8.1.3 REQUIREMENTS FOR VESSELS OF SPECIFIC CONSTRUCTION

8.1.3.1 Vessels Designed for Vacuum or Partial Vacuum Only. Vessels designed for vacuum or partial vacuum only and chambers of multi-chamber vessels designed for vacuum or partial vacuum only shall be subjected to a pressure test in accordance with 8.1.1. The internal test pressure shall not be less than $\gamma_{St/S}$ times the difference between normal atmospheric pressure and the minimum design internal absolute pressure.

8.1.3.2 Jacketed Vessels.
(a) For jacketed portions of vessels where the internal vessel is designed to operate at atmospheric pressure or vacuum conditions only, the pressure test need only be applied to the jacket volume. In such cases, the MAWP shall be set as the differential pressure between the jacket and the internal vessel for the purposes of determining the test pressure.
(b) If the jacket is designed to operate under vacuum conditions, it shall be tested in accordance with 8.1.3.1.
(c) If the jacket is designed to operate under both pressure and vacuum conditions, then it shall be tested at the greater of the pressures determined in accordance with (a) or (b).

8.1.3.3 Combination Units. Combination units shall be tested by one of the following methods
(a) Independent Pressure Chambers. Pressure chambers of combination units that have been designed to operate independently shall be hydrostatically tested as separate vessels; that is, each chamber shall be tested without pressure in the adjacent chamber. If the common elements of a combination unit are designed for a larger differential design pressure than the higher maximum allowable working pressure to be marked on the adjacent chambers, the hydrostatic test shall subject the common elements to at least their design differential pressure, corrected for temperature as described in 8.2.1(b), as well as meet the requirements of 8.2.1(a) or 8.2.1(e) for each independent chamber.
(b) Dependent Pressure Chambers. When pressure chambers of combination units have their common elements designed for the maximum differential pressure that can possibly occur during startup, operation (including upset conditions) and shutdown, and the differential pressure is less than the higher pressure in the adjacent chambers, then the common elements shall be subjected to a hydrostatic test pressure calculated using Equation (8.2), where the MAWP is the differential pressure to be marked on the unit.
   (1) Following the test of common elements as required in (a), and their inspection, the adjacent chambers shall be simultaneously tested at the test pressure required for internal pressure. Care must be taken to limit the differential pressure between the chambers to the pressure used when testing common elements.
   (2) The vessel stamping and vessel Data Report shall describe the common elements and their limiting differential pressure.

8.1.3.4 Lined Vessels.
(a) For lined vessels, a test is recommended for the pressure tightness of the applied lining that is appropriate for the intended service. Details of the test shall be a matter for agreement between the user and the Manufacturer. The test should be such as to ensure freedom from damage to the load-carrying base material. When corrosion of the base material is to be expected from contact with the contents of the vessel, particular care should be taken in devising and executing the tightness test.
(b) Following the hydrostatic pressure test, the interior of the vessel shall be inspected to determine if there is any seepage of the test fluid through the joints in the lining.
(c) When the test fluid seeps behind the applied liner, there is danger that the fluid will remain in place until the vessel is put in service. In cases where the operating temperature of the vessel is above the boiling point of the test fluid, the vessel should be heated slowly for a sufficient time to drive out all test fluid from behind the applied liner without damage to the liner. This heating operation shall be performed at the vessel manufacturing plant. After the test fluid is driven out, the lining should be repaired as required. Repetition of the radiography, the heat treatment, or the hydrostatic test of the vessel after lining repairs is not required except when there is reason to suspect that the repair welds may have defects that penetrate into the base material, in which case an Inspector shall decide which one or more shall be repeated.
(d) As an alternative to the procedure in 8.1.3.4(c), it is recommended that consideration be given to adding a weep hole at a low point in each pressure boundary component that is protected by a liner panel that is seal welded all around the panel to the pressure boundary component. These weep holes should be monitored for leakage during both testing and operation and will minimize pressure build-up behind the panels, a circumstance that could cause the panel to buckle upon release of the internal pressure in the vessel.

8.1.3.5 Layered Vessels. Pneumatic testing is not permitted when using the procedures of 4.13.12.2 to measure the contact between layers during construction.

