

$$d\sqrt{6Wh_g/SLd^2}$$

for noncircular heads and covers.

Fig. PG-31, sketches (m), (n), and (o): $C = 0.3$ for a circular plate inserted into the end of a shell, pipe, or header and held in place by a positive mechanical locking arrangement, and when all possible means of failure either by shear, tension, compression, or radial deformation, including flaring, resulting from pressure and differential thermal expansion, are resisted with a factor of safety of at least 4. Seal welding may be used, if desired.

Fig. PG-31, sketch (p): $C = 0.25$ for circular and noncircular covers bolted with a full-face gasket to shell, flanges, or side plates.

Fig. PG-31, sketch (q): $C = 0.75$ for circular plates screwed into the end of a shell, pipe, or header having an inside diameter d not exceeding 12 in. (305 mm); or for heads having an integral flange screwed over the end of a shell, pipe, or header having an inside diameter d not exceeding 12 in. (152 mm); and when the design of the threaded joint against failure by shear, tension, compression, or radial deformation, including flaring, resulting from pressure and differential thermal expansion, is based on a factor of safety of at least 4. If a tapered pipe thread is used, the requirements of Table PG-39 shall be met. Seal welding may be used, if desired.

Fig. PG-31, sketch (r): $C = 0.33$ for circular plates having a dimension d not exceeding 18 in. (457 mm) inserted into the shell, pipe, or header and welded as shown, and otherwise meeting the requirements for welded boiler drums including postweld heat treatment but omitting radiographic examination. The end of the shell, pipe, or header shall be crimped over at least 30 deg, but not more than 45 deg. The crimping may be done cold only when this operation will not injure the metal. The throat of the weld shall be not less than the thickness of the flat head or the shell, pipe, or header, whichever is greater.

Fig. PG-31, sketch (s): $C = 0.33$ for circular beveled plates having a diameter d not exceeding 18 in. (457 mm) inserted into a shell, pipe, or header, the end of which is crimped over at least 30 deg, but not more than 45 deg, and when the undercutting for seating leaves at least 80% of the shell thickness. The beveling shall be not less than 75% of the head thickness. The crimping shall be done when the entire circumference of the cylinder is uniformly heated to the proper forging temperature for the material used. For this construction, the ratio t_s/d shall be not less than the ratio P/S nor less than 0.05. The maximum allowable working pressure for this construction shall not exceed $P = 5S/d$.

OPENINGS AND COMPENSATION[14]

PG-32 OPENINGS IN SHELLS, HEADERS, AND HEADS

PG-32.1 Scope

PG-32.1.1 The rules for openings and compensation in PG-32 through PG-39 shall apply to all openings in shells, headers, and heads except as otherwise provided in PG-29.3, PG-29.7, PG-29.12, PG-32.1.2, PG-32.1.3.1, PG-32.1.4, and PG-32.1.5.

PG-32.1.2 Openings in a definite pattern, such as tube holes, may be designed in accordance with the rules for ligaments in PG-52, provided the diameter of the largest hole in the group does not exceed that permitted by the chart in Fig. PG-32.

The notation used in Fig. PG-32 is defined as follows:

[14] The rules governing openings as given in this Code are based on the stress intensification created by the existence of a hole in an otherwise symmetrical section. They are based on experience with vessels designed with safety factors of 4 and 5 applied to the specified minimum tensile strength of the shell material. External loadings such as those due to thermal expansion or to unsupported weight of connecting piping have not been evaluated. These factors should be given attention in unusual designs or under conditions of cyclic loading.

P = maximum allowable working pressure, psi (kPa)
d = maximum allowable diameter of openings, in. (mm)
D = outer diameter of the shell, in. (mm)
t = actual thickness of the shell, in. (mm)
S = maximum allowable stress value, psi (kPa), taken from Tables 1A and 1B of Section II, Part D

$$K = \frac{PD}{1.82St}$$

PG-32.1.3.1 No calculation need be made to determine the availability of compensation for a single opening, not covered by PG-38 or PG-52, in shells, headers, or formed heads whose inside diameter is not less than four times the diameter of the opening and which satisfies the following conditions:

PG-32.1.3.1.1 Welded connections not larger than NPS 2 attached in accordance with the applicable rules.

PG-32.1.3.1.2 Threaded, studded, or expanded connections in which the diameter of the hole in the vessel wall is not greater than NPS 2.

PG-32.1.3.2 No calculations need be made to demonstrate compliance with PG-33 for single openings not covered in PG-32.1.3.1 when the diameter of the opening in the shell or header does not exceed that permitted in Fig. PG-32.

PG-32.1.4 No calculation need be made to determine the availability of compensation for a single opening in a formed head that satisfies the following conditions.

PG-32.1.4.1 The minimum center-to-center distance between adjacent openings shall not be less than L as determined by the following equation:

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

where

$K = PD/1.82\ St$
L = the distance between centers of the two openings measured on the surface of the formed head, in. (mm)
A, B = the outside diameter of each opening respectively, in. (mm)
P = the maximum allowable working pressure, psig (kPa)
D = the outside diameter of the formed head, in. (mm)
t = the actual thickness of the head, in. (mm)
S = the maximum allowable stress value of the head material, as taken from Tables 1A and 1B of Section II, Part D, psi (MPa)

PG-32.1.4.2 The edge of the opening shall come no closer to the line bounding the spherical or ellipsoidal portion of the formed head, or around a flanged-in manhole, than a distance equal to the thickness of the head, and in no case, except for water column connections, shall the opening come within the part formed by the corner radius of a dished head.

PG-32.1.4.3 The maximum allowable diameter of any opening in a formed head, except in a full-hemispherical head, shall not exceed that permitted in PG-32.1.3.1 for an equivalent shell. The equivalent shell shall be of the same material as the head; of the same outside diameter as the outside diameter of the flange of the head; and of the same maximum allowable working pressure as the head.

PG-32.1.4.4 The maximum allowable diameter of any opening in a full-hemispherical head shall comply with the requirements in PG-32.1.4.3 except that the value of K used in PG-32.1.4.1 and the chart in Fig. PG-32 shall be one-half the value given by the equation in PG-32.1.4.1.

PG-32.1.5 No calculation need be made to demonstrate compliance with PG-33 for single openings not covered in PG-32.1.4 when the diameter of the opening in the formed head does not exceed that permitted in Fig. PG-32.

PG-32.2 Shape of Openings[15]

PG-32.2.1 Openings in cylindrical portions of vessels or in formed heads shall preferably be circular, elliptical, or obround.[16]

When the long dimension of an elliptical or obround opening exceeds twice the short dimension, the compensation across the short dimension shall be increased as necessary to provide against excessive distortion due to twisting moment.

[15] The opening made by a pipe or a circular nozzle, the axis of which is not perpendicular to the vessel wall or head, may be considered an elliptical opening for design purposes.

[16] An obround opening is one which is formed by two parallel sides and semicircular ends.

PG-32.2.2 Openings may be of other shapes than those given in PG-32.2.1, and all corners shall be provided with a suitable radius. When the openings are of such proportions that their strength cannot be computed with assurance of accuracy, or when doubt exists as to the safety of a vessel with such openings, the part of the vessel affected shall be subjected to a proof hydrostatic test as prescribed in PG-100.

PG-32.3 Size of Openings

PG-32.3.1 Properly reinforced openings in cylindrical and spherical shells are not limited as to size and shall comply with the provisions that follow, and with the additional provisions given under PG-32.3.2.

PG-32.3.2 The rules given herein for compensation apply to openings not exceeding the following dimensions:

For vessels 60 in. (1 520 mm) in diameter and less: $\frac{1}{2}$ the vessel diameter but not over 20 in. (508 mm).

For vessels over 60 in. (1 520 mm) in diameter: $\frac{1}{3}$ the vessel diameter but not over 40 in. (1 000 mm).

PG-32.3.3 Larger openings should be given special attention and may be provided with compensation in any suitable manner that complies with the intent of the Code rules. It is recommended that the compensation provided be distributed close to the opening. (A provision of about two-thirds of the required compensation within a distance of one-fourth of the nozzle diameter on each side of the finished opening is suggested.) Special consideration should be given to the fabrication details used and the inspection employed on critical openings; compensation often may be advantageously obtained by use of a thicker shell plate for a vessel course or inserted locally around the opening; welds may be ground to concave contour and the inside corners of the opening rounded to a generous radius to reduce stress concentrations. Appropriate proof testing may be advisable in extreme cases of large openings approaching full vessel diameter, openings of unusual shape, etc.

PG-33 COMPENSATION REQUIRED FOR OPENINGS IN SHELLS AND FORMED HEADS

PG-33.1 General. The rules in this subparagraph apply to all openings other than flanged-in openings in formed heads covered by PG-29.3, PG-29.7, and PG-29.12; openings in flat heads covered by PG-35; and openings covered within PG-32.1.2, PG-32.1.3.1, PG-32.1.3.2, PG-32.1.4, and PG-32.1.5.

Compensation shall be provided in such amount and distribution that the requirements for area of compensation are satisfied for all planes through the center of the opening and normal to the vessel surface. For a circular opening in a cylindrical shell, the plane containing the axis of the shell is the plane of greatest loading due to pressure.

PG-33.2 Area Required. The total cross-sectional area of compensation required in any given plane for a vessel under internal pressure shall be not less than A, as defined in Fig. PG-33.1. A02

PG-33.2.1 DELETED

PG-33.2.2 DELETED

PG-33.3 The notation used in this paragraph is defined as follows: A02

t_e = thickness of attached reinforcing pad or height of the largest 60 deg right triangle supported by the vessel and nozzle outside diameter projected surfaces and lying completely within the area of integral reinforcement, in. (mm) (see Fig. PG-33.2)

t = thickness of the vessel wall, in. (mm)

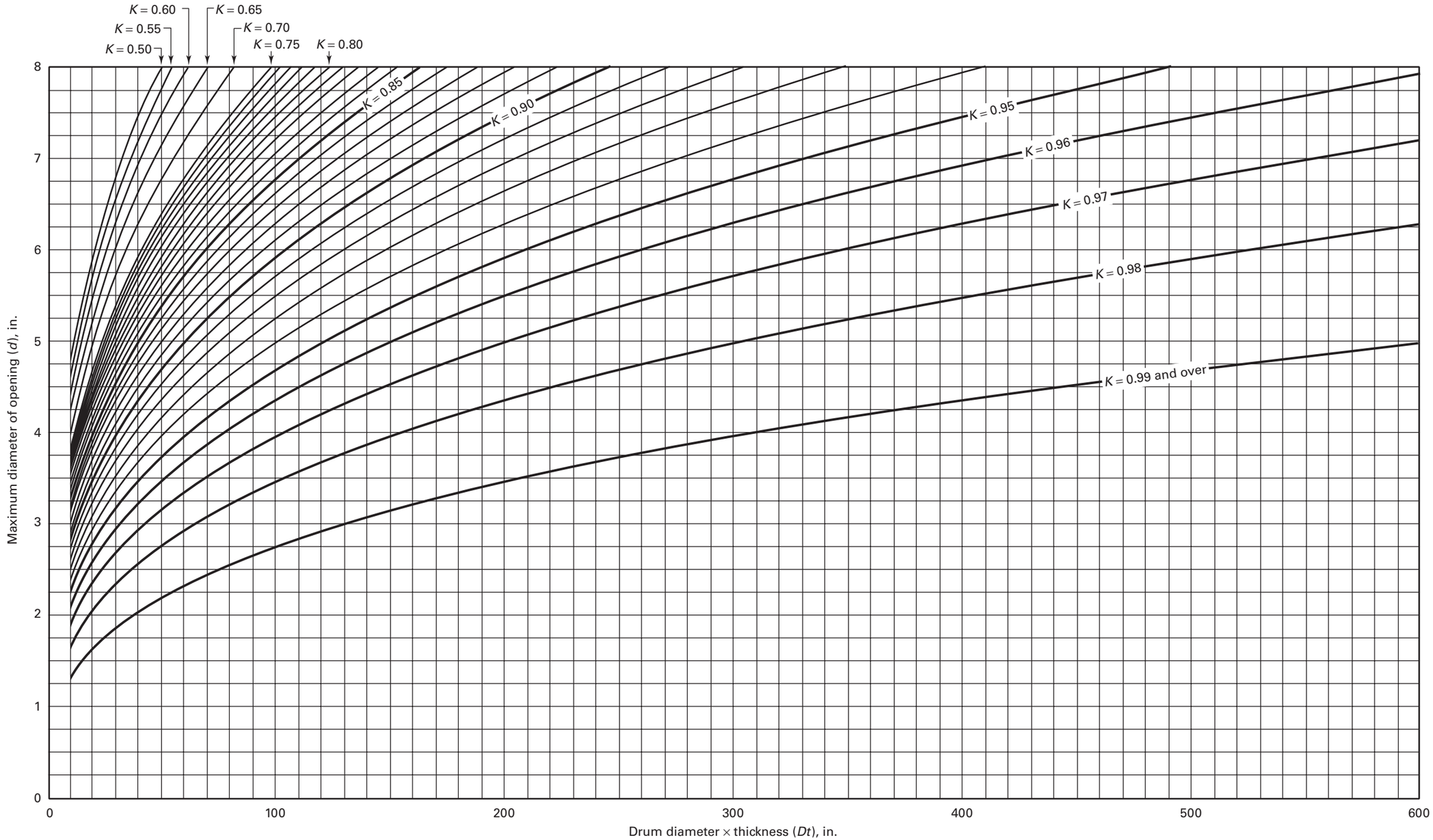
t_r = required thickness of a seamless shell or head computed by the rules of the Code for the designated pressure, in. except when:

(a) the opening and its compensation are in a torispherical head and are entirely within the spherical portion, t_r is the thickness required for a seamless hemispherical head of the same radius as that of the spherical portion; and

(b) the opening and its compensation are in an ellipsoidal head in which one-half of the minor axis is equal to one-fourth of the inside diameter, and are located entirely within a circle the center of which coincides with the center of the head and the diameter of which is equal to 80% of the shell inside diameter, t_r is the thickness required for a seamless hemispherical head of radius equal to 90% of the inside diameter of the shell.

t_n = nominal thickness of nozzle wall, in. (mm)

t_{rn} = required thickness of seamless nozzle wall, in. (mm); found by the formula used for t_r for the shell, omitting the C factor (the value of S used in determining t_{rn} shall be based on the nozzle material). The value of t_{rn} shall be taken as zero for the entire wall of manhole and handhole



GENERAL NOTES:
(a) The equation is provided for the user's option. Three significant figures shall be employed for the variables in the equation and in the resulting value of d. Additional significant figures are permitted but not required. Use of the equation beyond the range of the abscissa and ordinate shown in the diagram is prohibited. K as used in the equation is limited to 0.990.
(b) K-lines are shown only for 50% and higher. By the provisions of PG-33 an opening is fully compensated for K less than 0.5.
(c) $d = 2.75\,[Dt\,(1 - K)]^{1/3}$

FIG. PG-32 CHART SHOWING LIMITS OF SIZES OF OPENINGS WITH INHERENT COMPENSATION IN CYLINDRICAL SHELLS
Maximum Permissible Diameter of Opening Is 8 in. (1 in. = 25.4 mm)

rings projecting internally with the cover on the inside.

D_p = outside diameter of reinforcing element, in. (mm) (actual size of reinforcing element may exceed the limits of reinforcement established by PG-36; however, credit cannot be taken for any material outside these limits)

d = diameter in the plane under consideration of the finished opening, in. (mm) (see Fig. PG-33.2)

d = the maximum diameter of the threads, in the plane under consideration, in the finished opening, for inside tapped NPT fittings, in. (mm)

F = factor from PG-33 and Fig. PG-33.3, which compensates for the variation in pressure stresses on different planes with respect to the longitudinal axis of a cylindrical shell. $F = 1.0$ for formed or flat heads.

h = distance nozzle projects inward from the outer surface of the vessel wall, in. (mm) (extension of the nozzle beyond the inside surface of the vessel wall is not limited; however, for reinforcement calculations, credit shall not be taken for material outside the limits of reinforcement established by PG-36)

R_n = inside radius of the nozzle under consideration, in. (mm)

S = allowable stress value in tension, psi (kPa) (from Table 1A and 1B of Section II, Part D)

S_n = allowable stress in nozzle, psi (kPa) (see S above)

S_v = allowable stress in vessel, psi (kPa) (see S above)

S_P = allowable stress in reinforcing element (plate), psi (kPa) (see S above)

f_r = strength reduction factor, not greater than 1.0 (see Fig. PG-33.1)

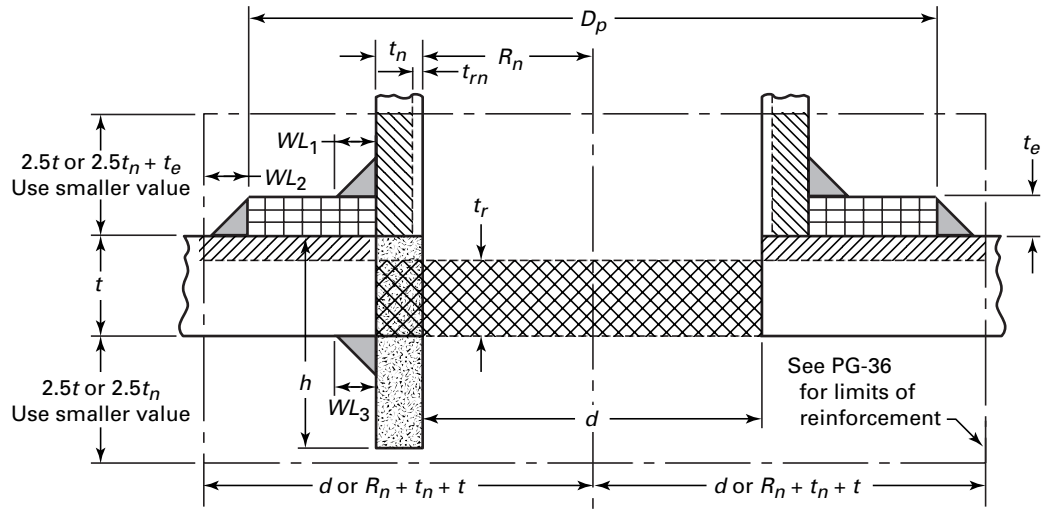
f_{r1} = S_n/S_v for nozzle wall inserted through the vessel wall

f_{r2} = (lesser of S_n or S_p) $/S_v$

f_{r3} = S_p/S_v

PG-34 FLANGED-IN OPENINGS IN FORMED HEADS

PG-34.1 All openings in torispherical, ellipsoidal, and hemispherical heads shall be provided with reinforcement in accordance with PG-33, except for heads which meet the requirements in PG-34.2 and PG-29.3, PG-29.7, and PG-29.12. A02

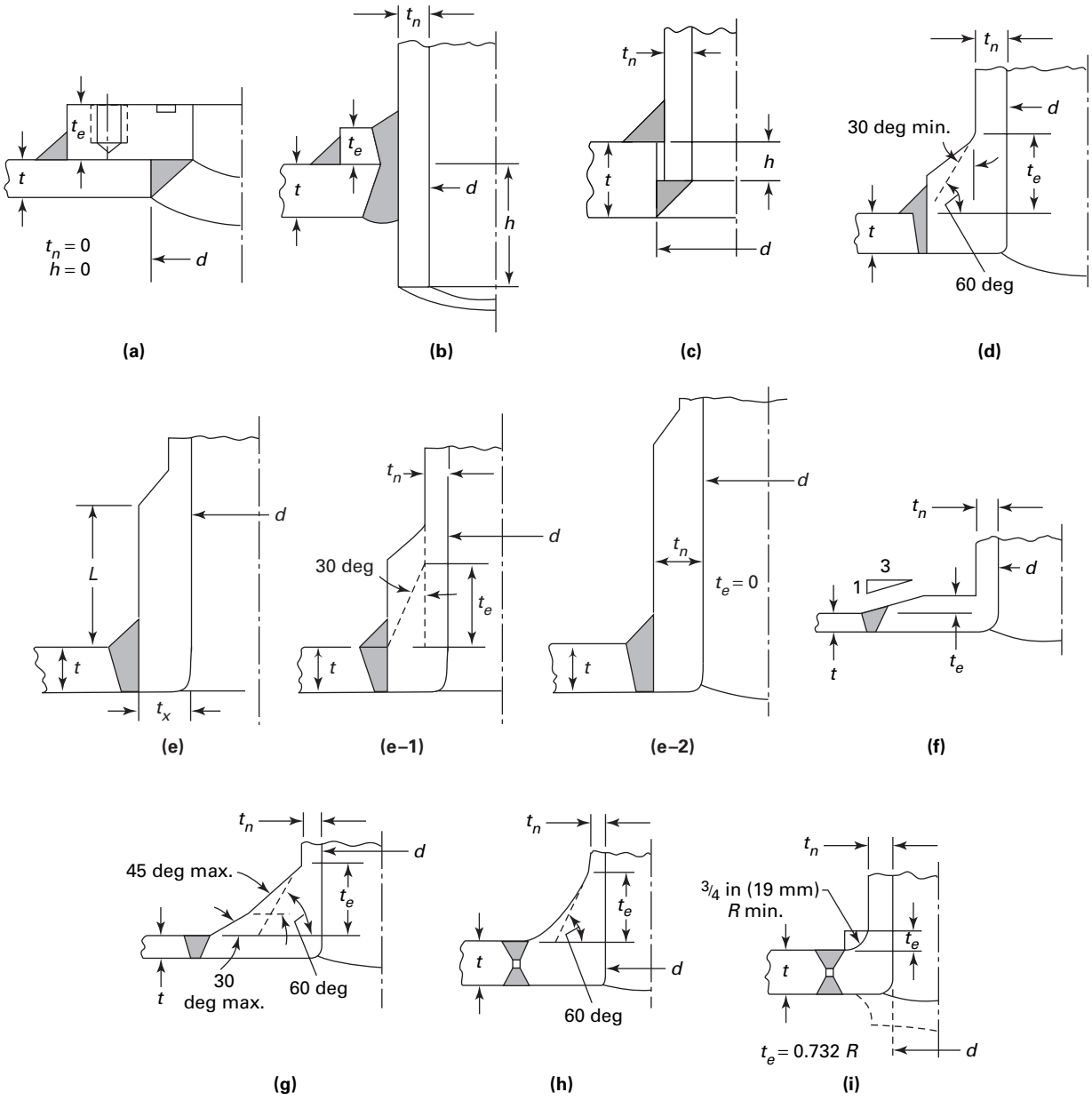


	For nozzle wall inserted through the vessel wall	For nozzle wall abutting the vessel wall
	Notes for set through nozzles, A extends to the nozzle O.D.	
Area required	$= A = (d + 2t_n)t_rF$	$A = dt_rF$
Area available in shell: use larger value	$= A_1 \begin{cases} = (d - 2t_n)(t - Ft_r) \\ = 2t(t - Ft_r) \end{cases}$	$A_1 \begin{cases} = d(t - Ft_r) \\ = 2(t + t_n)(t - Ft_r) \end{cases}$
Area available in nozzle projecting outward; use smaller value	$= A_2 \begin{cases} = 2(t_n - t_{rn})(2^1/_2 tf_{r1}) \\ = 2(t_n - t_{rn})(2^1/_2 t_n + t_e)f_{r1} \end{cases}$	$A_2 \begin{cases} = 2(t_n - t_{rn})(2^1/_2 tf_{r1}) \\ = 2(t_n - t_{rn})(2^1/_2 t_n + t_e)f_{r1} \end{cases}$
Area available in nozzle projecting inward	$= A_3 = 2t_nf_{r1}h$	$A_3 = 0$
Area available in outward nozzle weld	$= A_{41} = (WL_1)^2f_{r2}$	$A_{41} = (WL_1)^2f_{r2}$
Area available in inward nozzle weld	$= A_{43} = (WL_3)^2f_{r1}$	$A_{43} = 0$
	If $A_1 + A_2 + A_3 + A_{41} + A_{43} > A$	Opening is adequately reinforced
	If $A_1 + A_2 + A_3 + A_{41} + A_{43} < A$	Opening is not adequately reinforced so reinforcing elements must be added and /or thickness must be increased
With reinforcing element added:		
Area available in outer element weld	$= A_{42} = (WL_2)^2f_{r3}$	$A_{42} = (WL_2)^2f_{r3}$
Area available in element [Note (1)]	$= A_5 = (D_p - d - 2t_n)t_ef_{r3}$	$A_5 = (D_p - d - 2t_n)t_ef_{r3}$
	If $A_1 + A_2 + A_3 + A_{41} + A_{42} + A_{43} + A_5 > A$	Opening is adequately reinforced

GENERAL NOTES:
(a) This figure illustrates common nozzle configurations and is not intended to prohibit other configurations permitted by the Code.
(b) See PG-33.3 and PG-36 for definitions of nomenclature.

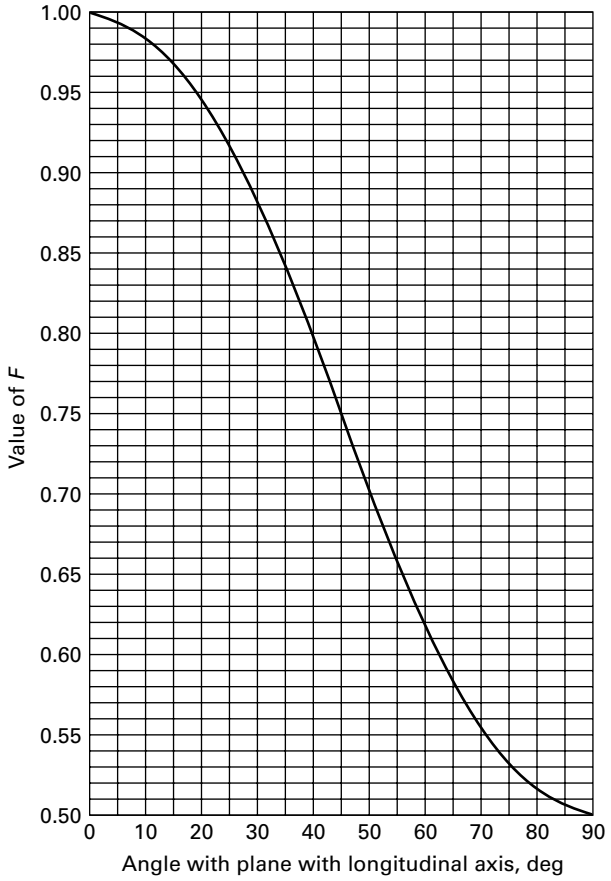
NOTE:
(1) This formula is applicable for a rectangular cross-sectional element that falls within the limits of reinforcement.

A02 FIG. PG-33.1 NOMENCLATURE AND FORMULAS FOR REINFORCED OPENINGS
A03



GENERAL NOTE: Use sketch (e) to determine whether sketch (e-1) or (e-2) applies:
(a) If $L < 2.5\ t_x$, use sketch (e-1).
(b) If $L \geq 2.5\ t_x$, use sketch (e-2).

