ASME BPV Sec.VIII, Div.1 - Pressure Vessel Design

Course by BECHT / Instructor: Don Kurrle / June 4-8, 2023 / Houston, Texas

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TSD Topic Meeting

10 August 2023

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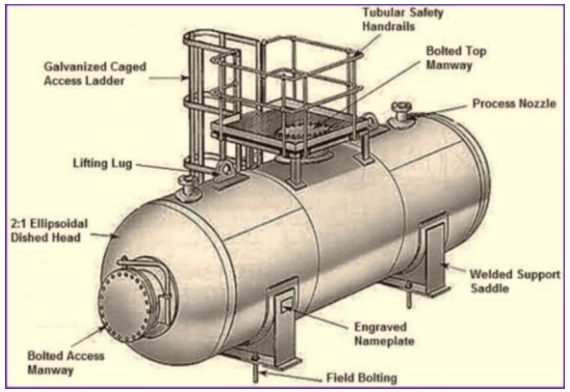
ASME Section VIII Fundamentals



- The **ASME Code** design criteria consist of basic rules specifying the design method, design loads, allowable stress, acceptable materials, fabrication, testing, certification and inspection requirements. The design method known as "design by rule" uses design pressure, allowable stress and a design formula compatible with the geometry to calculate the minimum required thickness of pressurized tanks, vessels and pipes.
- The formulae in **ASME Section VIII** are used to determine the minimum required thickness and design pressure of **piping, tubes, drums and headers** using the **Maximum Allowable Working Pressure (MAWP).** However, **Paragraph UG-31 states, that these formulae may be also used for calculating** wall thickness of **tubes and pipes** under internal pressure.
- **Design:**
  - The ASME Boiler Code Section VIII requires longitudinal and circumferential butt joints to be examined by full radiograph.
  - When the vessel design is required fully radiographed longitudinal butt-welded joint, the cylindrical shell will have a joint efficiency factor (E = 1.0). This factor corresponds to a safety factor (or material quality factor) of 3.5 in the parent metal.
  - When the vessel design is required non-radiographed longitudinal butt-welded joints the vessel will have a joint efficiency factor (E = 0.7, which corresponds to a safety factor of 0.5 in., resulting in an increase of 43% in the thickness of the plates.

Description:

This course is a comprehensive introduction to pressure vessel design in accordance with the ASME Boiler and Pressure Vessel Code, Section VIII, Div 1. General topics in the course include general design requirements, design requirements related to materials, welded joint design requirements and vessel component design.

Outline:

1. ASME Section VIII, Division 1 Scope and Responsibilities
    - Become familiar with the scope of ASME Section VIII, Division 1 a well as users' and manufacturers' responsibilities
2. General Requirements. Develop a more thorough understanding of the design rules
    - Cylinders, dished heads, conical heads, flat covers and opening reinforcemnt for internal and external pressure
    - External loadings, including wind and seismic
    - Appendix 2 flanges
    - Part UHX tubesheets (brief discussion)
3. Design Requirements for Welded Vessels
    - Welded joint categories and welded joint types
    - RT and UT examination and joint efficiencies
4. Material Requirements
    - Postweld heat treatment
    - Impact testing requirements

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Overview

- ASME code serves as a reference book, not a handbook
  - Officially published interpretations – http://go.asme.org/Interpretations
  - Code Cases contain rules for materials and constructions not covered by existing Code rules.
  - New Editions to the Code are published on a two-year cycle.
- ASME BPV VIII: D1 vs. D2 vs. D3
  - VIII Div.1
    - Design/build by the Code rules (with quality factors – joint efficiency)
    - Current design margin 3.5
    - Little stress analysis required (pure membrane)
  - VIII Div.2
    - Design/build by analysis (alternative rules)
    - Less margin (2.4 for class 1, 3.0 for class 2), but more engineering efforts from all perspectives
  - VIII Div 3 (for pressure above 10 ksi with elastic/plastic analysis)

Tips from the course

- Units in design
  - Unit conversion at very beginning and the end, buy not in middle of calculation
- If exceeding range of equation/description, go to U-2(g)
  - Where design rules do not exist in Section VIII D.I, one of the following three methods shall be used:
    - Mandatory Appendix 46
      - Tensile stress per UG-23
      - Compressive stress P4.4.12 (Div.2)
      - Joint efficiency per UW-11 & UW-12
    - Proof test in accordance with UG-101
    - Other recognized and generally accepted methods, such as those found in other ASME, EN, ISO, national standards or codes. This option shall provide details of design consistent with the allowable stress criteria provided in UG-23.