8.1.3.6 Expansion Joints.
(a) The completed expansion joint shall be pressure tested. The pressure testing may be performed as part of the final vessel pressure test, provided the joint is accessible for inspection during pressure testing.
PART 8
PRESSURE TESTING REQUIREMENTS

8.1 GENERAL REQUIREMENTS

8.1.1 SELECTION OF PRESSURE TEST METHODS

(a) Except as otherwise permitted in (b) and (c), a completed vessel designed for internal pressure shall be subjected to a hydrostatic test performed in accordance with 8.2. Pressure tests of vessels designed for vacuum or partial vacuum only shall be tested in accordance with 8.1.3.1. A vessel shall be considered a completed vessel after:

1. All fabrication has been completed, except for operations that could not be performed prior to the test such as weld end preparation, or cosmetic grinding on the base material that does not affect the required thickness including corrosion allowance.

2. All examinations have been performed, except those required after the test.

(b) Subject to the limitations and additional nondestructive weld examination requirements that may be imposed elsewhere in this Division, a pneumatic test performed in accordance with 8.23 may be substituted for a hydrostatic test if any of the following are true.

1. The vessel is constructed and supported such that the weight of the hydrostatic test fluid could cause permanent visible distortion.

2. The vessel cannot be readily dried and is to be used in services where traces of the testing liquid cannot be tolerated.

3. The vessel is so constructed that brittle fracture is not a credible mode of failure at the pressure test conditions.

4. The pneumatic test is monitored by acoustic emission examination in accordance with Section V, Article 12.

(c) Combined hydrostatic–pneumatic tests may be substituted in cases where it is desirable to test a vessel partially filled with liquid. Combined hydrostatic–pneumatic tests shall be performed in accordance with 8.34.1.

8.1.2 PRECAUTIONS

(a) Pressure tests shall be carried out under controlled conditions with appropriate safety precautions and equipment.

(b) Vents shall be provided at all high points of the vessel in the position in which it is to be tested to allow purging possible air pocket locations while the vessel is filled for hydrostatic testing. Attention shall be given to nozzle protrusions and vessel internals.

(c) When performing a pneumatic test, particular care shall be taken to avoid brittle fracture given the potential hazards of the energy stored in the compressed gas. In this regard, the decision to perform a pneumatic test shall be considered during the design of the vessel so that the minimum design temperature/coincident pressure conditions for all pressure-boundary components, including any reduction in temperature and to a coincident reduction in pressure of the service fluid as the design pressure is released (auto-refrigeration), are considered when selecting the materials of construction.

(d) Air or gas is hazardous when used as a testing medium. It is therefore recommended that the vessel be tested in such a manner as to ensure personnel safety from a release of the total internal energy of the vessel. See also ASME PCC-2, Article 5.1, Appendix III "Safe Distance Calculations for Pneumatic Pressure Test" and Appendix B "Stored Energy Calculations for Pneumatic Pressure Test." Liquid test media may also present hazards due to the stored energy in the compressed liquid and strain energy stored in the vessel material.

(e) Unless permitted by the user or an agent acting on behalf of the user, pressure-retaining welds of vessels shall not be painted or otherwise coated either internally or externally prior to the pressure test.

1. The user or an agent acting on behalf of the user shall state in the User’s Design Specification [see 2.2.2(h)(6)] if painting or coating prior to a pressure test is permitted.

2. When painting or coating is permitted, the welds shall first be leak tested in accordance with Section V, Article 10. Such a test may be waived with the approval of the user or an agent acting on behalf of the user.
8.1.3 REQUIREMENTS FOR VESSELS OF SPECIFIC CONSTRUCTION

8.1.3.1 Vessels Designed for Vacuum or Partial Vacuum Only. Vessels designed for vacuum or partial vacuum only and chambers of multi-chamber vessels designed for vacuum or partial vacuum only shall be subjected to a pressure test in accordance with 8.1.1. The internal test pressure shall not be less than \( \gamma \) times the difference between normal atmospheric pressure and the minimum design internal absolute pressure.

8.1.3.2 Jacketed Vessels. For jacketed portions of vessels where the internal vessel is designed to operate at atmospheric pressure or vacuum conditions only, the pressure test need only be applied to the jacket volume. In such cases, the MAWP shall be set as the differential pressure between the jacket and the internal vessel for the purposes of determining the test pressure.

(b) If the jacket is designed to operate under vacuum conditions, it shall be tested in accordance with 8.1.3.1.

(c) If the jacket is designed to operate under both pressure and vacuum conditions, then it shall be tested at the greater of the pressures determined in accordance with (a) or (b).

