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APPENDIX A
EXPLANATION OF THE CODE CONTAINING MATTER NOT MANDATORY UNLESS SPECIFICALLY REFERRED TO IN THE RULES OF THE CODE

BRACED AND STAYED SURFACES

A-8

The allowable loads based on the net cross-sectional areas of staybolts with V-threads are computed from the following formulas. The use of Whitworth threads with other pitches is permissible.

The formula for the diameter of a staybolt at the bottom of a V-thread is:

$$D - (P \times 1.732) = d$$

where

D = diameter of staybolt over the threads, in.
P = pitch of threads, in.
= 1/number of threads/in.
d = diameter of staybolt at bottom of threads, in.
1.732 = a constant

When ANSI Standard threads are used, the formula becomes

$$D - (P \times 1.732 \times 0.75) = d$$

METHOD OF CHECKING SAFETY-VALVE CAPACITY BY MEASURING MAXIMUM AMOUNT OF FUEL THAT CAN BE BURNED

A-12

The maximum quantity of fuel C that can be burned per hour at the time of maximum forcing is determined by a test. The maximum number of heat units per hour, or CH, is then determined, using the values of H given in A-17. The weight of steam generated per hour is found by the formula:

Customary Units

$$W = \frac{C \times H \times 0.75}{1{,}100}$$

SI Units

$$W = \frac{C \times H \times 0.75}{2\ 558}$$

where

W = weight of steam generated/hr, lb (kg/hr)
C = total weight or volume of fuel burned/hr (kN/hr) at time of maximum forcing, lb (kg) or cu ft/kg (m^3)
H = heat of combustion of fuel, Btu/lb or Btu/cu ft (see A-17)

The sum of the safety valve capacities marked on the valves shall be equal to or greater than W.

A-13 Example 1

A boiler at the time of maximum forcing uses 2,150 lb/hr of Illinois coal with a heating value of 12,100 Btu/lb. Boiler pressure is 225 psi gage.

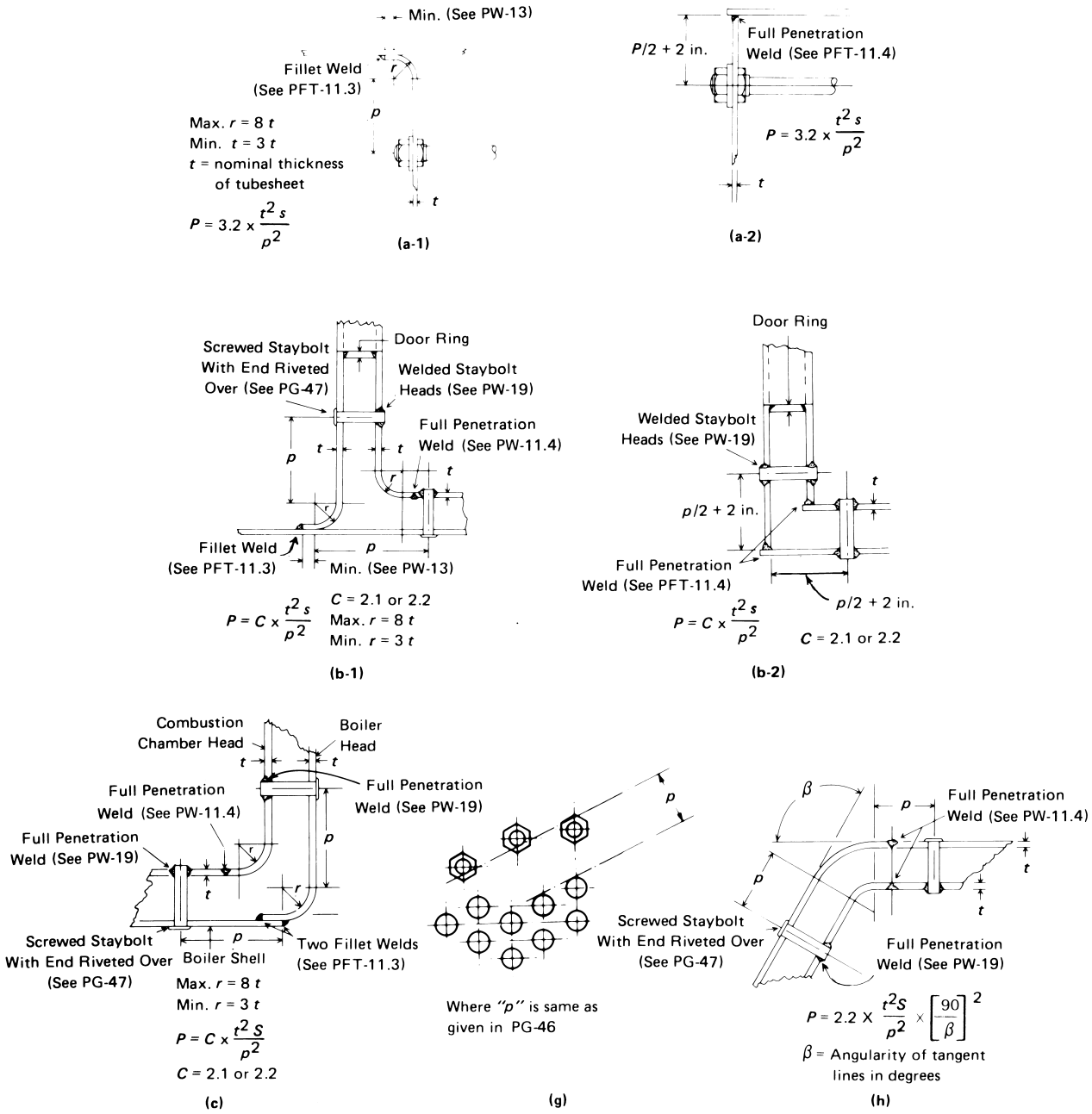
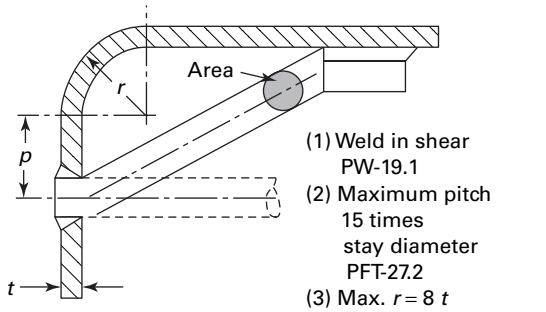
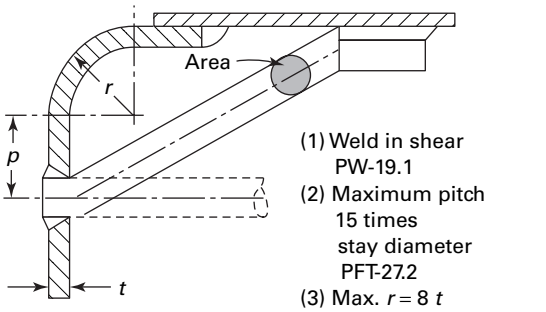


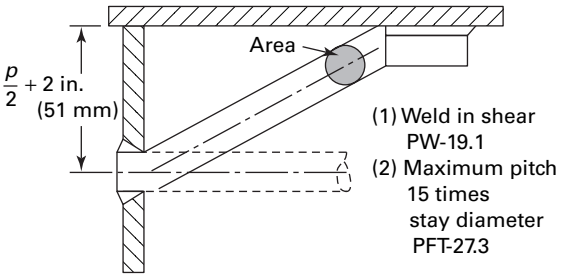
FIG. A-8 DETAIL SKETCHES SHOWING APPLICATION OF PG-48 AND PFT-27 TO THE STAYING OF BOILERS



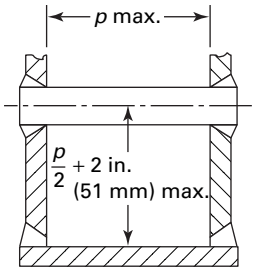
(i)



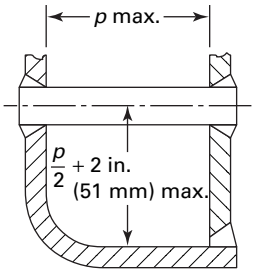
(j)



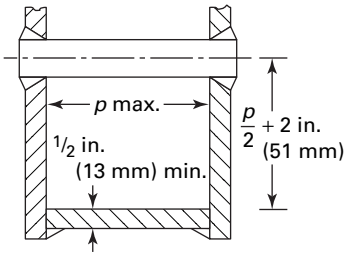
(k)



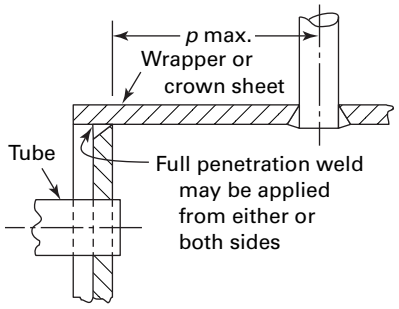
(l) Door Opening



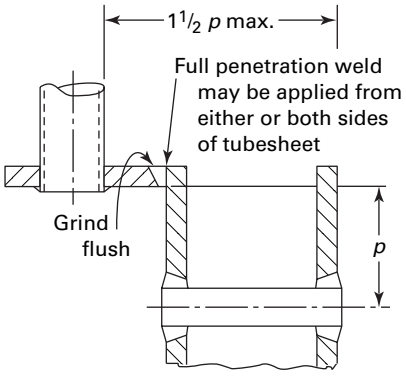
(m) Door Opening or Mud Ring



(n) Door Opening or Mud Ring

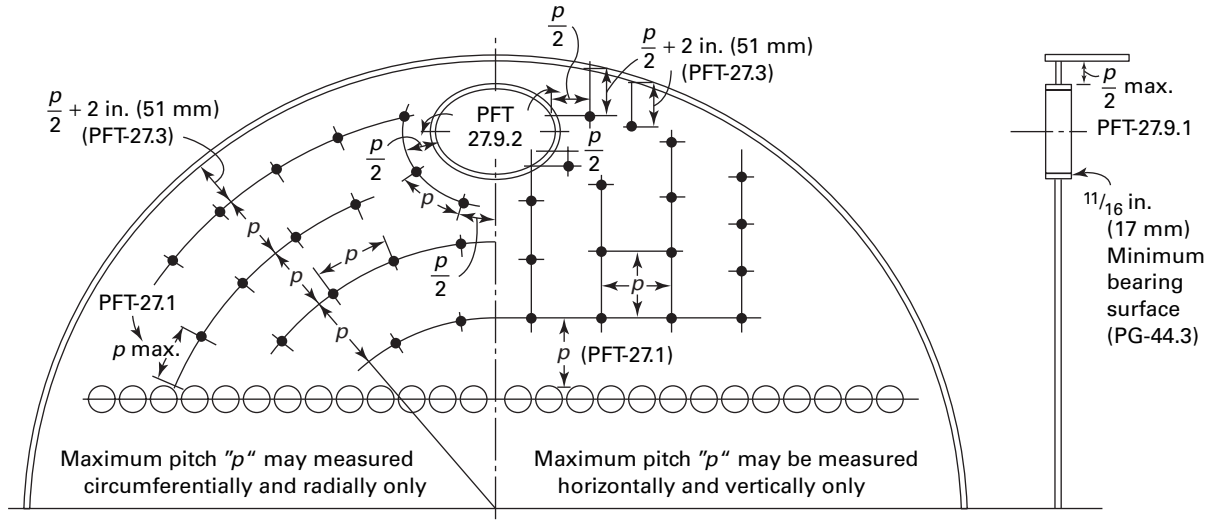


(o)



(p)

FIG. A-8 DETAIL SKETCHES SHOWING APPLICATION OF PG-48 AND PFT-27 TO THE STAYING OF BOILERS (CONT'D)

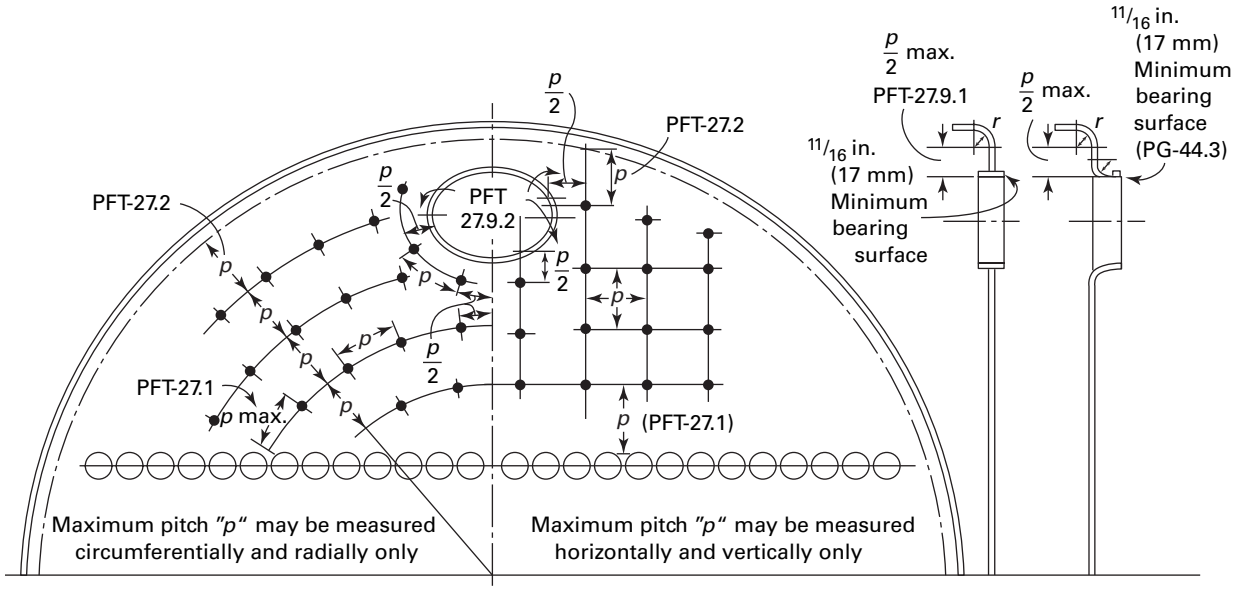


(1) Provide stay cross-sectional area required by PG-49 based upon allowable stresses from Table 1A of Section II, Part D.

(2) Provide the number of stays required to not exceed the maximum calculated pitch.

(3) Diagonal stay stresses must not exceed limits computed from PFT-32.

(q)



(1) Provide stay cross-sectional area required by PG-49 based upon allowable stresses from Table 1A of Section II, Part D.

(2) Provide the number of stays required to not exceed the maximum calculated pitch.

(3) Diagonal stay stresses must not exceed limits computed from PFT-32.