Tips from the course

- Area Replacement Method vs. Pressure Area Method for Design of Openings
  - Area replacement method is illustrated in Fig. UG-37.1 (details and formulas of areas), based on experience rather than much technical.
  - Pressure area method (Europe, stress based) can be referred to Div.2 P4.5.
- For pressure vessel from Europe, check with Div.2

- Weld efficient factor
  - For internal pressure rather than external pressure application

Tips from the course

- Two softwares as codeware for pressure vessel design
  - Compress program
  - PV elite
- TEMA (Turbular Exchanger Manufacturers Association)
  - Equations for heat exchanger related application

Difference Between ASME Section VIII Div1, Div2, and Div3

Parameters	ASME Section VIII Div 1	ASME Section VIII Div 2	ASME Section VIII Div 3
Code Published Year	less than 1940	Year – 1968	Year – 1997
Code Pressure limits	up to 3000 psig	No limits; usually more than 600 psig	No limit; usually more than 10,000 psig
Organization Structure	General, Construction Type & Material U, UG, UW, UF, UB, UCS, UNF, UCI, UCL, UCD, UHT, ULT	General, Material, Design, Fabrication and others AG, AM, AD, AF, AR, AI, AT, AS	Like Division 2 KG, KM, KD, KF, KR, KE, KT, KS
Design Safety Factor	Design Safety Factor is 3.5	Design Safety Factor is 2.4 for class 1 & 3.0 for class 2	Based on Yield with reduction factor for yield strength to tensile strength ratio less is than 0.7
Code Design Rules	Membrane – Maximum stress Generally Elastic analysis Very detailed design rules with Quality (joint efficiency) Factors. Little stress analysis required; pure membrane without consideration of discontinuities controlling stress concentration to a safety factor of 3.5 or higher	Shell of Revolution – Max. shear stress Generally Elastic analysis Membrane + Bending. Fairly detailed design rules. In addition to the design rules, discontinuities, fatigue, and other stress analysis considerations may be required unless exempted and guidance provided for in Appendix 4, 5 and 6	Maximum shear stress Elastic/Plastic Analyses and more. Some design rules provided; Fatigue analysis required; Fracture mechanics evaluation required unless proven leak-before-burst, Residual stresses become significant and maybe positive factors (e.g. autofrettage)
Experimental Stress Analysis	Normally not required	Introduced and may be required	Experimental design verification but may be exempted
Material and Impact Testing	Few restrictions on materials; Impact required unless exempted; extensive exemptions under UG-20, UCS 66/67	More restrictions on materials; impact required in general with similar rules as Division 1	Even more restrictive than Division 2 with different requirements. Fracture toughness testing requirement for fracture mechanics evaluation Crack tip opening displacement (CTOD) testing and establishment of KIc and/or JIc values
NDT Requirements	NDT requirements may be exempted through increased design factor	More stringent NDT requirements; extensive use of RT as well as UT, MT, and PT.	Even more restrictive than Division 2; UT used for all butt welds, RT otherwise, extensive use of PT and MT
Welding and fabrication	Different types with butt welds and others	Extensive use/requirement of butt welds and full penetration welds including non-pressure attachment welds	Butt Welds and extensive use of other construction methods such as threaded, layered, wire-wound, interlocking strip-wound, and others
User	User or designated agent to provide specifications (see U-2(a)	User's Design Specification with detailed design requirements (see AG-301.1) include AD 160 for fatigue evaluation	User's Design Specification with more specific details (see KG-310) including contained fluid data, etc with useful operation life expected and others. Designer define
Manufacturer	Manufacturer to declare compliance in data report	Manufacturer's Design Report certifying design specification and code compliance in addition to data report	Same as Division 2
Professional Engineer Certification	Normally not required	Professional Engineers' Certification of User's Design Specification as well as Manufacturer's Design Report Professional Engineer shall be experienced in pressure vessel de	Same as Division 2 but the Professional Engineer shall be experienced in high pressure vessel design and shall not sign for both User and Manufacturer
Safety Relief Valve	UV Stamp	UV Stamp	UV3 Stamp
Code Stamp and Marking	U Stamp with Addition markings including W, P, B, RES; L, UB, DF; RT, HT	U2 Stamp with Additional marking including H	U3 Stamp with additional marking denoting construction type; HT, PS, WL, M, F, W, UQT, WW, SW
Hydrostatic Pressure Test	1.3 time MAWP	1.25 times MAWP	1.25 times MAWP

