

ASME PTB-5-2019

ASME Boiler and
Pressure Vessel Code,
Section VIII, Division 3,
Example Problem Manual



ASME PTB-5-2019

**ASME BOILER AND
PRESSURE VESSEL CODE,
SECTION VIII, DIVISION 3,
EXAMPLE PROBLEM
MANUAL**

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FORWARD

During the 1980s, ASME's Special Working Group on High Pressure Vessels was established for the purpose of creating a standard dealing with the construction of high-pressure vessels, which generally operate at a pressure above 10,000 pounds per square inch ("psi"). This was done on the basis of recommendations made by the Operations, Applications, and Components Technical Committee of the ASME Pressure Vessel and Piping Division (the "Committee"). The ASME Boiler and Pressure Vessel Code ("BPVC"), Section VIII, Division 3, titled "Alternative Rules for Construction of High Pressure Vessels" was first published in 1997; the Committee continues to refine and develop this code.

Some of the innovative concepts which began with BPVC Section VIII, Division 3 include:

- Use of elastic-plastic finite element analysis in design of pressure equipment;
- One of the lowest design margins (originally published at 2.0 and then lowered to 1.8);
- Use of high strength materials in manufacturing of high-pressure equipment;
- Stringent requirements on fracture toughness for materials used in construction;
- Complete volumetric and surface examination after hydrotest;
- The use of fracture mechanics for evaluation of design life assessment in all cases where "leak-before-burst" cannot be shown; and
- Consideration of beneficial residual stresses in the evaluation of the design life of vessels.

This publication is provided to illustrate some of the design calculations and methodologies used in the BPVC Section VIII, Division 3. It is recognized that many high-pressure designs are unique and quite innovative and therefore, this example problem manual cannot cover all design aspects within the scope of BPVC Section VIII, Division 3. This is an attempt at covering some of the most common ones.

Established in 1880, ASME is a professional not-for-profit organization with more than 127,000 members promoting the art, science, and practice of mechanical and multidisciplinary engineering and allied sciences. ASME develops codes and standards to enhance public safety, and ASME provides lifelong learning and technical exchange opportunities benefiting the engineering and technology community. Visit www.asme.org for more information.

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To develop this Example Problem Manual, STLLC contracted with Structural Integrity Associates, Inc. to perform the work.

EXECUTIVE SUMMARY

An introduction to the example problems in this publication is described in Part 2 of this publication. The remaining parts of this publication contain the example problems. The remaining Parts of this publication coincide with the following sections of BPVC Section VIII Division 3:

- Part 2 Parts KM - Materials,
- Part 3 - KD-2 General Design Issues,
- Part 4 - KD-3 Fatigue Assessment,
- Part 5 - KD-4 Life Assessment Using Fracture Mechanics,
- Part 6 - KD-5 – Residual Stresses using Autofrettage,
- Part 7 KD-6 – Closures and Connections,
- Part 8 – KD-8 Residual Stresses in Multiwall Vessels,
- Part 9 – KD-9 Wire Wound Vessels,
- Part 10 – KT-3 - Determination of Hydrostatic Test Pressure, and
- Part 11 – Appendix E – Determination of Blind End Dimensions and Thread Load Distribution.

The example problems in this manual follow the calculation procedures in BPVC Section VIII, Division 3. It is suggested that users of this manual obtain a copy of “Criteria of the ASME Boiler and Pressure Vessel Code Section VIII, Division 3” [2], which contains the original criteria on its use when it was first published.

It should be noted that BPVC Section VIII, Division 3 requires the use of ASME Section 9-1/ASME FFS-1 [3] for some calculation procedures. When reviewing certain example problems in this manual, it is recommended that a copy be obtained of this standard for this purpose.

It is noted that many analysis techniques are covered in this manual as examples. Some of these modelling techniques are problem specific and are not requirements of the BPVC Section VIII, Division 3, but are provided herein as examples of methods of compliance with the code requirements. Alternative techniques may be used, as appropriate for certain problems, where complete guidance is not mandated in the BPVC Section VIII, Division 3.