(r)

FIG. A-8 DETAIL SKETCHES SHOWING APPLICATION OF PG-48 AND PFT-27 TO THE STAYING OF BOILERS (CONT'D)

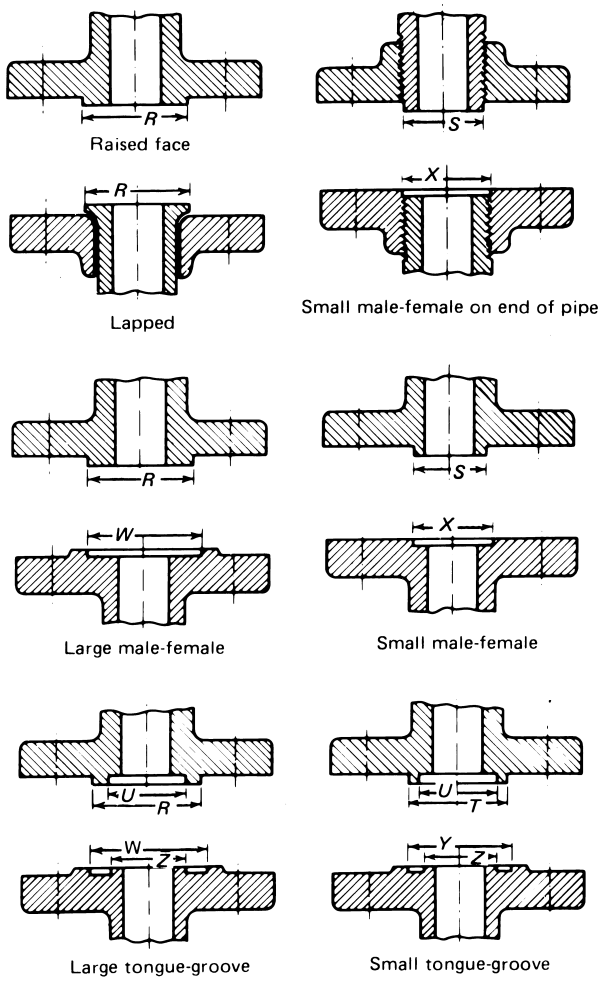


FIG. A-9 TYPICAL FACINGS

$$C \times H = 2{,}150 \times 12{,}100 = 26{,}015{,}000$$

$$W = \frac{C \times H \times 0.75}{1{,}100} = 17{,}740$$

A-14 Example 2

Wood shavings of heat of combustion of 6,400 Btu/lb are burned under a boiler at the maximum rate of 2,000 lb/hr. Boiler pressure is 100 psi gage.

$$C \times H = 2{,}000 \times 6{,}400 = 12{,}800{,}000$$

$$W = \frac{C \times H \times 0.75}{1{,}100} = 8{,}730$$

A-15 Example 3

An oil-fired boiler at maximum forcing uses 1,000 lb/hr of crude oil (Texas). Boiler pressure is 275 psi gage.

$$C \times H = 1{,}000 \times 18{,}500 = 18{,}500{,}000$$

$$W = \frac{C \times H \times 0.75}{1{,}100} = 12{,}620$$

A-16 Example 4

A boiler fired with natural gas consumes 3,000 cu ft/hr. The working pressure is 150 psi gage.

$$C \times H = 3{,}000 \times 960 = 2{,}880{,}000$$

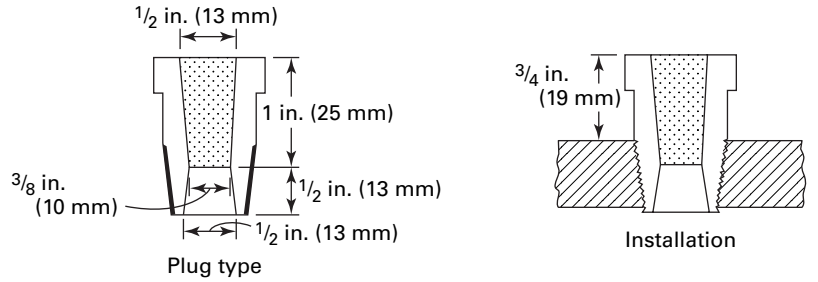
$$W = \frac{C \times H \times 0.75}{1{,}100} = 1{,}960$$

A-17

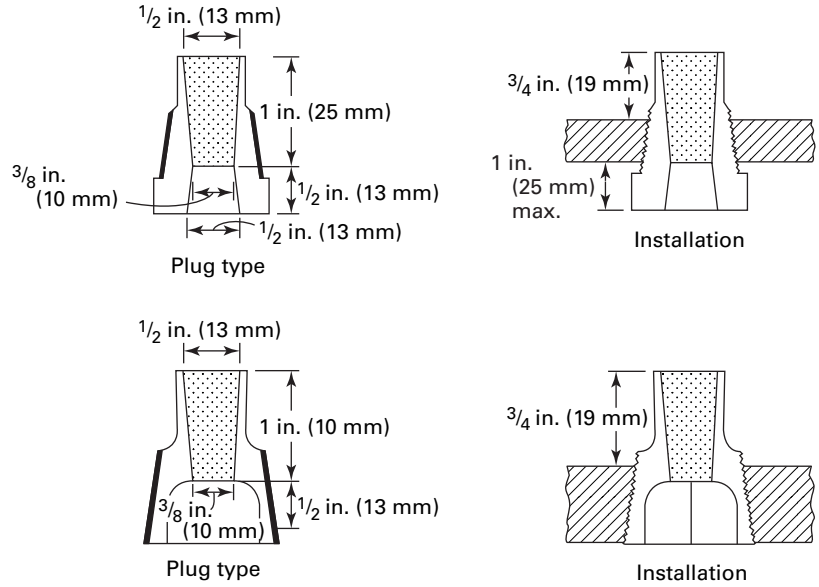
For the purpose of checking the safety valve capacity as described in A-12, the following values of heats of combustion of various fuels may be used:

	H = Btu/lb	(kJ/kg)
Semibituminous coal	14,500	34 000
Anthracite	13,700	32 000
Screenings	12,500	29 000
Coke	13,500	31 000
Wood, hard or soft, kiln dried	7,700	18 000
Wood, hard or soft, air dried	6,200	14 000
Wood shavings	6,400	14 400
Peat, air dried, 25% moisture	7,500	17 000
Lignite	10,000	23 300
Kerosene	20,000	46 500
Petroleum, crude oil, Pennsylvania	20,700	48 000
Petroleum, crude oil, Texas	18,500	43 000

	H = Btu/cu ft	(kJ/m^3)
Natural gas	960	35 700
Blast-furnace gas	100	3 700
Producer gas	150	5 600
Water gas, uncarbureted	290	11 000



(a) Water side plugs



(b) Fire side plugs

GENERAL NOTE: All dimensions minimum unless otherwise specified

FIG. A-10 TYPICAL FORMS OF FUSIBLE PLUGS

AUTOMATIC WATER GAGES

A-18

Automatic shutoff valves on water gages, if permitted to be used, shall conform to the following requirements.

A-18.1 Check valves in upper and lower fittings shall be of solid noncorrosive metal ball type to avoid need for guides.

A-18.2 Ball check valves in upper and lower fittings must open by gravity and the lower ball check valve must rise vertically to its seat.

A-18.3 The check balls must not be smaller than $\frac{1}{2}$ in. (13 mm) in diameter, and the diameter of the circle of contact with the seat must not be greater than two-thirds of the diameter of the check ball. The space around each ball must be not less than $\frac{1}{8}$ in. (3.2 mm), and the travel movement from the normal resting place to the seat must be not less than $\frac{1}{4}$ in. (6 mm).

A-18.4 The ball seat in the upper fitting must be a flat seat with either a square or hexagonal opening, or otherwise arranged so that the steam passage can never be completely closed by this valve.

A-18.5 The shutoff valve in the upper fitting must have a projection that holds the ball at least $\frac{1}{4}$ in. (6 mm) away from its seat when the shutoff valve is closed.

A-18.6 The balls must be accessible for inspection. Means must be provided for removal and inspection of the lower ball check valve while the boiler is under steam pressure.

These restrictions do not apply to closing the valves by external methods.

FUSIBLE PLUGS

A-19

A-19.1 Fire-actuated fusible plugs, if used, except as provided in A-20.9, shall be filled with tin of the following composition, having a melting point between 445°F and 450°F (229°C and 232°C):

Pure tin, min	99.3%
Copper, max	00.5%
Lead, max	00.1%
Total impurities	00.7%

A-19.2 The fusible metal shall extend from the water end of the plug to the point of least diameter of the hole and shall be carefully alloyed to the casing. A test shall be made to determine that the fusible metal is not loose in the plug.

A-19.3 Fusible plugs shall be renewed at least once each year. Casings that have been used shall not be refilled.

A-19.4 Fusible plugs filled with tin as specified in A-19.1 shall not be used for pressures and temperatures that will cause the plug to fail while it is submerged in the boiler water.

The fusible metal may be partly replaced by a bronze plug loosely fitted to the hole and of such size that it will pass freely through the hole on the fire side, from which side it must be inserted into the casing. Such plug shall be properly alloyed to the casing with the same fusible metal as required by A-19.1.

A-20

A-20.1 Water side plugs are fusible plugs that are inserted from the water side of the plate, flue, or tube to which they are attached. Fire side plugs are fusible plugs inserted from the fire side of the plate, flue, or tube to which they are attached.

A-20.2 The casing of the fusible plugs shall be made of a composition conforming to SB-61 or from phosphor-bronze rods conforming to ASTM B 139.

A-20.3 Typical designs of fusible plugs are given in Fig. A-10.

A-20.4 The bore of the casing shall be tapered continuously from the water end of the casing for a distance of at least 1 in. to a diameter of not less than $\frac{3}{8}$ in. (10 mm) at a point not less than $\frac{1}{2}$ in. (13 mm) from the fire end. The diameter of the bore at either end shall be not less than $\frac{1}{2}$ in. (13 mm). The hole on the fire end shall be as large as possible and may be of any shape provided the cross-sectional area at all points is greater than the area of the least cross section of the fusible metal.

A-20.5 A fusible plug shall be of such length that when installed it shall project at least $\frac{3}{4}$ in. (19 mm) on the water side of the plate, tube, or flue. It shall extend through the plate, tube, or flue on the fire side as little as possible but not more than 1 in. (25 mm).

A-20.6 A fire side plug may be designed so as to be inserted by means of a plug type wrench, so as to reduce the projection on the fire side.

A-20.7 If a fire-actuated fusible plug is inserted in a tube, the tube wall *at the plug* shall be not less than 0.22 in. thick, or sufficient to give four full threads.

A-20.8 Fusible plugs that comply with the requirements of A-19 and A-20 must be stamped on the casing with the name of the manufacturer, and on the water end of the fusible metal "ASME Std."

A-20.9 Fusible metal, other than tin as specified in A-19.1, for use under temperatures exceeding 450°F, may be used and the casing may be made of other material and shape than specified in A-20.2 through A-20.4 if the metal and the casing are approved by the administrative authority. Such plugs shall not be marked as "ASME Std."

A-21

Fire-actuated fusible plugs, if used, shall be located at the lowest permissible water level as determined by the boiler Manufacturer; steam-actuated plugs, if used, shall be so located that they will operate when the water level is at the point where a fire-actuated fusible plug would be located.

PROOF TESTS TO ESTABLISH MAXIMUM ALLOWABLE WORKING PRESSURE

A-22

A-22.1 Scope. The maximum allowable working pressure for pressure parts of boilers for which the strength cannot be computed with a satisfactory assurance of accuracy shall be established in accordance with the requirements of this paragraph, using one of the test procedures applicable to the type of loading and to the material used in its construction.

The tests in these paragraphs may be used only for the purpose of establishing the maximum allowable working pressure of those elements or component parts for which the thickness cannot be determined by means of the design rules given in this Code. The maximum allowable working pressure of all other elements or component parts shall not be greater than that determined by means of the applicable design rules.

A-22.2 Tests

A-22.2.1 Types. Provision is made for two types of tests for determining the internal maximum allowable working pressure:

A-22.2.1.1 Tests based on yielding of the part to be tested. These tests are limited to materials with a ratio of minimum specified yield to minimum specified ultimate strength of 0.625 or less.

A-22.2.1.2 Tests based on bursting of the part.

A-22.2.2 Retests. A retest shall be allowed on a duplicate pressure part if errors or irregularities are obvious in the test results.

A-22.2.3 Precautions. Safety of testing personnel should be given serious consideration when conducting proof tests, and particular care should be taken during bursting tests in A-22.6.3.

A-22.3 Pressure

A-22.3.1 Previously Applied. The pressure parts for which the maximum allowable working pressure is to be established shall not previously have been subjected to a pressure greater than $1\frac{1}{2}$ times the desired or anticipated maximum allowable working pressure, adjusted for design temperature as provided in A-22.8.

A-22.3.2 Application. In the procedures given in A-22.6.1 for the Strain Measurement Test, and A-22.6.2 for the Displacement Measurement Test, the hydrostatic pressure in the pressure part shall be increased gradually until approximately one-half the anticipated maximum allowable working pressure is reached. Thereafter, the test pressure shall be increased in steps of approximately one-tenth or less of the anticipated maximum allowable working pressure until the pressure required by the test procedure is reached. The pressure shall be held stationary at the end of each increment for a sufficient time to allow the observations required by the test procedure to be made, and shall be released to zero to permit determination of any permanent strain or displacement after any pressure increment that indicates an increase in strain or displacement over the previous equal pressure increment.

A-22.4 Critical Areas. As a check that the measurements are being taken on the most critical areas, the Inspector may require a brittle coating to be applied on all areas of probable high stress concentrations in the test procedures given in A-22.6.1 and A-22.6.2. The surfaces shall be suitably clean before the coating is applied in order to obtain satisfactory adhesion. The technique shall be suited to the coating material.

NOTE: Strains should be measured as they apply to membrane stresses and to bending stresses within the following range. It is recognized that high localized and secondary bending stresses may exist in pressure parts designed and fabricated in accordance with these rules. Insofar as practical, design rules for details have been written to hold such stresses at a safe level consistent with experience.

A-22.5 Yield Strength and Tensile Strength. For proof tests based on yielding, A-22.6.1 or A-22.6.2, the yield strength (or yield point for those materials which exhibit that type of yield behavior indicated by a “sharp-kneed” portion of the stress–strain diagram) of the material in the part tested, shall be determined in accordance with the method prescribed in the applicable material specification and as described in ASTM E 8, Tension Testing of Metallic Materials. For proof tests based on bursting, A-22.6.3, the tensile strength instead of the yield strength of the material in the part tested shall be similarly determined.

Yield or tensile strength so determined shall be the average from three or four specimens cut from the part tested after the test is completed. The specimens shall be cut from a location where the stress during the test has not exceeded the yield strength. The specimens shall not be oxygen cut because this might affect the strength of the material.

When excess stock from the same piece of wrought material is available and has been given the same postweld heat treatment as the pressure part, the test specimens may be cut from this excess stock. The specimens shall not be removed by flame cutting or

any other method involving sufficient heat to affect the properties of the specimen.

If yield or tensile strength are not determined by test specimens from the pressure part tested, alternative methods are given in A-22.6.1, A-22.6.2, and A-22.6.3 for evaluation of proof test results to establish the maximum allowable working pressure.

A-22.6 Procedure

A-22.6.1 Strain Measurement Test

A-22.6.1.1 Subject to limitations of A-22.2.1.1, this procedure may be used for pressure parts under internal pressure, constructed of any material permitted to be used under the rules of Section I. Strains shall be measured in the direction of the maximum stress at the most highly stressed parts (see A-22.4) by means of strain gages of any type capable of indicating strains to 0.00005 in./in. Pressure shall be applied as provided in A-22.3.2.

A-22.6.1.2 After each increment of pressure has been applied, readings of the strain gages and the hydrostatic pressure shall be taken and recorded. The pressure shall be released and any permanent strain at each gage shall be determined after any pressure increment that indicates an increase in strain for this increment over the previous equal pressure increment. Only one application of each increment of pressure is required.

A-22.6.1.3 Two curves of strain against test pressure shall be plotted for each gage line as the test progresses, one showing the strain under pressure and one showing the permanent strain when the pressure is removed. The test may be discontinued when the test pressure reaches the value H which will, by the formula, justify the desired working pressure, but shall not exceed the pressure at which the plotted points for the most highly strained gage line reaches the value given below for the material used.

A-22.6.1.3.1 0.2% permanent strain for carbon, low-alloy and high-alloy steels.

A-22.6.1.3.2 0.5% strain under pressure for copper-base alloys.

A-22.6.1.3.3 0.2% permanent strain for nickel alloys.

A-22.6.1.4 The maximum allowable working pressure P in pounds per square inch at test temperature for parts tested under this paragraph shall be computed by one of the following formulas.

A-22.6.1.4.1 If the average yield strength is determined by A-22.5:

$$P = 0.5H \frac{Y_s}{Y_a}$$

A-22.6.1.4.2 If the actual average yield strength is not determined by test specimens:

$$P = 0.4H$$

where

H = hydrostatic test pressure, psi (kPa), at which the test was stopped in accordance with A-22.6.1.3
Y_s = yield strength — specified minimum
Y_a = yield strength — actual average from test specimens

The maximum allowable working pressure at other temperatures shall be determined as provided in A-22.8.