FIG. PG-33.2 SOME REPRESENTATIVE CONFIGURATIONS DESCRIBING THE DIMENSIONS t_e, h, and d **A02**



A02 FIG. PG-33.3 CHART FOR DETERMINING VALUE OF *F*

PG-34.2 A flanged-in manhole opening in a dished head shall be flanged to a depth of not less than three times the required thickness of the head for plate up to $1\frac{1}{2}$ in. (38 mm) in thickness. For plate exceeding $1\frac{1}{2}$ in. (38 mm) in thickness, the depth shall be the thickness of the plate plus 3 in. (76 mm). 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 compensated by a manhole ring or other attachment in place of flanging in accordance with PG-33.

PG-35 COMPENSATION REQUIRED FOR OPENINGS IN FLAT HEADS

PG-35.1 General. The rules in this paragraph apply to all openings other than small openings covered by PG-32.1.3.1.

PG-35.2 Flat heads that have an opening with a diameter that does not exceed one-half of the head diameter or shortest span, as defined in PG-31, shall have a total cross-sectional area of compensation not less than 0.5 times the required area specified in PG-33.2. A02

As an alternative, the thickness may be increased to provide the necessary openings compensation as follows:

PG-35.2.1 By using $2C$ or 0.75 in place of C, whichever is less, in Formula (1) or (3) for calculating head thickness in PG-31.3; or

PG-35.2.2 In Formula (2) or (5) by doubling the quantity under the square root sign.

PG-35.3 Flat heads that have an opening with a diameter that exceeds one-half of the head diameter or shortest span, as defined in PG-31.3, shall be designed as a flange in accordance with accepted Rules for Bolted Flange Connections.

PG-36 LIMITS OF METAL AVAILABLE FOR COMPENSATION

PG-36.1 The boundaries of the cross-sectional area in any plane normal to the vessel wall and passing through the center of the opening within which area metal must be located in order to have value as compensation are designated as the limits of compensation for that plane. (See Fig. PG-33.1.) A02

PG-36.2 The limits of compensation, measured parallel to the vessel wall, shall be at a distance, on each side of the axis of the opening, equal to the greater of the following:

PG-36.2.1 The diameter of the finished opening.

PG-36.2.2 The radius of the finished opening plus the thickness of the vessel wall, plus the thickness of the nozzle wall.

PG-36.3 The limits of compensation, measured normal to the vessel wall, shall conform to the contour of the surface at a distance from each surface equal to the smaller of the following:

PG-36.3.1 $2\frac{1}{2}$ times the nominal shell thickness.

PG-36.3.2 $2\frac{1}{2}$ times the nozzle-wall thickness plus the thickness of any added compensation, exclusive of weld metal on the side of the shell under consideration.

PG-36.4 Metal within the limits of reinforcement that may be considered to have reinforcing value shall include the following:

FIG. PG-36

A02 DELETED

A02 **PG-36.4.1** Metal in the vessel wall over and above the thickness required to resist pressure. The area of the vessel wall available as compensation is the larger of the values of A_1 given by the formulas shown in Fig. PG-33.1.

A02 **PG-36.4.2** Metal over and above the thickness required to resist pressure in that part of a nozzle wall extending outside the vessel wall. The maximum area in the nozzle wall available as compensation is the smaller of the values of A_2 given by the formulas shown in Fig. PG-33.1.

All metal in the nozzle wall extending inside the vessel wall may be included. No allowance shall be taken for the fact that a differential pressure on an inwardly extending nozzle may cause opposing stress to that of the stress in the shell around the opening.

PG-36.4.3 Metal added as compensation (continuously about the nozzle) when welded to both the vessel and nozzle, and metal provided in attachment welds.

A02 PG-36.4.4 DELETED

PG-36.5 Typical examples of the application of the above rules are presented in A-65 through A-69.

PG-37 STRENGTH OF COMPENSATION

PG-37.1 Material used for compensation shall have an allowable stress value equal to or greater than that of the material in the vessel wall, except that material of lower strength may be used provided the area of compensation is increased in inverse proportion to the ratio of the allowable stress values of the two materials to compensate for the lower allowable stress value of the compensation. No credit may be taken for the additional strength of any compensation having a higher allowable stress value than that of the vessel wall. Deposited weld metal outside of either the vessel wall or any reinforcing pad used as reinforcement shall be credited with an allowable stress value equivalent to the weaker of the materials connected by the weld. Vessel-to-nozzle or pad-to-nozzle attachment weld metal within the vessel wall or within the pad may be credited with a stress value equal to that of the vessel wall or pad, respectively.

A02 **PG-37.2** The welds that attach elements of compensation that are not an integral part of the vessel wall shall have a strength, W, not less than the load carried by those elements defined as follows:

$$W = (A - A_1)\, S_v$$

where A, A_1, and S_v are defined in PG-33.3 and Fig. PG-33.1.

PG-37.2.1 DELETED

A02 **PG-37.3** When a reinforcing pad is required by the rules of PW-33, the welds attaching the nozzle to the pad and shell shall be checked independently to assure that the loads carried by the individual elements can be transmitted by the attaching welds. For detailed requirements and examples of calculating the strength of welds, see PW-15.

A02 **PG-37.4** Welds attaching elements of compensation need not satisfy the weld strength requirements of PG-37.2 under the following circumstances:

(a) openings that are exempt in PG-32 from compensation calculations;

(b) openings designed by ligaments rules of PG-52 and PG-53; and/or

(c) openings with elements of compensation attached by full penetration welds as listed in PW-15.1.6.

A02 **PG-37.5** The minimum weld sizes shall not be smaller than the minimum required by PW-16.

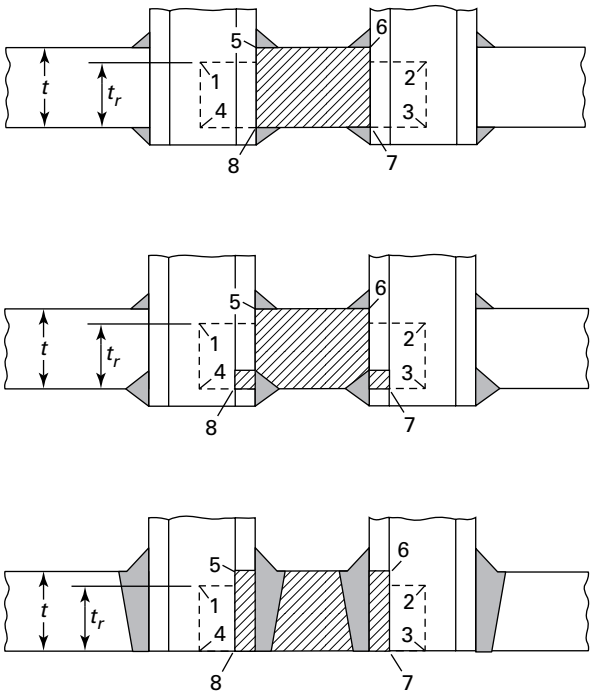
PG-38 COMPENSATION FOR MULTIPLE OPENINGS

PG-38.1 When any two adjacent openings that require compensation are spaced at less than two times the distance defined in PG-36.2 and PG-36.3 so that their limits of compensation overlap, the two openings (or similarly for any larger group of openings) shall be compensated in accordance with PG-33 with a compensation that has an area equal to the combined area of the compensation required for the separate openings. No portion of the cross section shall be considered as applying to more than one opening, or be evaluated more than once in a combined area.

PG-38.2 Two adjacent openings shall have a distance between centers not less than $1\frac{1}{3}$ times their average diameter.

FIG. PG-36.4

A02 REDESIGNATED AS FIG. PG-33.3



GENERAL NOTE: The cross-sectional area represented by 5, 6, 7, and 8 shall be at least equal to the area of the rectangle represented by 1, 2, 3, and 4 multiplied by $0.7F$, in which F is a value from Fig. PG-33.3 and t_r is the required thickness of a seamless shell.

A02 FIG. PG-38 ILLUSTRATIONS OF THE RULE GIVEN IN PG-38.4

PG-38.3 When a group of openings is provided with compensation by a thicker section buttwelded into the shell or head, the edges of the inserted section shall be tapered as prescribed in PW-9.3.

PG-38.4 When a shell or drum has a series of holes in a definite pattern, the net cross-sectional area between any two finished openings within the limits of the actual shell wall, excluding the portion of the compensation not fused to the shell wall, shall equal at least $0.7F$ of the cross-sectional area obtained by multiplying the center-to-center distance of the openings by the required thickness of a seamless shell, where the factor F is taken from Fig. PG-33.3 for the plane under consideration. (See Fig. PG-38.) A02

PG-39 METHODS OF ATTACHMENT OF PIPE AND NOZZLE NECKS TO VESSEL WALLS

PG-39.1 General. Except as limited in PG-32, nozzles may be attached to the shell or head of a vessel by any of the methods of attachment given in this paragraph.

PG-39.2 Welded Connections. Attachment by welding shall be in accordance with the requirements of PW-15 and PW-16.

PG-39.4 Studded Connections. Connections may be made by means of bolt studs. The vessel shall have a flat surface machined on the shell, or on a built-up pad, or on a properly attached plate or fitting. Drilled holes to be tapped for straight threads shall not penetrate within one-fourth of the wall thickness from the inside surface of the vessel, unless at least the minimum thickness required as above is maintained by adding metal to the inside surface of the vessel. Where tapped holes are provided for studs, the threads shall be full and clean and shall engage the stud for a length not less than the larger of d_s or

$$0.75d_s \times \frac{\text{Maximum allowable stress value of stud material at design temperature}}{\text{Maximum allowable stress value of tapped material at design temperature}}$$

in which d_s is the diameter of the stud, except that the thread engagement need not exceed $1\frac{1}{2}d_s$. Studded connections shall meet the requirements for compensation. No credit for compensation shall be allowed for any areas attached by studs only.

PG-39.5 Threaded Connections

PG-39.5.1 Where a threaded connection is to be made to a boiler component it shall be into a threaded hole. The threads shall conform to the requirements of ANSI B1.20.1 and provide for the pipe to engage the minimum number of threads specified in Table PG-39 after allowance has been made for curvature of the vessel wall. A built-up pad or properly attached plate or fitting may be used to provide the metal thickness and number of threads required in Table PG-39, or to furnish compensation when required.

PG-39.5.2 Threaded joints for boiler connections for external piping shall be in accordance with the following size and pressure limitations and shall not be used where the temperature exceeds 925°F.

Maximum Size, NPS (DN)	Maximum Pressure, psi (kPa)
3 (80)	400 (2 800)
2 (50)	600 (4 140)
1 (25)	1,200 (8 270)
$\frac{3}{4}$ (20) and smaller	1,500 (10 300)

PG-39.5.3 Threaded connections for plug closures used for inspection openings, end closures, and similar purposes may be used within the size and pressure limitations of Table PG-39.

PG-39.6 Expanded Connections. Provided the requirements for compensation are met, a pipe, tube, or forging not exceeding 6 in. (152 mm) in outside diameter may be attached to shells, heads, headers, or fittings by inserting through an opening and expanding in accordance with the rules for tube attachment in Parts PWT and PFT, whichever is applicable.

The sharp edges left in drilling tube holes shall be removed on both sides of the plate with a file or other tool. The inner surface of the tube hole in any form of attachment may be grooved or chamfered.

PG-39.7 All welded connections shall be postweld heat treated after attachment unless specifically allowed otherwise.

PG-42 GENERAL REQUIREMENTS FOR FITTINGS, FLANGES, AND VALVES

PG-42.1 Applicable ASME Standards. Except when supplied as miscellaneous pressure parts under the provisions of PG-11, all fittings, flanges, and valves shall meet the requirements of the following ASME Standards, including the restrictions contained within the standards, and any noted as part of this Code. The product standard establishes the basis for pressure–temperature rating and marking.

PG-42.1.1 ASME B16.1, Cast Iron Pipe Flanges and Flanged Fittings[17]

PG-42.1.3 ASME B16.3, Malleable Iron Threaded Fittings, Classes 150 and 300

PG-42.1.4 ASME B16.4, Gray Iron Threaded Fittings

PG-42.1.5 ASME B16.5, Pipe Flanges and Flanged Fittings (see PG-42.2)

[17] Classes 25 and 800 are not applicable to Section I.

TABLE PG-39
MINIMUM NUMBER OF THREADS PER CONNECTION

01

CUSTOMARY UNITS								
Pressure up to and including 300 psi								
Size of pipe connection (NPS)		1 & 1¼	1½ & 2	2½ to 4	5 & 6	8	10	12
Threads engaged		4	5	7	8	10	12	13
Min. plate thickness required, in.		0.348	0.435	0.875	1.0	1.25	1.5	1.625
Pressures above 300 psi								
Size of pipe connection, (NPS)	½ & ¾	1 to 1½	2	2½ & 3	4 to 6	8	10	12
Threads engaged	6	7	8	8	10	12	13	14
Min. plate thickness, required, in.	0.43	0.61	0.70	1.0	1.25	1.5	1.62	1.75
SI UNITS								
Pressure up to and including 2 070 kPa								
Size of pipe connection (DN)		25 & 32	40 & 50	65 to 100	125 & 150	200	10	12
Threads engaged		4	5	7	8	10	12	13
Min. plate thickness required (mm)		8.8	11.0	22.2	25.4	31.8	1.5	1.625
Pressures above 2 070 kPa								
Size of pipe connection (DN)	15 & 20	25 to 40	50	65 & 80	100 to 150	200	250	300
Threads engaged	6	7	8	8	10	12	13	14
Min. plate thickness, required (mm)	10.9	15.5	17.8	25.4	31.8	38.1	1.62	1.75

PG-42.1.5.1 Pressure–Temperature Ratings per Table 2

PG-42.1.5.2 Facing Dimensions (other than ring-joint) per Table 4

PG-42.1.5.3 Facing Dimensions for Ring-Joint Flanges per Table 5

PG-42.1.5.4 Dimensions of Flanges for Pressure Rating Classes per Tables 8 through 28

PG-42.1.6 ASME B16.9, Factory-Made Wrought Steel Buttwelding Fittings

When pressure ratings are established under the provisions of para. 2.1 of ASME B16.9 they shall be calculated as for straight seamless pipe in accordance with ASME B31.1.

PG-42.1.7 ASME B16.11, Forged Fittings, Socket-Welding and Threaded (see PG-42.2)

PG-42.1.8 ASME B16.15, Cast Bronze Threaded Fittings, Classes 125 and 250 (see PG-8.4 and PG-4.11)

PG-42.1.9 ASME B16.20, Ring-Joint Gaskets and Grooves for Steel Pipe Flanges

PG-42.1.10 ASME B16.24, Cast Copper Alloy Pipe Flanges and Flanged Fittings (see PG-8.4)

PG-42.1.11 ASME B16.25, Buttwelding Ends

PG-42.1.12 ASME B16.34, Valves — Flanged, Threaded, and Welding End (see PG-42.2 and PG-42.4.3)

PG-42.1.13 ASME B16.28, Wrought Steel Buttwelding Short Radius Elbows and Returns

PG-42.1.14 ASME B16.42, Ductile Iron Pipe Flanges and Flanged Fittings, Classes 150 and 300 (see PG-8.3)

PG-42.2 Marking. All valves and fittings shall be marked with the name, trademark, or other identification of the manufacturer and the primary service pressure rating except that the pressure rating marking may be omitted from:

PG-42.2.1 Cast iron threaded fittings for Class 125 working pressure

PG-42.2.2 Malleable iron threaded fittings for Class 150 working pressure

PG-42.2.3 Nonferrous threaded fittings for Classes 125 and 250 working pressure

PG-42.2.4 Cast iron and nonferrous companion flanges

PG-42.2.5 Additional markings for buttwelding fittings, as called for by several Code Standards for all valves and fittings, are recommended if the size and shape of the valve or fitting permit.

PG-42.3 Flange Materials. Flanges shall be made of materials permitted by this Section or of materials specifically listed in the applicable product standards listed in PG-42.1, but not of materials specifically prohibited or beyond the use limitations listed in this Section. Rolled or forged flanges may be made from material conforming to any forging specification among these permitted materials, except that SA-181 shall not be used for flanges whose pressure rating is higher than Class 300. Hub-type flanges shall not be cut or machined from plate material.

PG-42.4 Additional Requirements. Flanges made of other materials permitted under this Section shall be at least equal to the strength requirements, and the facing dimensions and bolt circles shall agree with the Standard otherwise required.

PG-42.4.1 The thickness of all fitting and valve bodies subject to pressure shall be not less than that required by the applicable ASME Standard listed in PG-42.1 for the corresponding maximum allowable working pressure and temperature for the material used. The cylindrical ends of cast steel welding end valves and fittings conforming to ASME B16.5 or B16.34 may be proportioned with a casting quality factor of 100% provided these areas are finish-machined both inside and outside, are carefully inspected, and that the contour of the welding end transition complies with PG-42.4.2.

PG-42.4.2 The welding ends of component bodies such as fittings and valves, whether constructed of cast products, wrought products, or any other fabrication process acceptable under the Code, shall provide a gradual change in thickness from that of the adjoining pipe to that of the component body. Any configuration of weld end transition that lies entirely within the envelope shown in Fig. PG-42.1 is acceptable provided that:

(a) the wall thickness in the transition region is not less than the smaller of the fitting or valve thickness required by PG-42.4.1 or the minimum value of the pipe thickness t_{min} defined under Fig. PG-42.1;

(b) the transition region including the weld joint shall avoid sharp reentrant angles and abrupt changes in slope. When the included angle between any two adjoining surfaces of a taper transition is less than 150 deg., the intersection or corner (except for the weld reinforcement) shall be provided with a radius of at least 0.05 t_{min}.

The configurations and tolerances suggested by such weld end standards as ASME B16.9 and ASME B16.25 are acceptable only to the extent that the resulting product and weld joint will comply with these requirements of PG-42.4.2. In Fig. PG-42.1 the thickness in the plane at the end of the fitting or valve shall not be less than t_{min} and shall not exceed a maximum of either: the greater of [t_{min} + 0.15 in. (4 mm)] or 1.15 t_{min} when ordered on a minimum wall basis, or the greater of [t_{min} + 0.15 in. (4 mm)] or 1.10 t_{nom} when ordered on a nominal wall basis.

PG-42.4.3 Fittings in which there are minor changes in the center-to-face dimensions or in which the angles of elbows differ from those given in an ASME Standard in PG-42.1 may be considered to fall within the scope of the standard provided the other requirements for materials, dimensions, and thickness are met.

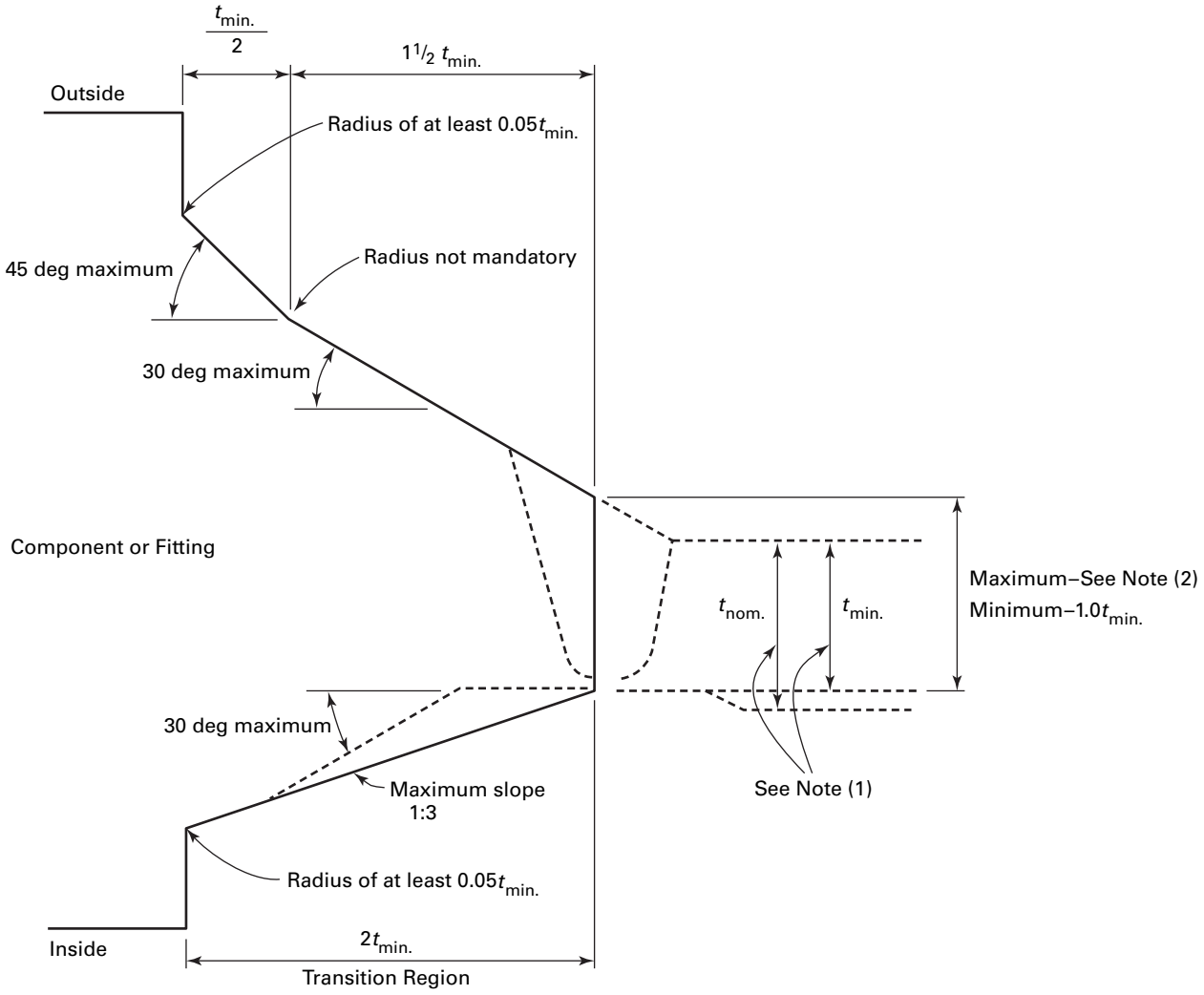
PG-42.4.4 Flanges and flanged fittings meeting the requirements of ASME B16.5 or valves meeting the requirements of ASME B16.34 may be used at the pressure–temperature ratings established by those standards. Standard Class, Special Class, or Limited Class valves may be used, provided that all parts of the valves are suitable for the pressure–temperature conditions at which they are to be used. Valves of intermediate rating or class, as described in ASME B16.34, are permitted.

PG-42.4.5 When the service requirements exceed the permissible values given in ASME B16.5 or ASME B16.34, the requirements of the Code will be met if the bolting material, flange thickness, and/or body thickness are increased so that the deflection limits are no greater and the factor of safety is no less than that of the nearest Pressure Rating Class in ASME B16.5 or ASME B16.34.

PG-42.4.6 Steel buttwelding fittings may be used provided they are at least equal to the requirements of ASME B16.9.

PG-42.4.7 ASME Standard slip-on flanges shall not exceed NPS 4 (DN 100). Attachment of slip-on flanges shall be by double fillet welds. The throats of the fillet welds shall not be less than 0.7 times the thickness of the part to which the flange is attached.

PG-42.4.8 ASME Standard socket welded flanges may be used in piping or boiler nozzles provided the dimensions do not exceed NPS 3 (DN 80) for Class



GENERAL NOTES:
(a) Weld bevel is shown for illustration only.
(b) The weld reinforcement permitted by PW-35 may be outside the maximum envelope.

NOTES:
(1) The value of $t_{min.}$ is whichever of the following is applicable:
  (a) the minimum ordered wall thickness of the pipe; or
  (b) the minimum ordered wall thickness of the tube; or
  (c) 0.875 times the nominal wall thickness of pipe ordered to a pipe schedule wall thickness that has an undertolerance of 12.5°; or
  (d) the minimum ordered wall thickness of the cylindrical welding end of a component or fitting (or the thinner of the two) when the joint is between two components.
(2) The maximum thickness at the end of the component is:
  (a) the greater of [$t_{min.}$ + 0.15 in. (4mm)] or $1.15t_{min.}$ when ordered on a minimum wall basis;
  (b) the greater of [$t_{min.}$ + 0.15 in. (4mm)] or $1.10t_{nom.}$ when ordered on a nominal wall basis.

FIG. PG-42.1 WELDING END TRANSITIONS MAXIMUM ENVELOPE

600 and lower, and NPS $2\frac{1}{2}$ (DN 65) in Classes 900 and 1,500.

PG-42.4.9 Threaded fittings of cast iron or malleable iron conforming to the requirements of the ASME Standards for Classes 125, 150, 250, and 300 pressure 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 (232°C).

PG-42.4.10 Cast- or forged-steel threaded fittings or valves that are at least equal to the strength requirements of the ASME Standard fittings that would otherwise be required may be used in all cases except where flanged fittings are specifically required.

PG-42.4.11 The casting quality factors given in PG-25 do not apply to ASME Standard cast steel fittings whose dimensions and ratings are incorporated in the Code.

Bronze threaded or flanged type fittings or valves may be used provided they are at least equal to the strength requirements of ASME B16.1 cast iron fittings that would otherwise be required. Bronze threaded fittings may be used if they comply with ASME B16.15. The material shall comply with PG-8.4 and the allowable working stresses are not to exceed the values given in Table 1B of Section II, Part D, except as provided in PG-67.7. Bronze shall not be used where steel or other material is specifically required. Threaded type fittings shall not be used where flanged types are specified.

A03 PG-43 NOZZLE NECK THICKNESS

The minimum thickness of a nozzle neck (including access openings and openings for inspection) shall not be less than the thickness required for the applicable loadings. Additionally, the minimum thickness of a nozzle neck (except for access openings and openings for inspection) shall not be less than the smaller of the following:

PG-43.1 The minimum required thickness of a seamless shell or head to which it is attached.

PG-43.2 The minimum wall thickness of standard-wall pipe listed in Table 2 of ASME B36.10M.

PG-44 INSPECTION OPENINGS

PG-44.1 All boilers or parts thereof shall be provided with suitable manhole, handhole, or other inspection openings for examination or cleaning, except for special types of boilers where such openings are manifestly not needed or used.

Specific requirements for access openings in certain types of boilers appear in other paragraphs.

An elliptical manhole opening shall be not less than 12 in. × 16 in. (152 mm × 406 mm) in size.

A circular manhole opening shall be not less than 15 in. (381 mm) in diameter.

A handhole opening in a boiler drum or shell shall be not less than $2\frac{3}{4}$ in. × $3\frac{1}{2}$ in. (70 mm × 89 mm), but it is recommended that, where possible, larger sizes be used.