ABBREVIATIONS AND ACRONYMS

Abbreviation Acronym	Description
$2c/a$	Assumed Crack Aspect Ratio
A_B	Cross-Sectional Area of Vessel Normal to Vessel Axis through Internal Threads
A_C	Cross-Sectional Area of Vessel Normal to Vessel Axis through External Threads
API	American Petroleum Institute
ASME	American Society of Mechanical Engineers
b	Assumed Seal Width
BPVC	ASME Boiler and Pressure Vessel Code
C_M	Combined Flexibility Factor of Body and Closure
C_T	Flexibility Factor of the Threads
CTOD	Crack Tip Opening Displacement
CVN	Charpy V-Notch
D	Diameter
D	Dead Weight Applied as Acceleration $1g$ in Finite Element Model
D_i	Inside Diameter
D_{if}	Diameter Interface between Cylinder and Winding
D_{if}	Interface Diameter Between Cylinder Layers
D_o	Outside Diameter
$D_{o.1}$	Liner Outside Diameter
$D_{o.2}$	Outer Body Outside Diameter
D_p	Pitch Diameter of the Threads
D_s	Opening Seal Diameter
D_w	Instantaneous Applied Outside Diameter of Winding
E	Elastic Modulus
El	Elongation
E_y	Modulus of Elasticity
FFS	Fitness-for-Service (ASME)
ft-lbf	Foot-Pounds, Force
FTT	Fracture Toughness Testing
in	Inch(es)
in^2	Square Inches
in^3	Cubic Inches
ISO	International Organization for Standardization
J_{Ic}	Fracture Toughness Testing
K_{Ic}	Fracture Toughness Testing
K_{Ic}	Critical Stress Intensity Factor
K_{Ic}	Material Fracture Toughness
K_r	Surface Toughness Factor
ksi	Kilopounds per Square Inch
L	Length
lb	Pound(s)
m	Seal Factor
MAWP	Maximum Allowable Working Pressure
Min.	Minimum
Mo	Molybdenum
N_p	Number of Threads
ND	Non-Destructive Examination
Ni	Nickel
OD	Outside Diameter
P	Pressure Load
P_A	Autofrettage Pressure
P_b	Primary Bending Stress Intensity
P_D	Design Pressure
$P_{D.Dual}$	Design Pressure for Dual Wall

Abbreviation Acronym	Description
P_{if}	Interface Pressure
P_L	Local Primary Membrane Stress Intensity
P_m	General Primary Membrane Stress Intensity
psi	Pounds per Square Inch
P_T	Hydrostatic Test Pressure
P_T	Thread Pitch
PTCS	ASME Pressure Technology Codes and Standards
Q	Secondary Stress Intensity
RA	Reduction in Area
R_c	Inside Corner Radius
S_a	Alternating Stress Component
$S_{alt\ i,j}$	Alternating Stress Intensities
S_{ij}	Stress Intensities
STLLC	ASME Standards Technology, LLC
S_u	Tensile Strength
S_y	Yield Strength
t_w	Wall Thickness
σ_{uts}	Tensile Strength
V	Vanadium
W	Weight
x_1	Any Diameter of the Cylinder
x_2	Any Diameter of the Winding
Y	Diameter Ratio, D_o / D_i
Y_i	Liner Wall Ratio
Y_o	Outer Body Ratio
ϵ_{ys}	Offset Strain
ΔAL	Elongation in Each Yoke Plate
δ	Diametral Interference
ϵ	Longitudinal Strain in Each Side of Yoke
ν	Poisson's Ratio
ν_l	Poisson's Ratio for Liner
ν_o	Poisson's Ratio for Body
ρ	Density
$\sigma_{m\ i,j}$	Associated Mean Stress
$\sigma_{n\ i,j}$	Stress Normal to the Plane of Maximum Shear
$\sigma_{nm\ i,j}$	Associated Mean Stress
σ	Longitudinal Stress on Each Side of Yoke
$S_{(eq\ i,j)}$	Equivalent Alternating Stress Intensity
ϵ_L	Limiting Triaxial Strain
ϵ_{cf}	Cold Forming Strain

PURPOSE AND USE

The BPVC Section VIII, Division 3 [1] contains mandatory requirements, specific prohibitions, and non-mandatory guidance for the design, materials, fabrication, examination, inspection, testing, and certification of high-pressure vessels and their associated pressure relief devices. This Example Problem Manual is based on the 2019 edition of the BPVC Section VIII, Division 3, and all paragraph references herein are to this same edition.

Scope

Example problems illustrating the use of the analysis methods in BPVC Section VIII, Division 3 are provided in this publication.