A-22.6.2 Displacement Measurement Test

A-22.6.2.1 Subject to the limitations of A-22.2.1.1 this procedure may be used only for pressure parts under internal pressure, constructed of materials having a definitely determinable yield point. Displacement shall be measured at the most highly stressed parts (see A-22.4) by means of measuring devices of any type capable of measuring to 0.001 in. (0.02 mm). This displacement may be measured between two diametrically opposed reference points in a symmetrical structure, or between a reference point and a fixed base point. Pressure shall be applied as provided in A-22.3.2.

A-22.6.2.2 After each increment of pressure has been applied, readings of the displacement and the hydrostatic pressure shall be taken and recorded. The pressure shall be released and any permanent displacement shall be determined after any pressure increment that indicates an increase in measured displacement for this increment over the previous equal pressure increment. Only one application of each increment is required. Care must be taken to assure that the readings represent only displacements of the parts on which measurements are being made and do not include any slip of the measuring devices or any movement of the fixed base points or of the pressure part as a whole.

A-22.6.2.3 Two curves of displacement against test pressure shall be plotted for each reference point as the test progresses, one showing the displacement under pressure, and one showing the permanent displacement when the pressure is removed. The application

of pressure shall be stopped when it is evident that the curve through the points representing displacement under pressure has deviated from a straight line.

A-22.6.2.4 The pressure coincident with the proportional limit of the material shall be determined by noting the pressure at which the curve representing displacement under pressure deviates from a straight line. The pressure at the proportional limit may be checked from the curve of permanent displacement by locating the point where the permanent displacement begins to increase regularly with further increases in pressure. Permanent deformation at the beginning of the curve that results from the equalization of stresses and irregularities in the material may be disregarded.

The maximum allowable working pressure P in pounds per square inch at test temperature for parts tested under this paragraph shall be computed by one of the following formulas.

A-22.6.2.4.1 If the average yield strength is determined by A-22.5:

$$P = 0.5H \frac{Y_s}{Y_a}$$

A-22.6.2.4.2 In order to eliminate the necessity of cutting tensile specimens and determining the actual yield strength of the material under test, one of the following formulas may be used to determine the maximum allowable working pressure:

A-22.6.2.4.2.1 For carbon steel, meeting an acceptable Code specification, with a specified minimum tensile strength of not over 70,000 psi (480 MPa):

Customary Units

$$P = 0.5H \left(\frac{S}{S + 5{,}000} \right)$$

SI Units

$$P = 0.5H \left(\frac{S}{S + 34\,000} \right)$$

A-22.6.2.4.2.2 For any material listed in Tables 1A and 1B of Section II, Part D, as acceptable for Section I construction:

$$P = 0.4H$$

where

H = hydrostatic test pressure coincident with the proportional limit of the weakest element of the component part tested, psi (kPa)

Y_s = yield strength — specified minimum

Y_a = yield strength — actual average from test specimens

S = specified minimum tensile strength

When the formula in A-22.6.2.4.2.1 or A-22.6.2.4.2.2 is used, the material in the pressure part shall have had no appreciable cold working or other treatment that would tend to raise the yield strength above the normal.

The maximum allowable working pressure at other temperatures shall be determined as provided in A-22.8.

A-22.6.3 Bursting Tests

A-22.6.3.1 This procedure may be used for pressure parts under internal pressure when constructed of any material permitted to be used under the rules of Section I. The maximum allowable working pressure of any component part proof tested by this method shall be established by a hydrostatic test to failure by rupture of a full-size sample of such pressure part. The hydrostatic pressure at which rupture occurs must be determined. Alternatively, the test may be stopped at any pressure before rupture that will satisfy the requirements for the desired maximum allowable working pressure. The item so tested shall not be used for Code construction.

A-22.6.3.2 The maximum allowable working pressure P in pounds per square inch at test temperature for parts tested under this paragraph shall be computed by one of the following formulas.

A-22.6.3.2.1 Parts constructed of materials other than cast materials: 01

$$P = \frac{B}{4} \times \frac{S}{(S_a \text{ or } S_m)}$$

A-22.6.3.2.2 Parts constructed of cast iron:

$$P = \frac{B}{6.67} \times \frac{S}{S_b}$$

A-22.6.3.2.3 Parts constructed of nodular iron:

$$P = \frac{Bf}{5} \times \frac{S}{S_b}$$

01 **A-22.6.3.2.4** For parts constructed of cast materials, except cast iron and nodular iron:

$$P = \frac{Bf}{4} \times \frac{S}{(S_a \text{ or } S_m)}$$

where

B = bursting test pressure, psi (kPa)
f = casting quality factor as defined in PG-25
S = specified minimum tensile strength (MPa)
S_a = average actual tensile strength of test specimens
S_m = maximum tensile strength of range of specification (MPa)
S_b = minimum tensile strength of test bar (MPa)

For all materials except cast iron and nodular iron, the maximum allowable working pressure at other temperatures shall be determined as provided in A-22.8.

A-22.7 Parts Subject to Collapse

A-22.7.1 Parts of the boiler normally subject to collapse for which specified rules are not provided in this Section shall withstand without excessive deformation a hydrostatic test of not less than three times the desired maximum allowable working pressure.

A-22.7.2 The maximum allowable working pressure at other than test temperatures shall be determined as provided in A-22.8.

A-22.8 Higher Temperatures. The maximum allowable working pressure for pressure parts that are designed for temperatures at which the allowable stress value of the material is less than that at the test temperature shall be determined by the following formula:

$$P_o = P_t \frac{S_o}{St}$$

where

P_o = maximum allowable working pressure at design temperature, psi (kPa)
P_t = maximum allowable working pressure at test temperature, psi (kPa)
S_o = maximum allowable stress value at the design temperature, as given in Table 1A or 1B of Section II, Part D, psi (kPa)
S_t = maximum allowable stress value at test temperature as given in Table 1A or 1B of Section II, Part D, psi (kPa)

A-22.9 Duplicate Parts. When the maximum allowable working pressure of a pressure part has been established by a proof test, duplicate parts of the same materials, design and construction need not be proof tested but shall be given the standard hydrostatic test at $1\frac{1}{2}$ times the maximum allowable working pressure. The dimensions and minimum thickness of the structure to be tested should not vary materially from those actually used. A geometrically similar part may be qualified by a series of tests covering the complete size range of the pressure part.

A-22.10 Inspection. Tests to establish the maximum allowable working pressure for pressure parts shall be witnessed and approved by an Authorized Inspector.

A-22.11 Test Gages

A-22.11.1 An indicating gage shall be connected directly to the pressure parts. If the indicating gage is not readily visible to the operator controlling the pressure applied, an additional indicating gage shall be provided where it will be visible to the operator throughout the duration of the test. For large pressure parts, it is recommended that a recording gage be used in addition to indicating gages.

A-22.11.2 Pressure gages used in testing shall comply with PG-99.4.

A-22.11.3 All gages used in proof testing shall be calibrated against a standard deadweight tester or a calibrated master gage before the proof test is begun. Gages shall be recalibrated at any time that there is reason to believe they are in error.

A-24 Table PG-23.1

See Table 1A of Section II, Part D.

A-25 Table PG-23.2

See Table 1B of Section II, Part D.

A-26 Table PG-23.3

See Table 1B of Section II, Part D.

A-27 Table PG-23.4

See Table Y-1 of Section II, Part D.

A-28 Figures G and CS-1 Through CS-6 A03

See Subpart 3, External Pressure Charts in Section II, Part D.

TABLE A-44
GUIDE FOR ESTIMATING STEAMING CAPACITY BASED ON HEATING SURFACE

	Firetube Boilers	Watertube Boilers
Boiler heating surface		
Hand fired	5	6
Stoker fired	7	8
Oil, gas, or pulverized fuel fired	8	10
Waterwall heating surface		
Hand fired	8	8
Stoker fired	10	12
Oil, gas, or pulverized fuel fired	14	16

GENERAL NOTE: When a boiler is fired only by a gas having a heat value not in excess of 200 Btu/cu ft, the minimum safety valve or safety relief valve relieving capacity may be based on the values given for hand-fired boilers above.

SUGGESTED RULES COVERING EXISTING INSTALLATIONS

A-30

For existing riveted construction, use suggested rules in the 1971 Edition of Section I.

SAFETY VALVES FOR POWER BOILERS

A-44

The minimum safety valve or safety relief valve relieving capacity for other than electric boilers, waste heat boilers, organic fluid vaporizers, and forced-flow steam generators with no fixed steam and waterline, when provided in accordance with PG-67.4.3, may be estimated on the basis of the pounds of steam generated per hour per square foot of boiler heating surface and waterwall heating surface, as given in Table A-44.

In many cases, a greater relieving capacity of safety relief valves will have to be provided than that estimated using Table A-44, in order to meet the requirements of the first paragraph of PG-67.2.

A-45

When boilers of different maximum allowable working pressures with minimum safety valve settings varying more than 6% are so connected that steam can flow toward the lower pressure units, the latter shall be protected by additional safety valve capacity, if necessary, on the lower pressure side of the system. The additional safety valve capacity shall be based upon the maximum amount of steam that can flow into the lower pressure system. The additional safety valves shall have at least one valve set at a pressure not to exceed the lowest allowable pressure and the other valves shall be set within a range not to exceed 3% above that pressure.

A-46

If the safety valve or safety relief valve capacity cannot be determined or if it is desirable to verify the computations, the capacity may be checked in one of the three following ways, and if found insufficient, additional capacity shall be provided.

A-46.1 By making an accumulation test, that is, by shutting off all other steam-discharge outlets from the boiler and forcing the fires to the maximum. The safety valve equipment shall be sufficient to prevent an excess pressure beyond that specified in PG-67.2. This method should not be used on a boiler with a superheater or reheater or on a high-temperature water boiler.

A-46.2 By measuring the maximum amount of fuel that can be burned and computing the corresponding evaporative capacity upon the basis of the heating value of the fuel (see A-12 through A-17).

A-46.3 By determining the maximum evaporative capacity by measuring the feedwater. The sum of the safety valve capacities marked on the valves shall be equal to or greater than the maximum evaporative capacity of the boiler. This method shall not be used on high-temperature water boilers.

A-48

When operating conditions are changed, or additional heating surface such as water screens or waterwalls is connected to the boiler circulation, the safety valve or safety relief valve capacity shall be increased, if necessary, to meet the new conditions and be in accordance with PG-67.2. The additional valves required on account of changed conditions may be installed on the piping between the boiler and the main stop valve except when the boiler is equipped with a superheater or other piece of apparatus. In the latter case they may be installed on the piping between the boiler drum and the inlet to the superheater or other apparatus, provided that the piping between the boiler and safety valve (or valves) connection has a cross-sectional area of at least three times the combined areas of the inlet connections to the safety valves applied to it.

A-63.2 During a hydrostatic test of a boiler, the safety valve or valves shall be removed or each valve disk shall be held to its seat by means of a testing clamp and not by screwing down the compression screw upon the spring.

A-64 Repairs to Existing Boilers

Where repairs are necessary that in any way affect the working pressure or safety of a boiler, a state inspector, municipal inspector, or an inspector employed regularly by an insurance company, which is authorized to do a boiler insurance business in the state in which the boiler is used, shall be called for consultation and advice as to the best method of making such repairs; after such repairs are made they shall be subject to the approval of a state inspector, municipal inspector, or an inspector regularly employed by an insurance company that is authorized to do a boiler insurance business in the state in which the boiler is used.

EXAMPLES OF METHODS OF COMPUTATION OF OPENINGS IN VESSEL SHELLS

Application of the rules in PG-32, PG-33, PG-36 through PG-39, PW-15, and PW-16 are given in the following examples. Common assumptions in all the examples are that the design temperature corresponds to the temperature of saturated steam at the maximum allowable working pressure, that all areas are expressed in terms of equivalent area of the vessel material (see PG-37), that the corrosion/erosion allowance is zero, and that all openings are single openings unless otherwise noted. Subscripts have been provided where necessary to eliminate confusion where an algebraic value has more than one meaning as used in these examples. (S_n denotes allowable stress of the nozzle material, S_v denotes allowable stress of the vessel material, R_n denotes radius of nozzle, etc.) The values t and t_n are assumed to be minimum in these examples.

A-65

A boiler shell, designed for 595 psig maximum allowable working pressure, has an inside diameter of 36 in. and is made of $\frac{1}{2}$ in. thick plate. Is it permissible to install an NPS 2 connection by tapping a hole for the pipe directly into the shell?

The NPS 2 connection complies with the pressure-size limitations in PG-39.5.2 and qualifies for the exception provided in PG-32.1.3.1 permitting the opening without requiring a calculation to determine the availability of compensation in the shell. PG-39.5.1 and Table PG-39, however, require a minimum plate thickness and thread engagement greater than that provided by the shell thickness. Therefore, the connection cannot be made as originally stated; however, either a heavier shell plate or a built-up pad or properly attached plate or fitting could be used to provide the minimum metal thickness and number of threads as required by PG-39 and Table PG-39. Should a plate or fitting, attached by welding, be used, the rules in PG-37, PW-15, and PW-16 shall be met.

A-66 A02

A forged steel fitting as shown in Fig. A-66, with a female 3 in. nominal pipe thread over the full fitting depth is to be inserted and welded into a vessel shell. The maximum allowable stress is 15,000 psi for the fitting material and 17,500 psi for the vessel shell material. The maximum allowable working pressure of the vessel is 375 psig. See Fig. A-66 for nozzle and vessel dimensions.

The fitting complies with the size, pressure, and thread depth limitations provided in PG-39.5 and Table PG-39. The welded attachment does not qualify for the exception that exempts the design from calculation of the required reinforcement as provided in PG-32 and must, therefore, comply with PG-33 as follows.

Minimum required thickness for reinforcement consideration:

$$R_v, \text{ the inside radius of the vessel} = \frac{48}{2}$$

$$= 24 \text{ in.}$$

$$\text{Shell } t_r = \frac{PR_v}{S_v - (1 - y)P}$$

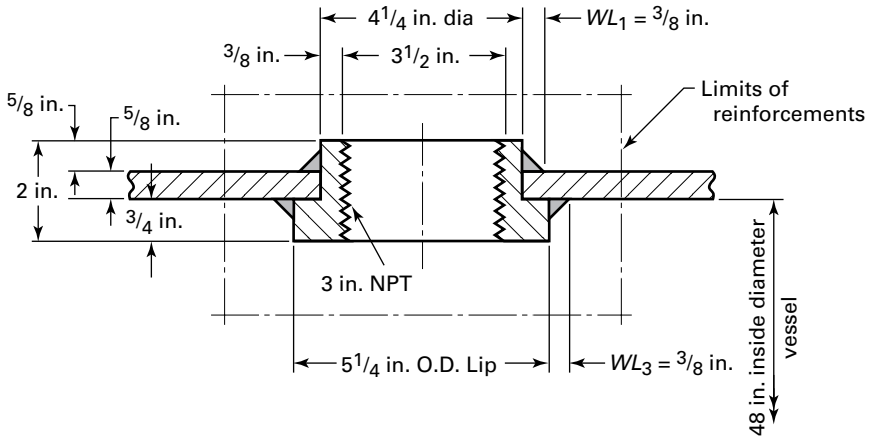
$$= \frac{375 \times 24}{17{,}500 - (1 - 0.4) \times 375}$$

$$= 0.521 \text{ in.}$$

$$\text{Nozzle } t_{rn} = \frac{PR_n}{S_n - (1 - y)P}$$

$$= \frac{375 \times 1.75}{15{,}000 - (1 - 0.4) \times 375}$$

$$= 0.044 \text{ in.}$$



GENERAL NOTE: This example was performed using computer software. The example was generated by performing the entire calculation without rounding off during each step. Accuracy of the final results beyond three significant figures is not intended or required.