8.1.3.3 Combination Units. Combination units shall be tested by one of the following methods

(a) Independent Pressure Chambers. Pressure chambers of combination units that have been designed to operate independently shall be hydrostatically tested as separate vessels; that is, each chamber shall be tested without pressure in the adjacent chamber. If the common elements of a combination unit are designed for a larger differential design pressure than the higher maximum allowable working pressure to be marked on the adjacent chambers, the hydrostatic test shall subject the common elements to at least their design differential pressure, corrected for temperature as described in 8.2.1(b), as well as meet the requirements of 8.2.1(a) or 8.2.1(c) for each independent chamber.

(b) Dependent Pressure Chambers. When pressure chambers of combination units have their common elements designed for the maximum differential pressure that can possibly occur during startup, operation (including upset conditions) and shutdown, and the differential pressure is less than the higher pressure in the adjacent chambers, then the common elements shall be subjected to a hydrostatic test pressure calculated using Equation (8.2) where the MAWP is the differential pressure to be marked on the unit.

(1) Following the test of common elements as required in (a), and their inspection, the adjacent chambers shall be simultaneously tested at the test pressure required for internal pressure. Care must be taken to limit the differential pressure between the chambers to the pressure used when testing common elements.

(2) The vessel stamping and vessel Data Report shall describe the common elements and their limiting differential pressure.

8.1.3.4 Lined Vessels.

(a) For lined vessels, a test is recommended for the pressure tightness of the applied lining that is appropriate for the intended service. Details of the test shall be a matter for agreement between the user and the Manufacturer. The test shall be such as to ensure freedom from damage to the load-carrying base material. When corrosion of the base material is to be expected from contact with the contents of the vessel, particular care should be taken in devising and executing the tightness test.

(b) Following the hydrostatic pressure test, the interior of the vessel shall be inspected to determine if there is any seepage of the test fluid through the joints in the lining.

(c) When the test fluid seeps behind the applied liner, there is danger that the fluid will remain in place until the vessel is put in service. In cases where the operating temperature of the vessel is above the boiling point of the test fluid, the vessel should be heated slowly for a sufficient time to drive out all test fluid from behind the applied liner without damage to the liner. This heating operation shall be performed at the vessel manufacturing plant. After the test fluid is driven out, the lining should be repaired as required. Repetition of the radiography, the heat treatment, or the hydrostatic test of the vessel after lining repairs is not required except when there is reason to suspect that the repair welds may have defects that penetrate into the base material, in which case an Inspector shall decide which one or more shall be repeated.

(d) As an alternative to the procedure in 8.1.3.4(c), it is recommended that consideration be given to adding a weep hole at a low point in each pressure boundary component that is protected by a liner panel that is seal welded all around the panel to the pressure boundary component. These weep holes should be monitored for leakage during both testing and operation and will minimize pressure build-up behind the panels, a circumstance that could cause the panel to buckle upon release of the internal pressure in the vessel.

8.1.3.5 Layered Vessels. Pneumatic testing is not permitted when using the procedures of 4.13.12.2 to measure the contact between layers during construction.

8.1.3.6 Expansion Joints.

(a) The completed expansion joint shall be pressure tested. The pressure testing may be performed as part of the final vessel pressure test, provided the joint is accessible for inspection during pressure testing.
8.1.4 PRESSURE GAGES

(a) Pressure gauges used in testing vessels shall be indicating pressure gauges and shall be connected directly to the vessel. If the indicating gage is not readily visible to the operator controlling the pressure applied from a safe location, an additional indicating gage shall be provided where it will be visible to the operator and Inspector throughout the duration of the test. It is recommended that a recording gage be used in addition to the indicating gage.

(b) Dial indicating pressure gauges used in testing shall be graduated over a range of about two times the maximum intended test pressure, but in no case shall the range be less than one and one-half times nor more than four times the intended test pressure. Digital reading pressure gauges having a wider range may be used, provided the readings give the same or a greater degree of accuracy than obtained with dial pressure gauges.

(c) All gages shall be calibrated against a standard deadweight tester or a calibrated master gage at least every 6 months or at any time there is a reason to believe that they are in error.

8.2 HYDROSTATIC TESTING

8.2.1 TEST PRESSURE

(a) Except as noted for vessels of specific construction identified in 8.1.3 or enameled vessels whose test pressure shall be at least the MAWP to be marked on the vessel, the minimum hydrostatic test pressure shall be the greater of computed from eq. (8.1) or eq. (8.2), where \( p_{\text{min}} \) and \( p_{\text{St/S}} \) shall be obtained from Table 4.1.3 for the applicable test medium and the applicable class.

\[
P_T = \min \left[ \frac{p_{\text{min}} \cdot \text{MAWP}}{S} \right]
\]

(b) The ratio \( S_p/S \) in eq (8.1) shall be the lowest ratio for the pressure-boundary materials, excluding bolting materials, of which the vessel is constructed.

