

Overview of Pressure Vessel Design using ASME Boiler and Pressure Vessel Code Section VIII Division-1 and Division-2

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Abstract: ASME Boiler and Pressure vessel code (BPVC) Section VIII Division 1 is focused on a design-by-rule approach and Division 2 on design-by-analysis approach. While ASME Section VIII, Division 1's design-by-rule approach is most commonly utilized by engineers to size the pressure vessel according to the application requirements, it is quite a conservative approach. The empirical relations and other mandatory and non-mandatory design criteria often result in an expensive pressure vessel design. ASME Section VIII, Division 2's design-by-analysis approach requires more detailed calculations than Division 1. Although this may increase the cost of pressure vessel design, it allows pressure vessels to withstand higher stresses. Based on size and design parameters imposed, choice will be determined. This paper emphasis on Pressure vessel design by analysis versus design by rule

Keywords: ASME, BPVC, Design.

1. Introduction

Pressure vessels are an integral part of many manufacturing facilities and processing plants, enabling the safe storage of pressurized liquids and gases. From industrial boilers to gasoline tankers, pressure vessels operate in a wide array of potentially hazardous environments. However, if not properly designed, constructed and maintained, pressure vessels can be extremely dangerous. ASME Boiler and Pressure vessel code Section VIII in itself consists of 3 divisions, where Division 1 is focused on a design-by-rule approach and Division 2 on design-by-analysis approach. Division 3 is meant for designing pressure vessels that require internal or external operating at a pressure above 10,000 PSI.

2. History of design code

Most pressure vessels employed in industries today are designed according to the ASME BPVC Section VIII, which consists of standard codes and rules that a manufacturer is required to follow. More than 60 nations generally recognize and apply the BPVC for pressure vessel design. BPVC Section VIII is specifically meant to guide mechanical engineers in designing, constructing and maintaining PVs operating at either internal or external pressure exceeding 15 PSIG. While ASME Section VIII, Division 1's design-by-rule approach is most

commonly utilized by engineers to size the pressure vessel according to the application requirements, it is quite a conservative approach. The empirical relations and other mandatory and non-mandatory design criteria often result in an expensive pressure vessel design. ASME Section VIII, Division 2 is intended for purpose-specific vessels with a defined fixed location. Another major difference between the Division 1 and Division 2 lies in failure theory. While Division 1 is based on normal stress theory, Division 2 is based on maximum distortion energy (Von Mises).

The codes mentioned under Section VIII for both divisions also include appendices. These appendices are alternative or supplementary rules that serve as guidelines, since they are less frequently employed than the main body codes. However, the appendices themselves contain both mandatory and non-mandatory sections.

3. Pressure vessel construction code requirement

Although it is possible to construct a pressure vessel of any shape and size, sections of cylinder, sphere and cone are usually preferred. A more common pressure vessel design consists of a cylinder closed with end caps, known as heads, that are usually hemispherical. Spherical pressure vessel design is typically stronger than a cylindrical shape with the same wall thickness. However, spherical pressure vessels are difficult and costly to manufacture, which makes cylindrical shape pressure vessels with semi-elliptical heads preferred in many cases.

Typically, pressure vessels are made of steel, but there are some that employ composite materials, such as carbon fiber, ceramics and polymers. Modern pressure vessels include safety features such as relief valves to relieve excessive pressure from the container and ensure safe operation. And most pressure vessels today are designed with a leak-before-burst feature, which enables the vessel to relieve pressure by leaking the contained fluid, rather than by means of an immediate and potentially explosive fracture. In cases where leak before burst design is not possible, pressure vessels are required to be designed with more stringent requirements for fatigue and fracture failure modes.

A. Division 1

- Pressure typically up to 3000 psig.
- Not much restrictions on materials; Impact Test required unless exempted.
- Design Factor 3.5 on tensile (4 used previously) and other yield and temperature considerations.
- NDE requirements may be exempted through increased design factor.
- Professional Engineer Stamp is usually not required.
- Hydrostatic Test of 1.3 design pressure (1.5 was used before 1999 Addenda)
- U Stamp

B. Division 2

- Pressure usually 600 psig and larger.
- More restrictions on materials; Impact Test required.
- Design Factor of 3 on tensile (lower factor under reviewed) and other yield and temperature considerations.
- More stringent NDE requirements.
- Professional Engineer Stamp is a must.
- Hydrostatic Test of 1.25 design pressure
- U2 Stamp

4. Design data requirement

A design engineer usually requires the following basic data to size a pressure vessel:

- Vessel function
- Process materials and services (corrosion, deposits, etc.)
- Operating conditions (temperature and pressure)
- Materials of construction
- Dimensions and orientation
- Type of vessel heads to be used
- Openings and connections required
- Heating/cooling requirements
- Agitation requirements
- Specification of internal fittings

Once the preliminary data is obtained, the pressure vessel

design can be initiated following the standard procedures outlines in BPVC Section VIII. This section is further subdivided into subsections and appendices, guiding the engineer to determine general design requirements, fabrication requirements and material requirements to effectively size the pressure vessel.

5. Conclusion

Now it is understood that one of the main differences between Divisions 1 and 2 is that Division 2 uses lower design margins often resulting in higher material allowable stresses. Design margins are reduction factors applied to the material's ultimate tensile strength (UTS) for the purpose of setting material allowable stresses in ASME II-D. The design margins are currently 3.5 for Division 1, 3.0 for Division 2, Class 1 and 2.4 for Division 2, Class 2. In Division 1, hydrotest stresses are not specifically limited and partial penetration nozzle welds are permitted. In Division 2, hydrotest stresses are limited so hydrotest stress calculations are mandatory and full penetration nozzle welds are required.

Another major difference is the theory of failure assumed and therefore the design equations used. Specifically, Division 1 uses the maximum principle stress theory while, starting with the 2007 Edition, Division 2 uses Von Mises. As a result, Division 1 uses two sets of design equations one for "thin" and another for "thick" vessels while Division 2 uses one set of equations for all vessel thicknesses. Of particular note are the more accurate nozzle design and allowable compressive stress (external pressure) rules in Division 2 both of which can provide additional savings.

In general, thinner Division 2 vessels retain safety factors that are comparable to thicker Division 1 vessels by incorporating more extensive engineering analysis and design requirements.

References

- [1] ASME BPVC section VIII Division-1, 2007 edition
- [2] ASME BPVC section VIII Division-2, 2007 edition
- [3] Dennis R. Moss and M. Michael, "Pressure Vessel Design Manual."
- [4] ASNT—Over view on NDT
- [5] ASME BPVC section V for NDT, 2007 edition.