A02 FIG. A-66 EXAMPLE FOR TYPICAL NOZZLE COMPUTATIONS

Area of reinforcement required (see PG-33.3 and Fig. PG-33.1):

$$A = (d + 2t_n)\, t_r F$$

$$= (3.5 + 2 \times 0.375) \times 0.521 \times 1.0$$

$$= 2.214 \text{ sq in.}$$

Area of reinforcement available in vessel wall (see PG-33.3, PG-36.4.1, and Fig. PG-33.1):

$$A_1 = (d - 2t_n)(t - Ft_r)$$

$$= (3.5 - 2 \times 0.375)(0.625 - 1.0 \times 0.521)$$

$$= 0.286 \text{ sq in.}$$

Area of reinforcement available in the nozzle wall external of the vessel (see PG-33.3, PG-36.4.2, and Fig. PG-33.1):

In that the actual nozzle projection is less than that permitted within the limits of reinforcement, modification of the equation provided in PG-33.1 will be required to reflect the actual area available for reinforcement.

$$A_2 = 2(t_n - t_{rn})(\text{actual projection})\ (S_n / S_v)$$

$$= 2 \times (0.375 - 0.044) \times 0.625 \times (15{,}000 / 17{,}500)$$

$$= 0.354 \text{ sq in.}$$

Area of reinforcement available in the nozzle and nozzle lip internal of the vessel (see PG-33.3, PG-36.4.2, and Fig. PG-33.1). (Due to the nozzle lip, modification of the equation provided in Fig. PG-33.1 will be required to reflect the actual area present.):

$$A_3 = 2t_n\, t_{r_1}\, h + \text{area present in lip}$$

$$= 2 \times 0.375\ (15{,}000/17{,}500)(1.375)$$

$$+ 2 \times 0.5 \times 0.75$$

$$= 1.634 \text{ sq in.}$$

Area of reinforcement available in attachment welds (see PG-36.4.3 and Fig. PG-33.1):

$$A_4 = (WL_1^2 + WL_2^2)\ (S_n / S_v)$$

$$= (0.375^2 + 0.375^2)\ (15{,}000 / 17{,}500)$$

$$= 0.241 \text{ sq in.}$$

Total area of reinforcement available:

$$A_1 + A_2 + A_3 + A_{4_1} + A_{4_3} = 2.515 \text{ sq in.} \geq A$$

as required for demonstration of compliance with PG-33.

Compliance with PG-37 and PW-15 is demonstrated by the following calculations.

Required minimum strength to be provided by the welds (see PG-37 and PW-15):

$$W = (A - A_1)\, S_v$$
$$= (2.214 - 0.286)\ 17{,}500$$
$$= 33{,}742 \text{ lb}$$

Strength of the welds (see PG-37 and PW-15):

Internal fillet weld in shear

$$= \tfrac{1}{2}\, \pi\, WL_3\, (OD \text{ lip} + WL_3) \text{ (factor in PW-15.2) } S_n$$
$$= \tfrac{1}{2} \times 3.142 \times 0.375 \times (5.25 + 0.375) \times 0.49 \times 15{,}000$$
$$= 24{,}353 \text{ lb}$$

External fillet weld in shear

$$= \tfrac{1}{2}\ \pi WL_1 (dl\ +\ WL_1) \text{(factor in PW-15.2) } S_n$$
$$= 0.5 \times 3.142 \times 0.375 \times (4.25 + 0.375) \times 0.49 \times 15{,}000$$
$$= 20{,}027 \text{ lb}$$

The combined strength of the welds equals 44,384 lb $\geq W$ as required for compliance with PG-37 and PW-15.

Verification of the minimum weld sizing as required by PW-16.1 and Fig. PW-16.1, sketch (u-2), is demonstrated by the following.

Required per Fig. PW-16.1, sketch (u-2):

$$t_1 + t_2 \geq 1.25\, t_{\min}$$
$$t_1 \geq 0.25$$
$$t_2 \geq 0.25$$

Actual per Fig. A-66:

$$t_1 = WL_1 \sin 45°$$
$$= 0.375 \times 0.7071$$
$$= 0.265 \text{ in.}$$
$$t_2 = WL_2 \sin 45°$$
$$= 0.375 \times 0.7071$$
$$= 0.265 \text{ in.}$$
$$t_{\min} = 0.375 \text{ (based on } t_n)$$

Verification:

$$(t_1 + t_2 = 0.530) \geq (1.25\, t_{\min} = 0.469)$$
$$(t_1 = 0.265) \geq 0.25$$
$$(t_2 = 0.265) \geq 0.25$$

As verified by the above demonstrations, the design is proved to be in compliance with the requirements of Section I.

A-67 A02

A vessel shell has a studding outlet connection mounted as shown in Fig. A-67. The maximum allowable stress of both the vessel and studding outlet material is 12,500 psi. The maximum allowable working pressure of the design is 325 psig. See Fig. A-67 for vessel and studding outlet dimensions.

The studding outlet conforms to the requirements of PG-39.4, both in arrangement and in tapped stud hole requirements. The welded attachment does not qualify for the exception provided in PG-32 and must therefore comply with PG-33 as follows.

Minimum required thickness for reinforcement consideration:

$$\text{Shell } t_r = \frac{PR_v}{S_v - (1 - y)\, P}$$
$$= \frac{325 \times 30}{12{,}500 - (1 - 0.4) \times 325}$$
$$= 0.792 \text{ in.}$$

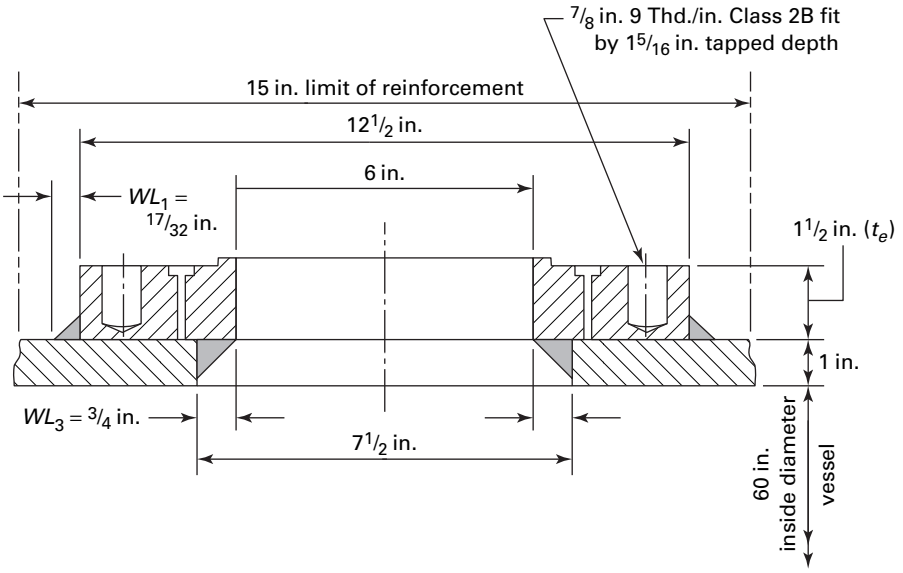
Nozzle $t_{rn} = 0.0$ [see Fig. PG-36.4, sketch (a)]

Area of reinforcement required (see PG-33.2):

$$A = t_r\, Fd$$
$$= 0.79236 \times 1.0 \times 7.5$$
$$= 5.943 \text{ sq in.}$$

Area of reinforcement available in the vessel wall (see PG-36.4.1):

$$A_1 = (t - Ft_r)\, d$$
$$= (1.0 - 1.0 \times 0.79236) \times 7.5$$
$$= 1.557 \text{ sq in.}$$



GENERAL NOTES:
(a) Stud holes are staggered about the line of the longitudinal section and are shown for clarification only.
(b) This example was performed using computer software. The example was generated by performing the entire calculation without rounding off during each step. Accuracy of the final results beyond three significant figures is not intended or required.

A02 FIG. A-67 EXAMPLE FOR TYPICAL NOZZLE COMPUTATIONS

Area of reinforcement available in attachment welds (see PG-36.4.3):

$$A_4 = WL_1^2 + WL_3$$
$$= 0.531^2 + 0.75^2$$
$$= 0.845 \text{ sq in.}$$

Area of reinforcement available in pad (see PG-36.4.3):

$$A_5 = (\text{O.D.}_{\text{pad}} - \text{I.D.}_{\text{pad}})\, t_e$$
$$= (12.5 - 6) \times 1.5$$
$$= 9.75 \text{ sq in.}$$

Total area of reinforcement available:

$$A_1 + A_4 + A_5 = 12.152 \text{ sq in.} \geq A$$

as required for demonstration of compliance with PG-33.

Compliance with PG-37 and PW-15 is demonstrated by the following calculations.

Required minimum strength to be provided by the welds (see PG-37 and PW-15):

$$W = (A - A_1)\, S_v$$
$$= (5.943 - 1.557) \times 12{,}500$$
$$= 54{,}818 \text{ lb}$$

Strength of the welds (see PG-37 and PW-15):
External fillet weld in shear

$$= \tfrac{1}{2}\, \pi\, WL_1\, (\text{O.D.}_{\text{pad}} + WL_1)\, (\text{factor in PW-15.2})\, S$$
$$= 0.5 \times 3.14159 \times 0.53125 \times (12.5 + 0.53125) \times 0.49 \times 12{,}500$$
$$= 66{,}606 \text{ lb}$$

Internal fillet weld in shear

$$= \tfrac{1}{2}\, \pi\, WL_3\, (dl - WL_3)\, (\text{factor in PW-15.2})\, S$$
$$= 0.5 \times 3.142 \times 0.75 \times (7.5 - 0.75) \times 0.49 \times 12{,}500$$
$$= 48{,}707 \text{ lb}$$

The combined strength of the welds equals 115,313 lb ≥ W as required for compliance with PG-37 and PW-15.

Verification of the minimum weld sizing as required by PW-16.1 and Fig. PW-16.1, sketch (t) is demonstrated by the following.

Required per Fig. PW-16.1(t):

External fillet weld throat ≥ $\frac{1}{2}t_{\min}$

Internal fillet weld throat ≥ $0.7t_{\min}$

Actual per Fig. A-67:

External fillet weld throat

$= WL_1 \sin 45°$
$= 0.531 \times 0.707$
$= 0.376$ in.

Internal fillet weld throat

$= WL_3 \sin 45°$
$= 0.75 \times 0.707$
$= 0.530$ in.
$t_{\min} = 0.75$ (based on PW-16.2)

Verification:

(External fillet weld throat = 0.376)

≥ ($\frac{1}{2}\, t_{\min} = 0.375$)

(Internal fillet weld throat = 0.530)

≥ ($0.7\, t_{\min} = 0.525$)

As verified by the above demonstrations, the design is proved to be in compliance with the requirements of Section I.

A-68

A boiler has an NPS 4 extra-strong pipe connection mounted as shown in Fig. A-68. The maximum allowable stress is 12,000 psi for the pipe material and 13,700 psi for the boiler shell material. The maximum allowable working pressure of the boiler is 250 psig. See Fig. A-68 for pipe and shell dimensions.

Check to determine if the welded attachment qualifies for the exception provided in PG-32.

$$K = \frac{PD}{1.82\, St} \qquad \textit{[see PG-32.1.2, Eq. (2)]}$$

$$= \frac{250 \times 30.875}{1.82 \times 13{,}700 \times 0.4375}$$

$$= 0.7076 \text{ or } 70.76\%$$

$$Dt = 30.875 \times 0.4375$$

$$= 13.5078$$

From Fig. PG-32, maximum size of opening with inherent compensation is 4.35 in.

Nominal ID of NPS 4 extra strong pipe is:

$$4.5 - 2(0.337) = 3.826 \text{ in.}$$

Since ID is less than maximum size opening from Fig. PG-32, no calculation need be made to demonstrate compliance with the compensation requirements of PG-33 (see PG-32.1.3.2).

A-69 A02

A vessel has a series of welded connections in a definite pattern as shown in Fig. A-69. The maximum allowable stress of all nozzle and vessel material is 17,500 psi. The maximum allowable working pressure of the design is 1,500 psig. See Fig. A-69 for all nozzle and vessel dimensions.

The welded attachments do not qualify for the exception provided in PG-32 and must therefore comply with PG-33 as follows.

Minimum required thickness for reinforcement consideration:

$$\text{Shell } t_r = \frac{PR_v}{S_v - (1 - y)\, P}$$

$$= \frac{1{,}500 \times 30}{17{,}500 - (1 - 0.4) \times 1500}$$

$$= 2.711 \text{ in.}$$

$$\text{Nozzle } t_{rn\,1\,and\,4} = \frac{P\,(0.5\, dl_1 - t_{n1})}{S_n - (1 - y)\, P}$$

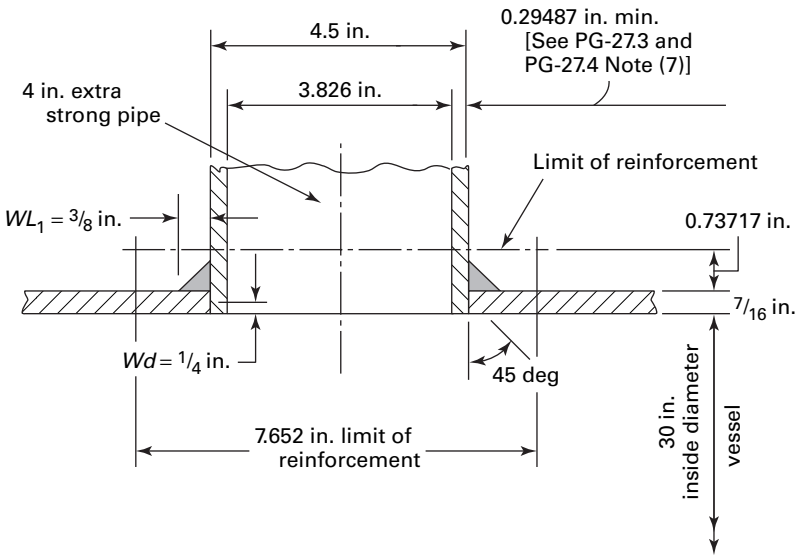


FIG. A-68 EXAMPLE FOR TYPICAL NOZZLE COMPUTATIONS

$$= \frac{1{,}500\ (0.5 \times 4.5 - 0.875)}{17{,}500 - (1 - 0.4) \times 1500}$$

$$= 0.124 \text{ in.}$$

$$\text{Nozzle } t_{rn\,2\ and\ 3} = \frac{P\ (0.5\ dl_2 - t_{n2})}{S_n - (1 - y)\ P}$$

$$= \frac{1{,}500(0.5 \times 5 - 1.0)}{17{,}500 - (1 - 0.4) \times 1500}$$

$$= 0.136 \text{ in.}$$

Check for overlapping limits:

The sum of the limits of reinforcement on the longitudinal axis between nozzles 1 and 2, as permitted under PG-36.2.2, is:

$$= \left(\frac{d_1}{2} + t_{n1} + t\right) + \left(\frac{d_2}{2} + t_{n\,2} + t\right)$$

$$= \frac{2.75}{2} + 0.875 + \frac{3.25}{2} + 3.0 + 1.0 + 3.25$$

$$= 11.25 \text{ in.} > D_1$$

The sum of the limits of reinforcement on the circumferential axis between nozzles 2 and 3 is:

$$= \left(\frac{d_2}{2} + t_{n2} + t\right) + \left(\frac{d_3}{2} + t_{n3} + t\right)$$

$$= \frac{3.0}{2} + 1.0 + 3.25 + \frac{3.0}{2} + 1.0 + 3.25$$

$$= 11.5 \text{ in.} > D_1$$

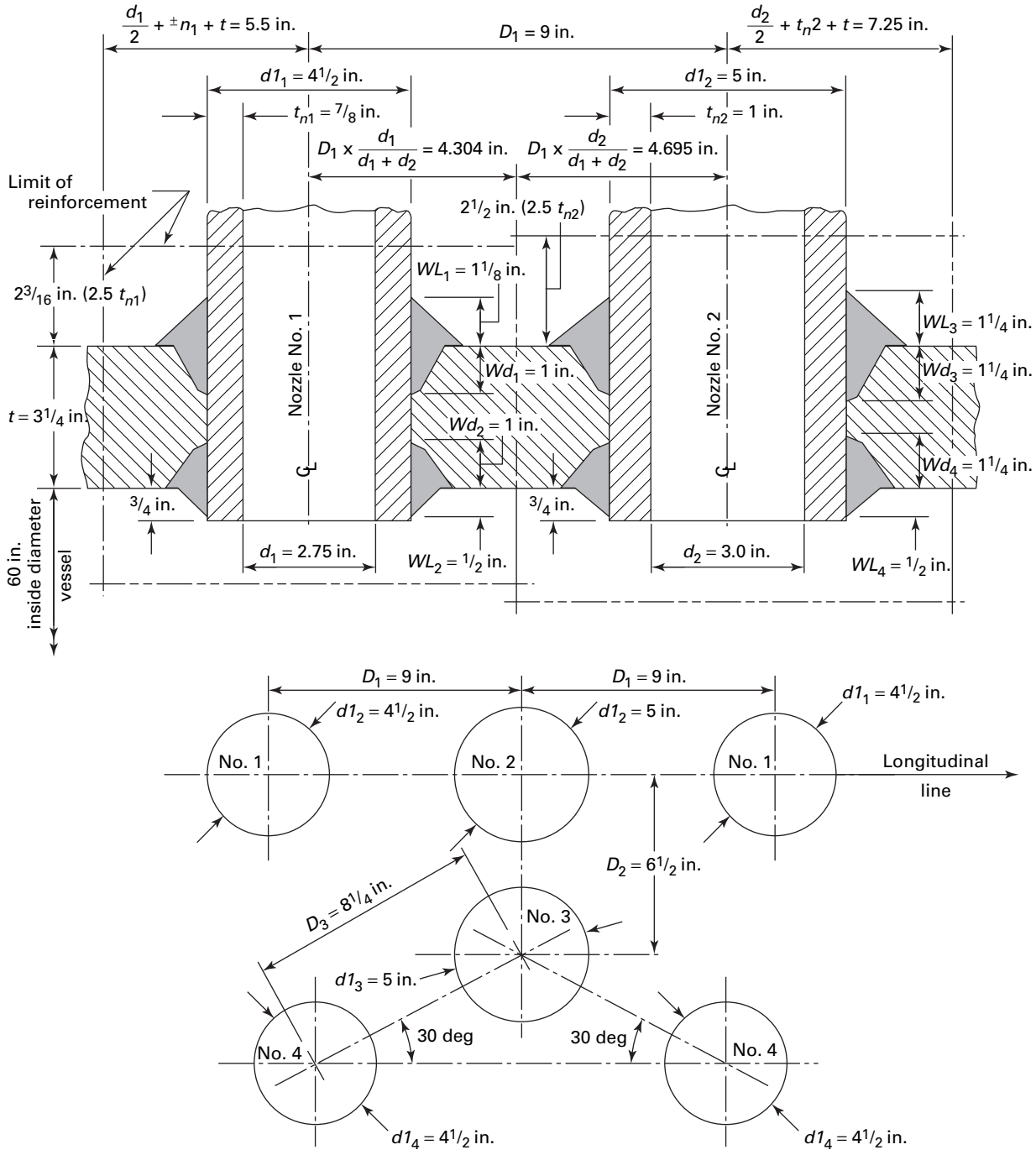
The sum of the limits of reinforcement on the diagonal between nozzles 3 and 4 is:

$$= \left(\frac{d_3}{2} + t_{n3} + t\right) + \left(\frac{d_4}{2} + t_{n4} + t\right)$$

$$= \frac{3.0}{2} + 1.0 + 3.25 + \frac{2.75}{2} + 0.875 + 3.25$$

$$= 11.25 \text{ in.} > D_1$$

Each of the above conditions is greater than the center-to-center distance, for the condition considered, between the openings; therefore, the limits of reinforcement overlap and the rule of PG-38.1 shall apply.



GENERAL NOTES:
(a) Nozzles 1 and 4 are identical dimensionally and nozzles 2 and 3 are identical dimensionally.
(b) This example was performed using computer software. The example was generated by performing the entire calculation without rounding off during each step. Accuracy of the final results beyond three significant figures is not intended or required.

FIG. A-69 EXAMPLE FOR TYPICAL NOZZLE COMPUTATIONS **A02**

Nozzle 1 and 4 — area of reinforcement required in the longitudinal plane:

$$A_{l1} = (d_1 + 2t_{n1})\, t_r F$$

$$= (2.75 + 2 \times 0.875) \times 2.711 \times 1.0$$

$$= 12.199 \text{ sq in.}$$

Nozzle 2 and 3 — area of reinforcement required in the longitudinal plane:

$$A_{l2} = (d_2 + 2\, t_{n2})\, t_r F$$

$$= (3.0 + 2 \times 1.0) \times 2.711 \times 1.0$$

$$= 13.554 \text{ sq in.}$$

Nozzle 2 and 3 — area of reinforcement required in the circumferential plane:

$$A_{c2} = (d_2 + 2t_{n2})\, t_r F$$

$$= (3.0 + 2 \times 1.0) \times 2.711 \times 0.5$$

$$= 6.777 \text{ sq in.}$$

Nozzle 3 — area of reinforcement required in the diagonal plane:

$$A_{d3} = (d_3 + 2t_{n3})\, t_r F$$

$$= (3.0 + 2 \times 1.0) \times 2.711 \times 0.88$$

$$= 11.928 \text{ sq in.}$$

Nozzle 4 — area of reinforcement required in the diagonal plane:

$$A_{d4} = (d_4 + 2t_{n4})\, t_r F$$

$$= (2.75 + 2 \times 0.875) \times 2.711 \times 0.88$$

$$= 10.735 \text{ sq in.}$$

Area of reinforcement provided in nozzle 1 in the longitudinal plane:

Due to the overlapping limits of reinforcement, the equation for A_1 (given in Fig. PG-33.1) will require modification. To prevent any reinforcement available between the nozzles from being counted more than once, the reinforcement limit is reduced such that the available reinforcement in the shell is divided and attributed to either nozzle's compensation in proportion to its relative size. For nozzle 1, this limit is $D_1\,[d_1/(d_1 + d_2)]$. The limit on the other side remains unchanged as $d_1/2 + t_{n1} + t$.

$$A_1 = \left\{t + D_1\,[d_1/(d_1 + d_2)] - d_1/2\right\}(t + Ft_r)$$

$$= \left\{3.25 + 9\,[2.75/(2.75 + 3.0)] - 4.5/2\right\}$$

$$\times (3.25 - 1.0 \times 2.711)$$

$$= 2.860 \text{ sq in.}$$

$$A_2 = 2\,(t_{n1} - t_{rn1})\, 2.5\, t_{n1}$$

$$= 2\,(0.875 - 0.12424) \times 2.5 \times 0.875$$

$$= 3.285 \text{ sq in.}$$

$$A_3 = 2\, t_{n1} h$$

$$= 2 \times 0.875 \times 4.0$$

$$= 7.0 \text{ sq in.}$$

$$A_4 = WL_1^2 + WL_2^2$$

$$= 1.125^2 + 0.5^2$$

$$= 1.516 \text{ sq in.}$$

Total area of available reinforcement provided by nozzle 1 in the longitudinal plane:

$$A_1 + A_2 + A_3 + A_{4_1} + A_{4_2} = 14.660 \text{ sq in.} \geq A_{l1}$$

as required for demonstration of compliance with PG-33.

Area of reinforcement provided in nozzle 2 in the longitudinal plane:

Since nozzle 2 has its limits of reinforcement restricted on both sides by nozzle 1, the reduced limit of $D_1\,[d_2/(d_1 + d_2)]$ is applicable to both sides.

$$A_1 = \left\{2 \times D_1\,[d_2/(d_1 + d_2)] - \frac{dl_2}{2}\right\}(t - Ft_r)$$

$$= \left\{2 \times 9\,[3.0/(2.75 + 3.0)] - \frac{5.0}{2}\right\}$$

$$\times (3.25 - 1.0 \times 2.711)$$

$= 3.716$ sq in.

$A_2 = 2\,(t_{n2} - t_{rn2})\,2.5t_{n2}$

$= 2\,(1.0 - 0.136) \times 2.5 \times 1.0$

$= 4.322$ sq in.

$A_3 = 2t_{n2}h$

$= 2 \times 1.0 \times 4.0$

$= 8.0$ sq in.

$A_4 = WL_3^2 + WL_4^2$

$= 1.25^2 + 0.5^2$

$= 1.812$ sq in.

Total area of available reinforcement provided by nozzle 2 in the longitudinal plane:

$$A_1 + A_2 + A_3 + A_4 = 17.850 \text{ sq in.} \geq A_{l2}$$

as required for demonstration of compliance with PG-33.

Area of reinforcement provided in nozzle 2 or 3 in the circumferential plane:

$$A_1 = \left\{t + D_1\,[d_2/(d_2 + d_3)] - \frac{dl_2}{2}\right\}(t - Ft_r)$$

$$= \left\{3.25 + 9\,[3.0/(3.0 + 3.0)] - \frac{5.0}{2}\right\} \times (3.25 - 0.5 \times 2.711)$$

$= 9.947$ sq in.

$A_2 = 2\,(t_{n2} - t_{rn2})\,2.5t_{n2}$

$= 2\,(1.0 - 0.13554) \times 2.5 \times 1.0$

$= 4.3223$ sq in.

$A_3 = 2\,t_{n2}h$

$= 2 \times 1.0 \times 4.0$

$= 8.0$ sq in.

$A_4 = WL_3^2 + WL_4^2$

$= 1.25^2 + 0.5^2$

$= 1.8125$ sq in.

Total area of available reinforcement provided by nozzle 2 or 3 in the circumferential plane:

$$A_1 + A_2 + A_3 + A_4 = 24.081 \text{ sq in.} \geq A_{c2}$$

as required for demonstration of compliance with PG-33.

Area of reinforcement provided by nozzle 3 in the diagonal plane:

Although nozzle 1 does not lie exactly in the same plane as nozzles 3 and 4 and is slightly farther away, for simplicity the limit on both sides of nozzle 3 are restricted to the reduced limit between nozzles 3 and 4.

$$A_1 = \left\{2 \times D_3 \times [d_3/(d_3 + d_4)] - \frac{dl_3}{2}\right\}(t - Ft_r)$$

$$= \left\{2 \times 8.25 \times [3.0/(3.0 + 2.75)] - \frac{5.0}{2}\right\} \times (3.25 \times 0.88 \times 2.711)$$

$= 5.281$ sq in.

$A_2 = 2\,(t_{n3} - t_{rn3})\,2.5t_{n3}$

$= 2\,(1.0 - 0.136) \times 2.5 \times 1.0$

$= 4.322$ sq in.

$A_3 = 2\,t_{n3}\,h$

$= 2 \times 1.0 \times 4.0$

$= 8.0$ sq in.

$A_4 = WL_3^2 + WL_4^2 = 1.25^2 + 0.5^2$

$= 1.812$ sq in.

Total area of available reinforcement provided by nozzle 3 in the diagonal plane:

$$A_1 + A_2 + A_3 + A_4 = 19.415 \text{ sq in.} \geq A_{d3}$$

as required for demonstration of compliance with PG-33.

Area of reinforcement provided in nozzle 4 in the diagonal plane:

$$A_1 = \left\{t + D_3 \times [d_4/(d_4 + d_3)] - \frac{d_4}{2}\right\}(t - F_{tr})$$

$$= \left\{3.25 + 8.25 \times [2.75/(2.75 + 3.0)] - \frac{4.5}{2}\right\} \times (3.25 - 0.88 \times 2.711)$$

$= 4.275$ sq in.

$A_2 = 2\,(t_{n4} - t_{rn4})\,2.5\,t_{n4}$

$= 2\,(0.875 - 0.124) \times 2.5 \times 0.875$

$= 3.285$ sq in.

$A_3 = 2\,t_{n4}\,h$

$= 2 \times 0.875 \times 4.0$

$= 7.0$ sq in.

$A_4 = WL_3^2 + WL_4^2$

$= 1.25^2 + 0.5^2$

$= 1.516$ sq in.

Total area of available reinforcement provided by nozzle 4 in the diagonal plane:

$$A_1 + A_2 + A_3 + A_4 = 16.076 \text{ sq in.} \geq A_{d4}$$

as required for demonstration of compliance with PG-33.

The rule of PG-38.4 for the minimum required net cross-sectional area between any two finished openings shall apply as follows.

Net area required in longitudinal plane between nozzles 1 and 2:

$nar = 0.7\,Ft_r\,D_1$

$= 0.7 \times 1.0 \times 2.711 \times 9$

$= 17.078$ sq in.

Net area provided in vessel wall:

$nav = [D_1 - 0.5\,(dl_1 + dl_2)]\,t$

$= [9 - 0.5 \times (4.5 + 5)] \times 3.25$

$= 13.812$ sq in.

Net area provided in nozzle wall fused to vessel wall:

$nan = t_{n1}Wd_1 + t_{n1}Wd_2 + t_{n2}Wd_3 + t_{n2}Wd_4$

$= 0.875 \times 1.0 + 0.875 \times 1.0 + 1.0 \times 1.25 + 1.0 \times 1.25$

$= 4.25$ sq in.

Total net area provided in the longitudinal plane between nozzles 1 and 2:

$nav + nan = 18.0625$ sq in. $\geq nar$ as required for demonstration of compliance with PG-38.4

Net area required in the circumferential plane between nozzles 2 and 3:

$nar = 0.7\,Ft_r\,D_2$

$= 0.7 \times 0.5 \times 2.711 \times 6.5$

$= 6.167$ sq in.

Net area provided in vessel wall:

$nav = [D_2 - 0.5\,(dl_2 + dl_3)]t$

$= [6.5 - 0.5 \times (5 + 5)] \times 3.25$

$= 4.875$ sq in.

Net area provided in the nozzle wall fused to the vessel wall:

$nan = Tt_{n2}\,Wd_3 + t_{n2}\,Wd_4 + t_{n3}\,Wd_3 + t_{n3}\,Wd_4$

$= 1.0 \times 1.25 + 1.0 \times 1.25 + 1.0 \times 1.25 + 1.0 \times 1.25$

$= 5$ sq in.

Total net area provided in the circumferential plane between nozzles 2 and 3:

$nav + nan = 9.875$ sq in. $\geq nar$ as required for demonstration of compliance with PG-38.4

Net area required in the diagonal plane between nozzles 3 and 4:

$nar = 0.7\,Ft_r\,D_3$

$= 0.7 \times 0.88 \times 2.711 \times 8.25$

$= 13.776$ sq in.

Net area provided in vessel wall:

$nav = [D_3 - 0.5\,(dl_3 + dl_4)]\,t$

$= [8.25 - 0.5 \times (5 + 4.5)] \times 3.25$

$= 11.375$ sq in.

Net area provided in the nozzle wall fused to the vessel wall:

$$nan = t_{n3}\,Wd_3 + t_{n3}Wd_4 + t_{n4}\,Wd_1 + t_{n4}\,Wd_2$$
$$= 1.0 \times 1.25 + 1.0 \times 1.25 + 0.875 \times 1.0 + 0.875 \times 1.0$$
$$= 4.25 \text{ sq in.}$$

Total net area provided in the diagonal plane between nozzles 3 and 4:

$nav + nan = 15.625$ sq in. $\geq nar$ as required for demonstration of compliance with PG-38.4

Nozzles 1 and 4 — The required minimum strength to be provided by the combined load-carrying elements through each load-carrying path (see PG-37 and PW-15):

$$W = (A - A_1)\,S_v$$
$$= (12.199 - 2.860) \times 17{,}500$$
$$= 163{,}431 \text{ lb}$$

Strength of the welds:

Fillet welds in shear

$$= \tfrac{1}{2}\,\pi \times (WL_1 + WL_2)\,dl_1 \text{ (factor in PW-15.2)}\,S$$
$$= 0.5 \times 3.142 \times (1.125 + 0.5) \times 4.5 \times 0.49 \times 17{,}500$$
$$= 98{,}495 \text{ lb}$$

Groove welds in tension

$$= \tfrac{1}{2}\,\pi\,(Wd_1 + Wd_2)\,dl_1 \text{ (factor in PW-15.2)}\,S$$
$$= 0.5 \times 3.142 \times (1.0 + 1.0) \times 4.5 \times 0.74 \times 17{,}500$$
$$= 183{,}076 \text{ lb}$$

The combined strength equals 281,571 lb $\geq W$ as required for demonstration of compliance with PG-37 and PW-15.