Manhole, handhole, inspection, and washout openings in a shell or unstayed head shall be designed in accordance with the rules of PG-32 to PG-42.

When a threaded opening is to be used for inspection or washout purposes, it shall be not less than 1 in. (25 mm) pipe size. The closing plug or cap shall be of nonferrous material except for pressures of over 250 psi (1 720 kPa).

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.

PG-44.2 Manhole and handhole cover plates shall be of rolled, forged or cast steel except that for pressures not exceeding 250 psi (1 720 kPa), and/or temperatures not exceeding 450°F (232°C), handhole cover plates may be made of cast iron complying with SA-278. Yokes, if used, shall be made of rolled, forged, or cast steel.

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.

PG-44.3 The minimum width of bearing surface for a gasket on a manhole opening shall be $\frac{11}{16}$ in. (18 mm). No gasket for use on a manhole or handhole of any boiler shall have a thickness greater than $\frac{1}{4}$ in. (6 mm), when compressed.

PG-46 STAYED SURFACES

PG-46.1 The minimum thickness and maximum allowable working pressure for stayed flat plates and those parts that, by these rules, require staying as flat plates with stays or staybolts of uniform diameter symmetrically spaced, shall be calculated by the following formulas:

$$t = p\sqrt{\frac{P}{SC}} \quad (1)$$

$$P = \frac{t^2SC}{p^2} \quad (2)$$

where

t = minimum thickness of plate, in. (mm)
P = maximum allowable working pressure, psi (kPa)
S = maximum allowable stress given in Table 1A of Section II, Part D, psi (kPa)
p = maximum pitch measured between straight lines passing through the centers of the staybolts in the different rows, which lines may be horizontal and vertical, or radial and circumferential, in. (mm)
C = 2.1 for welded stays or stays screwed through plates not over $^{7}/_{16}$ in. (11 mm) in thickness with ends riveted over
C = 2.2 for welded stays or stays screwed through plates over $^{7}/_{16}$ in. (11 mm) in thickness with ends riveted over
C = 2.5 for stays screwed through plates and fitted with single nuts outside of plate, or with inside and outside nuts, omitting washers
C = 2.8 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 stay before installing them, and not riveted over, said heads being made to have a true bearing on the plate
C = 3.2 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

PG-46.2 The minimum thickness of plates to which stays may be applied, in other than cylindrical or spherical outer shell plates, shall be $^{5}/_{16}$ in. (8 mm) except for welded construction covered by PW-19.

PG-46.3 When two plates are connected by stays and only one of these plates requires staying, the value of C shall be governed by the thickness of the plate requiring staying.

PG-46.4 Acceptable proportions for the ends of through-stays with washers are indicated in Fig. PG-46.2.

PG-46.5 The maximum pitch shall be $8^{1}/_{2}$ in. (216 mm) except that for welded-in staybolts the pitch may be greater provided it does not exceed 15 times the diameter of the staybolt.

For the application of PG-48 and PFT-26, see Fig. A-8.

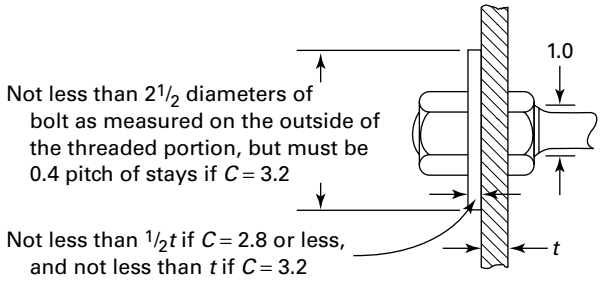


FIG. PG-46.2 ACCEPTABLE PROPORTIONS FOR ENDS OF THROUGH-STAYS

PG-46.6 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.

PG-46.7 The ends of stays fitted with nuts shall not be exposed to the direct radiant heat of the fire.

PG-46.8 Stays exceeding 120 diameters in length shall be supported at intervals not exceeding 120 diameters, or the cross-sectional area of the stay shall be increased by not less than 15% of its required area.

PG-47 STAYBOLTS

PG-47.1 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 plates; or they shall be fitted with threaded nuts through which the bolt or stay shall extend. The outside ends of solid staybolts 8 in. (203 mm) and less in length, if of uniform diameter throughout their length, shall be drilled with telltale holes at least $^{3}/_{16}$ in. (4.8 mm) in diameter to a depth extending at least $^{1}/_{2}$ in. (13 mm) beyond the inside of the plate. If such staybolts are reduced in section between their ends below their diameter at the root of the thread, the telltale holes shall extend at least $^{1}/_{2}$ in. (13 mm) beyond the point where the reduction in section commences. Hollow staybolts may

be used in place of solid staybolts with drilled ends. Solid staybolts over 8 in. (203 mm) long and flexible staybolts of either the jointed or ball-and-socket type need not be drilled. Staybolts used in waterlegs of watertube boilers shall be hollow or drilled at both ends, in accordance with the requirements above stated, irrespective of their length. All threaded staybolts not normal to the stayed surface shall have not less than three engaging threads of which at least one shall be a full thread, but if the thickness of the material in the boiler is not sufficient to give one full engaging thread, the plates shall be sufficiently reinforced on the inside by a steel plate welded thereto. Telltale holes are not required in staybolts attached by welding.

PG-47.2 The ends of steel stays upset for threading shall be fully annealed after upsetting.

PG-47.3 Requirements for welded-in staybolts are given in PW-19.

PG-48 LOCATION OF STAYBOLTS

PG-48.2 When the edge of a flat stayed plate is flanged, the distance from the center of the outermost stays to the inside of the supporting flange shall not be greater than the pitch of the stays plus the inside radius of the flange.

PG-49 DIMENSIONS OF STAYBOLTS

PG-49.1 The required area of a staybolt at its minimum cross section shall be obtained by dividing the load on the staybolt, computed in accordance with PFT-26, by the allowable stress value in accordance with Table 1A of Section II, Part D, and multiplying the results by 1.10.

PG-49.2 The diameter of a screw stay shall be taken at the bottom of the thread or wherever it is of the least diameter.

PG-52 LIGAMENTS

PG-52.1 The rules of this paragraph apply to groups of openings that form a definite pattern in pressure parts. (For patterns not definite see PG-53.) The efficiency of the ligament between the tube holes shall be determined as follows.

PG-52.2 Openings Parallel to Vessel Axis

PG-52.2.1 When the pitch of the tubes on every tube row is equal (as in Fig. PG-52.2), the formula is:

$$E = \frac{p - d}{p}$$

Example: Pitch of tube holes in the drum as shown in Fig. PG-52.2 = $5\frac{1}{4}$ in. Diameter of tube = $3\frac{1}{4}$ in. Diameter of tube holes = $3\frac{9}{32}$ in.

$$\frac{p - d}{p} = \frac{5.25 - 3.281}{5.25}$$

$$= 0.375 \text{ efficiency of ligament}$$

PG-52.2.2 When the pitch of the tube holes on any one row is unequal (as in Fig. PG-52.3 or PG-52.4), the formula is:

$$E = \frac{p_1 - nd}{p_1}$$

Example: Spacing shown in Fig. PG-52.3. Diameter of tube holes = $3\frac{9}{32}$ in.

$$\frac{p_1 - nd}{p_1} = \frac{12 - 2 \times 3.281}{12}$$

$$= 0.453 \text{ efficiency of ligament}$$

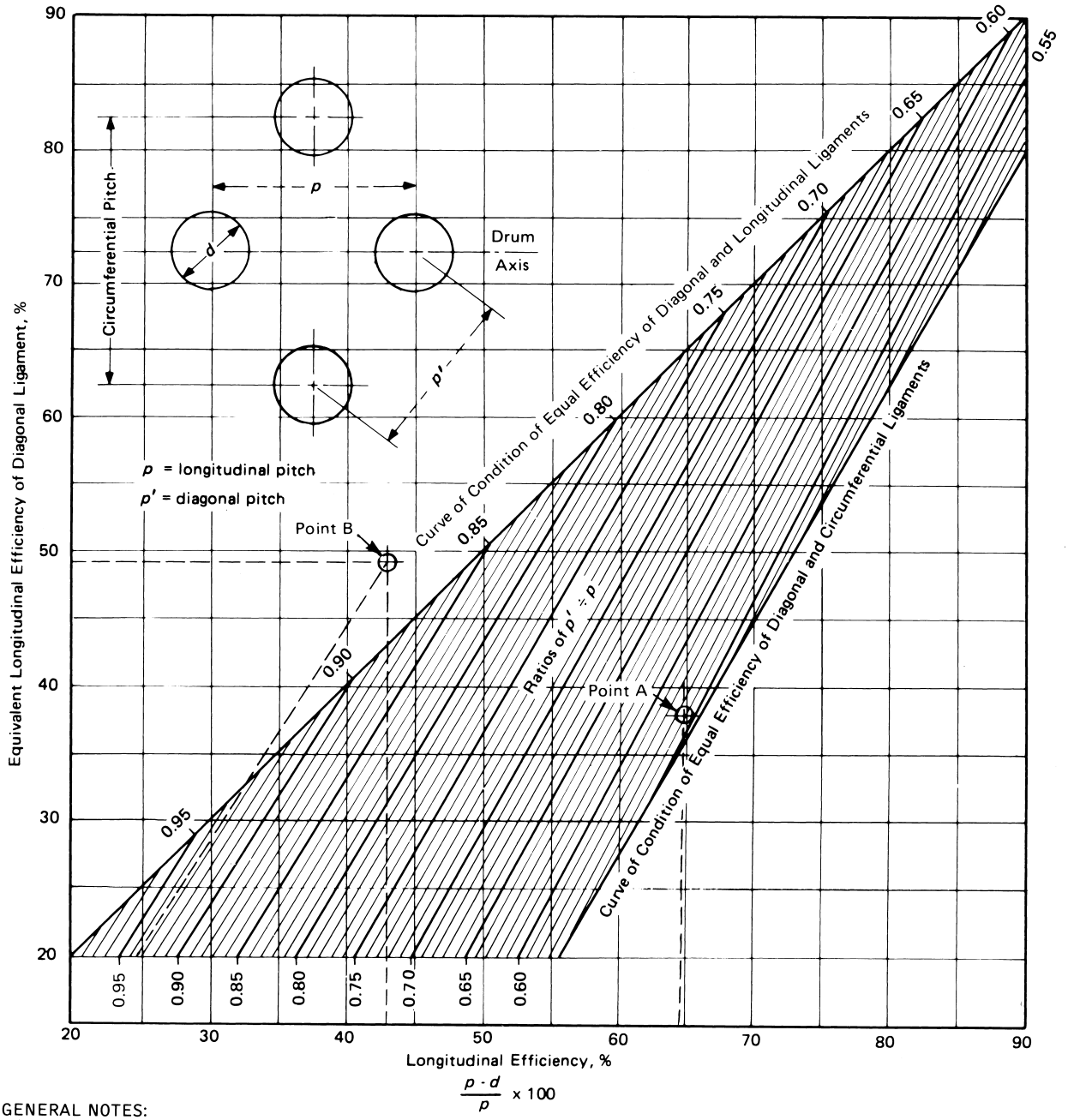
Example: Spacing shown in Fig. PG-52.4. Diameter of tube holes = $3\frac{9}{32}$ in.

$$\frac{p_1 - nd}{p_1} = \frac{29.25 - 5 \times 3.281}{29.25}$$

$$= 0.439 \text{ efficiency of ligament}$$

PG-52.3 Openings Transverse to Vessel Axis. The strength of those ligaments between the tube holes that are subjected to a longitudinal stress shall be at least one-half the required strength of those ligaments that come between the tube holes that are subjected to a circumferential stress.

PG-52.4 Holes Along a Diagonal. When a shell or drum is drilled for tube holes as shown in Fig. PG-52.5, the efficiency of these ligaments shall be that given by the diagram in Fig. PG-52.1. The abscissa $(p - d)/p$ and the ratio p'/p shall be computed. With these values the efficiency may be read off the ordinate. Should the point fall above the curve of equal efficiency for the diagonal and longitudinal ligaments, the longitu-



GENERAL NOTES:

(a) Equations are provided for the user's option in Notes (b), (c), and (d) below. The use of these equations is permitted for values beyond those provided by Fig. PG-53.1.

(b) Diagonal efficiency, % $= \dfrac{J + 0.25 - (1 - 0.01E_{long.})\sqrt{0.75 + J}}{0.00375 + 0.005J}$, where $J = (p'/p_1)^2$.

(c) Curve of condition of equal efficiency of diagonal and circumferential ligaments,

diagonal efficiency, % $= \dfrac{200M + 100 - 2(100 - E_{long.})\sqrt{1 + M}}{(1 + M)}$, where $M = [(100 - E_{long.})/(200 - 0.5E_{long.})]^2$.

(d) Longitudinal efficiency, % $= E_{long.} = [(p_1 - d)/p_1]\,100$.

FIG. PG-52.1 DIAGRAM FOR DETERMINING THE EFFICIENCY OF LONGITUDINAL AND DIAGONAL LIGAMENTS BETWEEN OPENINGS IN CYLINDRICAL SHELLS

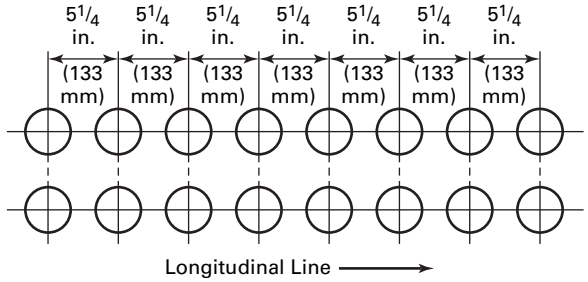


FIG. PG-52.2 EXAMPLE OF TUBE SPACING WITH PITCH OF HOLES EQUAL IN EVERY ROW

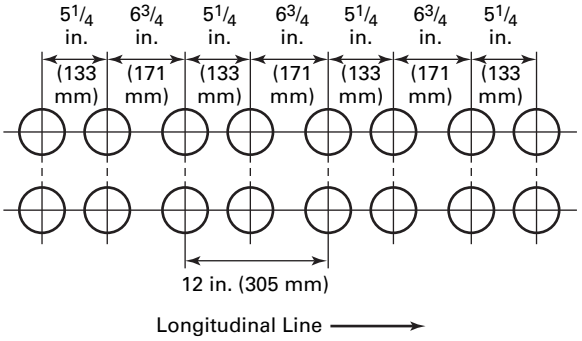


FIG. PG-52.3 EXAMPLE OF TUBE SPACING WITH PITCH OF HOLES UNEQUAL IN EVERY SECOND ROW

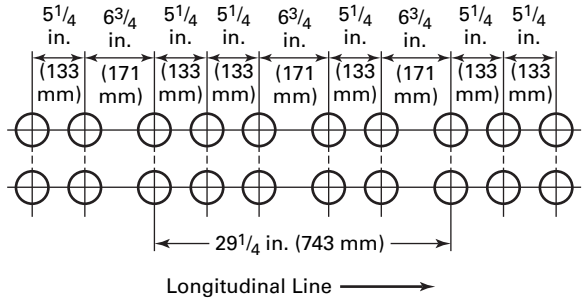


FIG. PG-52.4 EXAMPLE OF TUBE SPACING WITH PITCH OF HOLES VARYING IN EVERY SECOND AND THIRD ROW

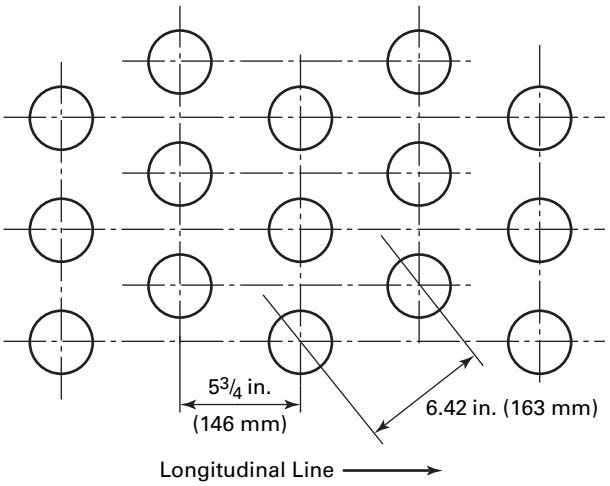


FIG. PG-52.5 EXAMPLE OF TUBE SPACING WITH TUBE HOLES ON DIAGONAL LINES

dinal ligaments will be the weaker, in which case the efficiency is computed from the following equation:

$$\frac{p - d}{p} \tag{1}$$

Example:

(1) Diagonal pitch of tube holes in drum as shown in Fig. PG-52.5 = 6.42 in. Diameter of holes = $4^{1}/_{32}$ in. Longitudinal pitch of tube holes = $11^{1}/_{2}$ in.

$$\frac{p - d}{p} = \frac{11.5 - 4.031}{11.5} = 0.649 \tag{2}$$

$$\frac{p'}{p} = \frac{6.42}{11.5} = 0.558 \tag{3}$$

The point corresponding to thesevalues is shown at A on the diagram in Fig. PG-52.1, and the corresponding efficiency is 37.0%. As the point falls below the curve of equal efficiency for the diagonal and longitudinal ligaments, the diagonal ligament is the weaker.

(2) Diagonal pitch of tube holes in drum = $6^{35}/_{64}$ in. Diameter of tube holes = $4^{1}/_{64}$ in. Longitudinal pitch of tube holes = 7 in.

$$\frac{p - d}{p} = \frac{7 - 4.0156}{7} = 0.426 \tag{4}$$

$$\frac{p'}{p} = \frac{6.547}{7} = 0.935$$

The point corresponding to these values is shown at *B* on the diagram in Fig. PG-52.1, and it will be seen that it falls above the line of equal efficiency for the diagonal and longitudinal ligaments, in which case the efficiency is computed from Eq. (1). Applying Eq. (1), we have:

$$\frac{7 - 4.0156}{7} = 0.426, \text{ efficiency of ligament, or } 42.6\%$$

PG-52.5 When tubes or holes are arranged in a drum or shell in symmetrical groups along lines parallel to the axis and the same spacing is used for each group, the efficiency for one of the groups shall be not less than the efficiency on which the maximum allowable working pressure is based.

PG-52.6 The symbols defined below are used in the formulas of this paragraph:

p = longitudinal pitch of adjacent openings, in. (mm)
p' = diagonal pitch of adjacent openings, in. (mm)
p_1 = pitch between corresponding openings in a series of symmetrical groups of openings, in. (mm)
d = diameter of openings, in. (mm)
n = number of openings in length p_1
E = efficiency of ligament

The pitch shall be measured either on the flat plate before rolling or on the median surface after rolling.

PG-53 LIGAMENTS

PG-53.1 The rules in this paragraph apply to groups of openings that do not form a definite pattern in pressure parts. (For definite patterns see PG-52.) The efficiency of the ligament between tube holes shall be determined as follows:

PG-53.2 When tubes or holes are unsymmetrically spaced, the average ligament efficiency shall be not less than that given by the following rules, which apply to ligaments between tube holes, and not to single openings. This procedure may give lower efficiencies in some cases than those for symmetrical groups which extend a distance greater than the inside diameter of the shell as covered under PG-52. When this occurs, the efficiencies computed by the rules under PG-52 shall be used.

PG-53.2.1 For a length equal to the inside diameter of the drum for the position that gives the minimum efficiency, the efficiency shall be not less than that on which the maximum allowable working pressure is based. When the diameter of the drum exceeds 60 in. (1 520 mm), the length shall be taken as 60 in. (1 520 mm) in applying this rule.

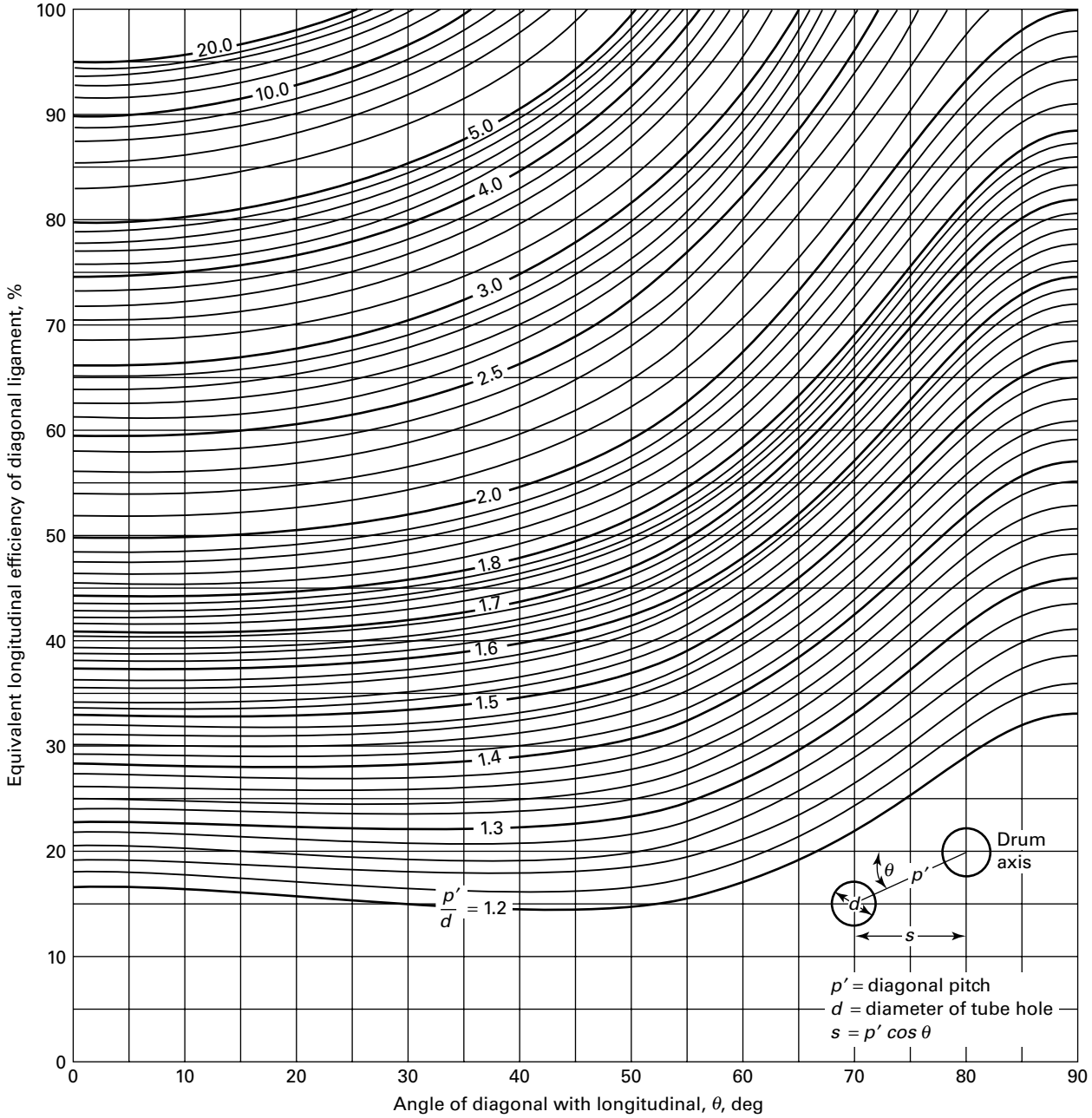
PG-53.2.2 For a length equal to the inside radius of the drum for the position that gives the minimum efficiency, the efficiency shall be not less than 80% of that on which the maximum allowable working pressure is based. When the radius of the drum exceeds 30 in. (762 mm), the length shall be taken as 30 in. (762 mm) in applying this rule.

PG-53.3 For holes placed longitudinally along a drum but that do not come in a straight line, the above rules for calculating efficiency shall hold except that the equivalent longitudinal width of a diagonal ligament shall be used. To obtain the equivalent width the longitudinal pitch of the two holes having a diagonal ligament shall be multiplied by the efficiency of the diagonal ligament. The efficiency to be used for the diagonal ligaments is given in Fig. PG-52.6.

PG-55 SUPPORTS AND ATTACHMENT LUGS

PG-55.1 Lugs or hangers when used to support a boiler of any type shall be properly fitted to the surfaces to which they are attached.

PG-55.2 Lugs, hangers, or brackets may be attached by fusion welding provided the welding meets the requirements of Part PW, including stress relieving but omitting radiographic examination and provided they are attached by full penetration welds, combination groove and fillet welds, or by fillet welds along the entire periphery or contact edges. Some acceptable forms of welds for lugs, hangers, or brackets are shown in Fig. PW-16.2. The materials for lugs, hangers, or brackets are not limited to those listed in Tables 1A and 1B of Section II, Part D, but shall be of weldable quality. The allowable load on the fillet welds shall equal the product of the weld area based on minimum leg dimension, the allowable stress value in tension of the material being welded, and the factor 0.55. When using welded pipe, the stress values given in Table 1A of Section II, Part D, may be increased to that of the basic material by eliminating the stated weld efficiencies.



GENERAL NOTES:

(a) The equation in Note (b) below is provided for the user's option. The use of the equation is prohibited beyond the range of the abscissa and ordinate shown.

(b) Equivalent longitudinal efficiency,

$$\% = \frac{\sec^2\theta + 1 - \left(\frac{\sec\theta}{p'/d}\right)\sqrt{3 + \sec^2\theta}}{0.015 + 0.005\sec^2\theta}$$

FIG. PG-52.6 DIAGRAM FOR DETERMINING EQUIVALENT LONGITUDINAL EFFICIENCY OF DIAGONAL LIGAMENTS BETWEEN OPENINGS IN CYLINDRICAL SHELLS

BOILER EXTERNAL PIPING AND BOILER PROPER CONNECTIONS

PG-58 OUTLETS AND EXTERNAL PIPING

PG-58.1 General. The rules of this subparagraph apply to the boiler external piping as defined in the Preamble.

PG-58.2 Boiler External Piping Connections to Boilers. All boiler external piping connected to a boiler for any purpose shall be attached to one of the types of joints listed in PG-59.1.1.1, PG-59.1.1.2, and PG-59.1.1.3.

PG-58.3 Boiler External Piping. The following defines the Code Jurisdictional Limits of the boiler external piping systems, including general requirements, valves, and inspection. The limits are also shown in Fig. PG-58.3.1 and Fig. PG-58.3.2. The materials, design, fabrication, installation, and testing shall be in accordance with ASME B31.1, Power Piping.

PG-58.3.1 The steam piping connected to the boiler drum or to the superheater outlet header shall extend up to and including the first stop valve in each connection, except as required by PG-58.3.2. In the case of a single boiler and prime mover installation, the stop valve required herein may be omitted provided the prime mover throttle valve is equipped with an indicator to show whether the valve is open or closed and is designed to withstand the required hydrostatic pressure test of the boiler.

