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PV Newsletter

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Part UG - General Requirements for All Methods of Construction and All Materials

The requirements of Part UG are applicable to all pressure vessels and vessel parts and are to be used in conjunction with specific requirements in Subsections B and C and the Mandatory Appendices that pertain to the methods of fabrication and the material used.

UG-16 Design

Minimum Thickness of Pressure Retaining Components

The minimum thickness permitted for shells and heads after forming and regardless of product form and material shall be 1.5 mm (1/16 in) exclusive of any corrosion allowance. Exceptions are:

1. The minimum thickness does not apply to heat transfer plates of plate-type heat exchangers
2. This minimum thickness does not apply to the inner pipe of double pipe heat exchangers nor to pipes and tubes that are enclosed and protected from mechanical damage by a shell, casing or ducting, where such pipes or tubes are DN 150 (NPS 6) or less. (All other pressure parts of these heat exchangers must meet the minimum thickness requirement)
   Note: This exemption applies whether or not the outer pipe, shell or protective element is constructed to Code rules. When the outer protective element is not provided by the manufacturer as part of the vessel, the Manufacturer shall note this on the Manufacturer's Data Report. When pipes and tubes are fully enclosed, consideration shall be given to avoiding buildup of pressure within the protective chamber due to pipe/ tube leak.
3. The minimum thickness of shells and heads of unfired steam boilers shall be 6 mm (1/4 in) exclusive of any corrosion allowance
4. The minimum thickness of shells and heads used in compressed air service, steam service, and water service, made from one of the carbon and low alloy steel materials listed in Table UCS-23, shall be 2.5 mm (3/32 in) exclusive of any corrosion allowance
5. This minimum thickness does not apply to the tubes in air cooled and cooling tower heat exchangers if all the following provisions are met:
   a. Tubes shall not be used for lethal service applications ("*lethal substances" are defined as poisonous gases or liquids of such a nature that a very small amount of gas or of the vapour of the liquid mixed or unmixed with air is dangerous to life when inhaled*)
   b. The tubes shall be protected by fins or other mechanical means
   c. The tube outside diameter shall be a minimum of 10 mm (3/8 in) and a maximum of 38 mm (1 ½ in)
   d. The minimum thickness used shall not be less than that calculated by formulas in UG-27 or in Appendix 1-1, and in no case less than 0.5 mm (0.022 in)

Mill Undertolerance

Plate material shall be ordered not thinner than the design thickness. Vessels made of plate furnished with an under-tolerance of not more than the smaller value of 0.25 mm (0.01 in) or 6% of the ordered thickness may be used at the full design pressure for the thickness ordered.

If the specification to which the plate is ordered allows a greater undertolerance, the ordered thickness of the materials shall be sufficiently greater than the design thickness so that the thickness of the material furnished is not more than the smaller of 0.25 mm (0.01 in) or 6% under the design thickness.

Pipe Undertolerance

If pipe or tube is ordered by its nominal wall thickness, the manufacturing undertolerance on wall thickness must be taken into account except for nozzle wall reinforcement area requirements. After the minimum wall thickness is determined, it shall be increased by an amount sufficient to provide the manufacturing undertolerance allowed in the pipe or tube specification.

UG-17 Methods of Fabrication in Combination

A vessel may be designed and constructed by a combination of methods of fabrication given in the Code provided the rules applying to the respective methods of fabrication are followed and the vessel is limited to service permitted by the method of fabrication having the most restrictive requirement.

UG-18 Materials in Combination

A vessel may be designed and constructed of any combination of materials permitted in Subsection C, provided the applicable rules are followed and requirements for welding dissimilar metals are met.

For example, if a carbon steel base metal is joined to a stainless steel base metal with a nickel filler metal, the rules of Part UCS apply to the carbon steel base metal and its HAZ (heat affected zone), Part UHA to stainless steel base metal and its HAZ, and Part UNF to the weld metal.

Because of different thermal coefficients of expansion of dissimilar materials, caution should be exercised in design and construction in order to avoid difficulties in service under extreme temperature conditions, or with unusual restraint of parts such as may occur at points of stress concentration and also because of metallurgical changes occurring at elevated temperatures.