(c) The test pressure is the pressure to be applied at the top of the vessel during the test. This pressure plus hydrostatic head, if applicable, is used in the applicable design equations to check the vessel under test conditions.

(d) The test pressure is the pressure to be applied at the top of the vessel during the test. This pressure plus hydrostatic head, if applicable, is used in the applicable design equations to check the vessel under test conditions.

8.2.2 PREPARATION FOR TESTING

Prior to testing, test equipment shall be examined to ensure that it is tight and all filling lines and other...
appurtenances that should not be subjected to the test pressure have been disconnected or isolated by valves or other suitable means.

Before applying test pressure, the test equipment shall be inspected to see that it is tight and that all low-pressure filling lines and other appurtenances that should not be subjected to the test pressure have been disconnected or isolated by valves or other suitable means.
8.2.3 TEST FLUID

(a) Any liquid, nonhazardous at any temperature, may be used for hydraulic testing if below its boiling point. Combustible liquids having a flash point less than 45°C (110°F) such as petroleum distillates, may be used only for atmospheric temperature tests.

(b) Any pressurizing medium used in pneumatic testing shall be nonflammable and nontoxic. When compressed air is used for a pressure test, the following should be considered:

1. The only class, dry, oil-free air meeting the requirements of Class 1, 2, or 3 air per ISO 8573.
2. The dew point of the air should be between −20°C to −70°C (−4°F to −94°F).
3. Verification that there is no hydrocarbon contamination or other organic residue within the vessel since this could result in the formation of an explosive mixture.

8.2.4 TEST PROCEDURES

(a) The metal temperature during a hydraulic pressure test shall be maintained at least 17°C (30°F) above the minimum design metal temperature of the vessel, but need not exceed 50°C (120°F), to minimize the risk of brittle fracture.

(b) The test pressure shall not be applied until the vessel and the test fluid are at about the same temperature.

(c) The test pressure shall be gradually increased until one-half of the test pressure is reached after which the test pressure shall be increased in steps of approximately one-tenth of the test pressure until the test pressure has been reached. The pressure shall then be reduced to a value not less than the test pressure divided by \( \gamma_{St/S} \) before examining for leakage in accordance with 8.2.5.

8.2.5 TEST EXAMINATION AND ACCEPTANCE CRITERIA

(a) Following the reduction of the test pressure to the level indicated in (8.2.4(c), a visual examination for leaks shall be made by the Inspector of all joints and connections and of all regions of high stress such as knuckles of formed heads, cone-to-cylinder junctions, regions around openings, and thickness transitions. Visual examination of the vessel may be waived, provided all of the following requirements are satisfied:

1. A suitable gas leak test is applied, 8.32.2.
2. Substitution of the gas leak test is by agreement between the Manufacturer and Inspector.
3. All welded seams that will be hidden by assembly are given a visual examination for workmanship prior to assembly.

(b) Any leaks that are present, except for that leakage that may occur at temporary test closures for those openings intended for welded connections, shall be corrected and the vessel shall be retested.

(c) The Inspector shall reserve the right to reject the vessel if there are any visible signs of permanent distortion.

8.3 PNEUMATIC TESTING

8.3.1 TEST PRESSURE

(a) Except for enameled vessels whose test pressure shall be at least the MAWP to be marked on the vessel, the minimum pneumatic test pressure shall be the greater of eq. (8.3) or eq. (8.4), where \( P_{TP} \) and \( P_{MB} \) shall be obtained from Table 8.1.3 for the pneumatic test medium and the applicable class.

\[
P_{TP} = \frac{P_{MB}}{\gamma_{St/S}}
\]

(b) The ratio \( S/S \) in eq. (8.4) shall be the lowest ratio for the pressure boundary materials, except bolting materials, of which the vessel is constructed.

(c) The requirements of (a) represent the minimum required pneumatic test pressure required by this Division. The upper limits of this test pressure can be determined using the method in 8.1.2, 9.2.2.5, 9.2.3.6, or 5.2.4. Any intermedrate value may be used.

