Design of Fittings

2.2 Design of Fittings

2.2.1 Acceptable Design Methods. The design of fittings shall be established by one of the following methods:

(a) mathematical analyses contained in nationally recognized pressure vessel or piping codes (e.g., ASME B31.3 para. 304.2 for elbows and para. 304.3 for tees).

(b) proof testing in accordance with section 9 of this Standard.

(c) experimental stress analysis, such as described in ASME BPVC, Section VIII, Division 2, Annex 5.F with validation of results. Hydrostatic testing can be used to validate experimental results.

(d) detailed stress analysis (e.g., finite element method) with results evaluated as described in ASME BPVC, Section VIII, Division 2, Part 5 with validation of results. Strain measurement, photoelastic testing, or hydrostatic testing can be used to validate calculated results.

2.2.2 Design Thickness. To meet design or manufacturing requirements, it is expected that some portion of formed fittings may have to be thicker than the pipe wall with which the fitting is intended to be used. The mathematical analyses, if used, may take into account such thicker sections.

2.2.3 Records. Copies of English-language records of the mathematical analysis, the successful proof test, or both shall be made available to the purchaser or regulatory authority upon request.

3 SIZE

NPS, followed by a dimensionless number, is the designation for nominal fitting size. NPS is related to the reference nominal diameter, DN, used in international standards. The relationship is, typically, as follows:

<table>
<thead>
<tr>
<th>DN</th>
<th>NPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>½</td>
</tr>
<tr>
<td>20</td>
<td>¾</td>
</tr>
<tr>
<td>25</td>
<td>1</td>
</tr>
<tr>
<td>32</td>
<td>1¼</td>
</tr>
<tr>
<td>40</td>
<td>1½</td>
</tr>
<tr>
<td>50</td>
<td>2</td>
</tr>
<tr>
<td>65</td>
<td>2½</td>
</tr>
<tr>
<td>80</td>
<td>3</td>
</tr>
<tr>
<td>100</td>
<td>4</td>
</tr>
</tbody>
</table>

NOTE: For NPS > 4, the equivalence is DN = 25 × NPS.

4 MARKING

4.1 Standard Marking

Each fitting shall be permanently marked to show the following:

(a) manufacturer’s name or trademark

(b) material identification, either the ASTM or ASME grade designation

(c) wall-thickness identification, schedule number, or nominal wall thickness in mm (in.)

(d) size — the nominal pipe size (NPS) identification number related to the end connections shall be used

(e) compliance — see para. 4.4 for standard and special fitting marking

A manufacturer may supplement these mandatory markings with others, including a DN size designation, but confusion with the required marking shall be avoided.

4.2 Exceptions

Where the size of the fitting does not permit complete marking, the identification marks may be omitted in reverse of the order presented in para. 4.1.

4.3 Depth of Stamping

Where steel stamps are used, care shall be taken so that the marking is not deep enough or sharp enough to cause cracks or to reduce the wall thickness of the fitting below the minimum allowed.

4.4 Compliance

4.4.1 Standard Fittings. That the fitting was manufactured in conformance with this Standard, including all dimensional requirements, is certified by a prefix “WP” in the material grade designation marking.

4.4.2 Special Fittings. That the fitting was manufactured in conformance with this Standard, except that dimensional requirements are as agreed between the purchaser and the manufacturer, is certified by a supplementary suffix to the material grade designation marking as follows:

(a) “S58” of ASTM A960 applies for fittings in accordance with ASTM A234, ASTM A403, and ASTM A420, and ASTM A815.

(b) “S8” applies for fittings in accordance with ASTM A815.

(c) “SPLD” applies for fittings in accordance with ASTM B361, ASTM B363, and ASTM B366.