For an isolable or separately fired superheater which discharges steam directly to a process stream, the stop valve required by this paragraph and the safety valve(s) required by PG-68 may be omitted provided the following conditions are satisfied:

(a) The boiler is a drum-type boiler in a single-boiler installation.

(b) The steam discharge passes through the process stream to the atmosphere with no intervening valves.

(c) The system shall be designed so that the process stream through which the steam discharge passes cannot be obstructed in such a way as to cause the pressure in the superheater to exceed that permitted by PG-67.2, with maximum steam flow from the boiler to the superheater. Flow and pressure calculations demonstrating that the superheater will not be overpressurized under any steam flow conditions shall be documented and made available to the Inspector. These calculations shall be certified by a Professional Engineer experienced in the mechanical design of power plants.

(d) There is no valve on the discharge side of the superheater.

(e) Section I jurisdiction shall include the pressure parts between the superheater inlet and the outlet at:

(1) the first circumferential joint for welding end connections; or

(2) the face of the first flange in bolted flange connections; or

(3) the first threaded joint in that type of connection.

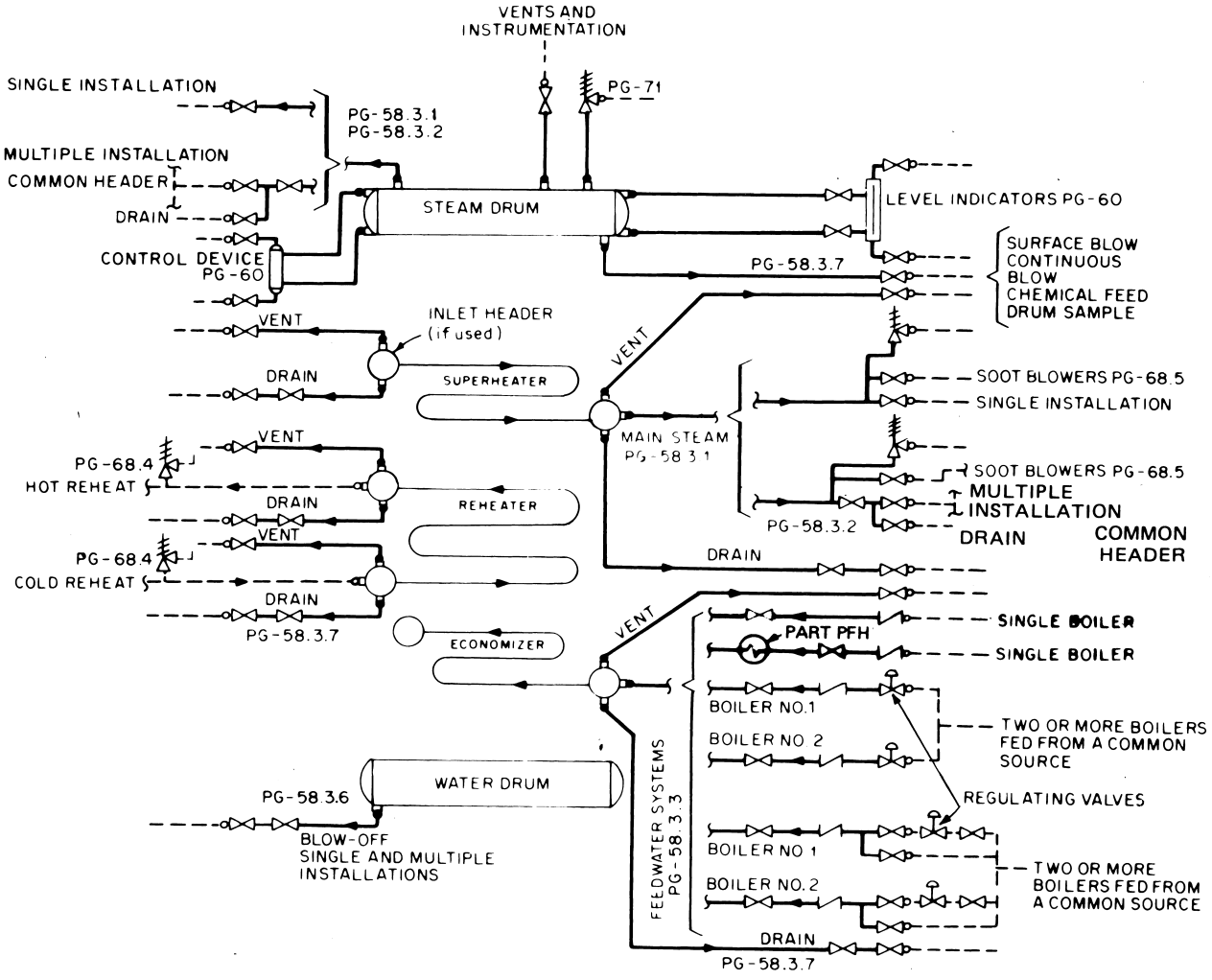
PG-58.3.2 When two or more boilers are connected to a common steam header, or when a single boiler is connected to a header having another steam source (e.g., a turbine extraction line), the connection from each boiler having a manhole opening shall be fitted with two stop valves having an ample free-blow drain between them. The boiler external piping includes all piping from the boiler proper up to and including the second stop valve and the free-blow drain valve.

PG-58.3.3 The feedwater piping for all boilers, except high-temperature water boilers and forced-flow steam generators complying with PG-58.3.5, shall extend through the required stop valve and up to and including the check valve except as required by PG-58.3.4. On a single boiler-turbine unit installation the boiler feed shutoff valve may be located upstream from the boiler feed check valve.

If a feedwater heater or heaters meeting the requirements of Part PFH are installed between the required stop valve and the boiler, and are fitted with isolation and bypass valves, provisions must be made to prevent the feedwater pressure from exceeding the maximum allowable working pressure of the piping or feedwater heater, whichever is less. Control and interlock systems are permitted in order to prevent overpressure.

PG-58.3.4 When two or more boilers are fed from a common source, the piping shall be up to and including a globe or regulating valve located between the check valve required in PG-58.3.3 and the source of supply. If the regulating valve is equipped with an isolation valve and a bypass valve, the piping shall be up to and including both the isolation valve downstream from the regulating valve and the shutoff valve in the bypass.

PG-58.3.5 The feedwater piping for a forced-flow steam generator with no fixed steam and waterline may terminate up to and including the stop valve near the boiler and omitting the check valve near the boiler, provided that a check valve having a pressure rating no less than the boiler inlet design pressure is installed



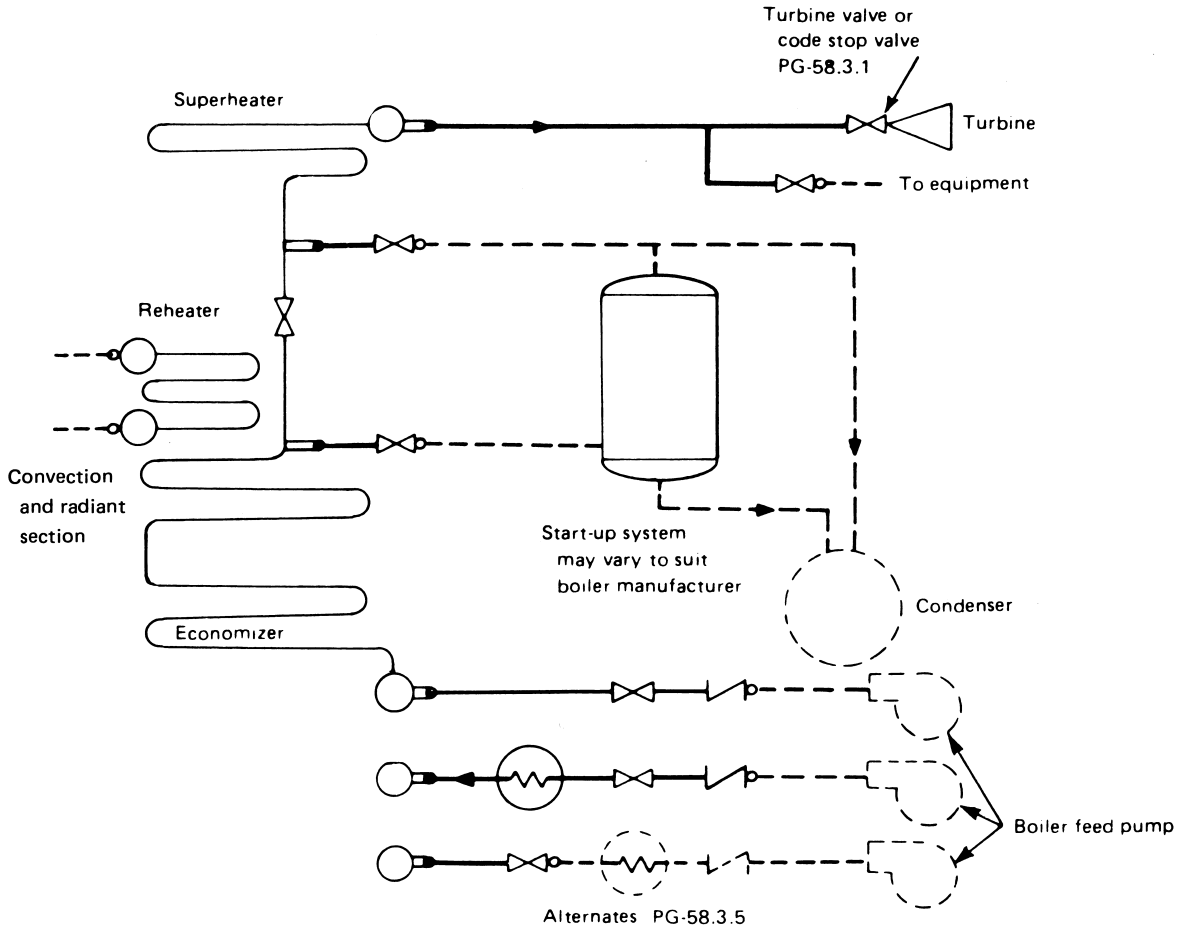
ADMINISTRATIVE JURISDICTION & TECHNICAL RESPONSIBILITY

Boiler Proper — The ASME Boiler and Pressure Vessel Code (ASME BPVC) has total administrative jurisdiction and technical responsibility (refer to Section I Preamble).

Boiler External Piping and Joint — The ASME BPVC has total administrative jurisdiction (mandatory certification by Code Symbol stamping, ASME Data Forms, and Authorized Inspection) of Boiler External Piping and Joint. The ASME Section Committee B31.1 has been assigned technical responsibility.

Non-Boiler External Piping and Joint — Not Section I jurisdiction (see applicable ASME B31 Code).

FIG. PG-58.3.1 CODE JURISDICTIONAL LIMITS FOR PIPING — DRUM TYPE BOILERS



ADMINISTRATIVE JURISDICTION & TECHNICAL RESPONSIBILITY

Boiler Proper — The ASME Boiler and Pressure Vessel Code (ASME BPVC) has total administrative jurisdiction and technical responsibility (refer to Section I Preamble).

Boiler External Piping and Joint — The ASME BPVC has total administrative jurisdiction (mandatory certification by Code Symbol stamping, ASME Data Forms, and Authorized Inspection) of Boiler External Piping and Joint. The ASME Section Committee B31.1 has been assigned technical responsibility.

Non-Boiler External Piping and Joint — Not Section I jurisdiction (see applicable ASME B31 Code).

FIG. PG-58.3.2 CODE JURISDICTIONAL LIMITS FOR PIPING — FORCED-FLOW STEAM GENERATOR WITH NO FIXED STEAM OR WATERLINE

at the discharge of the boiler feed pump or elsewhere in the feedline between the feed pump and the feed stop valve. If the feedwater heater(s) is fitted with isolation and bypass valves, the applicable requirements of PG-58.3.3 must be met.

PG-58.3.6 The blowoff piping for all boilers, except forced-flow steam generators with no fixed steam and waterline, high-temperature water boilers, and those used for traction and/or portable purposes, when the maximum allowable working pressure exceeds 100 psi (690 kPa) shall extend through and including the second valve. The blowoff piping for all traction and/or portable boilers and for forced circulation and electric boilers having a normal water content not exceeding 100 gal (379 L) are required to extend through only one valve.

PG-58.3.7 The miscellaneous piping shall include the piping for such items as drains, vents, surface-blow-off, steam and water piping for water columns, gage glasses and pressure gages, and the recirculation return line for a high-temperature water boiler. When a drain is not intended for blowoff purposes (when the boiler is under pressure) a single valve is acceptable, otherwise two valves in series are required except as permitted by PG-58.3.6.

PG-58.3.8 Welded piping in PG-58.3.1, PG-58.3.2, PG-58.3.3, PG-58.3.4, PG-58.3.5, PG-58.3.6, and PG-58.3.7 is also subject to the requirements of PG-104 for proper Code certification.

PG-59 APPLICATION REQUIREMENTS FOR THE BOILER PROPER

PG-59.1 Common to Steam, Feedwater, Blowoff, and Drain Systems

PG-59.1.1 Outlets of a boiler to which piping is to be attached for any purpose, and which piping comes within the Code requirements, shall meet the requirements of PG-39 and shall be:

PG-59.1.1.1 A tapped opening.

PG-59.1.1.2 Bolted flanged joints including those of the Van Stone type.

PG-59.1.1.3 Welding ends of the butt or socket welding type.

PG-59.1.1.4 Piping within the boiler proper may be expanded into grooved holes, seal welded if desired. Blowoff piping of firetube boilers shall be attached by threading into a tapped opening with a threaded fitting or valve at the other end if exposed to products of combustion, or by PG-59.1.1.1 or PG-59.1.1.2 if not so exposed (see PFT-49).

PG-59.1.2 Steam Mains. Provisions shall be made for the expansion and contraction of steam mains connected to boilers, by providing substantial anchorage at suitable points, so that there shall be no undue strain transmitted to the boiler. Steam reservoirs shall be used on steam mains when heavy pulsations of the steam currents cause vibration of the boiler shell plates.

PG-59.1.3 Figure PG-59.1 illustrates a typical form of connection for use on boiler shells for passing through piping such as feed, surface blowoff connections, etc., and which permits the pipes' being threaded in solid from both sides in addition to the reinforcing of the opening of the shell. The pipes shall be attached as provided in PG-59.1.1.

In these and other types of boilers where both internal and external pipes making a continuous passage are employed, the boiler bushing or its equivalent shall be used.

PG-59.2 Requirements for Feedwater Connections. The feedwater shall be introduced into a boiler in such a manner that the water will not be discharged directly against surfaces exposed to gases of high temperature or to direct radiation from the fire. For pressures of 400 psi or over, the feedwater inlet through the drum shall be fitted with shields, sleeves, or other suitable means to reduce the effects of temperature differentials in the shell or head. Feedwater, other than condensate returns as provided for in PG-59.3.6, shall not be introduced through the blowoff.

PG-59.3 Requirements for Blowoffs

PG-59.3.1 A blowoff as required herein is defined as a pipe connection provided with valves located in the external piping through which the water in the boiler may be blown out under pressure, excepting drains such as are used on water columns, gage glasses, or piping to feedwater regulators, etc., used for the purpose of determining the operating condition of such equipment. Piping connections used primarily for continuous operation, such as deconcentrators on continuous blowdown systems, are not classed as blowoffs but the pipe connections and all fittings up to and including the first shutoff valve shall be equal at least to the pressure requirements for the lowest set pressure of any safety valve on the boiler drum and with the corresponding saturated-steam temperature.

PG-59.3.2 A surface blowoff connection shall not exceed NPS $2\frac{1}{2}$ (DN 65), and the internal pipe and the terminal connection for the external pipe, when

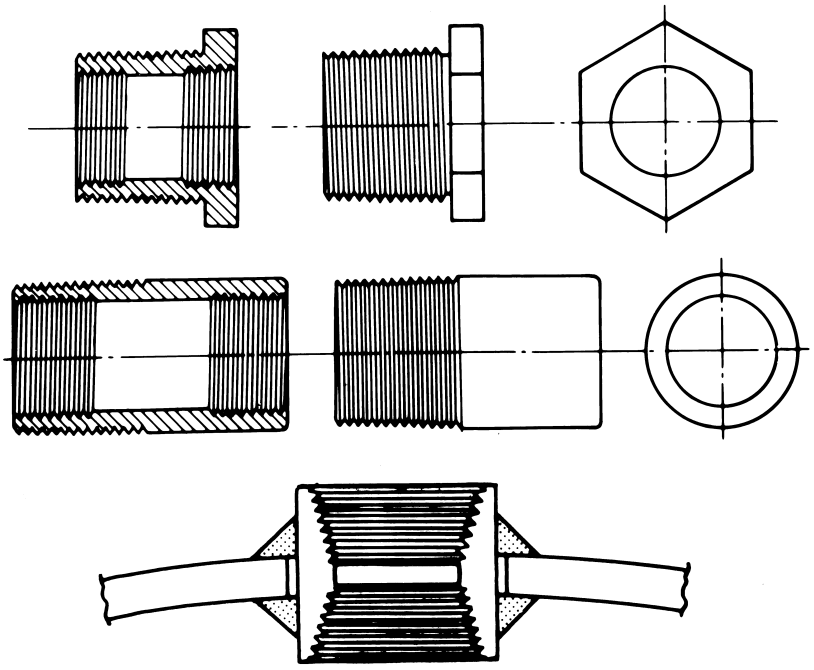


FIG. PG-59.1 TYPICAL BOILER BUSHINGS

used, shall form a continuous passage, but with clearance between their ends and arranged so that the removal of either will not disturb the other. A properly designed steel bushing, similar to or the equivalent of those shown in Fig. PG-59.1, or a flanged connection shall be used.

PG-59.3.3 Each boiler except forced-flow steam generators with no fixed steam and waterline and high-temperature water boilers shall have a bottom blowoff outlet in direct connection with the lowest water space practicable for external piping conforming to PG-58.3.6.

PG-59.3.4 All waterwalls and water screens that do not drain back into the boiler, and all integral economizers, shall be equipped with outlet connections for a blowoff or drain line and conform to the requirements of PG-58.3.6 or PG-58.3.7.

PG-59.3.5 Except as permitted for miniature boilers in Part PMB, the minimum size of blowoff connections shall be NPS 1 (DN 25), and the maximum size shall be NPS $2\frac{1}{2}$ (DN 65), except that for boilers with 100 sq ft (9.3 m^2) of heating surface or less, the minimum size of blowoff connections may be NPS $\frac{3}{4}$ (DN 20).

PG-59.3.6 Condensate return connections of the same size or larger than the size herein specified may be used, and the blowoff may be connected to them. In such case the blowoff shall be so located that the connection may be completely drained.

PG-59.3.7 A bottom blowoff pipe when exposed to direct furnace heat shall be protected by firebrick or other heat resisting material that is so arranged that the pipe may be inspected.

PG-59.3.8 An opening in the boiler setting for a blowoff pipe shall be arranged to provide free expansion and contraction.

PG-59.4 Requirements for Drains

PG-59.4.1 Ample drain connections shall be provided where required to permit complete drainage of all piping, superheaters, waterwalls, water screens, integral economizers, high-temperature water boilers, and all other boiler components in which water may collect. Piping shall conform to the requirements of PG-58.3.6 or PG-58.3.7.

PG-59.4.1.1 Each superheater shall be equipped with at least one drain connection so located as to most effectively provide for the proper operation of the apparatus.

PG-59.4.1.2 Each high-temperature water boiler shall have a bottom drain connection of at least NPS 1 (DN 25) in direct connection with the lowest water

space practical for external piping conforming to PG-58.3.7.

PG-59.5 Requirements for Valves and Fittings. The following requirements apply to the use of valves and fittings in the boiler proper.

PG-59.5.1 Steam Stop Valves

PG-59.5.1.1 If a shutoff valve is used between the boiler and its superheater, the safety valve capacity on the boiler shall comply with the requirements of PG-67.2 and PG-70, except as provided for in PG-59.5.1.2, no credit being taken for the safety valve on the superheater, and the superheater must be equipped with safety valve capacity as required by PG-68. A stop valve is not required at the inlet or the outlet of a reheater or separately fired superheater.

PG-59.5.1.2 When stop valves are installed in the water-steam flow path between any two sections of a forced-flow steam generator with no fixed steam and waterline, the safety valves shall satisfy the requirements of PG-67.4.4.

DESIGN AND APPLICATION

PG-60 REQUIREMENTS FOR MISCELLANEOUS PIPE, VALVES, AND FITTINGS

Piping referred to in this paragraph shall be designed in accordance with the applicable requirements of ASME B31.1.

A02 **PG-60.1 Water Level Indicators.** All boilers having a fixed water level (steam and water interface) shall have at least one gage glass (a transparent device that permits visual determination of the water level). Boilers not having a fixed water level, such as forced-flow steam generators and high-temperature water boilers of the forced circulation type, are not required to have a gage glass. The lowest visible water level in a gage glass shall be at least 2 in. (51 mm) above the lowest permissible water level, as determined by the boiler Manufacturer. Electrode type electric boilers are required to have only one gage glass, regardless of MAWP.

Gage glasses having multiple tubular sections shall have a minimum of 1 in. (25 mm) overlap of the sections in which the water level may be visible. Segmented gage glasses, such as ported or end-connected strip gages, shall be equipped to provide obvious visual discrimination between water and vapor in the individual sections.

PG-60.1.1 Boilers having a maximum allowable working pressure exceeding 400 psi (2 800 kPa) shall have two gage glasses. Instead of one of the two required gage glasses, two independent remote water level indicators (two discrete systems that continuously measure, transmit, and display water level) may be provided.

PG-60.1.1.1 When the water level in at least one gage glass is not readily visible to the operator in the area where control actions are initiated, either a fiber optic cable (with no electrical modification of the optical signal) or mirrors shall be provided to transfer the optical image of the water level to the control area. Alternatively, any combination of two of the following shall be provided: (a) an independent remote water level indicator; (b) an independent continuous transmission and display of an image of the water level in a gage glass.

PG-60.1.1.2 When two independent remote water level indicators are in reliable operation (continuously indicating water level), the one required gage glass may be shut off, but shall be maintained in the serviceable condition.

PG-60.1.1.3 The display of a remote water level indicator shall have a clearly marked minimum water level reference at least 2 in. (51 mm) above the lowest permissible water level, as determined by the Manufacturer.

PG-60.1.4 DELETED

PG-60.1.5 DELETED

PG-60.1.6 Each gage glass shall be fitted with a drain cock or valve having an unrestricted drain opening of not less than $\frac{1}{4}$ in. (6 mm) diameter to facilitate cleaning. When the boiler MAWP exceeds 100 psi (690 kPa), the gage glass shall be furnished with a connection to install a valved drain to a point of safe discharge.

Each gage glass shall be equipped with a top and a bottom shutoff valve of such through-flow construction as to prevent stoppage by deposits of sediments. If the bottom valve is more than 7 ft (2.1 m) above the floor or platform from which it is operated, the operating mechanism shall indicate by its position whether the valve is open or closed. The pressure–temperature rating

of valves, fittings, and piping shall be at least equal to the boiler MAWP and the corresponding saturated-steam temperature.

Straight-run globe valves shall not be used on such connections. Automatic shutoff valves, if permitted to be used, shall conform to the requirements given in A-18.

A02 **PG-60.2 Water Columns**

PG-60.2.1 A water column shall be so mounted that it will be correctly positioned, relative to the normal water level under operating conditions.

PG-60.2.3 Each water column shall be furnished with a connection of at least NPS $^{3}/_{4}$ (DN 20) to install a valved drain to a safe point of discharge.

PG-60.2.4 The design and material of a water column shall comply with the requirements of PG-8.2, PG-8.3, and PG-42.

A02 **PG-60.3 Connections**

PG-60.3.1 Gage glasses that are required by PG-60.1 shall be connected directly to the shell or drum of the boiler or to an intervening water column. When two gage glasses are required, both may be connected to a single water column.

PG-60.3.2 The lower edge of the steam connection between a water column or gage glass in the boiler shall not be below the highest visible water level in the gage glass. There shall be no sag or offset in the piping that will permit the accumulation of water.

PG-60.3.3 The upper edge of the water connection between a water column or gage glass and the boiler shall not be above the lowest visible water level in the gage glass. No part of this pipe connection shall be above the point of connection at the water column.

A03 **PG-60.3.4** Connections from the boiler to the water column shall be at least NPS 1 (DN 25). Connections for gage glasses connected directly to the boiler or to an intervening water column shall be at least NPS $^{1}/_{2}$ (DN 15). Connections from the boiler to the remote level indicator shall be at least NPS $^{3}/_{4}$ (DN 20) to and including the isolation valve and from there to the remote level indicator at least $^{1}/_{2}$ in. (13 mm) O.D. tubing.

PG-60.3.5 When the boiler MAWP exceeds 400 psi (2 800 kPa), lower connections to drums for water columns and remote level indicators shall be provided with shields, sleeves, or other suitable means to reduce the effect of temperature differentials in the shells or heads.

PG-60.3.6 The steam and water connections to a water column or a gage glass shall be readily accessible for internal inspection and cleaning. Some acceptable methods of meeting this requirement are by providing a cross or fitting with a back outlet at each right-angle turn to permit inspection and cleaning in both directions, or by using pipe bends or fittings of a type that does not leave an internal shoulder or pocket in the pipe connection and with a radius of curvature that will permit the passage of a rotary cleaner. Screwed plug closures using threaded connections as allowed by PG-39.5.3 are acceptable means of access for this inspection and cleaning. When the boiler MAWP exceeds 400 psig (2 800 kPa), socket-welded plugs may be used for this purpose in lieu of screwed plugs. If the water connection to the water column has a rising bend or pocket that cannot be drained by means of the water-column drain, an additional drain shall be placed on this connection so that it may be blown off to clear any sediment from the pipe.

PG-60.3.7 Shutoff valves, if provided in the pipe connections between a boiler and a water column or between a boiler and the shutoff valves required for the gage glass (PG-60.1.6), shall be of such through-flow construction as to prevent stoppage by deposits of sediment and shall indicate whether they are in open or closed position of the operating mechanism.

Some examples of acceptable valves are:

(a) outside-screw-and-yoke type gate valve;

(b) lever-lifting type gate valve with permanently fastened lever;

(c) stopcock with the plug held in place by a guard or gland; and

(d) ball valve.

Such valves shall be locked or sealed open except under the following additional conditions:

(1) the boiler MAWP shall not exceed 250 psig (1 720 kPa).

(2) The boiler shall not be hand fired or fired with solid fuel not in suspension.

(3) Interlocks between the valve and the burner control system shall stop fuel supply and prevent firing whenever the valve between the drum and the water column is not in the fully open position.

(4) The minimum valve size shall be NPS 1 (DN 25).