https://letsfab.in/difference-between-asme-section-viii-div1-div2-and-div3/

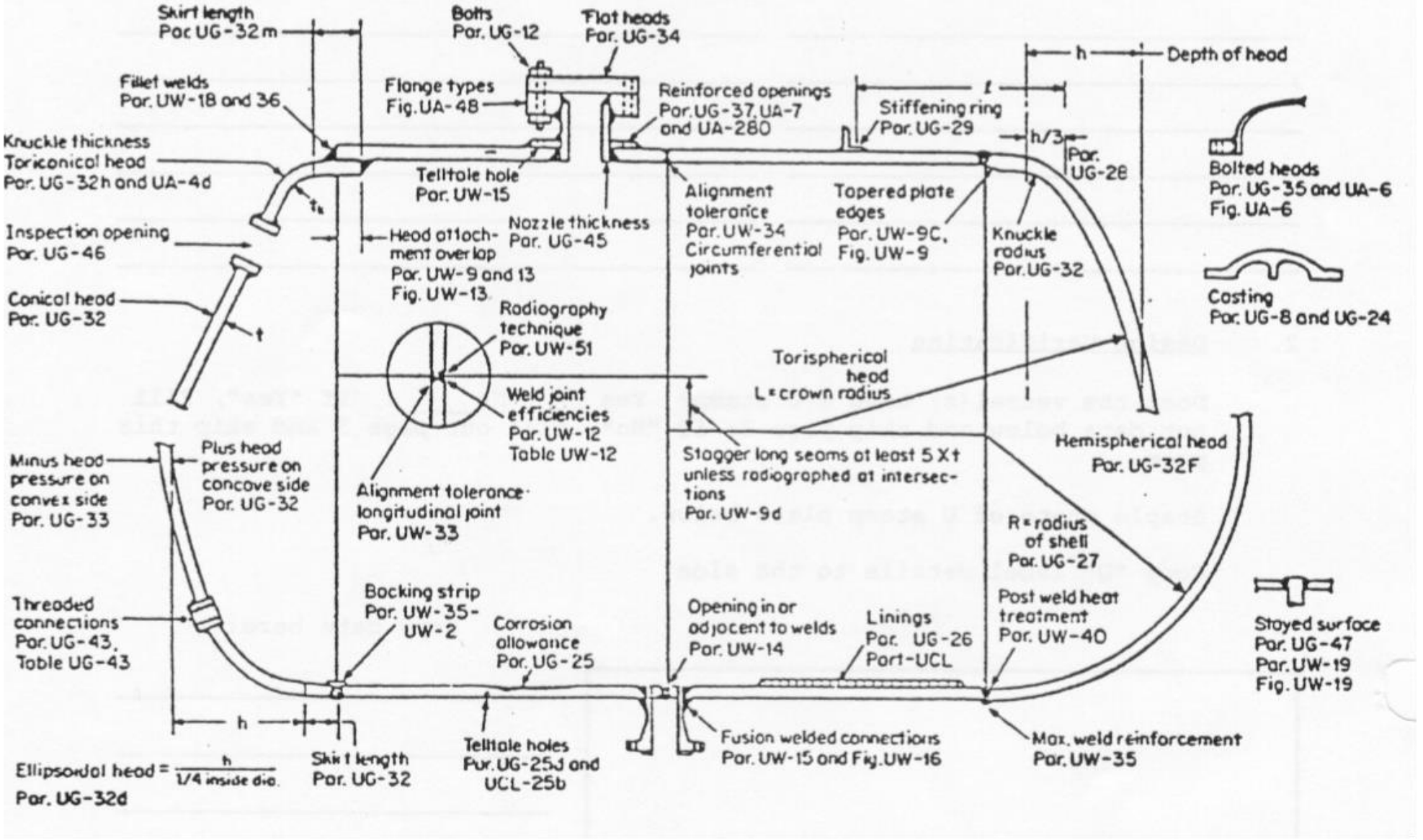
Practice in Fermilab

FESHM 5031

Calculation results w/ ASME code

(to be filled in EN)

Provide ASME design calculations in an appendix. On the sketch below, circle all applicable sections of the ASME code per Section VIII, Division I. (Only for non-coded vessels)



THANKS !

Terms

- UG, UW, UF, UB, UCS, UNF, UHA, UCI, UCL, UCD, UHT, ULW, ULT, UHX, U
  - G: General
  - W: Weld
  - F: Forge
  - B: Braze
  - CS: Carbon and low alloy steels
  - NF: Nonferrous materials
  - HA: High alloy steel
  - CI: Cast iron
  - CL: Materials with corrosion resistant integral cladding, weld metal overlay cladding, or applied linings
  - CD: Cast ductile iron
  - HT: Ferritic steels with tensile properties enhanced by heat treatment
  - LW: Layered construction
  - LT: Materials at low temperature
  - HX: Heat exchangers
  - IG: Impregnated graphite

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Terminology, story, …

- Jacketed vessel (in chemical engineering)
- NASA lawsuit against ASME, static head (cann't find in internet)
- Fabricated lap joint tub ends
- Auto refrigeration
- Post weld heat treatment (PWHT)
- Volume XLIII.I~II: ASME Sec I & Sec VIII Fundamentals – Part 1~3
  - https://www.boardmaninc.com/news.html/2020/01/07/volume-xliii-vol-i-asme-pressure-vessels/
  - https://www.boardmaninc.com/news.html/2020/01/07/volume-xliii-vol-ii-asme-pressure-vessels/
  - https://www.boardmaninc.com/news.html/2020/01/07/volume-xliv-vol-iii-asme-pressure-vessels/

Food process by high pressure