Nozzles 2 and 3 — The required minimum strength of the welds (see PG-37 and PW-15):

$$W = (A - A_1)\,S_v$$
$$= (13.544 - 3.715) \times 17{,}500$$
$$= 172{,}177 \text{ lb}$$

Strength of the welds:

Fillet welds in shear

$$= \tfrac{1}{2}\,\pi\,(WL_3 + WL_4)dl_2 \text{(factor in PW-15.2)}\,S$$
$$= 0.5 \times 3.142 \times (1.25 + 0.5) \times 5 \times 0.49 \times 17{,}500$$
$$= 117{,}859 \text{ lb}$$

Groove welds in tension

$$= \tfrac{1}{2}\,\pi\,(Wd_3 + Wd_4)dl_2 \text{(factor in PW-15.2)}S$$
$$= 0.5 \times 3.142 \times (1.25 + 1.25) \times 5 \times 0.74 \times 17{,}500$$
$$= 254{,}273 \text{ lb}$$

The combined strength of path number 3 equals 372,132 lb $\geq W$ as required for demonstration of compliance with PG-37 and PW-15.

Nozzles 1 and 4 — Verification of minimum weld sizing as required by PW-16.1 and Fig. PW-16.1, sketch (f):

Required per Fig. PW-16.1, sketch (f):

$$t_1 + t_2 \geq 1.25t_{\min}$$
$$t_c \geq 0.25$$
$$t_1 \geq 0.25$$
$$t_2 \geq 0.25$$

Actual per Fig. A-69:

$$t_1 = WL_1 \sin 45°$$
$$= 1.125 \times 0.707$$
$$= 0.795 \text{ in.}$$

$$t_2 = Wd_1 + Wd_2$$
$$= 1.0 + 1.0$$
$$= 2 \text{ in.}$$

$$t_c = WL_2 \sin 45°$$
$$= 0.5 \times 0.7071$$
$$= 0.354 \text{ in.}$$

$t_{\min} = 0.75$ in. (based on PW-16.2)

Verification:

$$(t_1 + t_2 = 2.795) \geq (1.25t_{min} = 0.937)$$

$$(t_c = 0.354) \geq 0.25$$

$$(t_1 = 0.795) \geq 0.25$$

$$(t_2 = 2) \geq 0.25$$

Nozzles 2 and 3 — Verification of minimum weld sizing as required by PW-16.1 and Fig. PW-16.1, sketch (f):

Required per Fig. PW-16.1, sketch (f):

$$t_1 + t_2 \geq 1.25t_{min}$$

$$t_c \geq 0.25$$

$$t_1 \geq 0.25$$

$$t_2 \geq 0.25$$

Actual per Fig. A-69:

$$t_1 = WL_3 \sin 45°$$
$$= 1.25 \times 0.7071$$
$$= 0.884 \text{ in.}$$

$$t_2 = Wd_3 + Wd_4$$
$$= 1.25 + 1.25$$
$$= 2.5 \text{ in.}$$

$$t_c = WL_4 \sin 45°$$
$$= 0.5 \times 0.707$$
$$= 0.354$$

$t_{min} = 0.75$ in. (based on PW-16.2)

Verification:

$$(t_1 + t_2 = 3.384) \geq (1.25t_{min} = 0.937)$$

$$(t_c = 0.354) \geq 0.25$$

$$(t_1 = 0.884) \geq 0.25$$

$$(t_2 = 2.5) \geq 0.25$$

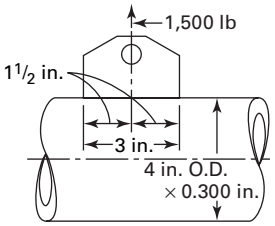


FIG. A-71

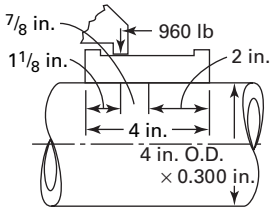


FIG. A-72

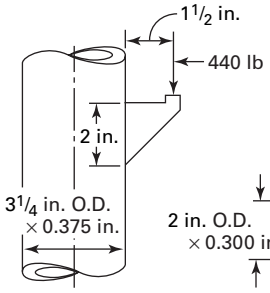


FIG. A-73

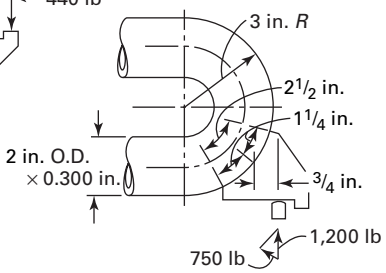


FIG. A-74

FIGS. A-71—A-74 TYPES OF STRUCTURAL ATTACHMENTS TO TUBES

As verified by the above demonstrations, the design is proved to be in compliance with the requirements of Section I.

EXAMPLES OF COMPUTATION OF ALLOWABLE LOADING ON STRUCTURAL ATTACHMENTS TO TUBES

A-71

A tube is suspended by a welded attachment with the loads and dimensions as shown in Fig. A-71. This is a condition of direct radial loading on the tube.

The allowable lug loading is calculated for the following conditions:

material = SA-213-T22
MAWP = 2258 psi
T = 800°F
D = 4.0 in.
t = 0.30 in.

1/4 in. thick lug

7 deg attachment angle

$S_a = 15{,}000$ psi

$S = 15{,}000$ psi

$S_t = 2.0\ S_a - S = 15{,}000$ psi

From Table PW-43.1, $K = 1.07$

From Fig. PW-43.1 or PW-43.2.1 or PW-43.2.2

$$X = D/t^2 = 44.4$$

Compression $L_f = 0.0326$

Tension $L_f = 0.0405$

$$L_a = K\,(L_f)S$$

Compression $L_a = (1.07)(0.0326)(15{,}000)$
$= 523$ lb/in.

Tension $L_a = (1.07)(0.0405)(15{,}000)$
$= 650$ lb/in.

Actual load:

$$W = 1{,}500 \text{ lb (Tension)}$$

$$L = 1{,}500 \text{ lb}/3 \text{ in.} = 500 \text{ lb/in.} < 650 \text{ lb/in.}$$

The loading indicated is therefore within the values allowed by the chart in Fig. PW-43.1.

A-72 A03

A load is supported on a rubbing strip welded to a tube, as shown in Fig. A-72. This problem illustrates a condition where the load is not applied on the center of welded attachment.

The allowable lug loading is calculated for the same conditions given in example A-71:

Compression $L_a = (1.07)(0.0326)(15{,}000)$
$= 523$ lb/in.

Tension $L_a = (1.07)(0.0405)(15{,}000)$
$= 650$ lb/in.

Actual unit load:

$$W = 960 \text{ lb}$$

$$L = \frac{960}{4} \pm \frac{(6 \times 960 \times 0.875)}{4^2} = 240 \pm 315$$

$$= 555 \text{ lb/in. compression; } 75 \text{ lb/in. tension}$$

The actual loading does not exceed values of allowable loading.

A-73

A03 **A-73.1** A load is supported from a vertical tube with a welded bracket attachment as shown in Fig. A-73. This example illustrates a condition of eccentric loading where the direct loading is not additive.

The allowable lug loading is calculated for the following conditions:

material = SA-213-T22
$MAWP$ = 3722 psi
T = 800°F
D = 3.25 in.
t = 0.375 in.

$\frac{1}{4}$ in. thick lug

10 deg attachment angle

S_a = 15,000 psi
S = 15,000 psi
$S_t = 2.0\ S_a - S$ = 15,000 psi

From Table PW-43.1, $K = 1.108$

From Fig. PW-43.1, PW-43.2.1, or PW-43.2.2

$$X = D/t^2 = 23.11$$

Compression $L_f = 0.0637$
Tension $L_f = 0.090$

$$L_a = K\,(L_f)S$$

Compression $L_a = (1.108)(0.0637)(15{,}000)$
$= 1{,}058$ lb/in.

Tension $L_a = (1.108)(0.090)(15{,}000) = 1{,}495$ lb/in.

Actual:

$$W = 440 \text{ lb}$$

$$L = \frac{6 \times 440 \times 1.5}{2^2}$$

$$= 990 \text{ lb/in. compression or tension}$$

The actual loading does not exceed values of allowable loading.

A-73.2 To determine the maximum allowable loading on structural attachments to tubes, a test may be conducted on a full-size section of tube with attachment. The test may be considered as meeting the Code requirements provided:

A-73.2.1 The loading applied to the test specimen is at least equivalent to the design loading, and at the same time the tube is subjected to a hydrostatic pressure corresponding to design conditions.

A-73.2.2 The test is conducted in accordance with the requirements of A-22 with the exception that the hydrostatic pressure shall be held at expected design pressure, and the loading on the support shall be increased until permanent set occurs.

A-73.2.3 The maximum load P, allowed on the attachment at or below the pressure corresponding to the hydrostatic pressure, is given by the following formula:

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

where

P = maximum allowable load on attachment, lb
H = test load at the proportional limit of the structure, lb
S = working stress permitted in Table 1A of Section II, Part D, for the tube material at the design temperature that in no case shall be taken at less than 700°F, psi
E = average proportional limit of the tube material, psi

A-74 A03

A superheater section is supported by welded attachment to the short-radius return bend section as shown in Fig. A-74. This example illustrates a condition where

a direct and eccentric load is applied to a bent tube section.

The allowable lug loading is calculated for the following conditions:

material = SA-213-T22
$MAWP$ = 5,087 psi
T = 700°F
D = 2.0 in.
t = 0.30 in.

$\frac{1}{4}$ in. thick lug

15 deg attachment angle

S_a = 15,000 psi
S = 15,000 psi
$S_t = 2.0\ S_a - S$ = 15,000 psi

From Table PW-43.1, $K = 1.16$

From Fig. PW-43.1, PW-43.2.1, or PW-43.2.2

$$X = D/t^2 = 22.2$$

Compression $L_f = 0.0664$
Tension $L_f = 0.0948$

For bend:

$$X = (\text{Bend dia})/t^2 = 6/0.3^2 = 66.6$$

From Fig. PW-43.1 or Eqs. PW-43.2.1 or PW-43.2.2
Compression $L_f = 0.0215$

Tension $L_f = 0.0257$

$$L_a = K(\Sigma L_f)\ S_t$$

Compression $L_a = (1.16)(0.0664 + 0.0215)(15{,}000) = 1{,}529$ lb/in.
Tension $L_a = (1.16)(0.0948 + 0.0257)(15{,}000) = 2{,}096$ lb/in.

Actual unit load:

$$P = \frac{750}{2.5} \pm \frac{6 \times 1{,}200 \times 0.75}{2.5^2}$$

= 300 ± 864 = 1,164 lb/in. compression; 564 lb/in. tension

The actual applied load is less than the values allowed by the chart in Fig. PW-43.1.

PREHEATING

A-100

A-100.1 Preheating may be employed during welding to assist in completion of the welded joint. The need for and the temperature of preheat are dependent on a number of factors such as chemical analysis, degree of restraint of the parts being joined, elevated temperature mechanical properties, and material thicknesses. Mandatory rules for preheating are, therefore, not given in this Section except as required in Table PW-39. As a general guide, some minimum temperatures for preheating are given in A-100.4. It is cautioned that the preheating temperatures listed in A-100.4 do not necessarily ensure satisfactory completion of the welded joint. Requirements for individual materials within the P-Number listing may have preheating requirements more or less restrictive than this general guide. The Welding Procedure Specification for the material being welded shall specify the minimum preheating requirements described in the welding procedure qualification requirements of Section IX.

A-100.2 The heat of welding may assist in maintaining preheat temperatures after the start of welding and, for inspection purposes, temperature measurements may be made near the weld. The method or extent of application of preheat is not, therefore, specifically given. Normally, when materials of two different P-Number groups are joined by welding, the preheat used will be that of the material with the higher preheat specified on the Welding Procedure Specification.

A-100.3 Thicknesses referred to are nominal at the weld for the parts to be joined.

A-100.4 Minimum Temperatures for Preheating

A-100.4.1 P-No. 1, Group No. 1, 2, 3. 175°F (79°C) for material that has both a specified maximum carbon content in excess of 0.30% and a thickness at the joint in excess of 1 in. (25 mm); 50°F (10°C) for all other materials in this grouping.

A-100.4.2 P-No. 3, Group No. 1, 2, 3. 175°F (79°C) for material that has either a specified minimum tensile strength in excess of 70,000 psi (480 MPa) or a thickness at the joint in excess of $\frac{5}{8}$ in. (16 mm); 50°F (10°C) for all other materials in this grouping.

A-100.4.3 P-No. 4, Group No. 1, 2. 250°F (79°C) for material that has either a specified minimum tensile strength in excess of 60,000 psi (410 MPa) or a thickness at the joint in excess of $\frac{1}{2}$ in. (13 mm); 50°F (10°C) for all other materials in this grouping.

A-100.4.4 P-No. 5A, B, C. 400°F (204°C) for material that has either a specified minimum tensile strength in excess of 60,000 psi (410 MPa) or has both a specified minimum chromium content above 6.0% and a thickness at the joint in excess of $\frac{1}{2}$ in. (13 mm); 300°F (149°C) for all other materials in this grouping.

A-100.4.5 P-No. 6, Group No. 1, 2, 3. 400°F (204°C).

A-100.4.6 P-No. 7, Group No. 1, 2. None.

A-100.4.7 P-No. 8, Group No. 1, 2. None.

A-100.4.10 P-No. 10A, Group No. 1. 175°F (79°C).

A03 **A-100.4.11 P-No. 10I, Group No. 1.** 300°F (149°C) with interpass maintained between 350°F and 450°F (177°C and 232°C).

MAXIMUM ALLOWABLE WORKING PRESSURES — THICK SHELLS

01 A02 **A-125 Shells for Internal Pressure**

When the thickness of the shell exceeds one-half of the inside radius, the required thickness and maximum allowable working pressure on the cylindrical shell of a boiler or drum shall be determined by the following formulas:

$$t = (\sqrt{Z_1} - 1)\,R = \left(\frac{\sqrt{Z_1} - 1}{\sqrt{Z_1}}\right) R_o$$

or

$$P = SE\,\frac{Z_2 - 1}{Z_2 + 1}$$

where

P = maximum allowable working pressure, psi (kPa)

S = maximum allowable working unit stress, psi (kPa), taken from Table 1A of Section II, Part D

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

for fusion welded joints = efficiency specified in PG-27.4, Note 1

for seamless shells = 100% (unity)

for ligaments between openings, the efficiency shall be calculated by the rules given in PG-52

$Z_1 = (SE + P) / (SE - P)$

$Z_2 = [(R + t) / R\,]^2 = (R_o / R)^2$

t = minimum thickness of shell plates in weakest course, in. (mm)

R = inside radius of the weakest course of the shell, in. (mm)

R_o = outside radius of the weakest course of the shell, in. (mm)

NOTE: Restrictions of PG-27.2.2 also apply to this paragraph.

ROUNDED INDICATION CHARTS

A-250 Acceptance Standard for Radiographically Determined Rounded Indications in Welds

A-250.1 Applicability of These Standards. These standards are applicable to ferritic, austenitic, and nonferrous materials.

A-250.2 Terminology

A-250.2.1 Rounded Indications. Indications with a maximum length of three times the width or less on the radiograph are defined as rounded indications. These indications may be circular, elliptical, conical, or irregular in shape and may have tails. When evaluating the size of an indication, the tail shall be included. The indication may be from any imperfection in the weld, such as porosity, slag, or tungsten.