PG-60.3.8 Except for control devices such as damper regulators and feedwater regulators, drains, steam pressure gages, or apparatus of such form as does not permit the escape of an appreciable amount of steam or water therefrom, no outlet connections

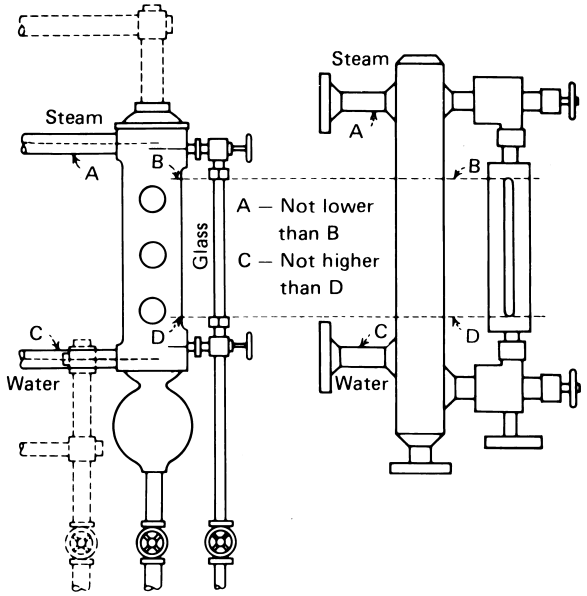


FIG. PG-60 TYPICAL ARRANGEMENT OF STEAM AND WATER CONNECTIONS FOR A WATER COLUMN

shall be placed on the piping connecting a water column or gage glass to a boiler. No outlet connections shall be placed on the piping connecting a remote level indicator to the boiler or to a water column for any function other than water level indication.

PG-60.3.9 An acceptable arrangement is shown in Fig. PG-60.

PG-60.4 Gage Cocks. Not required.

PG-60.5 Water Fronts. Each boiler fitted with a water jacketed boiler-furnace mouth protector, or similar appliance having valves on the pipes connecting them to the boiler shall have these valves locked or sealed open. Such valves, when used, shall be of the straightway type.

PG-60.6 Pressure Gages

PG-60.6.1 Each boiler shall have a pressure gage so located that it is easily readable. The pressure gage shall be installed so that it shall at all times indicate the pressure in the boiler. Each steam boiler shall have the pressure gage connected to the steam space or to the water column or its steam connection. A valve or cock shall be placed in the gage connection adjacent to the gage. An additional valve or cock may be located near the boiler providing it is locked or sealed in the open position. No other shutoff valves shall be located between the gage and the boiler. The pipe connection shall be of ample size and arranged so that it may be cleared by blowing out. For a steam boiler the gage or connection shall contain a syphon or equivalent device that will develop and maintain a water seal that will prevent steam from entering the gage tube. Pressure gage connections shall be suitable for the maximum allowable working pressure and temperature, but if the temperature exceeds 406°F (208°C), brass or copper pipe or tubing shall not be used. The connections to the boiler, except the syphon, if used, shall not be less than NPS $\frac{1}{4}$ (DN 8) but where steel or wrought iron pipe or tubing is used, they shall not be less than $\frac{1}{2}$ in. (13 mm) inside diameter. The minimum size of a syphon, if used, shall be $\frac{1}{4}$ in. (6 mm) inside diameter. The dial of the pressure gage shall be graduated to approximately double the pressure at which the safety valve is set, but in no case to less than $1\frac{1}{2}$ times this pressure.

PG-60.6.2 Each forced-flow steam generator with no fixed steam and waterline shall be equipped with pressure gages or other pressure measuring devices located as follows:

PG-60.6.2.1 At the boiler or superheater outlet (following the last section which involves absorption of heat), and

PG-60.6.2.2 At the boiler or economizer inlet (preceding any section that involves absorption of heat), and

PG-60.6.2.3 Upstream of any shutoff valve that

may be used between any two sections of the heat absorbing surface.

PG-60.6.3 Each boiler shall be provided with a valve connection at least NPS $\frac{1}{4}$ (DN 8) for the exclusive purpose of attaching a test gage when the boiler is in service, so that the accuracy of the boiler pressure gage can be ascertained.

PG-60.6.4 Each high-temperature water boiler shall have a temperature gage so located and connected that it shall be easily readable. The temperature gage shall be installed so that it at all times indicates the temperature in degrees Fahrenheit of the water in the boiler, at or near the outlet connection.

PG-61 FEEDWATER SUPPLY

PG-61.1 Except as provided for in PG-61.2 and PG-61.4, boilers having more than 500 sq ft (47 m^2) of water-heating surface shall have at least two means of feeding water. Except as provided for in PG-61.3, PG-61.4, and PG-61.5, each source of feeding shall be capable of supplying water to the boiler at a pressure of 3% higher than the highest setting of any safety valve on the boiler. For boilers that are fired with solid fuel not in suspension, and for boilers whose setting or heat source can continue to supply sufficient heat to cause damage to the boiler if the feed supply is interrupted, one such means of feeding shall not be susceptible to the same interruption as the other, and each shall provide sufficient water to prevent damage to the boiler.

01 **PG-61.2** Except as provided for in PG-61.1, a boiler fired by gaseous, liquid, or solid fuel in suspension, or heated by combustion turbine engine exhaust, may be equipped with a single means of feeding water provided means are furnished for the shutting off of its heat input prior to the water level reaching the lowest permissible level established by PG-60.

PG-61.3 For boilers having a water-heating surface of not more than 100 sq ft (9.3 m^2) the feed connection to the boiler shall not be smaller than NPS $\frac{1}{2}$ (DN 15). For boilers having a water-heating surface more than 100 sq ft (9.3 m^2) the feed connection to the boiler shall not be less than NPS $\frac{3}{4}$ (DN 20).

PG-61.4 High-temperature water boilers shall be provided with means of adding water to the boiler or system while under pressure.

PG-61.5 A forced-flow steam generator with no fixed steam and waterline shall be provided with a source of feeding capable of supplying water to the boiler at a pressure not less than the expected maximum sustained pressure at the boiler inlet, as determined by the boiler Manufacturer, corresponding to operation at maximum designed steaming capacity with maximum allowable working pressure at the superheater outlet.

SAFETY VALVES AND SAFETY RELIEF VALVES[18]

PG-67 BOILER SAFETY VALVE REQUIREMENTS

PG-67.1 Each boiler shall have at least one safety valve or safety relief valve and if it has more than 500 sq ft (47 m^2) of bare tube water-heating surface, or if an electric boiler has a power input more than 1,100 kW, it shall have two or more safety valves or safety relief valves. For a boiler with combined bare tube and extended water-heating surface exceeding 500 sq ft (47 m^2), two or more safety valves or safety relief valves are required only if the design steam generating capacity of the boiler exceeds 4,000 lb/hr (1 800 kg/hr). Organic fluid vaporizer generators require special consideration as given in Part PVG.

PG-67.2 The safety valve or safety relief valve capacity for each boiler (except as noted in PG-67.4) shall be such that the safety valve, or valves will discharge all the steam that can be generated by the boiler without allowing the pressure to rise more than 6% above the highest pressure at which any valve is set and in no case to more than 6% above the maximum allowable working pressure.

PG-67.2.1 The minimum required relieving capacity of the safety valves or safety relief valves for all types of boilers shall not be less than the maximum designed steaming capacity as determined by the Manufacturer and shall be based on the capacity of all the fuel burning equipment as limited by other boiler functions.

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[18] Safety Valve: An automatic pressure relieving device actuated by the static pressure upstream of the valve and characterized by full-opening pop action. It is used for gas or vapor service.

Relief Valve: An automatic pressure relieving device actuated by the static pressure upstream of the valve which opens further with the increase in pressure over the opening pressure. It is used primarily for liquid service.

Safety Relief Valve: An automatic pressure-actuated relieving device suitable for use either as a safety valve or relief valve, depending on application.

Unless otherwise defined, the definitions relating to pressure relief devices in Appendix I of ASME PTC 25-1994, Pressure Relief Devices, shall apply.

PG-67.2.2 The minimum required relieving capacity for a waste heat boiler shall be determined by the Manufacturer. When auxiliary firing is to be used in combination with waste heat recovery, the maximum output as determined by the boiler Manufacturer shall include the effect of such firing in the total required capacity. When auxiliary firing is to be used in place of waste heat recovery, the minimum required relieving capacity shall be based on auxiliary firing or waste heat recovery, whichever is higher.

PG-67.2.3 The minimum required relieving capacity for electric boilers shall be in accordance with PEB-15.

PG-67.2.4 The minimum required relieving capacity in lb/hr for a high-temperature water boiler shall be determined by dividing the maximum output in Btu/hr at the boiler nozzle, produced by the highest heating value fuel for which the boiler is designed, by 1,000.

PG-67.2.5 The minimum required relieving capacity for organic fluid vaporizers shall be in accordance with PVG-12.

PG-67.2.6 Any economizer that may be shut off from the boiler, thereby permitting the economizer to become a fired pressure vessel, shall have one or more safety relief valves with a total discharge capacity, in lbs/hr, calculated from the maximum expected heat absorption in Btu/hr, as determined by the Manufacturer, divided by 1,000. This absorption shall be stated in the stamping (PG-106.4).

PG-67.3 One or more safety valves on the boiler proper shall be set at or below the maximum allowable working pressure (except as noted in PG-67.4). If additional valves are used the highest pressure setting shall not exceed the maximum allowable working pressure by more than 3%. The complete range of pressure settings of all the saturated-steam safety valves on a boiler shall not exceed 10% of the highest pressure to which any valve is set. Pressure setting of safety relief valves on high-temperature water boilers[19] may exceed this 10% range.

PG-67.4 For a forced-flow steam generator with no fixed steam and waterline, equipped with automatic controls and protective interlocks responsive to steam pressure, safety valves may be provided in accordance with the above paragraphs or the following protection against overpressure shall be provided:

PG-67.4.1 One or more power-actuated pressure relieving valves[20] shall be provided in direct communication with the boiler when the boiler is under pressure and shall receive a control impulse to open when the maximum allowable working pressure at the superheater outlet, as shown in the master stamping (PG-106.3), is exceeded. The total combined relieving capacity of the power-actuated relieving valves shall be not less than 10% of the maximum design steaming capacity of the boiler under any operating condition as determined by the Manufacturer. The valve or valves shall be located in the pressure part system where they will relieve the overpressure. 01 A03

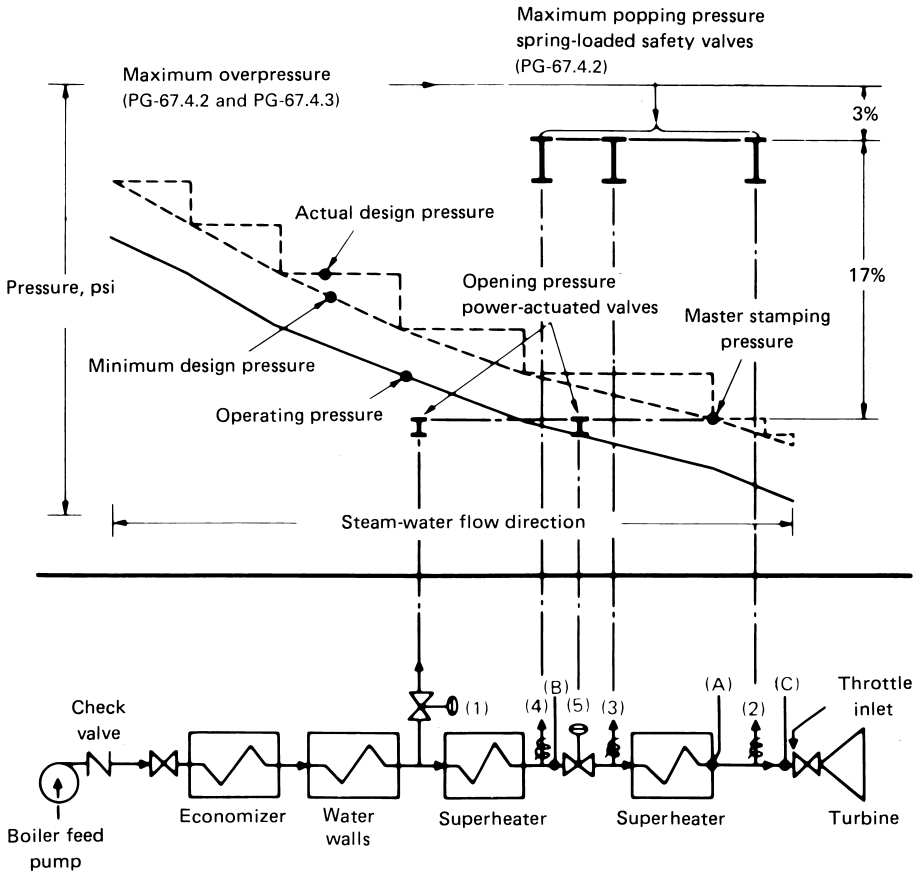
An isolating stop valve of the outside-screw-and-yoke or ball type may be installed between the power-actuated pressure relieving valve and the boiler to permit repairs provided an alternate power-actuated pressure relieving valve of the same capacity is so installed as to be in direct communication with the boiler in accordance with the requirements of this paragraph.

The isolating stop valve port area shall at least equal the area of the inlet of the power-actuated pressure relieving valve. If the isolating stop valve is of the ball type, the valve shall include a means to clearly identify whether the valve is in the open or closed position. If the isolating stop valve is power actuated (air, motor, hydraulic, etc.), a manual override mechanism shall be provided.

Power-actuated pressure relieving valves discharging to intermediate pressure and incorporated into bypass and/or startup circuits by the boiler Manufacturer need not be capacity certified. Instead, they shall be marked by the valve manufacturer with a capacity rating at a set of specified inlet pressure and temperature conditions. Power-actuated pressure relieving valves discharging directly to atmosphere shall be capacity certified. This capacity certification shall be conducted in accordance with the provisions of PG-69.3. The valves shall be marked in accordance with the provisions of PG-69.4.

[19] Safety relief valves in hot water service are more susceptible to damage and subsequent leakage, than safety valves relieving steam. It is recommended that the maximum allowable working pressure of the boiler and the safety relief valve setting for high-temperature water boilers be selected substantially higher than the desired operating pressure so as to minimize the times the safety relief valve must lift.

[20] The power-actuated pressure relieving valve is one whose movements to open or close are fully controlled by a source of power (electricity, air, steam, or hydraulic). The valve may discharge to atmosphere or to a container at lower pressure. The discharge capacity may be affected by the downstream conditions, and such effects shall be taken into account. If the power-actuated pressure relieving valves are also positioned in response to other control signals, the control impulse to prevent overpressure shall be responsive only to pressure and shall override any other control function.



Pressure
(A) = master stamping (PG-106.3)
(B) = component design at inlet to stop valve (5) (PG-67.4.4.1)
(C) = turbine throttle inlet (ANSI/ASME B31.1, paragraph 122.1.2, A.4)

Pressure Relief Valves
(1) = power actuated (PG-67.4.1)
(2), (3), and (4) = spring loaded safety (PG-67.4.2)
(5) = superheater stop (PG-67.4.4)

Relief Valve Flow Capacity (minimum, based on rated capacity of boiler)
(1) = 10 – 30% (PG-67.4.1)
(2) = minimum of one valve (PG-68.1)
(2) + (3) when downstream to stop valve (5) = that required for independently fired superheaters (PG-68.3)
(2) + (3) + (4) = 100% – (1) (PG-67.4.2)

Relief Valve Opening Pressure (maximum)
(1) = (A), and (B) when there is stop valve (5) (PG-67.4.1)
(2), (3), and (4) = (A) + 17% (PG-67.4.2)
(5) = (A) (PG-67.4.1)

Alternate Requirements for Safety Valves

Relief Valve Flow Capacity (minimum, based on rated capacity of boiler)
(1) = 10 – 30% (PG-67.4.1)
(2) = one valve minimum (PG-68.1)
(2) + (3) when downstream to stop valve (5) = that required for independently fired superheaters (PG-68.3)
(4) = 10% total with minimum of 2 valves when there is a stop valve (5) (PG-67.5.3.3)
(2) + (4) = 10% with minimum of 2 valves when there is no stop valve (5) (PG-67.4.3.3)

Relief Valve Opening Pressure (maximum)
(1) = (A), and (B) when there is stop valve (5) (PG-67.4.1)
(2), (3), and (4) = (A) + 20% (PG-67.4.3.3)
(5) = (A) (PG-67.4.1)

Automatic Pressure Controls (PG-67.4.3)
(a) at (C) for normal operation under load (PG-67.4.3.2.1)
(b) at (A) + 10% to overide control (a) (PG-67.4.3.2.2)
(c) at (A) + 20% to shut off flow of fuel and feedwater (PG-67.4.3.2.3)
(d) safety valves at (4) to shut off flow of fuel and feedwater by "fail-safe" power circuit (PG-67.4.3.4)

FIG. PG-67.4 REQUIREMENTS FOR PRESSURE RELIEF FORCED-FLOW STEAM GENERATOR

PG-67.4.2 Spring-loaded safety valves shall be provided, having a total combined relieving capacity, including that of the power-actuated pressure relieving capacity installed under PG-67.4.1, of not less than 100% of the maximum designed steaming capacity of the boiler, as determined by the Manufacturer, except the alternate provisions of PG-67.4.3 are satisfied. In this total, no credit in excess of 30% of the total required relieving capacity shall be allowed for the power-actuated pressure relieving valves actually installed. Any or all of the spring-loaded safety valves may be set above the maximum allowable working pressure of the parts to which they are connected, but the set pressures shall be such that when all of these valves (together with the power-actuated pressure relieving valves) are in operation the pressure will not rise more than 20% above the maximum allowable working pressure of any part of the boiler, except for the steam piping between the boiler and the prime mover.

PG-67.4.3 The total installed capacity of spring-loaded safety valves may be less than the requirements of PG-67.4.2 provided all of the following conditions are met.

PG-67.4.3.1 The boiler shall be of no less steaming capacity than 1,000,000 lb/hr (450 000 kg/hr) and installed in a unit system for power generation (i.e., a single boiler supplying a single turbine-generator unit).

PG-67.4.3.2 The boiler shall be provided with automatic devices, responsive to variations in steam pressure, which include no less than all the following:

PG-67.4.3.2.1 A control capable of maintaining steam pressure at the desired operating level and of modulating firing rates and feedwater flow in proportion to a variable steam output; and

PG-67.4.3.2.2 A control that overrides PG-67.4.3.2.1 by reducing the fuel rate and feedwater flow when the steam pressure exceeds the maximum allowable working pressure as shown in the master stamping (PG-106.3) by 10%; and

PG-67.4.3.2.3 A direct-acting overpressure-trip-actuating mechanism, using an independent pressure sensing device, that will stop the flow of fuel and feedwater to the boiler, at a pressure higher than the set pressure of PG-67.4.3.2.2, but less than 20% above the maximum allowable working pressure as shown in the master stamping (PG-106.3).

PG-67.4.3.3 There shall be not less than two spring-loaded safety valves and the total rated relieving capacity of the spring-loaded safety valves shall be not less than 10% of the maximum designed steaming capacity of the boiler as determined by the Manufacturer. These spring-loaded safety valves may be set above the maximum allowable working pressure of the parts to which they are connected but shall be set such that the valves will lift at a pressure no higher than 20% above the maximum allowable working pressure as shown in the master stamping (PG-106.3).

PG-67.4.3.4 At least two of these spring-loaded safety valves shall be equipped with a device that directly transmits the valve stem lift action to controls that will stop the flow of fuel and feedwater to the boiler. The control circuitry to accomplish this shall be arranged in a "fail-safe" manner (see Note).

NOTE: "Fail-safe" shall mean a circuitry arranged as either of the following:

(1) Energize to trip: There shall be at least two separate and independent trip circuits served by two power sources, to initiate and perform the trip action. One power source shall be a continuously charged dc battery. The second source shall be an ac-to-dc converter connected to the dc system to charge the battery and capable of performing the trip action. The trip circuits shall be continuously monitored for availability.

It is not mandatory to duplicate the mechanism that actually stops the flow of fuel and feedwater.

(2) De-energize to trip: If the circuits are arranged in such a way that a continuous supply of power is required to keep the circuits closed and operating and such that any interruption of power supply will actuate the trip mechanism, then a single trip circuit and single power supply will be enough to meet the requirements of this subparagraph.

PG-67.4.3.5 The power supply for all controls and devices required by PG-67.4.3 shall include at least one source contained within the same plant as the boiler and which is arranged to actuate the controls and devices continuously in the event of failure or interruption of any other power sources.

PG-67.4.4 When stop valves are installed in the water-steam flow path between any two sections of a forced-flow steam generator with no fixed steam and waterline:

PG-67.4.4.1 The power-actuated pressure relieving valve(s) required by PG-67.4.1 shall also receive a control impulse to open when the maximum allowable working pressure of the component, having the lowest pressure level upstream to the stop valve, is exceeded; and

PG-67.4.4.2 The spring-loaded safety valves shall be located to provide the pressure protection requirements in PG-67.4.2 or PG-67.4.3.

PG-67.4.5 A reliable pressure-recording device shall always be in service and records kept to provide evidence of conformity to the above requirements.

01 **PG-67.5** All safety valves or safety relief valves shall be so constructed that the failure of any part cannot obstruct the free and full discharge of steam and water from the valve. Safety valves shall be of the direct spring-loaded pop type, with seat inclined at any angle between 45 deg and 90 deg, inclusive, to the center line of the spindle. The coefficient of discharge of safety valves shall be determined by actual steam flow measurements at a pressure not more than 3% above the pressure at which the valve is set to blow and when adjusted for blowdown in accordance with PG-69.1.4. The valves shall be credited with capacities as determined by the provisions of PG-69.2.

Safety valves or safety relief valves may be used that give any opening up to the full discharge capacity of the area of the opening of the inlet of the valve, provided the movement of the steam safety valve is such as not to induce lifting of water in the boiler.

Deadweight or weighted lever safety valves or safety relief valves shall not be used.

For high-temperature water boilers safety relief valves shall be used. Such valves shall have a closed bonnet. For purposes of selection the capacity rating of such safety relief valves shall be expressed in terms of actual steam flow determined on the same basis as for safety valves. In addition the safety relief valves shall be capable of satisfactory operation when relieving water at the saturation temperature corresponding to the pressure at which the valve is set to blow.

PG-67.6 A safety valve or safety relief valve over NPS 3 (DN 80), used for pressures greater than 15 psig (103 kPa), shall have a flanged inlet connection or a weld-end inlet connection. The dimensions of flanges subjected to boiler pressure shall conform to the applicable ASME Standards as given in PG-42. The facing shall be similar to those illustrated in the Standard.

PG-67.7 Safety valves or safety relief valves may have bronze parts complying with either SB-61 or SB-62, provided the maximum allowable stresses and temperatures do not exceed the values given in Table 1B of Section II, Part D, and shall be marked to indicate the class of material used. Such valves shall not be used on superheaters delivering steam at a temperature over 450°F (232°C) and 306°F (152°C) respectively, and shall not be used for high-temperature water boilers.

PG-68 SUPERHEATER AND REHEATER SAFETY VALVE REQUIREMENTS

PG-68.1 Except as permitted in PG-58.3.1, every attached superheater shall have one or more safety valves in the steam flow path between the superheater outlet and the first stop valve. The location shall be suitable for the service intended and shall provide the overpressure protection required. The pressure drop upstream of each safety valve shall be considered in the determination of set pressure and relieving capacity of that valve. If the superheater outlet header has a full, free steam passage from end to end and is so constructed that steam is supplied to it at practically equal intervals throughout its length so that there is a uniform flow of steam through the superheater tubes and the header, the safety valve, or valves, may be located anywhere in the length of the header.

PG-68.2 The discharge capacity of the safety valve, or valves, on an attached superheater may be included in determining the number and size of the safety valves for the boiler, provided there are no intervening valves between the superheater safety valve and the boiler, and provided the discharge capacity of the safety valve, or valves, on the boiler, as distinct from the superheater is at least 75% of the aggregate valve capacity required.

PG-68.3 Every separately fired superheater which may be shut off from the boiler and permit the superheater to become a fired pressure vessel shall have one or more safety valves having a discharge capacity equal to 6 lb of steam per hour per square foot of superheater surface measured on the side exposed to the hot gases. As an alternative the Manufacturer may also calculate the minimum safety valve discharge capacity in lbs. of steam per hour from the maximum expected heat absorption (as determined by the Manufacturer) in Btu/hr, divided by 1,000. In the case of electrically heated superheaters, the safety valve capacity shall be based upon $3\frac{1}{2}$ lb/hr/kW input. The number of safety valves installed shall be such that the total capacity is at least equal to that required.

PG-68.4 Every reheater shall have one or more safety valves, such that the total relieving capacity is at least equal to the maximum steam flow for which the heater is designed. The capacity of the reheater safety valves shall not be included in the required relieving capacity for the boiler and superheater.

One or more valves with a combined relieving capacity not less than 15% of the required total shall be located along the steam flow path between the reheater outlet and the first stop valve. The pressure drop

upstream of the valves on the outlet side of the reheater shall be considered in determining their set pressure.

PG-68.5 A soot blower connection may be attached to the same outlet from the superheater or reheater that is used for the safety valve connection.

PG-68.6 Every safety valve used on a superheater or reheater discharging superheated steam at a temperature over 450°F (232°C) shall have a casing, including the base, body, and bonnet and spindle, of steel, steel alloy, or equivalent heat-resisting material.

The valve shall have a flanged inlet connection, or a weld-end inlet connection. It shall have the seat and disk of suitable heat erosive and corrosive resisting material, and the spring fully exposed outside of the valve casing so that it shall be protected from contact with the escaping steam.

PG-69 CERTIFICATION OF CAPACITY OF SAFETY AND SAFETY RELIEF VALVES

PG-69.1 Before the Code symbol is applied to any safety or safety relief valve, the valve manufacturer shall have the relieving capacity of his valves certified in accordance with the provisions of this paragraph.

PG-69.1.1 Capacity certification tests shall be conducted using dry saturated steam. The limits for test purposes shall be 98% minimum quality and 20°F (11°C) maximum superheat. Correction from within these limits may be made to the dry saturated condition.

PG-69.1.2 Tests shall be conducted at a place that meets the requirements of Appendix A-312.

PG-69.1.3 Capacity test data reports for each valve design and size, signed by the manufacturer and Authorized Observer witnessing the tests, together with drawings showing the valve construction, shall be submitted to the ASME designee for review and acceptance.[21]

PG-69.1.4 Capacity certification tests shall be conducted at a pressure that does not exceed the set pressure by 3% or 2 psi (14 kPa), whichever is greater. Safety and safety relief valves shall be adjusted so that the blowdown does not exceed 4% of the set pressure. For valves set at or below 100 psi (690 kPa), the blowdown shall be adjusted so as not to exceed 4 psi (28 kPa). Safety valves used on forced-flow steam generators with no fixed steam and waterline, and safety relief valves used on high-temperature water boilers shall be adjusted so that the blowdown does not exceed 10% of the set pressure. The reseating pressure shall be noted and recorded.