1 Schedule number is a dimensionless number that is widely used as a convenient designation for use in ordering pipe and fittings. It is normally associated with a group of standardized pipe wall thicknesses. Refer to ASME B36.10M and ASME B36.19M for complete details on pipe schedule numbers. The wall-thickness identifications Standard (STD), Extra-Strong (XS), and Double Extra-Strong (XXS) or schedule number as described in ASME B36.10M and ASME B36.19M.
5 MATERIAL

Wrought fittings covered by this Standard shall be in accordance with ASTM A234, ASTM A403, ASTM A420, ASTM A815, ASTM B361, ASTM B363, ASTM B366, or the corresponding specification listed in ASME BPVC, Section II. The term “wrought” denotes fittings made of pipe, tubing, plate, or forgings. For purposes of determining proof testing requirements of section 9, the materials are grouped by similar properties as shown in Table 5-1.

Fittings made from block forgings may only be supplied subject to agreement between the manufacturer and purchaser. Such fittings need not meet the requirements of section 7.

6 FITTING DIMENSIONS

6.1 General

This Standard provides for a fixed position for the welding ends with reference to either the centerline of the fittings or the overall dimensions. Dimensional requirements for these fittings are in Tables 6.1-1 through 6.1-11.

6.2 Special Optional Dimensions

6.2.1 Fatigue Loading. For applications where fatigue loading is a concern, required minimum dimensions shall be furnished by the purchaser.

6.2.2 Bore Diameter. Bore diameters away from the ends are not specified. If special flow path requirements are needed, the bore dimensions shall be specified by the purchaser.

6.2.3 Stub Ends. Service conditions and joint construction often dictate stub end length requirements. Therefore, the purchaser must specify long or short pattern fitting when ordering. [See General Note (b) in Table 6.1-9.]

6.2.4 Segmental Elbows. Factory-made segments of short radius, long radius, and 3D radius elbows may be made to meet customer angle requirements. With the exception of the B dimension, factory-made segments of elbows shall meet all other requirements of this Standard. The B dimension for segmented elbows can be calculated as follows:

\[ B_s = A \times \tan(\theta/2) \]

where

- \( A \) = dimension A for appropriate 90-deg elbow being segmented from
  - (a) Table 6.1-1 for long radius elbow, mm (in.)
  - (b) Table 6.1-4 for short radius elbow, mm (in.)
  - (c) Table 6.1-6 for 3D radius elbow, mm (in.)

6.2.4.1 Center-to-end dimension for segmented elbow

When special elbows are intended for field segmenting, the outside or inside diameter tolerance shall be furnished throughout the fitting by agreement between the manufacturer and the purchaser. Any mismatch on the outside or inside diameter needs to be corrected in the field by grinding, back-welding, or bridging of weld to meet the applicable piping code requirements. Although the elbow intended for field segmenting must meet the requirements of this Standard, once the field-segmented elbow is cut, it is not a B16.9 product.

7 SURFACE CONTOURS

Where adjacent openings in fittings are not in parallel planes, they shall be joined by a circular arc or radius on the external surfaces. The arc or radius may be terminated in tangents. Except as provided for block forgings (see section 5), the projected profile of external surfaces of fittings shall not have sharp intersections (corners) and/or collapsed arcs.

8 END PREPARATION

Unless otherwise specified, the details of the welding end preparation shall be in accordance with Table 8-1. Transitions from the welding bevel to the outside surface of the fitting and from the root face to the inside surface of the fitting lying within the maximum envelope shown in Figure 8-1 are at the manufacturer’s option, except as covered in Note (5) of Figure 8-1 or unless otherwise specifically ordered.

9 DESIGN PROOF TEST

9.1 Required Tests

Proof tests shall be made as set forth in this Standard when the manufacturer chooses proof testing to qualify the fitting design. The pressure design thickness for critical areas of each type of fitting shall be determined and recorded. The design thickness for other sizes or wall thicknesses covered in para. 9.4 shall require a similar percentage of reinforcement proportional by size or thickness. Critical areas are normally the inner radius of elbows, the crotch of tees and crosses, the knuckle radius of caps, and the large ends of reducers. Proof test shall be based on the computed burst pressure of the fitting and its connecting piping as defined in para. 9.3.