A-250.2.2 Aligned Indications. A sequence of four or more rounded indications shall be considered to be aligned when they touch a line parallel to the length of the weld drawn through the center of the two outer rounded indications.

A-250.2.3 Thickness *t*. t is the thickness of the weld, of the pressure–retaining material, or of the thinner of the sections being joined, whichever is least. If a full penetration weld includes a fillet weld, the thickness of the fillet weld throat shall be included in t.

A-250.3 Acceptance Criteria

A-250.3.1 Image Density. Density within the image of the indication may vary and is not a criterion for acceptance or rejection.

A-250.3.2 Relevant Indications (See Table 1 for Examples). Only those rounded indications which exceed the following dimensions shall be considered relevant.

TABLE 1
MAXIMUM PERMISSIBLE SIZE OF ROUNDED INDICATION
(Examples Only)

Customary Units

Thickness t, in.	Maximum Size of Acceptable Rounded Indication, in.		Maximum Size of Nonrevelant Indication, in.
	Random	Isolated	
Less than 1/8	1/4 t	1/3 t	1/10 t
1/8	0.031	0.042	0.015
3/16	0.047	0.063	0.015
1/4	0.063	0.083	0.015
5/16	0.078	0.104	0.031
3/8	0.091	0.125	0.031
7/16	0.109	0.146	0.031
1/2	0.125	0.168	0.031
9/16	0.142	0.188	0.031
5/8	0.156	0.210	0.031
11/16	0.156	0.230	0.031
3/4 to 2 incl.	0.156	0.250	0.031
Over 2	0.156	0.375	0.063

SI Units

Thickness t, mm	Maximum Size of Acceptable Rounded Indication, mm		Maximum Size of Nonrevelant Indication, mm
	Random	Isolated	
Less than 3.18	1/4 t	1/3 t	1/10 t
3.18	0.79	1.07	0.38
4.76	1.19	1.60	0.38
6.35	1.60	2.11	0.38
7.94	1.98	2.64	0.79
9.52	2.31	3.18	0.79
11.11	2.77	3.71	0.79
12.70	3.18	4.27	0.79
14.29	3.61	4.78	0.79
15.88	3.96	5.33	0.79
17.46	3.96	5.84	0.79
19.05 to 50.80 incl.	3.96	6.35	0.79
Over 50.80	3.96	9.53	1.60

1/10 t for t less than 1/8 in. (3.2 mm)
1/64 in. (0.4 mm) for t 1/8 in. to 1/4 in. (6 mm), inclusive
1/32 in. (0.8 mm) for t 1/4 in. (6 mm) to 2 in. (51 mm), inclusive
1/16 in. (1.6 mm) for t greater than 2 in. (51 mm)

A-250.3.3 Maximum Size of Rounded Indication (See Table 1 for Examples). The maximum permissible size of any indication shall be 1/4t, or 5/32 in. (4 mm), whichever is smaller; except that an isolated indication separated from an adjacent indication by 1 in. (25 mm) or more may be 1/3t, or 1/4 in. (6 mm), whichever is less. For t greater than 2 in. (51 mm) the maximum permissible size of an isolated indication shall be increased to 3/8 in. (10 mm).

A-250.3.4 Aligned Rounded Indications. Aligned rounded indications are acceptable when the summation of the diameters of the indications is less than t in a length of 12t. (See Fig. 1.) The length of groups of aligned rounded indications and the spacing between the groups shall meet the requirements of Fig. 2.

A-250.3.5 Spacing. The distance between adjacent rounded indications is not a factor in determining acceptance or rejection, except as required for isolated indications or groups of aligned indications.

A-250.3.6 Rounded Indication Charts. The rounded indications characterized as imperfections shall not exceed that shown in the charts.

The charts in Fig. 3.1 through Fig. 3.6 illustrate various types of assorted, randomly dispersed, and clustered rounded indications for different weld thicknesses greater than 1/8 in. (3.2 mm). These charts represent the maximum acceptable concentration limits for rounded indications.

The chart for each thickness range represents full-scale 6 in. (152 mm) radiographs, and shall not be enlarged or reduced. The distributions shown are not necessarily the patterns that may appear on the radiograph, but are typical of the concentration and size of indications permitted.

A-250.3.7 Weld Thickness t Less Than 1/8 in. (3.2 mm). For t less than 1/8 in. (3.2 mm) the maximum number of rounded indications shall not exceed 12 in a 6 in. (152 mm) length of weld. A proportionally fewer number of indications shall be permitted in welds less than 6 in. in length.

A-250.3.8 Clustered Indications. The illustrations for clustered indications show up to four times as many indications in a local area, as that shown in the illustrations for random indications. The length of an acceptable cluster shall not exceed the lesser of 1 in. or 2t. Where more than one cluster is present, the sum of the lengths of the clusters shall not exceed 1 in. (25 mm) in a 6 in. (152 mm) length of weld.

GENERAL NOTE: Sum of L_1 to L_x shall be less than t in a length of 12 t.

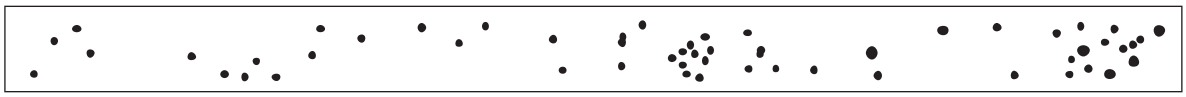
FIG. 1 ALIGNED ROUNDED INDICATIONS

Maximum Group Length
$L = 1/4$ in. (6 mm) for t less than $3/4$ in. (19 mm)
$L = 1/3\ t$ for $t\ 3/4$ in. (19 mm) to $2\,1/4$ in. (57 mm)
$L = 3/4$ in. (19 mm) for t greater than $2\,1/4$ in. (57 mm)

Minimum Group Spacing
$3L$ where L is the length of the longest adjacent group being evaluated.

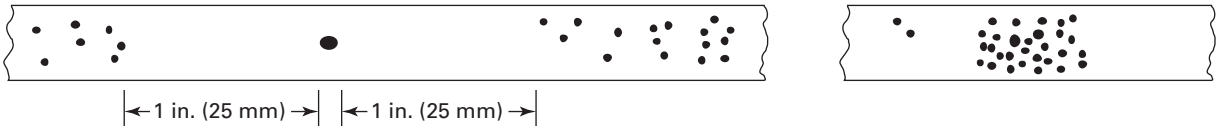
GENERAL NOTE: Sum of the group lengths shall be less than t in a length of 12 t.

FIG. 2 GROUPS OF ALIGNED ROUNDED INDICATIONS



GENERAL NOTE: Typical concentration and size permitted in any 6 in. (152 mm) length of weld

(a) Random Rounded Indications



(b) Isolated Indication (Maximum size per Table I)

(c) Cluster

FIG. 3.1 CHARTS FOR t $\frac{1}{8}$ in. (3.2 mm) TO $\frac{1}{4}$ in. (6 mm), INCLUSIVE

METHODS FOR MAGNETIC PARTICLE EXAMINATION (MT)

A-260

A-260.1 Scope. This Appendix provides for procedures that shall be followed whenever magnetic particle examination is required by PG-93. The detailed examination method of Article 7 of Section V shall be used with the acceptance criteria specified in this Appendix. Magnetic particle examination shall be performed in accordance with a written procedure, certified by the Manufacturer to be in accordance with the requirement of T-150 of Section V.

A-260.2 Certification of Personnel. The Manufacturer shall certify that each magnetic particle examiner meets the following requirements.

(a) The examiner has vision, with correction if necessary, to enable him to read a Jaeger Type No. 2 Standard Chart at a distance of not less than 12 in. and is capable of distinguishing and differentiating contrast between colors used. These capabilities shall be checked annually.

(b) The examiner is competent in the techniques of the magnetic particle examination method for which he is certified, including making the examination and interpreting and evaluating the results, except that where the examination method consists of more than one operation, he may be certified as being qualified only for one or more of these operations.

A-260.3 Evaluation of Indications. Indications will be revealed by retention of magnetic particles. All such indications are not necessarily imperfections, however, since excessive surface roughness, magnetic permeability variations (such as at the edge of heat affected zones), etc., may produce similar indications. 01

An indication of an imperfection may be larger than the imperfection that causes it; however, the size of the indication is the basis for acceptance evaluation. Only indications that have any dimension greater than $\frac{1}{16}$ in. shall be considered relevant.

(a) A linear indication is one having a length greater than three times the width.

(b) A rounded indication is one of circular or elliptical shape with a length equal to or less than three times its width.

(c) Any questionable or doubtful indications shall be reexamined to determine whether or not they are relevant.

A-260.4 Acceptance Standards. All surfaces to be examined shall be free of: 01

(a) relevant linear indications;

(b) relevant rounded indications greater than $\frac{3}{16}$ in. (4.8 mm); and

(c) four or more relevant rounded indications in a line separated by $\frac{1}{16}$ in. (1.6 mm) or less, edge to edge.

METHODS FOR LIQUID PENETRANT EXAMINATION (PT)

NOTE: Satisfactory application of this method of examination requires special skills in the techniques involved and in interpreting the results. The requirements specified herein presume application by suitably experienced personnel.

A-270

A-270.1 Scope. This Appendix provides for procedures that shall be followed whenever liquid penetrant examination is required by PG-93. The detailed examination method of Article 6 of Section V shall be used with the acceptance criteria specified in this Appendix. Liquid penetrant examination shall be performed in accordance with a written procedure, certified by the Manufacturer to be in accordance with the requirement of T-150 of Section V.

A-270.2 Certification of Personnel. The Manufacturer shall certify that each liquid penetrant examiner meets the following requirements.

(a) The examiner has vision, with correction if necessary, to enable him to read a Jaeger Type No. 2 Standard Chart at a distance of not less than 12 in. (305 mm) and is capable of distinguishing and differentiating contrast between colors used. These capabilities shall be checked annually.

(b) The examiner is competent in the techniques of the liquid penetrant examination method for which he is certified, including making the examination and interpreting and evaluating the results, except that where the examination method consists of more than one operation, he may be certified as being qualified only for one or more of these operations.

01 **A-270.3 Evaluation of Indications.** An indication of an imperfection may be larger than the imperfection that causes it; however, the size of the indication is the basis for acceptance evaluation. Only indications that have any dimension greater than $^{1}/_{16}$ in. (1.6 mm) shall be considered relevant.

(a) A linear indication is one having a length greater than three times the width.

(b) A rounded indication is one of circular or elliptical shape with a length equal to or less than three times its width.

(c) Any questionable or doubtful indications shall be reexamined to determine whether or not they are relevant.

01 **A-270.4 Acceptance Standards.** All surfaces to be examined shall be free of:

(a) relevant linear indications;

(b) relevant rounded indications greater than $^{3}/_{16}$ in. (4.8 mm); and

(c) four or more relevant rounded indications in a line separated by $^{1}/_{16}$ in. (1.6 mm) or less, edge to edge.

QUALITY CONTROL SYSTEM

A-300

A-301 General

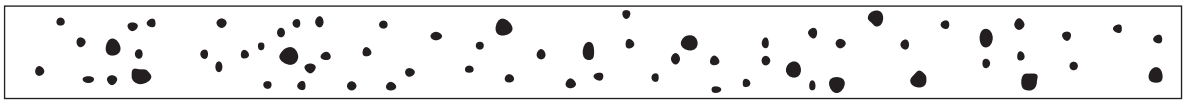
A-301.1 Quality Control System. The Manufacturer or assembler shall have and maintain a quality control system which will establish that all Code requirements, including material, design, fabrication, examination (by the Manufacturer) and inspection of boilers and boiler parts (by the Authorized Inspector), will be met. The quality control systems of electric boiler Manufacturers, safety valve or safety relief valve manufacturers or assemblers shall include duties of a Certified Individual when required by this Section. A03

Provided that Code requirements are suitably identified, the system may include provisions for satisfying any requirements by the Manufacturer or user which exceed minimum Code requirements and may include provisions for quality control of non-Code work. In such systems, the Manufacturer may make changes in parts of the system which do not affect the Code requirements without securing acceptance by the Authorized Inspector. Before implementation, revisions to quality control systems of Manufacturers and Assemblers of safety and safety relief valves shall have been found acceptable to an ASME designee if such revisions affect Code requirements.

The system that the Manufacturer or assembler uses to meet the requirements of this Section must be one suitable for his own circumstances. The necessary scope and detail of the system shall depend on the complexity of the work performed and on the size and complexity of the Manufacturer's (or assembler's) organization. A written description of the system the Manufacturer or assembler will use to produce a Code item shall be available for review. Depending upon the circumstances, the description may be brief or voluminous.

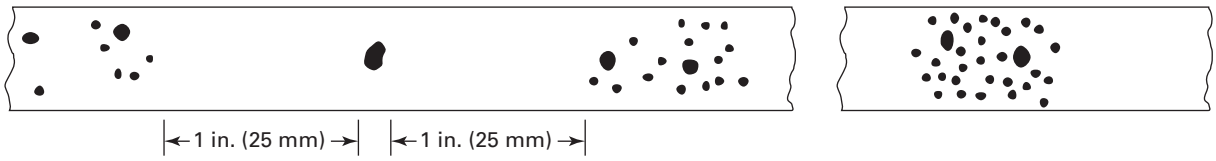
The written description may contain information of proprietary nature relating to the Manufacturer's (or assembler's) processes. Therefore, the Code does not require any distribution of this information, except for the Authorized Inspector or ASME designee.

It is intended that information learned about the system in connection with evaluation will be treated as confidential and that all loaned descriptions will be returned to the Manufacturer upon completion of the evaluation.



GENERAL NOTE: Typical concentration and size permitted in any 6 in. (152 mm) length of weld

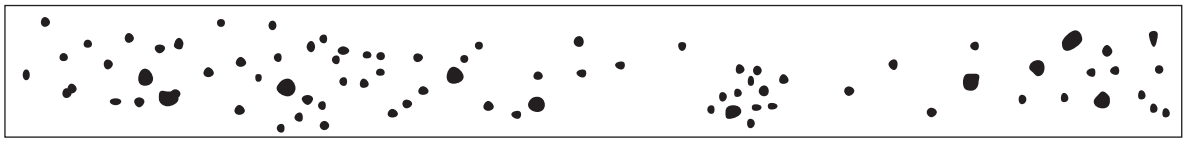
(a) Random Rounded Indications



(b) Isolated Indication (Maximum size per Table I)

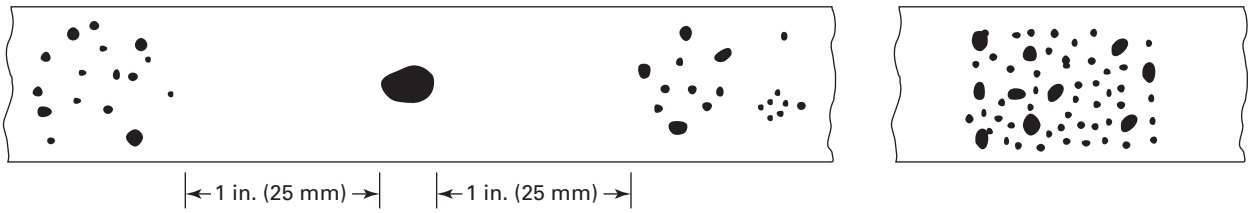
(c) Cluster

FIG. 3.2 CHARTS FOR *t* OVER 1/4 in. (6 mm) TO 3/8 in. (10 mm), INCLUSIVE



GENERAL NOTE: Typical concentration and size permitted in any 6 in. (152 mm) length of weld

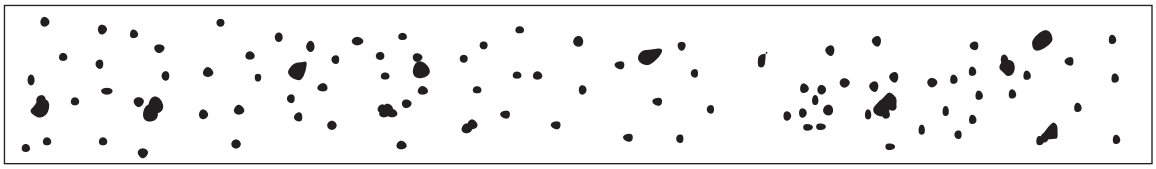
(a) Random Rounded Indications



(b) Isolated Indication (Maximum size per Table I)

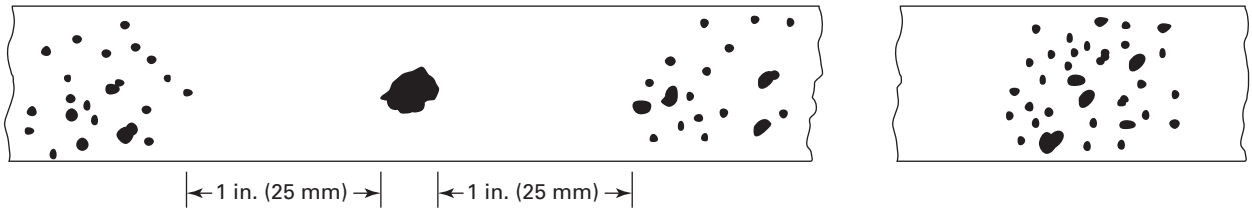
(c) Cluster

FIG. 3.3 CHARTS FOR *t* OVER 3/8 in. (10 mm) TO 3/4 in. (19 mm), INCLUSIVE



GENERAL NOTE: Typical concentration and size permitted in any 6 in. (152 mm) length of weld.