PG-69.2 Relieving capacities shall be determined using one of the following methods.

PG-69.2.1 Three Valve Method. A capacity certification test is required on a set of three valves for each combination of size, design, and pressure setting. The capacity of each valve of the set shall fall within a range of ±5% of the average capacity. If one of the three valves tested falls outside this range, it shall be replaced by two valves, and a new average shall be calculated based on all four valves, excluding the replaced valve. Failure of any of the four capacities to fall within a range of ±5% of the new average shall be cause to refuse certification of that particular valve design.

The rated relieving capacity for each combination of design, size, and test pressure shall be 90% of the average capacity.

PG-69.2.2 Slope Method. If a Manufacturer wishes to apply the Code Symbol to a design of pressure relief valves, four valves of each combination of pipe size and orifice size shall be tested. These four valves shall be set at pressures which cover the approximate range of pressures for which the valve will be used or covering the range available at the certified test facility that shall conduct the tests. The capacities based on these four tests shall be as follows:

(a) The slope *W/P* of the actual measured capacity versus the flow pressure for each test point shall be calculated and averaged:

$$\text{slope} = \frac{W}{P} = \frac{\text{measured capacity}}{\text{absolute flow rating pressure, psia}}$$

All values derived from the testing must fall within ±5% of the average value:

$$\text{minimum slope} = 0.95 \times \text{average slope}$$

$$\text{maximum slope} = 1.05 \times \text{average slope}$$

If the values derived from the testing do not fall between the minimum and maximum slope values, the

[21] Valve capacities are published in "Pressure Relief Device Certifications." This publication may be obtained from the National Board of Boiler and Pressure Vessel Inspectors, 1055 Crupper Ave., Columbus, OH 43229.

Authorized Observer shall require that additional valves be tested at the rate of two for each valve beyond the maximum and minimum values with a limit of four additional valves.

The relieving capacity to be stamped on the valve shall not exceed 90% of the average slope times the absolute accumulation pressure:

$$\text{rated slope} = 0.90 \times \text{average slope}$$

Customary Units

stamped capacity ≤ rated slope (1.03 × set pressure + 14.7) or (set pressure + 2 psi + 14.7), whichever is greater

SI Units

stamped capacity ≤ rated slope (1.03 × set pressure + 101) or (set pressure + 14 kPa + 101), whichever is greater

PG-69.2.3 Coefficient of Discharge Method. A coefficient of discharge for the design, *K*, may be established for a specific valve design according to the following procedure.

(a) For each design, the safety or safety relief valve manufacturer shall submit for test at least three valves for each of three different sizes (a total of nine valves). Each valve of a given size shall be set at a different pressure, covering the range of pressures for which the valve will be used or the range available at the facility where the tests are conducted.

(b) Tests shall be made on each safety or safety relief valve to determine its lift at capacity, popping, and blowdown pressures, and actual relieving capacity. An individual coefficient, K_D, shall be established for each valve as follows:

$$K_D = \frac{\text{actual flow}}{\text{theoretical flow}} = \text{individual coefficient of discharge}$$

Where actual flow is determined by test and theoretical flow, W_T is calculated by one of the following equations:

For 45 deg seat

Customary Units

$$W_T = 51.5 \times \pi DLP \times 0.707$$

SI Units

$$W_T = 5.25 \times \pi DLP \times 0.707$$

For flat seat

Customary Units

$$W_T = 51.5 \times \pi DLP$$

SI Units

$$W_T = 5.25 \times \pi DLP$$

For nozzle

Customary Units

$$W_T = 51.5\ AP$$

SI Units

$$W_T = 5.25\ AP$$

where

W_T = theoretical flow, lb/hr (kg/hr)
A = nozzle throat area, sq in. (sq m)
P = (1.03 × set pressure + 14.7), psia, or
= (set pressure + 2 + 14.7), psia, whichever is greater
P = (1.03 × set pressure + 101), kPa, or
= (set pressure + 14 + 101), kPa, whichever is greater
L = lift pressure at P, in. (mm)
D = seat diameter, in. (mm)

The average of the coefficients K_D of the nine tests required shall be multiplied by 0.90, and this product shall be taken as the coefficient *K* of that design. All individual coefficients of discharge, K_D, shall fall within a range of ±5% of the average coefficient found. If a valve fails to meet this requirement, the Authorized Observer shall require two additional valves to be tested as replacements for each valve having an individual coefficient, K_D, outside the ±5% range, with a limit of four additional valves. Failure of a coefficient, K_D, to fall within ±5% of the new average value, excluding the replaced valve(s), shall be cause to refuse certification of that particular valve design.

The rated relieving capacity of all sizes and set pressures of a given design, for which *K* has been

established under the provision of this paragraph, shall be determined by the equation:

$$W \le W_T \times K$$

where

W = rated relieving capacity, lb/hr
W_T = theoretical flow, defined by the same equation used to determine K_D, lb/hr
K = coefficient of discharge for the design

The coefficient of discharge for the design shall not be greater than 0.878 (the product of 0.9 × 0.975). The coefficient shall not be applied to valves whose beta ratio (ratio of valve throat to inlet diameter) lies outside the range of 0.15 to 0.75, unless tests have demonstrated that the individual coefficient of discharge, K_D, for valves at the extreme ends of a larger range, is within ±5% of the average coefficient, K_D.

For designs where the lift is used to determine the flow area, all valves shall have the same nominal lift to seat diameter ratio (L/D).

For pressures over 1,500 psig and up to 3,200 psig, the value of W shall be multiplied by the correction factor:

Customary Units

$$\frac{0.1906P - 1{,}000}{0.2292P - 1{,}061}$$

SI Units

$$\frac{0.1906P - 6\,895}{0.2292P - 7\,315}$$

PG-69.3 If a manufacturer wishes to apply the Code symbol to a power-actuated pressure relieving valve under PG-67.4.1, one valve of each combination of inlet pipe size and orifice size to be used with that inlet pipe size shall be tested. The valve shall be capacity tested at four different pressures approximately covering the range of the certified test facility on which the tests are conducted. The capacities, as determined by these four tests, shall be plotted against the absolute flow test pressure and a line drawn through these four test points. All points must lie within ±5% in capacity value of the plotted line and must pass through 0-0. From the plotted line, the slope of the line dW/dP shall be determined and a factor of (0.90/51.45)× (dW/dP) shall be applied to capacity computations in the supercritical region at elevated pressures by means of the isentropic flow equation.

Customary Units

$$W = 1{,}135.8 \frac{0.90}{51.45} \times \frac{dW}{dP} \sqrt{\frac{P}{v}}$$

SI Units

$$W = 1\,135.8 \frac{0.95}{5.25} \times \frac{dW}{dP} \sqrt{\frac{P}{v}}$$

where

W = capacity, lb of steam/hr (kg/hr)
P = absolute inlet pressure, psia (kPa)
v = inlet specific volume, cu ft/lb (m^3/kg)
dW/dP = rate of change of measured capacity with respect to absolute pressure

NOTE: The constant 1,135.8 is based on a γ factor of 1.30, which is accurate for superheated steam at temperature above approximately 800°F (427°C). In interest of accuracy, other methods of capacity computations must be used at temperatures below 800°F (427°C) at supercritical pressures.

PG-69.4 Power-actuated pressure relieving valves, having capacities certified in accordance with the provision of PG-69.3 and computed in accordance with the formula contained therein, shall be marked as required by PG-110 with the computed capacity, corresponding to 3% above the full load operating pressure and temperature conditions at the valve inlet when the valve is operated by the controller, and they shall also be stamped with the set pressure of the controller. When the valve is marked as required by this paragraph, it shall be the guarantee by the manufacturer that the valve also conforms to the details of construction herein specified.

PG-69.6 When changes are made in the design of a safety or safety relief valve in such a manner as to affect the flow path, lift, or performance characteristics of the valve, new tests in accordance with this Section shall be performed.

PG-70 CAPACITY OF SAFETY VALVES

PG-70.1 Subject to the minimum number required by PG-67.1, the number of safety valves or safety relief valves required shall be determined on the basis of the maximum designed steaming capacity, as determined by the boiler Manufacturer, and the relieving capacity marked on the valves by the manufacturer.

PG-71 MOUNTING

PG-71.1 When two or more safety valves are used on a boiler, they may be mounted either separately or

as twin valves made by placing individual valves on Y-bases, or duplex valves having two valves in the same body casing. Twin valves made by placing individual valves on Y-bases, or duplex valves having two valves in the same body, shall be of approximately equal capacity.

When not more than two valves of different sizes are mounted singly the relieving capacity of the smaller valve shall be not less than 50% of that of the larger valve.

PG-71.2 The safety valve or safety relief valve or valves shall be connected to the boiler independent of any other connection, and attached as close as possible to the boiler or the normal steam flow path, without any unnecessary intervening pipe or fitting. Such intervening pipe or fitting shall be not longer than the face-to-face dimension of the corresponding tee fitting of the same diameter and pressure under the applicable ASME Standard listed in PG-42 and shall also comply with PG-8 and PG-39. Every safety valve or safety relief valve shall be connected so as to stand in an upright position, with spindle vertical. On high-temperature water boilers of the watertube forced-circulation type, the valve shall be located at the boiler outlet.

PG-71.3 The opening or connection between the boiler and the safety valve or safety relief valve shall have at least the area of the valve inlet. No valve of any description shall be placed between the required safety valve or safety relief valve or valves and the boiler, nor on the discharge pipe between the safety valve or safety relief valve and the atmosphere. When a discharge pipe is used, the cross-sectional area shall be not less than the full area of the valve outlet or of the total of the areas of the valve outlets, discharging thereinto. It shall be as short and straight as possible and so arranged as to avoid undue stresses on the valve or valves.

All safety valve or safety relief valve discharges shall be so located or piped as to be carried clear from running boards or platforms. Ample provision for gravity drain shall be made in the discharge pipe at or near each safety valve or safety relief valve, and where water of condensation may collect. Each valve shall have an open gravity drain through the casing below the level of the valve seat. For iron- and steel-bodied valves exceeding NPS $2\frac{1}{2}$ (DN 65), the drain hole shall be tapped not less than NPS $\frac{3}{8}$ (DN 10).

Discharge piping from safety relief valves on high-temperature water boilers shall be provided with adequate provisions for water drainage as well as the steam venting.

The installation of cast iron bodied safety relief valves for high-temperature water boilers is prohibited.

PG-71.4 If a muffler is used on a safety valve or safety relief valve, it shall have sufficient outlet area to prevent back pressure from interfering with the proper operation and discharge capacity of the valve. The muffler plates or other devices shall be so constructed as to avoid a possibility of restriction of the steam passages due to deposit. Mufflers shall not be used on high-temperature water boiler safety relief valves.

When a safety valve or safety relief valve is exposed to outdoor elements which may affect operation of the valve, it is permissible to shield the valve with a satisfactory cover. The shield or cover shall be properly vented and arranged to permit servicing and normal operation of the valve.

PG-71.5 When a boiler is fitted with two or more safety valves or safety relief valves on one connection, this connection to the boiler shall have a cross-sectional area not less than the combined areas of inlet connections of all the safety valves or safety relief valves with which it connects and shall also meet the requirements of PG-71.3.

PG-71.6 Safety valves may be attached to drums or headers by welding provided the welding is done in accordance with Code requirements.

PG-71.7 Every boiler shall have proper outlet connections for the required safety valve, or safety relief valve, or valves, independent of any other outside steam connection, the area of opening to be at least equal to the aggregate areas of inlet connections of all of the safety valves or safety relief valves to be attached thereto. An internal collecting pipe, splash plate, or pan may be used, provided the total area for inlet of steam thereto is not less than twice the aggregate areas of the inlet connections of the attached safety valves. The holes in such collecting pipes shall be at least $\frac{1}{4}$ in. (6 mm) in diameter and the least dimension in any other form of opening for inlet of steam shall be $\frac{1}{4}$ in. (6 mm).

Such dimensional limitations to operation for steam need not apply to steam scrubbers or driers provided the net free steam inlet area of the scrubber or drier is at least 10 times the total area of the boiler outlets for the safety valves.

PG-71.8 If safety valves are attached to a separate steam drum or dome, the opening between the boiler proper and the steam drum or dome shall be not less than required by PG-71.7.

PG-72 OPERATION

A02 **PG-72.1** Safety valves shall be designed and constructed to operate without chattering and to attain full lift at a pressure no greater than 3% above their set pressure. After blowing down, all valves set at pressures of 375 psi (2 600 kPa) or greater shall close at a pressure not lower than 96% of their set pressure, except that all drum valves installed on a single boiler may be set to reseat at a pressure not lower than 96% of the set pressure of the lowest set drum valve. All valves set at pressures below 375 psi (2 600 kPa) shall have a blowdown not greater than that specified in the following table, except that all drum valves installed on a single boiler may be set to reseat at a pressure not lower than the reseating pressure of the lowest set drum valve:

Set Pressure, psi (kPa)	Maximum Blowdown
< 67 (462)	4 psi (14 kPa)
≥ 67 (462) and ≤ 250 (1 720)	6% of set pressure
> 250 (1 720) and < 375 (2 590)	15 psi (103 kPa)

If agreed by the boiler owner and, for new boiler construction, the boiler Manufacturer, greater values of blowdown may be acceptable. The valves with these greater blowdown values must be so adjusted and marked by the manufacturer.

The minimum blowdown for all safety or safety relief valves shall be 2 psi (13.8 kPa) or 2% of the set pressure, whichever is greater.

Safety valves used on forced-flow steam generators with no fixed steam and waterline, and safety relief valves used on high-temperature water boilers may be set and adjusted to close after blowing down not more than 10% of the set pressure. The valves for these special uses must be so adjusted and marked by the manufacturer.

PG-72.2 The popping point tolerance plus or minus shall not exceed that specified in the following table:

Set Pressure, psi (kPa)	Tolerance, plus or minus from set pressure
≤ 70 (480)	2 psi (14 kPa)
> 70 (480) and ≤ 300 (2 070)	3% of set pressure
> 300 (2 070) and ≤ 1,000 (6 900)	10 psi (69 kPa)
> 1,000 (6 900)	1% of set pressure

PG-72.3 The spring in a safety valve or safety relief valve shall not be reset for any pressure more than 5% above or below that for which the valve is marked unless the new setting is within the spring design range established by the manufacturer or is determined to be acceptable to the manufacturer.

If the set pressure is to be adjusted within the limits specified above, the adjustment shall be performed by the manufacturer, his authorized representative, or an assembler. An additional valve data tag identifying the new set pressure, capacity, and date shall be furnished and installed, and the valve shall be resealed.

PG-72.4 If the set pressure of a valve is changed so as to require a new spring, the spring shall be acceptable to the manufacturer. The spring installation and valve adjustment shall be performed by the manufacturer, his authorized representative, or an assembler. A new nameplate as described in PG-110 shall be furnished and installed, and the valve shall be resealed.

PG-73 MINIMUM REQUIREMENTS FOR SAFETY AND SAFETY RELIEF VALVES A03

Keeps related requirements in same part.

PG-73.1 Mechanical Requirements

PG-73.1.1 The design shall incorporate guiding arrangements necessary to insure consistent operation and tightness.

PG-73.1.2 The spring shall be designed so that the full lift spring compression shall be no greater than 80% of the nominal solid deflection. The permanent set of the spring (defined as the difference between the free height and height measured 10 min after the spring has been compressed solid three additional times after presetting at room temperature) shall not exceed 0.5% of the free height.

PG-73.1.3 To provide a means for verifying whether it is free, each safety valve or safety relief valve shall have a substantial lifting device, which when activated will release the seating force on the disk when the valve is subjected to pressure of at least 75% of the set pressure. The lifting device shall be such that it cannot lock or hold the valve disk in lifted position when the exterior lifting force is released. Disks of safety relief valves used on high-temperature water boilers shall not be lifted while the temperature of the water exceeds 200°F (93°C). If it is desired to lift the valve disk to assure that it is free, this shall be done when the valve is subjected to a pressure of at least 75% of the set pressure. For high-temperature water boilers, the lifting mechanism shall be sealed against leakage.

PG-73.1.4 The seat of a safety valve shall be fastened to the body of the valve in such a way that there is no possibility of the seat lifting.

PG-73.1.5 A body drain below seat level shall be provided in the valve and this drain shall not be plugged during or after field installation. For valves exceeding NPS $2\frac{1}{2}$ (DN 65), the drain hole or holes shall be

tapped not less than NPS $\frac{3}{8}$ (DN 10). For valves of NPS $2\frac{1}{2}$ (DN 65) or smaller, the drain hole shall not be less than $\frac{1}{4}$ in. (6 mm) in diameter.

PG-73.1.6 In the design of the body of the valve, consideration shall be given to minimizing the effects of water deposits.

PG-73.1.7 Valves having screwed inlet or outlet connections shall be provided with wrenching surfaces to allow for normal installation without damaging operating parts.

PG-73.1.8 Means shall be provided in the design of all valves for use under this Section, for sealing all external adjustments. Seals shall be installed by the manufacturer, his authorized representative, or an assembler at the time of the initial adjustment. After spring replacement and/or subsequent adjustment, the valve shall be resealed. Seals shall be installed in such a manner as to prevent changing the adjustment without breaking the seal and, in addition, shall serve as a means of identifying the manufacturer, his authorized representative, or the assembler making the adjustment.

PG-73.2 Material Selections

PG-73.2.1 Cast iron seats and disks are not permitted.

PG-73.2.2 Adjacent sliding surfaces such as guides and disks or disk holders shall both be of corrosion resistant material. Springs of corrosion resistant material or having a corrosion resistant coating are required. The seats and disks of safety valves or safety relief valves shall be of suitable material to resist corrosion by the lading fluid.

NOTE: The degree of corrosion resistance, appropriate to the intended service, shall be a matter of agreement between the manufacturer and the purchaser.

PG-73.2.3 Materials used in bodies and bonnets or yokes shall be listed in Section II, Parts A and B, and identfied in Tables 1A and 1B of Section II, Part D, as permitted for Section I construction. Materials used in nozzles, disks, and other parts contained within the external structure of the safety or safety relief valves shall be one of the following categories:

(1) listed in ASME Section II;

(2) listed in ASTM Specifications (see Note below);

(3) controlled by the manufacturer of the safety or safety relief valve by a specification insuring control of chemical and physical properties and quality at least equivalent to ASTM Standards (see Note below).

NOTE: It shall be the manufacturer's responsibility to insure that the allowable stresses at temperature meet the requirements of Section II, Part D, Appendix 1, Nonmandatory Basis for Establishing Stress Values in Tables 1A and 1B.

PG-73.3 Inspection of Manufacturing and/or Assembly

PG-73.3.1 A manufacturer shall demonstrate to the satisfaction of an ASME designee that his manufacturing, production, and test facilities and quality control procedures will insure close agreement between the performance of random production samples and the performance of those valves submitted for capacity certification.

PG-73.3.2 Manufacturing, assembly, inspection, and test operations including capacity, are subject to inspections at any time by an ASME designee.

PG-73.3.3 A Manufacturer or assembler may be granted permission to apply the V Code Symbol to production pressure relief valves capacity-certified in accordance with PG-69, provided the following tests are successfully completed. This permission shall expire on the fifth anniversary of the date it is initially granted. This permission may be extended for 5 year periods if the following tests are successfully repeated within the 6 month period before expiration.

(1) Two sample production pressure relief valves of a size and capacity within the capability of an ASME accepted laboratory shall be selected by an ASME designee.

(2) Operational and capacity tests shall be conducted in the presence of an ASME designee at an ASME accepted laboratory. The valve manufacturer or assembler shall be notified of the time of the test and may have representatives present to witness the test.

(3) Should any valve fail to relieve at or above its certified capacity or should it fail to meet performance requirements in PG-72, the test shall be repeated at the rate of two replacement valves, selected in accordance with PG-73.3.3(1), for each valve that failed.

(4) Failure of any of the replacement valves to meet capacity or the performance requirements of this Section shall be cause for revocation within 60 days of the authorization to use the Code symbol on that particular type of valve. During this period, the Manufacturer or assembler shall demonstrate the cause of such deficiency and the action taken to guard against future occurrence, and the requirements of PG-73.3.3 above shall apply.

PG-73.3.4 Use of the Code Symbol Stamp by an assembler indicates the use of original unmodified parts in strict accordance with the instructions of the

manufacturer of the valve. However, an assembler may convert original finished parts by machining to another finished part for a specific application under the following conditions:

(a) Conversions shall be specified by the Manufacturer. Drawings and/or written instructions used for part conversion shall be obtained from the Manufacturer and shall include a drawing or description of the converted part before and after machining.

(b) The Assembler's quality control system, as accepted by a representative from an ASME designated organization, must describe in detail the conversion of original parts, provisions for inspection and acceptance, personnel training, and control of current Manufacturer's drawings and/or written instructions.

(c) The Assembler must document each use of a converted part.

(d) The Assembler must demonstrate to the Manufacturer the ability to perform each type of conversion. The Manufacturer shall document all authorizations granted to perform part conversions. The Manufacturer and Assembler shall maintain a file of such authorizations.

(e) At least annually a review shall be performed by the Manufacturer of an Assembler's system and machining capabilities. The Manufacturer shall document the results of these reviews. A copy of this documentation shall be kept on file by the Assembler. The review results shall be made available to a representative from an ASME designated organization.

NOTE: Within the requirements of PG-73.3 and PG-73.4, a *manufacturer* is defined as a person or organization who is completely responsible for design, material selection, capacity certification, manufacture of all component parts, assembly, testing, sealing, and shipping of safety and safety relief valves certified under this Section.

An *assembler* is defined as a person or organization who purchases or receives from a manufacturer the necessary component parts or valves and assembles, adjusts, tests, seals, and ships safety or safety relief valves certified under this Section at a geographical location other than and using facilities other than those used by the manufacturer.

PG-73.4 Testing by Manufacturers or Assemblers

PG-73.4.1 Valves exceeding 1 in. (DN 25) inlet size or 300 psig (2 070 kPa) set pressure shall meet the following requirements. Primary pressure containing cast and welded parts of pressure relief valves shall be tested at a pressure at 1.5 times the design pressure of the parts. These tests shall be conducted after all machining operations to the parts have been completed. There shall be no visible signs of leakage.

Closed bonnet pressure relief valves designed for discharge to a closed system shall be tested with a minimum of 30 psig (207 kPa) air or other gas in the secondary pressure zone. There shall be no visible signs of leakage.

PG-73.4.2 Every valve shall be tested with steam by the manufacturer or assembler to demonstrate its popping point, blowdown, and pressure containing integrity. A02

PG-73.4.2.1 Tests shall be conducted either on equipment that meets the requirements of PG-73.4.6, or on the boiler, by raising the pressure to demonstrate the popping pressure and blowdown.

PG-73.4.2.2 When the valve is beyond the production test equipment capabilities, an alternative test method presented in PG-73.4.2.2.1 or PG-73.4.2.2.2 may be used, provided all of the following conditions are met:

(a) testing the valve at full pressure may cause damage to the valve, or testing of the valve is impractical due to boiler system operational safety considerations;

(b) the boiler owner, and for new boiler construction the boiler Manufacturer, has accepted the use of the alternative test method;

(c) the valve lift has been mechanically verified to meet or exceed the required lift;

(d) the blowdown control elements of the safety valve are set to the valve manufacturer's specification in lieu of a blowdown demonstration; and

(e) the valve design is compatible with the alternative test method selected.

PG-73.4.2.2.1 The valve, with its lift temporarily restricted during the test, if required to prevent valve damage, shall be tested on steam to demonstrate popping pressure.

PG-73.4.2.2.2 The valve may be fitted with a hydraulic or pneumatic lift assist device and tested on steam at a pressure less than the valve set pressure. The lift assist device and test procedure shall be calibrated to provide the set pressure setting within the tolerance of PG-72.2.

PG-73.4.3 A seat tightness test shall be conducted at maximum expected operating pressure, but at a pressure not exceeding the reseating pressure of the valve. When being tested, a valve exhibiting no visible signs of leakage shall be considered adequately tight.

PG-73.4.4 A manufacturer or assembler shall have a documented program for the application, calibration, and maintenance of test gages.

PG-73.4.5 Testing time on steam valves shall be sufficient to assure that test results are repeatable and representative of field performance.

PG-73.4.6 Test fixtures and test drums, where applicable, shall be of adequate size and capacity to assure that the observed set pressure is consistent with the stamped set pressure within the tolerance required by PG-72.2.

PG-73.5 Design Requirements. At the time of submission of valves for capacity certification or testing in accordance with PG-69, the ASME designee has the authority to review design for conformity with the requirements of this Section and to reject or require modification of designs that do not conform, prior to capacity testing.

A03 **PG-73.6 Code Symbol "V" Stamp.** Each safety valve or safety relief valve to which the Code "V" symbol (see Fig. PG-105.4) will be applied shall have been fabricated or assembled by a manufacturer or assembler holding a valid Certificate of Authorization (PG-105.2) and capacity certified in accordance with the requirements of this Section. A Certified Individual (CI) shall provide oversight to assure that each use of the Code "V" symbol on a safety valve or safety relief valve is in accordance with the requirements of this Section, and that each use of the Code "V" symbol is documented on a Certificate of Conformance, Form P-8.

PG-73.6.1 Requirements for the Certified Individual (CI). The CI shall

(a) be an employee of the manufacturer or assembler

(b) be qualified and certified by the manufacturer or assembler. Qualifications shall include as a minimum:

(1) knowledge of the requirements of this Section for the application of the Code "V" symbol

(2) knowledge of the manufacturer's or assembler's quality program

(3) training commensurate with the scope, complexity, or special nature of the activities to which oversight is to be provided

(c) have a record, maintained and certified by the manufacturer or assembler, containing objective evidence of the qualifications of the CI and the training program provided.

PG-73.6.2 Duties of the Certified Individual (CI). The CI shall

(a) verify that each item to which the Code "V" symbol is applied has a current capacity certification and meets all applicable requirements of this Section

(b) review documentation for each lot of items to be stamped to verify, for the lot, that requirements of this Section have been completed

(c) sign the Certificate of Conformance, Form P-8, prior to release of control of the safety or safety relief valves

PG-73.6.3 Certificate of Conformance, Form P-8

(a) The Certificate of Conformance, Form P-8, shall be filled out by the manufacturer or assembler and signed by the Certified Individual. Multiple duplicate safety valves or safety relief valves may be recorded as a single entry, provided the valves are identical and are produced in the same lot.

(b) The manufacturer's or assembler's written quality control program shall include requirements for completion of Certificates of Conformance, Form P-8, and retention, by the manufacturer or assembler, for a minimum of 5 years.

FABRICATION

PG-75 GENERAL

The fabrication of boilers and parts thereof shall conform to the general fabrication requirements in the following paragraphs and in addition to the specific requirements for fabrication in the Parts of this Section that pertain to the methods of construction used.