9.2 Test Assembly

9.2.1 Representative Components. Each fitting type shall be tested, except that testing of certain types of fittings can qualify other fittings as described in Table
containment from the tested fitting before or during the time it is to be held at or above the computed pressure. A proof test is successful only when the fitting being tested withstands for at least 180 s a continuous proof test pressure of at least the computed minimum (see para. 9.3.2) without exhibiting loss of containment or evidence of cracking, fissuring, tearing, etc. in the fitting under test.

9.4 Applicability of Test Results

It is not necessary to conduct an individual test of fittings with all combinations of sizes, wall thicknesses, and materials. A successful proof test on one representative fitting may qualify others to the extent described in paras. 9.4.1, 9.4.2, and 9.4.3.

9.4.1 Size Range. One test fitting may be used to qualify similarly proportioned fittings as defined in para. 9.2.1 with a size range from one-half to twice that for the tested fitting.

9.4.2 Thickness Range. One test fitting may be used to qualify similarly proportioned fittings as defined in para. 9.2.1 with t/D ranges from one-half to three times that for the tested fitting.

9.4.3 Material Grades. The pressure-retaining capacity of a fitting of the same basic design configuration and method of manufacture made from material in a material group as listed in Table 5-1 will be directly proportional to the tensile properties of the materials. Therefore, it is necessary to test only a representative fitting to prove the design of a fitting for all materials in a group.

9.5 Maintenance of Results

The manufacturer shall have a quality control (QC) program that verifies the manufacturing process and material used and ensures that the resulting geometry and design thickness of the fittings or joints manufactured reasonably conform to the geometries tested. The QC program shall control the manufacturing drawings and maintain the QC records showing conformance to these drawings.

Tests made in accordance with and at the time of previous editions of this Standard are not intended to be nullified by the changes made in this edition's test procedure and requirements, provided the design conformity and criteria for the type tested can be determined and the test report, or an attachment, includes:

(a) the critical areas of design,
(b) the material grade or material group,
(c) the method of manufacture,
(d) the actual thickness of test part critical areas.

The pressure design thickness in critical areas shall be determined according to this edition of the standard.

Whenever a significant change is made in the geometry or method of manufacture, the manufacturer shall either retest the new production or show by analysis that the change would not affect the results of prior tests. Examples of changes in geometry that require retests are a change in starting thickness or revised tooling configuration.

9.6 Proof Test Report

A report of the testing for each joint configuration shall be prepared and shall include:

(a) description of the test, including the material grade, the material group, the method of manufacture, and the number of tests and f factor used to establish the target proof test
(b) instrumentation and methods of calibration used
(c) material test reports for the assembly's materials (fitting, pipe, and end caps, if used)
(d) actual final test pressures achieved for each test
(e) length of time at or above the required test pressure (see para. 9.3.4)
(f) calculations performed
(g) location of rupture, if any, including a sketch or photographs of the assembly
(h) pressure design thickness required in critical areas
(i) certification by the manufacturer and by a licensed Authorized Inspector or other third party having experience in pressure component design and testing

10 PRODUCTION TESTS

Hydrostatic testing of wrought fittings is not required by this Standard. All fittings shall be capable of withstanding, without leakage or impairment of serviceability, a hydrostatic test pressure required by the applicable piping code for seamless pipe of material equivalent to the fitting material, and of the size and wall thickness the fitting marking identifies.

11 TOLERANCES

Tolerances for fittings are shown in Table 11-1 and apply to the nominal dimensions given in Tables 6.1-1 through 6.1-11. Where given in the tables, the minimum and maximum dimensions are based on these tolerances. The listings with decimals do not imply precision measurement, such as use of vernier, micrometer, or electronic readout equipment.