UG-19(a) Combination Units

A combination unit is a pressure vessel that consists of more than one independent pressure chamber, operating at the same or different pressures and temperatures. The parts separating each independent pressure chamber are the common elements. Each element, including the common elements, should be designed for at least the most severe condition of coincident pressure and temperature expected in normal operation.

Design of Common Element

Provided that the vessel is installed in a system that controls the common element design conditions, each common element can be designed for:

A differential pressure less than the maximum of design pressures of its adjacent chambers (differential pressure design),
OR
A mean metal temperature less than the maximum of design temperatures of its adjacent chambers (mean metal temperature design),
OR
both

Differential Pressure Design:

When differential pressure design is permitted, the common element design pressure shall be the maximum differential design pressure expected between the adjacent chambers. The differential pressure shall be controlled to ensure the common element design pressure is not exceeded. The common element and its corresponding differential pressure shall be indicated in the "Remarks" section of the Manufacturer's Data Report and marked on the vessel.

Mean Metal Temperature Design:

When mean metal temperature design is permitted, the maximum common element design temperature may be less than the greater of the maximum design temperatures of its the adjacent chambers; however, it shall not be less than the lower of the maximum design temperatures of its adjacent chambers. The fluid temperature, flow and pressure shall be controlled to ensure that the common element design temperature is not exceeded. The common element and its corresponding design temperature shall be indicated in the "Remarks" section of the Manufacturer's Data Report and marked on the vessel.

UG-19(b) Special Shapes

Vessels other than cylindrical and spherical and for those for which no design rules are provided in this Code may be designed under the conditions set forth in U-2.

UG-19(c) No Design Rules

When no design rules are given and the strength of the pressure vessel or the vessel part cannot be determined with a satisfactory assurance of accuracy, the maximum allowable working pressure of the completed vessel shall be established in accordance with the provisions of UG-101.

UG-20 Design Temperature

The maximum temperature used in design shall not be less than the mean metal temperature (through the thickness) expected under operating conditions for the part considered. If necessary, the metal temperature shall be determined by computation or by measurement from equipment in service under equivalent operating conditions.

The minimum metal temperature used in design shall be lowest expected in service. The minimum mean metal temperature shall be determined by methods similar to those employed for determining the maximum temperature. Consideration shall include the lowest operating temperature, operational upsets, auto-refrigeration, atmospheric temperature, and any other sources of cooling. The MDMT marked on the nameplate shall correspond to a coincident pressure equal to MAWP.

Design temperatures that exceed the temperature limit in the applicability column shown in Section II, Part D, Subpart 1, Tables, 1A, 1B and 3 are not permitted. In addition, design temperatures for vessels under external pressure shall not exceed the maximum temperatures given on the external pressure charts.

The design of zones with different metal temperatures may be based on their determined temperatures.

Suggested methods for obtaining operating temperature of the vessel walls in service are given in Appendix C of the Code.

Impact test is a test designed to give information on how a specimen of a known material will a suddenly applied stress, e.g. shock. The Charpy test ascertains whether the material is tough or brittle. A notched test piece is generally employed and the result is generally reported as the energy required to fracture the test piece.

The Code provides rules for impact tests in the paragraph UG-84.

Impact testing is not required for pressure vessel materials that satisfy all of the following:

1. The material is limited to P-No. 1, Gr. No. 1 or 2, and the thickness shall not exceed that given below:
    a. 13 mm (½ in) for materials listed in Curve A of Fig. UCS-66

b. 25 mm (1 in) for materials listed in Curve B, C, or D of Fig. UCS-66

2. The completed vessel is hydrostatically tested.
3. Design temperature is no warmer than 345°C (650°F) nor colder than -29°C (-20°F). Occasional temperature colder than -29°C (-20°F) are acceptable when due to lower seasonal atmospheric temperature.
4. The thermal or mechanical shock loadings are not a controlling design requirement.
5. Cyclic loading is not a controlling design requirement.