PG-76 CUTTING PLATES AND OTHER STOCK

PG-76.1 Plates may be cut by machining, punching, shearing, or cutting by the electric arc or gas process,

providing enough metal is left at any unfinished edges to meet the requirements of PG-79.

PG-76.2 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 $\frac{1}{8}$ in. (3.2 mm) of additional metal is removed by any method that will produce a smooth finish.

PG-77 PLATE IDENTIFICATION

PG-77.1 When the boiler is completed, there shall remain visible on shell plates, furnace sheets, and heads, one group of the plate manufacturer's stamps, consisting of the manufacturer's name, plate identification number, material specification number with grade, class, and type as appropriate, except that heads containing tube holes and buttstraps shall have visible at least a sufficient portion of such stamps for identification.

PG-77.2 It is permissible for an authorized representative of the boiler Manufacturer to transfer the markings on the plate provided a record is made of such transfer. In lieu of the above and PG-77.1, identification may be by applying a coded marking traceable to the original required markings or by recording the required markings using methods such as material tabulations or as built sketches which assure identification of each piece of material during fabrication and subsequent identification in the completed boiler. Such transfers of markings shall be made prior to cutting, except that the Manufacturer may transfer markings immediately after cutting, provided the control of these transfers is described in his written Quality Control System (A-300). The procedure for making such transfer shall be acceptable to the Authorized Inspector.

PG-77.3 An authorized representative of the plate manufacturer may duplicate the required stamping on any material wherever located.

PG-77.4 When plate specification heat treatments are not performed by the mill, they shall be performed by or under the control of the fabricator, who shall then place the letter "T" following the letter "G" in the mill plate marking (see SA-20) to indicate that the material specification heat treatments have been performed. The fabricator shall also show by a supplement to the appropriate Mill Test Report that the specified heat treatment has been performed.

PG-78 REPAIRS OF DEFECTS IN MATERIALS

Defects in material may be repaired by the boiler Manufacturer provided acceptance by the Inspector is first obtained for the method and extent of repairs. Material that cannot be satisfactorily repaired shall be rejected.

PG-79 TUBE HOLES AND ENDS

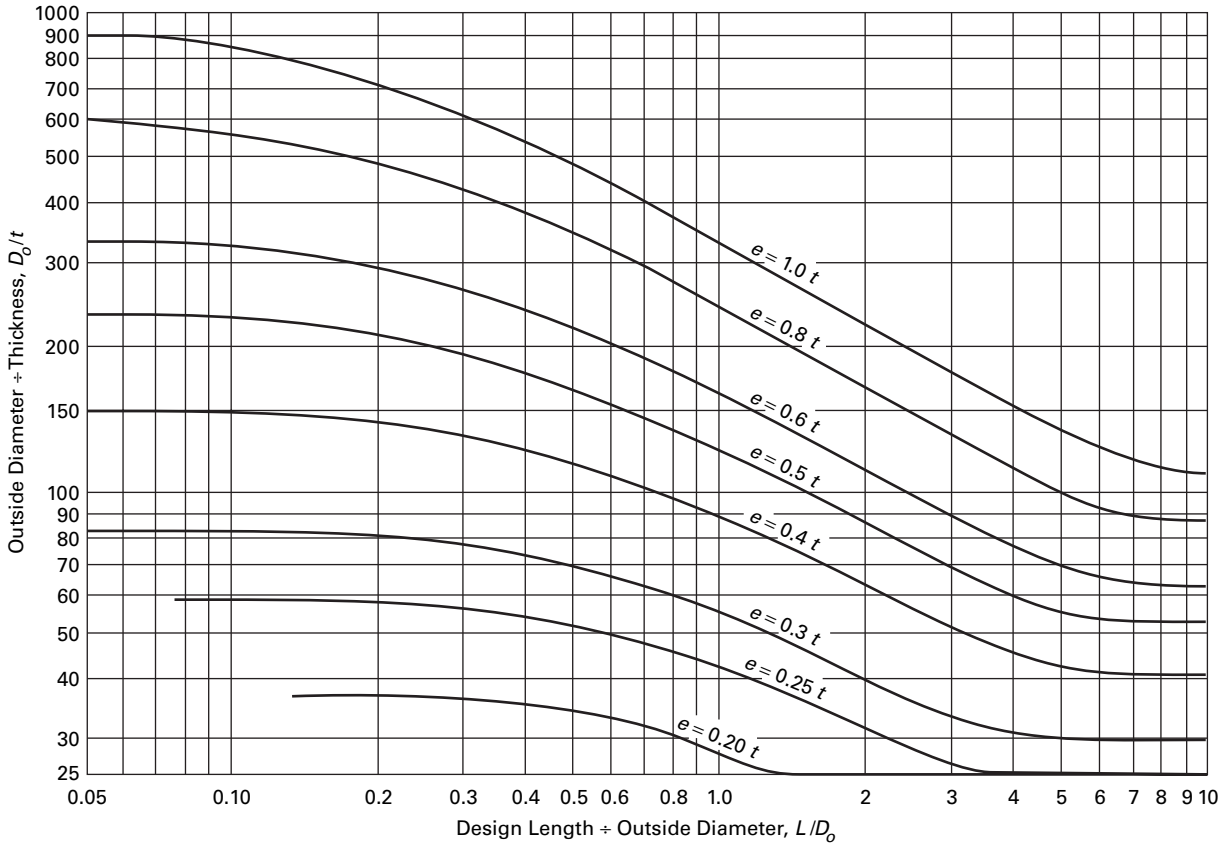
Tube holes shall be drilled full size from the solid plate, or they may be punched at least $\frac{1}{2}$ in. (13 mm) smaller in diameter than full size, and then drilled, reamed, or finished full size with a rotating cutter. The thermal- or plasma-arc cut holes, when made, shall be sufficiently smaller in diameter than full size, such that subsequent machining to full size shall completely remove all metal whose mechanical and metallurgical properties have been affected as a result of the thermal- or plasma-arc cutting. Tube holes may be counterbored where the metal is thicker than that required to get a proper bearing by expanding, so as to form narrow seats into which the tube ends can be properly expanded, provided there is space available to permit a proper amount of flare of the tube end.

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

PG-80 PERMISSIBLE OUT-OF-ROUNDNESS OF CYLINDRICAL SHELLS

PG-80.1 Internal Pressure. The cylinder or barrel of a drum or shell shall be circular at any section within a limit of 1% of the mean diameter, based on the differences between the maximum and minimum mean diameters at any section, and if necessary to meet this requirement shall be reheated, rerolled, or reformed. 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 the plate thicknesses as they may apply, to determine the diameters at the middle line of the plate thickness.

PG-80.2 External Pressure. Welded cylindrical furnaces and other cylindrical parts subjected to external pressure shall be rolled to practically a true circle with a maximum plus or minus deviation not to exceed the following:



GENERAL NOTES:
(a) The above chart applies to cylinders over 24 in. (610 mm) O.D.
(b) Use the curves $e = 1.0t_s$ or $e = 0.2t_s$, respectively, for points falling above or below those curves.

FIG. PG-80 MAXIMUM PERMISSIBLE DEVIATION FROM A CIRCULAR FORM *e* FOR CYLINDRICAL PARTS UNDER EXTERNAL PRESSURE

(a) For components greater than 24 in. (610 mm) O.D., the maximum permissible deviation, "*e*," shall be obtained from Fig. PG-80. The symbols L, D_O, and t_S are as defined in PFT-51.1.1.

(b) For components equal to or less than 24 in. (610 mm) O.D., the maximum deviation shall not exceed 1% of the O.D.

PG-81 TOLERANCE FOR FORMED HEADS

When heads are made to an approximate ellipsoidal shape, the inner surface of such heads must lie outside and not inside of a true ellipse drawn with the major axis equal to the inside diameter of the head and one-half the minor axis equal to the depth of the head. The maximum variation from this true ellipse shall not exceed 0.0125 times the inside diameter of the head.

PG-82 HOLES FOR STAYS

PG-82.1 Holes for threaded stays shall be drilled full size or punched and subsequently drilled or reamed. Punched holes shall not exceed $\frac{1}{4}$ in. (6 mm) less than full diameter for plates over $\frac{5}{16}$ in. (8 mm) or $\frac{1}{8}$ in. (3.2 mm) less than full diameter for plates not exceeding $\frac{5}{16}$ in. (8 mm) thickness prior to finished drilling or reaming. Threaded holes shall be tapped fair and true with a full thread.

PG-82.2 Holes for welded stays shall be cut and prepared in accordance with PW-29.

INSPECTION AND TESTS

PG-90 GENERAL

PG-90.1 Each boiler, superheater, waterwall, or steel economizer shall be inspected during construction and after completion by an Authorized Inspector (AI). The AI may perform inspections at other stages of the work as he may designate. (PW-46.2) Each Manufacturer or Assembler is required to arrange for the services of Authorized Inspectors (see Foreword and PG-91) to perform inspections on all of his work within the scope of this Section, whether performed in the shop or in the field. Duties of the AI are described elsewhere in this Section and include the following:

PG-90.1.1 Verifying that the Manufacturer or Assembler has a valid ASME Certificate of Authorization covering the scope of his Code activities (PG-104.2.1, PG-105.5).

PG-90.1.2 Monitoring compliance with the accepted Quality Control Program and verifying that any changes meet the requirements of this Section (PG-105.4, PEB-18, A-300).

PG-90.1.3 Verifying that the Certificate Holder has the necessary Code books, Addenda, and Code Cases to cover the work being performed.

PG-90.1.4 Reviewing a selected number of the Manufacturer's design calculations to verify compliance with Section I (PG-90.3).

PG-90.1.5 Witnessing and approving proof tests to establish Maximum Allowable Working Pressure (MAWP) (A-22).

PG-90.1.6 Verifying that the Certificate Holder has sufficient material control to assure that material used for construction complies with the applicable requirements of this Section (PG-10, PG-11, PG-105.4, A-302.4).

PG-90.1.7 When cutting plate material into two or more pieces is necessary, verifying that the Certificate Holder's controls provide a positive means of identification to maintain traceability of materials (PG-77.2, A-302.4).

PG-90.1.8 Verifying that the Certificate Holder's personnel are examining cut edges before welding (PW-29.3).

PG-90.1.9 Verifying that all welding procedure specifications, procedure qualification records, welder and welding operator qualification records conform to the requirements of this Section (PW-1.2, PW-28, PW-40.2, PW-47, PW-48, PW-53).

PG-90.1.10 If welded repairs are necessary, accepting the method and extent of repairs and verifying that only qualified welding procedures, welders, and welding operators are used (PG-78, PW-40.2, PW-54.2).

PG-90.1.11 Verifying that all required heat treatments have been performed and are properly documented (PW-11.3.4, PW-39, PW-49).

PG-90.1.12 Verifying that required nondestructive examinations and tests have been performed by qualified personnel and that the results are properly documented (PG-25.2, PW-11, PW-51, PW-52).

PG-90.1.13 Performing the required inspections and witnessing hydrostatic tests (PG-99, PW-54).

PG-90.1.14 Verifying that the responsible representative of the Certificate Holder has signed the Data Report and that it is correct before being signed (PG-104, PG-112, PG-113, PW-1.2.5).

PG-90.1.15 Prior to stamping, verifying that the item is in compliance with the requirements of this Section. After stamping, verifying that the stamping is correct and that the nameplate, if used, has been properly attached (PG-106, PG-108, PG-109, PW-1.2.5).

PG-90.3 The Manufacturer is responsible for the preparation of design calculations to show compliance with the rules of Section I and his signature on the Manufacturers' Data Report Form shall be considered to include certification that has been done. The Manufacturer shall make available such design calculations as the Authorized Inspector may request. The Authorized Inspector has the duty to review a selected number of the Manufacturer's design calculations to verify compliance with Section I.

PG-91 QUALIFICATION OF INSPECTORS

The inspection required by this Section shall be by an Inspector employed by an ASME accredited Authorized Inspection Agency,[22] that is, the inspection organization of a state or municipality of the United States, a Canadian province, or of an insurance company authorized to write boiler and pressure vessel insurance. These Inspectors shall have been qualified by written

[22] Whenever *Authorized Inspection Agency* or *AIA* is used in this Code, it shall mean an Authorized Inspection Agency accredited by ASME in accordance with the requirements in the latest edition of ASME QAI-1, Qualification for Authorized Inspection.

examination under the rules of any state of the United States or province of Canada which has adopted the Code.

PG-93 INSPECTION AND REPAIR OF FLAT PLATE IN CORNER JOINTS

PG-93.1 When flat plate greater than $\frac{1}{2}$ in. (13 mm) thickness is welded to other pressure parts to form a corner joint, such as in flat heads [Fig. PG-31, sketches (g) and (i)], waterlegs of firebox boilers or combustion chambers of wetback boilers [Fig. A-8, sketches (l), (m), (n), and (p)], and the exposed edges of the plate are closer to the edge of the weld than a distance equal to the thickness of the plate, the peripheral plate edges and any remaining exposed surface of the weld joint preparation shall be examined after welding by either the magnetic particle or liquid penetrant method. When the plate is nonmagnetic, only the liquid penetrant method shall be used. The requirements of this paragraph shall not apply to those joints when 80% or more of the pressure load is carried by tubes, stays, or braces, or when the exposed edges of the plate are farther from the edge of the weld than a distance equal to the thickness of the plate.

PG-93.2 Laminations, cracks, or other imperfections found during the examination required by PG-93.1 that would affect the safety of the vessel shall be repaired in accordance with PG-78. The imperfection(s) may be pursued by any suitable method (grinding, chipping, etc.). The repaired area shall be subjected to the same examination that first revealed the imperfection.

PG-93.3 Methods and acceptance criteria for magnetic particle and liquid penetrant examination shall be in accordance with A-260 or A-270 respectively.

A03 PG-99 HYDROSTATIC TEST

Hydrostatic testing of the completed boiler unit shall be conducted in accordance with the following requirements:

After a boiler has been completed (see PG-104), it shall be subjected to pressure tests using water at no less than ambient temperature, but in no case less than 70°F (21°C). Where required, test pressures are specified in this paragraph; whether minimum or maximum pressures, they apply to the highest point of the boiler system. At no time during the hydrostatic test shall any part of the boiler be subjected to a general primary membrane stress greater than 90% of its yield strength (0.2% offset) at test temperature. The primary membrane stress to which the boiler components are subjected during hydrostatic testing shall be taken into account when designing the components. When the boiler is completed in the Manufacturer's shop without boiler external piping, subsequent hydrostatic testing of the boiler external piping shall be the responsibility of any holder of a valid "S," "A," or "PP" stamp. The safety valves need not be included in the hydrostatic test. The tests shall be made in two stages in this sequence:

PG-99.1 Hydrostatic pressure tests shall be applied by raising the pressure gradually to $1\frac{1}{2}$ times the maximum allowable working pressure as shown on the data report to be stamped on the boiler. The pressure shall be under proper control at all times so that the required test pressure is never exceeded by more than 6%. Close visual inspection for leakage is not required during this stage.

PG-99.2 The hydrostatic test pressure may then be reduced to the maximum allowable working pressure, as shown on the Data Report, to be stamped on the boiler and maintained at this pressure while the boiler is carefully examined. The metal temperature shall not exceed 120°F (49°C) during the close examination.

PG-99.3 A completed forced-flow steam generator with no fixed steam and waterline, having pressure parts designed for different pressure levels along the path of water-steam flow, shall be subjected to a hydrostatic pressure test by the above procedure (PG-99.1 and PG-99.2) based upon:

PG-99.3.1 For the first stage test (PG-99.1) a hydrostatic test pressure of not less than $1\frac{1}{2}$ times the maximum allowable working pressure at the superheater outlet as shown in the master stamping (PG-106.3) but no less than $1\frac{1}{4}$ times the maximum allowable working pressure of any part of the boiler, excluding the boiler external piping.

PG-99.3.2 For the second stage test (PG-99.2) the hydrostatic test pressure may be reduced to not less than the maximum allowable working pressure at the superheater outlet.

PG-99.4 Test Gages

PG-99.4.1 An indicating gage, visible to the operator controlling the pressure applied, shall be connected to the pressure parts. Hydrostatic head on the gage shall be considered such that the required test pressure is achieved at the top of the boiler. A03

PG-99.4.2 Dial pressure gages used in testing shall preferably have dials graduated over their entire range of about double the intended maximum test pressure, but in no case shall the range be less than $1\frac{1}{2}$ times that pressure. The spacing between graduations shall be such that the inspector and the operator controlling

the test shall be able to determine when the required test pressure has been applied. Digital pressure gages having a wider range of pressure readings may be used provided the readings give the same or greater degree of accuracy as obtained with dial pressure gages.

PG-100 HYDROSTATIC DEFORMATION TEST

Where no rules are given and it is impossible to calculate with a reasonable degree of accuracy the strength of a boiler structure or any part thereof, a full-sized sample shall be built by the Manufacturer and tested in accordance with the Standard Practice for Making a Hydrostatic Test on a Boiler Pressure Part to Determine the Maximum Allowable Working Pressure, given in A-22 or in such other manner as the Committee may prescribe.

CERTIFICATION BY STAMPING AND DATA REPORTS

PG-101 HEATING SURFACE COMPUTATION

PG-101.1 For the stamping required by PG-106, the heating surface shall be computed as follows:

PG-101.1.1 Heating surface, as part of a circulating system in contact on one side with water or wet steam being heated and on the other side with gas or refractory being cooled, shall be measured on the side receiving heat.

PG-101.1.2 Boiler heating surface and other equivalent surface outside the furnace shall be measured circumferentially plus any extended surface.

PG-101.1.3 Waterwall heating surface and other equivalent surface within the furnace shall be measured as the projected tube area (diameter × length) plus any extended surface on the furnace side. In computing the heating surface for this purpose, only the tubes, fireboxes, shells, tubesheets, and the projected area of headers need to be considered, except that for vertical firetube steam boilers only that portion of the tube surface up to the middle of the gage glass is to be computed.

PG-104 GENERAL

PG-104.1 The completed boiler unit includes all piping and piping components as defined in the Preamble.

The Manufacturer (see Note 1 below) of any complete boiler unit to be stamped with the Code symbol has the responsibility of assuring through proper Code certification that all work performed by him or others responsible to him complies with all requirements of the Code, including design, construction, materials, and workmanship. With the exception of field installed boiler external piping, when some portions of a complete boiler unit are supplied by, or Code work is performed by others not responsible to the Manufacturer, the Manufacturer has the duty of obtaining from these other organizations their proper Code certification, covering such portions of work.

When the Manufacturer furnishes a shop assembled boiler that is complete except for boiler external piping, and the boiler has been hydrostatically tested in the shop and properly stamped with the Manufacturer's "S" symbol, the subsequent installation in the field of the external piping within the scope of Section I is not by itself considered "field assembly of the boiler" (see Note 2 below).

No Manufacturer or assembler may accept Code responsibility for work that falls within the scope of the Code, that is performed by workmen employed by any other organization, except through proper Code certification. The responsibilities set forth herein relate only to Code compliance and are not to be construed as involving contractual relations or legal liabilities.

NOTE 1: Boiler Manufacturer or Manufacturer as used in PG-104 or other paragraphs referenced to this Note may also be an Engineering-Contractor organization with or without fabricating facilities, but having the capability of providing a design specification that establishes the pressure and temperature conditions for each component of a complete boiler unit and of assembling the fabricated parts in the field with authorization from the Society to use the Code symbol stamp "S" in accordance with the Code provisions in PG-105.3.

NOTE 2: When boiler external piping within the scope of Section I is furnished by other than the boiler Manufacturer, the boiler Manufacturer is not responsible for the Code certification of such piping. The organizations that furnish and that install such external piping by welding shall furnish proper Code certification (PG-104.2) for such piping including Manufacturers' Data Report Form P-4A as required by PG-112.2.5 and PG-112.3.

PG-104.2 Proper Code certification refers to the furnishing of stamping and Data Reports as evidence to establish the following.

PG-104.2.1 The organization that performed that portion of the work held an appropriate Certificate of Authorization.



FIG. PG-105.1 OFFICIAL SYMBOLS FOR STAMPS TO DENOTE THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS' STANDARD FOR BOILERS



FIG. PG-105.2 OFFICIAL SYMBOL FOR STAMP TO DENOTE THE AMERICANSOCIETY OF MECHANICAL ENGINEERS' STANDARD FOR ASSEMBLY

FIG. PG-105.3 OFFICIAL SYMBOL FOR STAMP TO DENOTE THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS' STANDARD FOR WELDED PIPING





FIG. PG-105.4 OFFICIAL SYMBOL FOR STAMP TO DENOTE THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS' STANDARD FOR SAFETY VALVES

PG-104.2.2 By signing and furnishing the appropriate data report, that organization certified compliance with Code rules for that portion of the work.

PG-104.2.3 By proper use of the Code symbol stamp, that organization identified the portions of the work covered by its Data Report Form.

PG-104.2.4 By countersignature on the same Data Report a qualified Inspector confirmed that portion of the work complied with applicable Code rules.

PG-105 CODE SYMBOL STAMPS

A03 **PG-105.1 Authorization.** Except as permitted in PG-105.5, no organization may assume responsibility for Code construction without having first received from the ASME a Certificate of Authorization to use one of the Code symbol stamps shown in Figs. PG-105.1 through PG-105.4. There are six such stamps, defined as follows:

S — power boiler symbol stamp ..... see Fig. PG-105.1
M — miniature boiler symbol stamp ..... see Fig. PG-105.1
E — electric boiler symbol stamp ..... see Fig. PG-105.1
A — boiler assembly symbol stamp ..... see Fig. PG-105.2
PP — pressure piping symbol stamp ..... see Fig. PG-105.3
V — safety valve symbol stamp ..... see Fig. PG-105.4

Stamps for applying the Code symbol shall be obtained from the Society. Each boiler, superheater, waterwall, economizer, or boiler part to which a Code symbol is to be applied shall be fabricated by a Manufacturer who is in possession of an appropriate Code symbol stamp. A Certificate of Authorization to use the Code symbol "S," "M," "E," "A," "PP," or "V" stamp will be granted by the Society pursuant to the provisions of these paragraphs.

PG-105.2 Application for Certificate of Authorization. Any organization desiring a Certificate of Authorization shall apply to the Boiler and Pressure Vessel Committee of the Society, on forms issued by the Society, specifying the stamp desired and the scope of Code activities to be performed. When an organization intends to build Code items in plants in more than one geographical area, separate applications for each plant or a single application listing the addresses of all such plants may be submitted. Each application shall identify the Authorized Inspection Agency providing Code inspection at each plant. A separate Certificate of Authorization will be prepared and a separate fee charged by the Society for each plant.

Each applicant must agree that each Certificate of Authorization and each Code symbol stamp are at all times the property of the Society, that they will be used according to the rules and regulations of this Section of the Code, and that they will be promptly returned to the Society upon demand, or when the applicant discontinues the Code activities covered by his certificate, or when the Certificate of Authorization has expired and no new certificate has been issued. The holder of a Code symbol stamp shall not allow any other organization to use it.

Authorization to use Code symbol stamps may be granted or withheld by the Society in its absolute discretion. If authorization is granted, and the proper administrative fee paid, a Certificate of Authorization evidencing permission to use any such symbol, expiring on the triennial anniversary date thereafter, will be forwarded to the applicant. Each such certificate will identify the Code symbol to be used, and the type of shop and/or field operations for which authorization is granted. (See Appendix A-370.) The certificate will be signed by the Chairman of the Boiler and Pressure Vessel Committee and the Director of Accreditation. Six months prior to the date of expiration of any such certificate, the applicant must apply for a renewal of such authorization and the issuance of a new certificate. The Society reserves the absolute right to cancel or refuse to renew such authorization returning *pro rata*, fees paid for the unexpired term.

PG-105.3 Agreement With Authorized Inspection Agency. As a condition of obtaining and maintaining a Certificate of Authorization to use the "S," "M," "E," "A," or "PP" Code symbol stamps, the Manufacturer or Assembler must have in force at all times, an inspection contract or agreement with an Authorized Inspection Agency as defined in PG-91 to provide inspection services. This inspection contract is a written agreement between the Manufacturer or Assembler and the inspection agency that specifies the terms and conditions under which the inspection services are to be furnished and that states the mutual responsibilities of the Manufacturer or Assembler and the Authorized Inspectors. The certificate holder shall notify the Society whenever its agreement with an Authorized Inspection Agency is cancelled or changed to another Authorized Inspection Agency.

Manufacturers or assemblers of safety valves are not required to have an inspection agreement with an Authorized Inspection Agency. A Certificate of Authorization may be granted to a manufacturer or assembler of safety valves to use the safety valve symbol stamp providing such stamp is applied only to safety valves that have been capacity certified in accordance with the requirements of this Section.

PG-105.4 Quality Control System. Any Manufacturer or Assembler holding or applying for a Certificate of Authorization to use the "S," "M," "E," "A," "PP," or "V" stamp shall have, and demonstrate, a quality control system to establish that all Code requirements including material, design, fabrication, examination (by the Manufacturer), and inspection for boilers and boiler parts (by the Authorized Inspector) will be met. The quality control system shall be in accordance with the requirements of Appendix A-300.

Before issuance or renewal of a Certificate of Authorization for use of the "S," "M," "E," "A," or "PP" stamps, the Manufacturer's facilities and organization are subject to a joint review by a representative of his inspection agency and an individual certified as an ASME designeee who is selected by the concerned legal jurisdiction. When the jurisdiction assumes responsibility for leading the review, it shall have certified that its representative has met ASME criteria. A written description or checklist of the quality control system which identifies what documents and what procedures the Manufacturer will use to produce a Code item shall be available for review. The purpose of the review is to evaluate the applicant's quality control system and its implementation. The applicant shall demonstrate sufficient administrative and fabrication functions of the system to show that he has the knowledge and ability to produce the Code items covered by his quality control system. Fabrication functions may be demonstrated using current work, a mock-up, or a combination of the two. A written report to the Society shall be made jointly by the jurisdiction and the inspection agency employed by the Manufacturer to do his Code inspection. This report is then reviewed by the Subcommittee on Boiler and Pressure Vessel Accreditation, which will either issue a Certificate of Authorization or notify the applicant of deficiencies revealed by the review. In such a case, the applicant will be given an opportunity to explain or correct these deficiencies.

Certificates of Authorization will be endorsed to indicate the scope of activity authorized. Authorization may include field operations if the review team determines that these operations are adequately described in the quality control manual, and this determination is accepted by the Society.

Before issuance or renewal of a Certificate of Authorization for use of the "V" stamp, the valve manufacturer's or assembler's facilities and organization are subject to a review by an ASME designee. A written description or checklist of the quality control system, which identifies the documents and procedures the manufacturer or assembler will use to produce Code safety and safety relief valves, shall be available for review. The ASME designee shall make a written report to the Society, where the Subcommittee on Boiler and Pressure Vessel Accreditation will act on it as described above.