(a) Random Rounded Indications



(b) Isolated Indication (Maximum size per Table 1)

(c) Cluster

FIG. 3.4 CHARTS FOR *t* OVER 3/4 in. (19 mm) TO 2 in. (51 mm), INCLUSIVE

A-302 Outline of Features to Be Included in the Written Description of the Quality Control System

The following is a guide to some of the features that should be covered in the written description of the quality control system and that is equally applicable to both shop and field work.

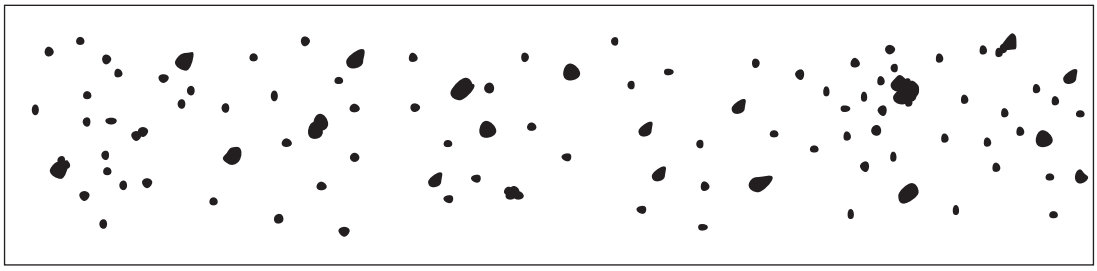
A-302.1 Authority and Responsibility. The authority and responsibility of those in charge of the quality control system shall be clearly established. Persons performing quality control functions shall have sufficient and well-defined responsibility, the authority, and the organizational freedom to identify quality control problems and to initiate, recommend, and provide solutions.

A-302.2 Organization. An organization chart showing the relationship between management and engineering, purchasing, manufacturing, field assembling, inspection, and quality control, is required to reflect the actual organization. The purpose of this chart is to identify and associate the various organizational groups with the particular function for which they are responsible. The Code does not intend to encroach on the Manufacturer's right to establish, and from time to time to alter, whatever form of organization the Manufacturer considers appropriate for its Code work.

A-302.3 Drawings, Design Calculations, and Specification Control. The Manufacturer's or assembler's quality control system shall provide procedures which will assure that the latest applicable drawings, design calculations, specifications and instructions, required by the Code, as well as authorized changes, are used for manufacture, assembly, examination, inspection, and testing.

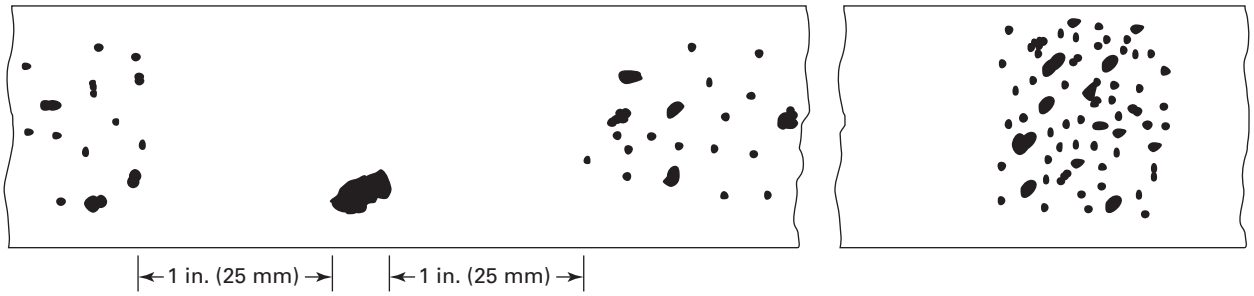
A-302.4 Material Control. The Manufacturer or assembler shall include a system of receiving control that will insure that the material received is properly identified and has documentation, including required material certifications or material test reports, to satisfy Code requirements as ordered. The material control system shall insure that only the intended material is used in Code construction.

A-302.5 Examination and Inspection Program. The Manufacturer's quality control system shall describe the fabrication operations, including examinations, sufficiently to permit the Authorized Inspector to determine at what stages specific inspections are to be performed.



GENERAL NOTE: Typical concentration and size permitted in any 6 in. (152 mm) length of weld.

(a) Random Rounded Indications



(b) Isolated Indication (Maximum size per Table I)

(c) Cluster

FIG. 3.5 CHARTS FOR *t* OVER 2 in. (51 mm) TO 4 in. (102 mm), INCLUSIVE

A-302.6 Correction of Nonconformities. There shall be a system agreed upon with the Authorized Inspector for correction of nonconformities. A nonconformity is any condition that does not comply with the applicable rules of this Section. Nonconformities must be corrected or eliminated in some way before the completed component can be considered to comply with this Section.

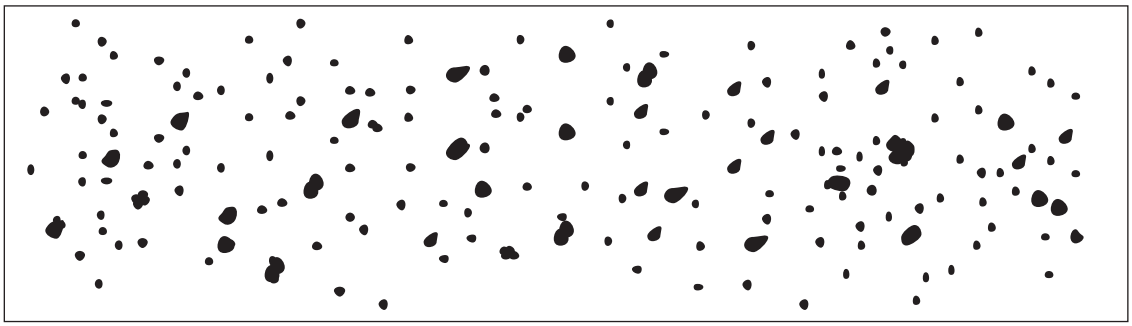
A-302.7 Welding. The quality control system shall include provisions for indicating that welding conforms to requirements of Section IX as supplemented by this Section. Manufacturers intending to use AWS Standard Welding Procedures shall describe control measures used to assure that the welding meets the requirements of this Section (see PW-1.2) and Section IX.

A-302.8 Nondestructive Examination. The quality control system shall include provisions for identifying nondestructive examination procedures the Manufacturer will apply to conform with requirements of this Section.

A-302.9 Heat Treatment. The quality control system shall provide controls to assure that heat treatments as required by the rules of this Section are applied. Means shall be indicated by which the Authorized Inspector can satisfy himself that these Code heat treatment requirements are met. This may be by review of furnace time–temperature records or by other methods as appropriate.

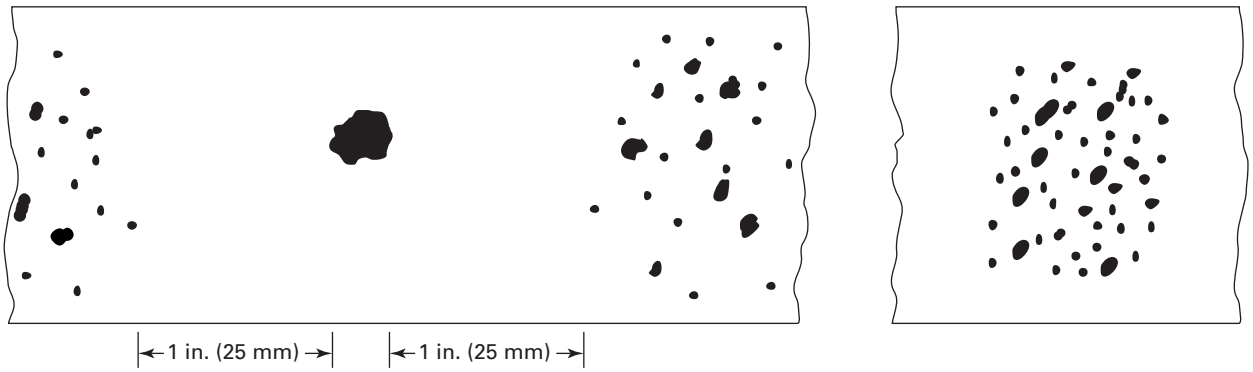
A-302.10 Calibration of Measurement and Test Equipment. The Manufacturer or assembler shall have a system for the calibration of examination, measuring, and test equipment used in fulfillment of requirements of this Section.

A-302.11 Records Retention. The Manufacturer or assembler shall have a system for the maintenance of radiographs and Manufacturers' Data Reports as required by this Section.



GENERAL NOTE: Typical concentration and size permitted in any 6 in. (152 mm) length of weld.

(a) Random Rounded Indications



(b) Isolated Indication (Maximum size per Table I)

(c) Cluster

FIG. 3.6 CHARTS FOR *t* OVER 4 in. (102 mm)

A-302.12 Sample Forms. The forms used in the quality control system and any detailed procedures for their use shall be available for review. The written description shall make necessary references to these forms.

A-302.13 Inspection of Boilers and Boiler Parts

A-302.13.1 Inspection of boilers and boiler parts shall be by the Authorized Inspector described in PG-91.

A03 **A-302.13.2** The written description of the quality control system shall include reference to the Authorized Inspector and when required, the Certified Individual.

A-302.13.2.1 The Manufacturer (or assembler) shall make available to the Authorized Inspector at the Manufacturer's plant (or construction site) a current copy of the written description or the applicable quality control system.

A-302.13.2.2 The Manufacturer's quality control system shall provide for the Authorized Inspector at the Manufacturer's plant to have access to all drawings, calculations, specifications, procedures, process sheets, repair procedures, records, test results, and any other documents as necessary for the Inspector to perform his duties in accordance with this Section. The Manufacturer may provide such access either to his own files of such documents or by providing copies to the Inspector.

A-302.14 Inspection of Safety and Safety Relief Valves

A-302.14.1 Inspection of safety and safety relief valves shall be by designated representative of the ASME, as described in PG-73.3.

A03 **A-302.14.2** The written description of the quality control system shall include reference to the CI and the ASME designee.

A-302.14.2.1 The valve Manufacturer (or assembler) shall make available to the ASME designee at the Manufacturer's plant a current copy of the written description of the applicable quality control system.

A-302.14.2.2 The valve Manufacturer's (or assembler's) quality control system shall provide for the ASME designee to have access to all drawings, calculations, specifications, procedures, process sheets, repair procedures, records, test results, and any other documents as necessary for the designee to perform his duties in accordance with this Section. The Manufacturer may provide such access either to his own files of such documents or by providing copies to the designee.

A-310 ACCEPTANCE OF TESTING LABORATORIES AND AUTHORIZED OBSERVERS FOR CAPACITY CERTIFICATION OF SAFETY AND SAFETY RELIEF VALVES

A-311 Scope

These rules cover the requirements for ASME acceptance of testing laboratories and Authorized Observers for conducting capacity certification tests of safety and safety relief valves.

A-312 Test Facilities and Supervision A03

The tests shall be conducted at a place where the testing facilities, methods, procedures, and person supervising the tests (Authorized Observer) meet the applicable requirements of ASME PTC 25-2001, Pressure Relief Devices. The tests shall be made under the supervision of and certified by the Authorized Observer. The testing facilities, methods, procedures, and the qualifications of the Authorized Observer shall be subject to the acceptance of the ASME Boiler and Pressure Vessel Committee on recommendation of an ASME designee. Acceptance of the testing facility is subject to review within each 5 year period. The testing laboratory shall have available for reference a copy of ASME PTC 25-2001 and Section I.

A-313 Acceptance of Testing Facility A03

Before recommendation is made to the ASME Boiler and Pressure Vessel Committee on the acceptability of a testing facility, an ASME designee shall review the applicant's quality control system and testing facility, and shall witness test runs. Before a favorable recommendation can be made to the Committee, the testing facility must meet all applicable requirements of ASME PTC 25-2001. Uncertainty in final flow measurement results shall not exceed ±2%. To determine the uncertainty in final flow measurements, the results of flow tests on an object tested at the applicant's testing laboratory will be compared to flow test results on the same object tested at the National Board Testing Laboratory.

A-314 Quality Control System of Testing Laboratory A03

The applicant shall prepare a Quality Control Manual describing his quality control system which shall clearly establish the authority and responsibility of those in

charge of the quality control system. The manual shall include a description of the testing facility, testing arrangements, pressure, size and capacity limitations, and the testing medium used. An organization chart showing the relationship among the laboratory personnel is required to reflect the actual organization.

The Quality Control Manual shall include, as a minimum, the applicable requirements of this Section and ASME PTC 25-2001, including but not limited to, a description of the Quality Control Manual and document control, the procedure to be followed when conducting tests, the methods by which test results are to be calculated, how test instruments and gages are to be calibrated, and methods of identifying and resolving nonconformities. Sample forms shall be included. If testing procedure specifications or other similar documents are referenced, the Quality Control Manual shall describe the methods of their approval and control.

A03 **A-315 Testing Procedures**

(a) Flow tests shall be conducted at the applicant's facility, including the testing of one or more valves and other flow devices (nozzle orifice or other object with a fixed flow path) in accordance with the methods specified by this Section and ASME PTC 25-2001. The capacity of the devices to be tested shall fall within the testing capability of the laboratory being evaluated and the National Board Testing Laboratory. The ASME designee will observe the procedures and methods of tests, and the recording of results.

(b) The devices tested at the applicant's facility will then be tested at the National Board Testing Laboratory in Columbus, Ohio, to confirm the test results obtained. Agreement between the results of the two laboratories shall be within ±2%. The purpose of comparing test results at the two laboratories is not only to check procedures but also all test instruments and equipment of the applicant's facility over the capacity and pressure range proposed. Since the capabilities of each laboratory are different, no specific number of tests can be predetermined. The number will be in accordance with the flow capability and measurement techniques available at the laboratory being evaluated. Provided the above tests and comparisons are found acceptable, the ASME designee will submit a report to the Society recommending the laboratory be accepted for the purpose of conducting capacity certification tests. If a favorable recommendation cannot be given, the ASME designee will provide, in writing to the Society, the reasons for such a decision.

A-316 Authorized Observers

An ASME designee shall review and evaluate the experience and qualifications of persons who wish to be designated as Authorized Observers. Following such review and evaluation the ASME designee shall make a report to the Society. If a favorable recommendation is not made, full details shall be provided in the report.

Persons designated as Authorized Observers by the ASME Boiler and Pressure Vessel Committee shall supervise capacity certification tests only at testing facilities specified by the Committee.