To reduce the number of welding and brazing procedure qualifications required, base metals have been assigned P-Numbers by ASME BPVC. Ferrous metals which have specified impact test requirements have been assigned Group Numbers within P-Numbers.

Carbon steels have been assigned P. No.1 .

UG-21 Design Pressure

Each element of a pressure vessel shall be designed for at least the most severe condition of coincident pressure and temperature expected in normal operation. For this condition, the maximum difference in pressure between the inside and outside of a vessel, or between any two units of a combination unit, shall be considered.

UG-22 Loadings

The loadings to be considered in designing a vessel shall include those from:

a. Internal or external design pressure
b. Weight of the vessel and normal contents under operating or test conditions
c. Superimposed static reactions from weight of attached equipment, such as motors, machinery, other vessels, piping, linings and insulation
d. The attachment of
    1. Internals
    2. Vessel supports such as lugs, rings, skirts, saddles, and legs
e. Cyclic and dynamic reactions due to pressure or thermal variations, or from equipment mounted on a vessel and mechanical loadings
f. Wind, snow and seismic reactions, where required
g. Impact reactions such as those due to fluid shock
h. Temperature gradients and differential thermal expansion
i. Abnormal pressures such as those caused by deflagration
j. Test pressure and coincident static head acting during the test

UG-23 Maximum Allowable Stress Values

a. The maximum allowable stress value is the maximum unit stress permitted in a given material used in a pressure vessel constructed according to the rules of this Code. The maximum allowable tensile stress values permitted for different materials are given in Subpart 1 of Section II, Part D.
A listing of these materials is given in the following tables, which are included in Subsection C:

Table UCS-23 Carbon and Low Alloy Steels (stress values in Section II-D, Table 3 for bolting and Table 1A for other carbon steels)

Table UNF-23 Nonferrous metals (stress values in Section II-D, Table 3 for bolting and Table 1B for other nonferrous metals)

Table UHA-23 High Alloy Steel (stress values in Section II-D, Table 3 for bolting and Table 1A for other high alloy steels)

Table UCI-23 Maximum Allowable Stress Values in Tension for Cast Iron

Table UCD-23 Maximum Allowable Stress Values in Tension for Cast Ductile Iron

Table UHT-23 Ferritic Steels with Properties Enhanced by Heat Treatment (stress values in Section II-D, Table 1A)

Table ULT-23 Maximum Allowable Stress Values in Tension for 5%, 8% and 9% Nickel Steels and 5083-0 Aluminium Alloy at Cryogenic Temperatures for Welded and Nonwelded Construction

b. The maximum allowable longitudinal compressive stress to be used in design of cylindrical shells or tubes, either butt welded or seamless, subjected to loadings that produce longitudinal compression in the shell or tube shall be the smaller of following values:

1. The maximum allowable tensile stress value permitted for the material
2. The value of factor B determined by following procedure:

Step 1: Using the selected values of t (minimum required thickness of cylinder or tube) and R_o (outside radius of the cylinder or tube), calculate the value of factor A using the formula:

$$A = 0.125/ (R_o/t)$$

Step 2: Using this value of A, enter the applicable material chart in Section II-D, Subpart 3 for the material under consideration. Move vertically to an intersection with the material/ temperature line for the design temperature. Interpolation may be used between lines for intermediate temperatures. [*See chart below*]

If tabular values are used, linear interpolation may be used to determine a B value that lies between two adjacent tabular values for a specific temperature. Such interpolation may also be used to determine a B value at an intermediate temperature that lies between two sets of tabular values, after first determining B values for each set of tabular values.

In cases where the value at A falls to the right of the end of material/ temperature line, assume an intersection with the horizontal projection of the upper end of the material/ temperature line. If tabular values are used, the last (maximum) tabulated value shall be used. For values of A falling to the left of the material/ temperature line, see Step 4.

Step 3: From the intersection obtained in Step 2, move horizontally to the right and read the value of factor B. This is the maximum allowable compressive stress for the values of t and R_o used in Step 1.