The Manufacturer may at any time make changes in the quality control system concerning the methods of achieving results subject to acceptance by the Authorized Inspector. For manufacturers and assemblers of

"V" stamped safety or safety relief valves, such acceptance shall be by the ASME designee.

For those areas where there is no jurisdiction or where a jurisdiction does not choose to select an ASME designee to review a vessel or vessel parts manufacturer's facility, that function shall be performed by an ASME designee selected by ASME. In either case, the ASME designee shall certify its representative has met ASME criteria. Where the jurisdiction is the Manufacturer's inspection agency, the joint review and joint report shall be made by the jurisdiction and another representative designated by the Society.

A03 **PG-105.5 Code Construction Before Receipt of Certificate of Authorization.** When used to demonstrate his quality control system, a Manufacturer may start fabricating Code items before receipt of a Certificate of Authorization to use a Code symbol stamp under the following conditions:

(a) The fabrication is done with the participation of the Authorized Inspector and is subject to his acceptance.

(b) The activity shall have been performed in conformance with the applicant's accepted quality control system.

(c) The item is stamped with the appropriate Code symbol and certified once the applicant receives his Certificate of Authorization from the Society.

PG-105.6 Regulations on Use of Code Symbol Stamps. The Boiler and Pressure Vessel Committee may at any time make such regulations concerning the issuance and use of Code symbol stamps as it deems appropriate, and all such regulations shall become binding upon the holders of any valid Certificates of Authorization.

PG-106 STAMPING OF BOILERS

PG-106.1 The Manufacturer shall stamp each boiler, superheater, waterwall, or steel economizer constructed in compliance with this Section in the presence of the Authorized Inspector, after the hydrostatic test, in the shop of the Manufacturer, except that in cases where boilers, superheaters, waterwalls, or steel economizers are not completed and hydrostatically tested before shipment, proper stamping shall be applied at the shop and the data reports required in PG-112 and PG-113 shall be signed by the same or different Inspectors who shall indicate the portions of the inspections made at the shop and the field. The stamping shall consist of the appropriate Code symbol shown in Fig. PG-105.1 which shall be put on each piece of equipment listed above in the locations specified in PG-111, except as provided in PG-106.2.

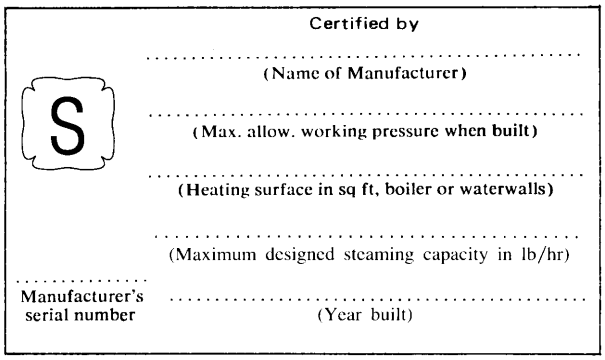


FIG. PG-106 FORM OF STAMPING

PG-106.2 When the watertube boiler is arranged integrally with its economizer, superheater and/or waterwalls, the stamping required in PG-106.1 for such parts as are fabricated by the Manufacturer of the boiler may be combined into a *single* stamping located as specified in PG-111.5. Identifying marks shall be placed on all headers as required in PG-111.10, PG-111.11, and PG-111.12.

PG-106.3 For forced-flow steam generators with no fixed steam and waterline, consisting of groups of pressure parts or components designed at several different levels of maximum allowable working pressures (PG-21), the stamping, required in PG-106.1 for such parts as are fabricated by the Manufacturer of the boiler, shall be combined into a single stamping. In addition, whichever Manufacturer (see PG-104, Note 1) has the responsibility for assurance of Code certification for a completed boiler unit, that Manufacturer shall provide a master stamping for the complete unit which shall show the maximum allowable working (minimum design) pressure at the superheater outlet as determined by the Manufacturer as item PG-106.4.1(3). In no case shall the master stamping pressure be more than the maximum allowable working pressure of any part of the unit, excluding the steam piping between the boiler and the prime mover. The master stamping shall be located as required in PG-111.5.2. A03

PG-106.4 In addition to the symbol, the following items shall also be stamped with letters and figures at least $^{5}/_{16}$ in. (8 mm) high [$^{5}/_{32}$ in. (4 mm) on miniature boilers if necessary], arranged as shown in Fig. PG-106.

PG-106.4.1 Items on Boilers

(1) Manufacturer's serial number

(2) Certified by (Name of Manufacturer)

(3) Maximum allowable working pressure when built

(4) Heating surface (or kilowatt power input for electric boilers)

(5) Year built

(6) Maximum designed steaming capacity, lb/hr (kg/hr) [or, for high-temperature water boilers, maximum designed output, Btu/hr (J/hr)]

PG-106.4.2 Items on Waterwalls, Superheaters, or Steel Economizers

(1) Manufacturer's serial number

(2) Certified by (Name of Manufacturer)

(3) Maximum allowable working pressure when built

(4) Heating surface in square feet (not required for integral superheaters) (rated Btu per hour absorption for an isolable economizer)

(5) For independently fired superheaters, heating surface in square feet or the minimum safety valve discharge capacity in lbs. of steam per hour calculated from the maximum expected heat absorption (as determined by the Manufacturer) in Btu/hr, divided by 1,000.

PG-106.5 For boilers with no pressure retaining part larger than 16 in. (406 mm) O.D., or for equipment operating at temperatures above 800°F (427°C), a cast, etched, or stamped metallic nameplate may be used to provide the data required by PG-106 instead of stamping directly on the pressure retaining material. This plate shall be securely attached to the item it describes. If the attachment is by welding, the welding shall meet the requirements of this Section. The Authorized Inspector shall witness the stamping of the Code symbol and verify that the nameplate has been attached.

PG-106.6 Each Manufacturer shall furnish, in addition, a metallic plate or plates on which the above data are reproduced for all the items manufactured by him, except when the original stampings are so located on the completed (or assembled) boiler unit that all will be readily visible from one place on the operating floor or platform. These plates, if used, shall be located as specified in PG-111.13. All data on such additional plates, including the Code symbol, shall be cast, etched, or stamped and this marking need not be witnessed by an Authorized Inspector. The letters and figures on these nameplates shall be not less than $^{5}/_{32}$ in. (4 mm) high.

PG-106.7 When the Manufacturer is an Engineering Contractor (see PG-104, Note 1), the Engineering Contractor shall provide a metallic master stamping plate or plates. The letters and figures on this plate shall be not less than $^{5}/_{32}$ in. (4 mm) high. This plate shall include, in addition to the Code symbol, all the data required by PG-106.4. Such data, except the Code symbol, may be cast, etched, or stamped on this plate. The Code symbol shall be stamped. The stamping of the master stamping plate with the Code symbol shall be in the presence of the Authorized Inspector after the Inspector has examined the Design Specification for the complete boiler unit, verified the plate data, and is satisfied that the Engineering Contractor has provided for the construction of a complete boiler unit. The Inspector shall then sign the Certification of Engineering Contractor portion of Form P-3A.

The master stamping plate shall be located on the boiler as specified in PG-111.13 by the boiler Assembler in the presence of and when authorized by the field Inspector after the required inspections and the hydrostatic test of the completed unit. The Certificate of Field Assembly Inspection portion of Form P-3A shall then be signed by the field Inspector.

PG-106.8 Stamping and Marking of Parts 01

PG-106.8.1 When only a part of the boiler is supplied and the data are recorded on Form P-4, Manufacturers' Partial Data Report (see PG-112.2.4), the part shall be stamped with: 01

(1) ASME Code Symbol above the word "part"

(2) Certified by (Name of Manufacturer)

(3) Manufacturer's serial number of the part

(4) Year built

Parts may be stamped with the ASME Code Symbol without being pressure tested prior to shipment. (See PG-112 for requirements for documentation and stamping of pressure parts that do not contain pressure retaining welds.)

PG-106.8.2 In lieu of such stamping, small parts (5 in. OD and under) may be marked with an identification acceptable to the Inspector (e.g., bar coding, etching, paint stencil, etc.) and traceable to the Form P-4, Manufacturers' Partial Data Report. Such marking shall be of a type that will remain visible until the part is installed. The Code symbol stamp is not required. 01

PG-106.9 No accessory or part of a boiler may be marked "ASME" or "ASME Std." unless so specified in the Code.

PG-106.10 Shell plates, furnace sheets, and heads shall have identification stamping in conformance with PG-77.

PG-106.11 The American Society of Mechanical Engineers' standard symbols and the boiler builder's stamps shall not be covered permanently by insulating or other material.

PG-106.12 Multiple Pressure Steam Generators consisting of several sections of heat exchange surface designed for different pressure levels may be considered as a single boiler and the Manufacturer's stamping required by PG-106.1 combined into a single stamping provided:

PG-106.12.1 The different circuits of the boiler are not intended to be operated separately or independently.

PG-106.12.2 The extent and design of the boiler external piping for each circuit shall be established in accordance with PG-58.3.

PG-106.12.3 The various circuits shall be separated from each other by providing a stop valve and a check valve in the feedwater piping leading to each circuit, in accordance with PG-58.3.3.

PG-106.12.4 Each circuit shall be given a hydrostatic test corresponding to its MAWP, as required by PG-99.

PG-106.12.5 Each circuit shall be stamped with the information required by PG-106.4. The stamping shall be located in accordance with PG-111.

PG-106.12.6 The Manufacturer shall furnish, in addition, a single metallic plate on which the above data are reproduced for all of the circuits. This plate shall be located in accordance with PG-111.13. All data on such plates shall be cast, etched or stamped. The Code symbol shall be stamped on this plate and shall be witnessed by an Authorized Inspector. The letter and figures on these nameplates shall be no less than $^{5}/_{32}$ in. high.

PG-107 FIELD ASSEMBLY

Code responsibility for a completed boiler unit that is field assembled (excluding the shop assembled boiler with field installed piping, see PG-104, Note 2) may be assumed only under the following conditions:

PG-107.1 By the boiler Manufacturer (see PG-104, Note 1) provided:

PG-107.1.1 Assembly work is performed by workmen employed by the boiler Manufacturer.

PG-107.1.2 Any work performed by others, such as erection of piping, that falls within the scope of the Code, is handled by proper Code certification.

PG-107.1.3 The completed boiler unit is properly stamped with the Manufacturer's "S" symbol in accordance with PG-108.1.

PG-107.1.4 Data Reports are prepared in accordance with PG-113.1.

PG-107.2 Jointly by the boiler Manufacturer (see PG-104, Note 1) and the assembler provided:

PG-107.2.1 Assembly work is performed by workmen employed by the assembler.

PG-107.2.2 The assembler uses his own properly qualified welding procedures, welders and/or welding operators.

PG-107.2.3 Any work performed in the field by others, such as erection of piping, that falls within the scope of the Code, is handled by proper Code Certification.

PG-107.2.4 The completed boiler unit is properly stamped with the Manufacturer's "S" symbol and the assembler's "A" symbol in accordance with PG-108.2.

PG-107.2.5 Data Reports are prepared in accordance with PG-113.2 and such Data Reports clearly define the work completed by the Manufacturer and the assembler.

PG-108 STAMPING FOR FIELD ASSEMBLED BOILERS

Field assembly of a completed boiler unit may be made by anyone possessing a valid Certificate of Authorization for a power boiler stamp or an assembly stamp provided responsibility is assumed in accordance with the requirements of PG-107. Stamping for field assembled boiler units shall be completed as follows.

PG-108.1 When responsibility for the completed boiler unit is assumed under PG-107.1, no additional stamping beyond that required by PG-106 is necessary.

PG-108.2 When responsibility for the completed boiler unit is assumed under PG-107.2, the Manufacturer's (see PG-104, Note 1) stamping shall be supplemented with the assembler's stamp, together with the name of the assembler or an acceptable abbreviation. This supplementary stamping shall be applied in the

field on the boiler near the stamping called for by PG-106 when authorized by the field Inspector after the required inspections and the hydrostatic test of the completed boiler unit. This supplementary stamping shall also be reproduced on a nameplate as required by PG-106.6 or PG-106.7.

PG-109 STAMPING OF PRESSURE PIPING

PG-109.1 Boiler external piping, as defined in the Preamble, may be fabricated by a manufacturer other than the Manufacturer of the boiler, provided that the manufacturer has been issued a Certificate of Authorization to use the "S" or "PP" symbol stamp. Boiler external piping may be installed by welding by a manufacturer or contractor other than the Manufacturer of the boiler, provided such an organization has been issued a Certificate of Authorization to use the "S," "PP," or "A" symbol stamp. When boiler external piping is installed by welding, the welding, including the qualification of welding procedures, welders, and welding operators, shall be done in accordance with the applicable rules of ASME B31.1. The welding shall be inspected by an Authorized Inspector at such stages of the work as he may elect. The organizations which fabricate or install such piping shall furnish proper code certification (PG-104.2) for it including a Manufacturers' Data Report Form P-4A as required by PG-112.2.5 and PG-112.3.

PG-109.2 Welded boiler external piping included within the scope of this Code, over NPS 2 (DN 50), shall be stamped with a Code symbol, together with the manufacturer's or contractor's name and serial number. Such stamping shall be on the pipe, valve, or fitting adjacent to the welded joint farthest from the boiler. For piping operating at temperatures above 800°F (427°C) the symbol may be stamped on a nameplate that is irremovably attached by welding, provided such welding is postweld heat treated, or on a circular metal band at least $\frac{1}{4}$ in. (6 mm) thick. This band around the pipe shall be secured in such a manner as to prevent it from slipping off during handling and installation.

Welded piping NPS 2 (DN 50) or less included within the scope of this Code shall be marked with an identification acceptable to the Inspector and traceable to the required Data Report. Such marking shall be of a type that will remain visible until the piping has been installed.

PG-109.3 Parts of boilers, such as superheater, waterwall, or economizer headers, or any construction involving only welding as covered by PW-41, may be fabricated by a manufacturer in possession of the pressure piping symbol stamp, and so stamped and reported on a Manufacturers' Partial Data Report Form (Form P-4) as called for in PG-112.2.4.

PG-109.4 Mechanically assembled boiler external piping which contains no pressure boundary welds does not require stamping, and as such may be assembled by a non-stamp holder. Note that the responsibility for documentation and hydrostatic testing of a mechanically assembled boiler external piping must be assumed by a holder of a valid "S," "A," or "PP" stamp (see PG-112.2.5).

PG-110 STAMPING OF SAFETY VALVES 01

Each safety valve shall be plainly marked with the required data by the Manufacturer or Assembler (see PG-73.3.4) in such a way that the marking will not be obliterated in service. The marking shall be placed on the valve or on a nameplate securely fastened to the valve. The Code "V" symbol shall be stamped on the valve or nameplate by the Manufacturer or Assembler, as applicable. The other required data may be stamped, etched, impressed, or cast on the valve or nameplate. The marking shall include the following:

(1) the name (or an acceptable abbreviation) of the Manufacturer and Assembler, as applicable;

(2) Manufacturer's design or type number;

(3) NPS (the nominal pipe size of the valve inlet);

(4) set pressure____psi (kPa);

(5) capacity____lb/hr (kg/hr) (in accordance with PG-67.5 and with the valve adjusted for the blowdown permitted by PG-72);

(6) year built, or alternatively, a coding may be marked on the valve such that the valve Manufacturer or Assembler can identify the year the valve was assembled and tested;

(7) ASME symbol as shown in Fig. PG-105.4.

PG-111 LOCATION OF STAMPINGS

The location of the required stampings shall be as listed below. These stampings shall be left uncovered or an easily removable marked cover may be provided over the stamping when a boiler is covered with insulation, or jacketed. No piping, boiler appliance, or other obstructions shall interfere with reading of the stamping.

PG-111.1 Horizontal-return tubular boilers — on the front head above the central rows of tubes.

PG-111.2 Horizontal-flue boilers — on the front head above the flues.

PG-111.3 Traction, portable, or stationary boilers of the locomotive type or Star watertube boilers — on the furnace end above the handhole. Or on traction boilers of the locomotive type — on the left wrapper sheet forward of the driving wheel.

PG-111.4 Vertical firetube and vertical submerged tube boilers — on the shell above the firedoor and handhole opening.

PG-111.5 Watertube Boilers

PG-111.5.1 Drum type — on a head of the steam outlet drum near and above the manhole.

PG-111.5.2 Forced-flow steam generator with no fixed steam and waterline — the master stamping (PG-106.3) shall be located on a major pressure part, located near the main operating floor where readily visible. The Data Report Form shall record the location of the master stamping.

PG-111.6 Scotch marine boilers — on either side of the shell near the normal water level line and as near as practical to the front tubesheet.

PG-111.7 Economic boilers — on the front head, above the center row of tubes.

PG-111.8 Miniature and electric boilers — on some conspicuous and accessible place on the boiler proper, or on a stamping plate at least $^{3}/_{64}$ in. (1.2 mm) thick, permanently fastened (adhesives prohibited) to the boiler.

PG-111.9 On any of the above types where there is not sufficient space in the place designated, and for other types and new designs — in a conspicuous place on the boiler proper. The Data Report Form shall record the location of the required stamping.

PG-111.10 Superheaters — on superheater header near the outlet. Other headers shall carry identifying marks.

PG-111.11 Economizers — at a handy location on water inlet header or drums. Other headers shall carry identifying marks.

PG-111.12 Waterwalls — on one end of a lower header. Other headers shall carry identifying marks.

PG-111.13 When required by PG-106.6 and PG-106.7, the Manufacturer (see PG-104, Note 1) shall furnish a nameplate or plates on which the appropriate Code Symbol and design data for the scope of his responsibility are permanently imprinted. The nameplate shall be securely attached to the front of the boiler, its setting or casing, at a place readily visible from the operating floor or platform.

PG-112 MANUFACTURERS' DATA REPORT FORMS

PG-112.1 Eight types of Manufacturers' Data Report Forms are shown in the Appendix under the heading "Data Report Forms and Guides" at the end of this Section. These forms shall be used by the Manufacturer (see PG-104, Note 1) to record all the items of a complete boiler unit, in accordance with the provisions of PG-112.2. When the certification of the complete boiler unit is accomplished by more than one Data Report, the principal Data Report (P-2, P-2A, P-3, P-3A, or P-5) shall be designated as the Master Data Report (see PG-113).

For forced-flow steam generators with no fixed steam and waterline, consisting of groups of pressure parts or components designed at several different pressure levels, a separate Manufacturers' Data Report shall clearly identify the pressure parts at each pressure level and show the maximum allowable working pressure. These several Data Reports shall be attached to a Master Data Report (PG-113) that shall clearly identify each component as part of the complete unit.

PG-112.2 Types of Data Report Forms. The types of Data Report Forms and the purposes for which they are to be used are as follows:

PG-112.2.1 Form P-2, Manufacturers' Data Report for All Types of Boilers Except Watertube and Electric, shall be used to record all types of boilers other than watertube boiler units and parts thereof which are included under Form P-3.

PG-112.2.1.1 Form P-2A, Manufacturers' Data Report for All Types of Electric Boilers, shall be used to record all types of electric boilers.

PG-112.2.2 Form P-3, Manufacturers' Data Report for Watertube Boilers, Superheaters, Waterwalls, and Economizers, shall be used to record all of the items comprising a watertube boiler.

The Form P-3 shall also be used to record a superheater, waterwall, or economizer when the design of such an item is certified by a manufacturer other than the boiler Manufacturer, or when such an item is to be added to an existing boiler. The item shall be stamped with the ASME "S" symbol and the additional information, as applicable, shown in PG-106.4.2.

Item 10 on Form P-3 shall be used to record other parts connected at the openings listed in Item 11 if such parts are fabricated of materials or by processes that require Code inspection. If such parts have not been connected prior to the hydrostatic test, a notation shall be made under Item 10 reading: "No parts connected to the openings listed in Item 11 except as noted."

PG-112.2.3 Form P-3A, Engineering-Contractor Data Report for a Complete Boiler Unit, shall be used when such an organization assumes the Manufacturer's Code responsibility as provided for by PG-104, Note 1. This form shall be used to certify Code responsibility for the design specification of the complete boiler unit, of which the components are individually certified by their individual manufacturers in accordance with the Code rules. This form also provides for field assembly certification.

A03 **PG-112.2.4** Form P-4, Manufacturers' Partial Data Report, shall be used to record boiler parts requiring inspection and stamping under this Section which are furnished by other than the Manufacturer responsible for the completed boiler, superheater, waterwall, or economizer.

(a) Except as provided in (b) below, Form P-4 shall be used only to provide supporting data for the information given on the Master Data Report (see PG-113) or on the Form P-3 used to record a superheater, waterwall, or economizer.

(b) When used to record parts furnished to the user of an existing boiler as replacement or repair parts, Form P-4 is sufficient and need not support a Master Data Report. A copy of the parts Manufacturers' Form P-4 shall be forwarded to the purchaser.

(c) The parts manufacturer shall indicate under "remarks" the extent to which he has performed the design functions. When the parts manufacturer performed only a portion of the design, he shall state which portion of the design he has performed.

PG-112.2.5 Form P-4A, Manufacturers' Data Report for Fabricated Piping, shall be used to record all shop or field-welded piping that falls within the scope of this Section but is not furnished by the boiler Manufacturer. Form P-4B, Manufacturers' Data Report for Field Installed Mechanically Assembled Piping, shall be used to record all field installed mechanically assembled boiler external piping. Form P-4B shall be used only for piping that contains no joints brazed or welded by the field installer.

PG-112.2.6 Form P-5, Summary Data Report for Process Steam Generators, shall be used by the Manufacturer (see PG-104, Note 1) to record all items of field-assembled process steam generators of the waste heat or heat recovery type, comprising one or more drums and one or more arrays of heat exchange surface. All such component items shall be constructed to the applicable rules of the Code and shall be certified by individual Data Report Forms executed by the component manufacturer and the Authorized Inspector. The Summary Data Report Form P-5 shall collect and list all the properly executed Data Report Forms for components comprising the complete process steam generator unit.

PG-112.2.7 Form P-6, Manufacturers' Data Report Supplementary Sheet, shall be used to record additional data where space was insufficient on a Data Report Form. This Manufacturers' Data Report Supplementary Sheet will be attached to the Manufacturers' Data Report Form where used.

PG-112.2.8 Form P-7, Manufacturers' Data Report for Safety Valves, shall be used to record required safety valves. Form P-7 shall be used as supporting data for Forms P-2, P-3, P-3A, or P-5. Form P-7 is not required for boilers certified on Form P-2A, or for boilers with a single safety valve when the safety valve size, set pressure, and capacity [lb/hr (kg/hr)] are included in the remarks section of Forms P-2 or P-3.

PG-112.3 Manufacturers' Data Reports and all associated Partial Data Reports shall be furnished to the purchaser, the inspection agency, and the state, municipal, or provincial authority at the place of installation. Partial Data Reports for pressure parts requiring inspection under this Section, and which are furnished by other than the Manufacturer having Code responsibility for the boiler or the superheater, waterwall, or economizer, shall be executed by the parts manufacturer and the Inspector in accordance with the requirements of this Section.

Except as provided in PG-112.2.4(2), the Partial Data Reports shall be forwarded, in duplicate, to the Manufacturer of the boiler or the superheater, waterwall, or economizer. These Partial Data Reports, together with his own inspection, shall be the final Inspector's authority to witness the application of the Code symbol to the boiler or the superheater, waterwall, or economizer. The Partial Data Reports shall be attached to the associated Forms P-2, P-2A, P-3, or P-5 by the Manufacturer having Code responsibility for the boiler or the superheater, waterwall, or economizer.

PG-112.4 Appendix A-350 includes nonmandatory guides to aid in the completion and certification of the Manufacturers' Data Report Forms.

PG-112.5 Multiple Pressure Steam Generators shall be documented as follows:

PG-112.5.1 Master Data Report Form P-3, P-3A, or P-5 shall be used by the Manufacturer as a Summary Data Report to record all items of a steam generator of the waste heat or heat recovery type, comprising one or more circuits of heat exchange surface designed for different pressure levels. The Summary Data Report shall list all of the properly executed data report forms for the items comprising the complete steam generator unit.

PG-112.5.2 Other forms such as P-3, P-4, P-4A, and P-6 shall be used as necessary to provide supporting information for the Summary Data Report.

PG-112.6 Manufacturer's Partial Data Report Form P-4 and stamping in accordance with PG-106 are neither required nor prohibited for pressure parts that do not contain pressure retaining welds (e.g., boiler furnace walls, floor panel assemblies, tubes with support or hanger lugs, etc.). However, the Manufacturer shall certify that the material and construction are in accordance with the requirements of this Section.

PG-112.6.1 Certification may be supplied in the form of bills of material and drawings with a statement of compliance or Certificate of Compliance from the Manufacturer.

PG-112.6.2 The Certification shall state what materials were used including size (OD and wall thickness) and which edition and addenda of the Code were used to construct the parts.

PG-112.6.3 The parts shall be clearly identified with markings traceable to the certification. The markings may be in the form of labels, tags, stamping, paint, or coded identification.

PG-113 MASTER DATA REPORT FORM

PG-113.1 The Master Data Report (using Manufacturers' Data Report Forms P-2, P-2A, P-3, P-3A, or P-5, as applicable) shall be used by the boiler Manufacturer (see PG-104, Note 1) to fully document all parts of a complete boiler unit (excluding boiler external piping; see PG-104, Note 2) as having Code certification in accordance with the Code requirements for design, construction, and workmanship.

PG-113.2 When a field-assembled boiler unit is documented by Data Forms from manufacturers other than the Manufacturer (see PG-104, Note 1) responsible for the complete boiler unit, the boiler Manufacturer shall complete the applicable Master Data Report Form by recording the required data from all supporting Data Report Forms that are required for the complete boiler unit. All Data Forms shall be securely attached to the Master Data Report. The Data Reports shall clearly separate shop fabrication from field assembly and in the case of large units, supplemental sheets may be used to record the information. The certificate of shop inspection block and the certificate of field assembly block shall clearly designate the items to be certified by the Inspector in the shop and those to be certified by the Inspector in the field. The certified Data Reports furnished by the several manufacturers shall be the shop or field Inspector's authority to accept the components fabricated by the other manufacturers and included in the construction of the complete boiler unit.

PG-113.3 The boiler Manufacturer (see PG-104, Note 1) shall have the responsibility for distributing copies of the complete Master Data Report Form (Data Report Form P-2, P-2A, P-3, P-3A, or P-5, as applicable) to the inspection agency and the required number of proper authorities. The Manufacturer's written quality control system shall include requirements for completion of Manufacturer's Data Reports. The Manufacturer shall retain the Manufacturer's Data Reports for a minimum of 5 years. A03

PG-113.4 When boiler external piping is furnished by an organization not contractually responsible to the Manufacturer (see PG-104, Note 1), the organization responsible for the fabrication and installation of this piping shall have the responsibility for distributing copies of Form P-4A to the inspection agency and proper authorities.