8.3.2 PREPARATION FOR TESTING

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Prior to testing, test equipment shall be examined to ensure that it is tight and all filling lines and other appurtenances that should not be subjected to the test pressure have been disconnected or isolated by valves or other suitable means.

8.3.3 TEST FLUID

Any pressurizing medium used in pneumatic testing shall be nonflammable and nontoxic. When compressed air is used for a pressure test, the following should be considered:

(a) Use only clean, dry, oil-free air meeting the requirements of Class 1, 2, or 3 in per ISO 8573-1.

(b) The dew point of the air should be between −20°C to −70°C (-4°F to -94°F).

(c) Verification that there is no hydrocarbon contamination or other organic residue within the vessel since this could result in the formation of an explosive mixture.
8.3.4 TEST PROCEDURES

(a) The metal temperature during a pneumatic test shall be maintained at least 17°C (30°F) above the minimum design metal temperature to minimize the risk of brittle fracture.

(b) The test pressure shall not be applied until the vessel and the test fluid are at about the same temperature.

(c) Test pressure shall be gradually increased until one-half of the test pressure is reached after which the test pressure shall be increased in steps of approximately one-tenth of the test pressure until the test pressure has been reached. The pressure shall then be reduced to a value not less than the test pressure divided by 1.15 before examining for leakage in accordance with 8.3.5.

8.3.5 TEST EXAMINATION AND ACCEPTANCE CRITERIA

(a) Following the reduction of the test pressure to the level indicated in 8.3.4(c), the reduced pressure shall be held for sufficient time to allow a visual examination for leakage. This visual examination shall be made, and the Inspector shall witness the examination. Visual examination of the vessel may be waived provided:

1. a suitable gas leak test is applied, see 8.4.2,

2. substitution of the gas leak test is by agreement between the Manufacturer and Inspector,

3. all welded seams that will be hidden by assembly are given a visual examination for workmanship prior to assembly.

(b) Any leaks that are present, except for that leakage that may occur at temporary test closures for those openings intended for welded connections, shall be corrected and the vessel shall be retested.

(c) The Inspector shall reserve the right to reject the vessel if there are any visible signs of permanent distortion.

8.3 ALTERNATIVE PRESSURE TESTING

8.3.1 HYDROSTATIC–PNEUMATIC TESTS

In cases where it is desirable to pressure test a vessel partially filled with liquid, the requirements of 8.23 shall be met, except the pneumatic pressure applied above the liquid level shall at no point result in a total pressure that causes the general membrane stress to exceed 80% of the specified minimum yield strength of the material at test temperature.

8.3.2 LEAK TIGHTNESS TESTING

(a) Leak tightness tests include a variety of methods of sufficient sensitivity to allow for the detection of leaks in pressure elements, including, but not limited to the use of direct pressure and vacuum bubble test methods, and various gas detection tests.

(b) The selection of a leak tightness test to be employed should be based on the suitability of the test for the particular pressure element being tested.

(c) The metal temperature for leak tightness tests shall be in accordance with 8.24(a). Additionally, the temperature shall be maintained within the specified range for the test equipment being used.

(d) Leak tightness tests shall be performed in accordance with Section V, Article 10.

8.4 DOCUMENTATION

For all pressure tests, as a minimum, the following data shall be recorded by the Manufacturer and shall be issued as part of the vessel’s Data Report:

(a) Vessel Manufacturer and identification of the pressure vessel

(b) Name of Authorized Inspection Agency

(c) Type of test (hydrostatic, pneumatic, hydrostatic–pneumatic)

(d) Test pressure at the top of the vessel in the test position

(e) Position of the vessel (horizontal, vertical, normal operating)

(f) Test fluid and temperature

(g) Date of pressure test

(h) If a written pressure test procedure is followed, reference shall be made to this procedure.

8.5 NOMENCLATURE

MAWP = maximum allowable working pressure.
sure.
$S$ = allowable stress from Annex 3-A evaluated at the design temperature.
$S_t$ = allowable stress from Annex 3-A evaluated at the test temperature.
$\beta_T$ = test load factor for hydrostatic or pneumatic test and for Class 1 or Class 2 construction (see Table 4.1.3)
$\gamma_{\min}$ = minimum test load factor for hydrostatic or pneumatic test and for Class 1 or Class 2 construction (see Table 4.1.3)
$\gamma_{S/S_t}$ = test load factor considering the ratio of the allowable stress at the test condition to the allowable stress at the design condition for hydrostatic or pneumatic test and for Class 1 or Class 2 construction (see Table 4.1.3)