Step 4: For the values of A falling to the left of applicable material/ temperature line, the value of B shall be caluclated using the follwing formula:

$B = AE/2$ E = modulus of elasticity of material at design temperature

If tabulated values are used, determine B as in Step 2 and apply it to the equation in Step 4.

Step 5: Compare the value of B determined in Steps 3 or 4 with the computed longitudinal compressive stress in the cylindrical shell or tube, using the selected values of t and R_o. If the value of B is smaller than the computed compressive stress, a greater value of t must be selected and the design procedure repeated until a value of B is obtained that is greater than the compressive stress computed for the loading on the cylindrical shell or tube.

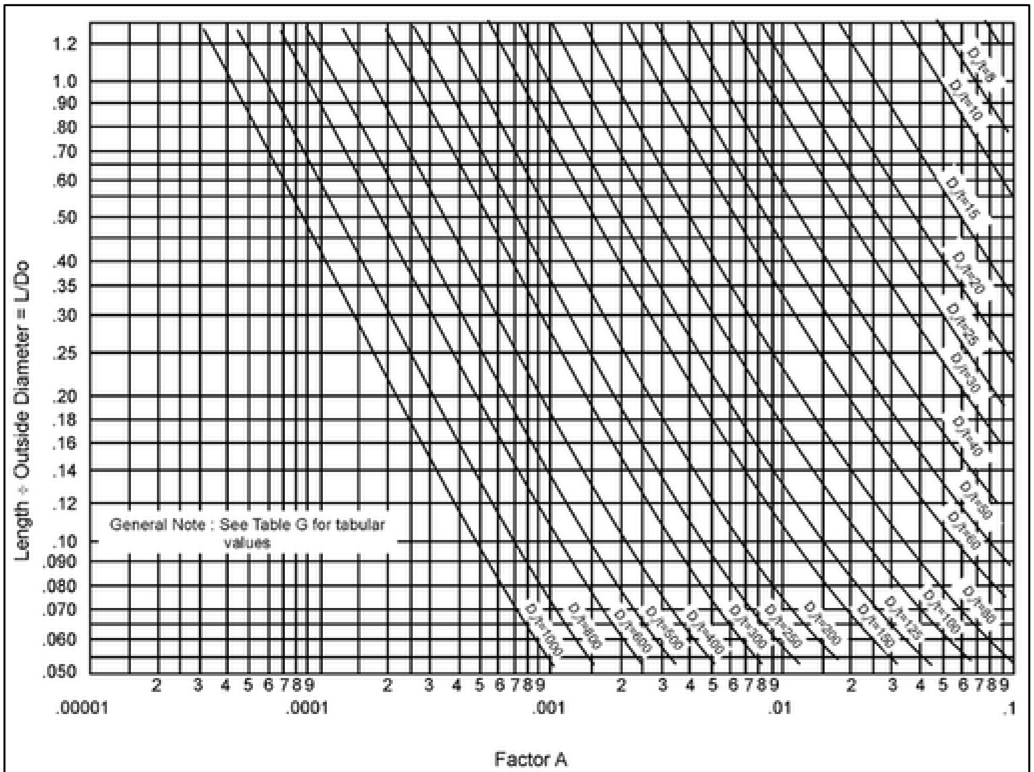

Figure. G Geometric Chart for Components Under External or Compressive Loadings (for All Materials)

c. The wall thickness of a vessel computed by these rules shall be determined such that, for any combination of loadings listed in UG-22 that induce primary stress and are expected to occur simultaneously during normal operation of the vessel, the induced maximum general primary membrane stress does not exceed the maximum allowable stress value in tension. The above loads shall not induce a combined maximum primary membrane stress plus primary bending stress across the thickness that exceeds 1 ½ times the maximum allowable stress value in tension. It is recognized that high localized discontinuity stress may exist in vessels designed and fabricated in accordance with this Code. Insofar as practical, design rules for details have been written to limit such stresses to a safe level consistent with experience.

Primary Stress: The stresses applied more or less continuously and uniformly across an entire section of the vessel are primary stresses.

Primary Membrane Stress: When thickness is small in comparison with other dimensions ($R_m/t > 10$), vessels are referred to as membranes and the associated stresses resulting from the contained pressure are called membrane stresses. These membrane stresses are the average tension or compression stresses. They are assumed to be uniform across the vessel wall and act tangentially to its surface. The membrane or the wall is assumed to offer no resistance to bending. The stresses due to pressure and wind are primary membrane stresses. These stresses should be limited to the Code allowables.

General Primary Membrane Stress: This stress occurs across the entire cross ection of the vessel. It is remote from the discontinuities such as head-shell intersections, cone-cylinder intersections, nozzles and supports. Examples are:

1. Circumferential and longitudinal stress due to pressure
2. Compressive and tensile axial stresses due to wind
3. Longitudinal stress due to bending of the horizontal vessel over the saddles
4. Membrane stress in the center of the flat head

5. Membrane stress in the nozzle wall within the area of reinforcement due to pressure or external loads
6. Axial compression due to weight

Primary Bending Stress: These stresses are due to sustained loads and are capable of causing collapse of the vessel. There are relatively few areas where primary bending occurs:

1. Bending stress in the center of flat head or crown of a dished head
2. Bending stress in a shallow conical head
3. Bending stress in the ligaments of closely spaced openings

d. For combination of earthquake loading, or wind loading with other loadings in UG-22, the wall thickness of a vessel computed by these rules shall be determined such that the general primary membrane stress shall not exceed 1.2 times the maximum allowable stress permitted permitted in a), b) and c) above. This rule is applicable to stresses caused by internal pressure, external pressure, and axial compressive load on a cylinder.

   Earthquake loading and wind loading need not be considered to act simultaneously.

e. Localized discontinuity stresses are calculated in Appendix 1, 1-5(g) and 1-8(e), Part UHX, and Appendix 5. The primary plus secondary stresses at these discontinuities shall be limited to S_{PS}, where S_{PS} = 3S, and S is the maximum allowable stress at the temperature.
   In lieu of using S_{PS} = 3S, a value of S_{PS} = 2S_Y may be used, where S_Y is the yield strength at temeprature, if the following conditions are met:

   1. The allowable stress of the material S is not governed by time-dependent properties as provided in Tables 1A or 1B of Section II-D
   2. The room temperature ratio of the specified minimum yield strength to specified minimum tensile strength for the material does not exceed 0.7
   3. The value for S_Y at temperature can be obtained from Table Y-1 of Section II-D

UG-24 Castings

Part UCI of the Code provides the requirements for pressure vessels constructed of cast iron, and Appendix 7 of the Code covers examination requirements for all steel castings.

Quality Factors:

A casting quality factor as indicated below shall be applied to the allowable stress values for cast materials given in Subsection C. At a welded joint in casting, only the lesser of the casting quality factor or the weld joint efficiency applies, but not both.

1. Static castings: a factor not to exceed 80% shall be applied. In addition, all surfaces of centrifugal castings shall be machined after heat treatment to a finish not coarser than 6.3 µm (250 µin) arithmatical average deviation, and a factor not to exceed 85% shall be used.
2. Nonferrous and ductile cast iron materials: if the conditions listed below are met in addition to the requirements listed in 1) above, a factor not to exceed 90% shall be used.
   a. Each casting is subjected to a thorough examination of all surfaces, particularly such as are exposed by machining or drilling, without revealing any defects
   b. At least three pilot castings representing the first lot of five castings made from a new or altered design are sectioned or radiographed at all critical sections, without revealing any defects
   c. One additional casting taken at random from every subsequent lot of five is sectioned or radiographed at all critical sections without revealing any defects

    d. All castings other than those that have been radiographed are examined at all critical sections by the magnetic particle or liquid penetrant methods in accordance with requirements of Appendix 7
3. Nonferrous and ductile cast iron materials, single casting that has been radiographed at all critical sections and found free of defects: a factor not to exceed 90% may be used.
4. Nonferrous and ductile cast iron materials, casting machined to the extent that all critical sections are exposed for examination for the full wall thickness: a factor not to exceed 90% may be used.
5. Carbon, low alloy, or high alloy steels: higher quality factor may be used if following examinations are made in addition to those indicated in 1) above.
    a. For centrifugal castings, a factor not to exceed 90% may be applied if castings are examined by magnetic particle or liquid penetrant methods
    b. For static and centrifugal castings, a factor not to exceed 100% may be used if castings are examined in accordance with all of the requirements of Appendix 7
6. Castings used in vessels containing lethal substances:
    a. **Castings of cast iron and cast ductile iron are prohibited**
    b. each casting of nonferrous material shall be radiographed at all critical sections without revealing any defects. A quality factor not excedding 90% may be used.
    c. Each casting of steel shall be examined per Appendix 7 for severe service application. Quality factor shall not exceed 100%.

Defects:

Imperfections defined as unacceptable by either the material specification or by Appendix 7, 7-3, whichever is more restrictive, are considered to be defects and shall be the basis for rejections of the casting. Where defects have been repaired by welding, the repaired casting shall be postweld heat treated and, to obtain 90% or 100% quality factor, the repaired casting shall be stress relieved.

Identification and Marking:

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

UG-25 Corrosion

The corrosion allowance is generally specified by the user or his designaed agent. When no corrosion allowances are provided, this fact shall be indicated on the Data Report. Those vessels or vessel parts subject to thinning by corrosion, erosion or mechanical abrasion shall have provision made for the desired life of the vessel by a suitable increase in thickness of the material over that determined by design formulas. Other suggested methods indicated in Appendix E for protection against corrosion may also be used.

Telltale holes may be used to provide some positive indication when the thickness has been reduced to a dangerous degree. Telltale holes are not allowed on vessels in lethal service except for the vent holes in layered construction. Telltale holes should have a diameter from 1.5 to 5 mm (1/16 to 3/16 in) and shall have depth not less than 80% of the the thickess required for a seamless shell of like dimensions. These holes shall be provided in the opposite surface to that where detrioration is expected.

Vessels subjected to corrosion shall be supplied with a suitable drain opening at the lowest point practicable in the vessel; or a pipe may be used extending inward from any other location to within 6 mm (1/4 in) of the lowest point.

UG-26 Linings

Corrosion resistant or abrasion resistant linings, whether or not attached to the vessel, shall not be considered as contributing to the strength of the wall except as permitted in Part UCL for cladded or lined vessels or in Appendix F for suggested good practices regarding linings.

Sources:

1. ASME Boiler & Pressure Vessel Code, Section VIII, Division 1: Edition 2010
2. Moss, Dennis R., *Pressure Vessel Design Manual*, Gulf Publishing Company, 1987

***** E N D O F T H E A R T I C L E *****

About CoDesign Engineering

CoDesign Engineering is involved in projects that promote sustainable development and improvement in system efficiencies with specific focus on energy and waste management. Its operations can be broadly classified into following business groups:

- Pressure Vessels and Heat Exchangers
- Combined Cycle Power Plants
- Solar Photovoltaic Power Plants
- Solid Waste Management

We provides training, consultancy, and operation and maintenance services as described below:

Training

- Pressure vessel & heat exchanger design (ASME Section VIII, Div. 1)
- Power and process piping design (ASME B31.1 & B31.3)
- Combined cycle power plant system design
- Solar PV power plant design

Consultancy

- Supply and installation of static equipment in power plants and refineries
- Project Management Consultancy for construction of combined cycle power plants
- PMC as well as EPC services for solar PV power plants
- Turnkey waste management solutions, including disposal of e-waste

We have designed a 3-day training course for ASME BPVC Section VIII, Div. 1 that can be offered at most cities in India. In-house training can also be provided at any location in India or in US upon request. The training is designed as a workshop where the delegates are encouraged to do all calculations using only pencil, paper and calculators. Please contact Ramesh Tiwari at rtiwari123@gmail.com for 2012 training calendar, rates and the contents of the course.

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