

PTB-4-2012

# ASME Section VIII – Division 1 Example Problem Manual



**PTB-4-2012**

# **ASME Section VIII - Division 1 Example Problem Manual**

**James C. Sowinski, P.E.**

**David A. Osage, P.E.**

**The Equity Engineering Group, Inc.**



**PTB-4-2012**

Date of Issuance: June 30, 2012

This document was prepared as an account of work sponsored by ASME Pressure Technology Codes and Standards (PTCS) through the ASME Standards Technology, LLC (ASME ST-LLC).

Neither ASME, the author, nor others involved in the preparation or review of this document, nor any of their respective employees, members or persons acting on their behalf, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe upon privately owned rights.

Reference herein to any specific commercial product, process or service by trade name, trademark, manufacturer or otherwise does not necessarily constitute or imply its endorsement, recommendation or favoring by ASME or others involved in the preparation or review of this document, or any agency thereof. The views and opinions of the authors, contributors and reviewers of the document expressed herein do not necessarily reflect those of ASME or others involved in the preparation or review of this document, or any agency thereof.

ASME does not “approve,” “rate”, or “endorse” any item, construction, proprietary device or activity.

ASME does not take any position with respect to the validity of any patent rights asserted in connection with any items mentioned in this document, and does not undertake to insure anyone utilizing a standard against liability for infringement of any applicable letters patent, nor assume any such liability. Users of a code or standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, is entirely their own responsibility.

Participation by federal agency representative(s) or person(s) affiliated with industry is not to be interpreted as government or industry endorsement of this code or standard.

ASME is the registered trademark of The American Society of Mechanical Engineers.

No part of this document may be reproduced in any form,  
in an electronic retrieval system or otherwise,  
without the prior written permission of the publisher.

The American Society of Mechanical Engineers  
Three Park Avenue, New York, NY 10016-5990

Copyright © 2012 by  
THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

All rights reserved

Printed in the U.S.A.



# TABLE OF CONTENTS

<b>PART 1</b> .....	<b>7</b>
1.1 INTRODUCTION .....	7
1.2 SCOPE .....	7
1.3 DEFINITIONS .....	7
1.4 ORGANIZATION AND USE.....	7
1.5 COMPARISON OF VIII-1 AND VIII-2 DESIGN RULES .....	7
1.6 ASME CODE CASE 2695 .....	7
1.7 REFERENCES.....	8
1.8 TABLES .....	9
<b>PART 2</b> .....	<b>11</b>
2.1 GENERAL .....	11
2.2 EXAMPLE PROBLEM FORMAT.....	11
2.3 CALCULATION PRECISION .....	11
<b>PART 3</b> .....	<b>13</b>
3.1 COMMENTARY ON RULES TO ESTABLISH THE MINIMUM DESIGN METAL TEMPERATURE (MDMT).....	13
3.2 EXAMPLE E3.1 – USE OF MDMT EXEMPTIONS CURVES .....	17
3.3 EXAMPLE E3.2 – USE OF MDMT EXEMPTION CURVES WITH STRESS REDUCTION .....	18
3.4 EXAMPLE E3.3 – DETERMINE THE MDMT FOR A NOZZLE-TO-SHELL WELDED ASSEMBLY .....	19
<b>PART 4</b> .....	<b>25</b>
4.1 GENERAL REQUIREMENTS .....	25
<i>Example E4.1.1 – Review of General Requirements for a Vessel Design</i> .....	25
<i>Example E4.1.2 – Required Wall Thickness of a Hemispherical Head</i> .....	26
4.2 WELDED JOINTS .....	28
4.2.1 <i>Example E4.2.1 – Nondestructive Examination Requirement for Vessel Design</i> .....	28
4.2.2 <i>Example E4.2.2 – Nozzle Detail and Weld Sizing</i> .....	29
4.2.3 <i>Example E4.2.3 – Nozzle Detail with Reinforcement Pad and Weld Sizing</i> .....	31
4.3 INTERNAL DESIGN PRESSURE .....	34
4.3.1 <i>Example E4.3.1 – Cylindrical Shell</i> .....	34
4.3.2 <i>Example E4.3.2 – Conical Shell</i> .....	34
4.3.3 <i>Example E4.3.3 – Spherical Shell</i> .....	35
4.3.4 <i>Example E4.3.4 – Torispherical Head</i> .....	36
4.3.5 <i>Example E4.3.5 – Elliptical Head</i> .....	39
4.3.6 <i>Example E4.3.6 – Combined Loadings and Allowable Stresses</i> .....	43
4.3.7 <i>Example E4.3.7 – Conical Transitions Without a Knuckle</i> .....	51
4.3.8 <i>Example E4.3.8 – Conical Transitions with a Knuckle</i> .....	73
4.4 SHELLS UNDER EXTERNAL PRESSURE AND ALLOWABLE COMPRESSIVE STRESSES .....	79
4.4.1 <i>Example E4.4.1 – Cylindrical Shell</i> .....	79
4.4.2 <i>Example E4.4.2 – Conical Shell</i> .....	82
4.4.3 <i>Example E4.4.3 – Spherical Shell and Hemispherical Head</i> .....	86
4.4.4 <i>Example E4.4.4 – Torispherical Head</i> .....	89
4.4.5 <i>Example E4.4.5 – Elliptical Head</i> .....	92
4.4.6 <i>Example E4.4.6 – Combined Loadings and Allowable Compressive Stresses</i> .....	95
4.4.7 <i>Example E4.4.7 – Conical Transitions without a Knuckle</i> .....	115
4.4.8 <i>Example E4.4.8 – Conical Transitions with a Knuckle</i> .....	143



## TABLE OF CONTENTS

4.5	SHELLS OPENINGS IN SHELLS AND HEADS .....	152
4.5.1	<i>Example E4.5.1 – Radial Nozzle in Cylindrical Shell</i> .....	152
4.5.2	<i>Example E4.5.2 – Hillside Nozzle in Cylindrical Shell</i> .....	159
4.5.3	<i>Example E4.5.3 – Radial Nozzle in Ellipsoidal Head</i> .....	169
4.5.4	<i>Example E4.5.4 – Radial Nozzle in Cylindrical Shell</i> .....	177
4.5.5	<i>Example E4.5.5 – Pad Reinforced Radial Nozzle in Cylindrical Shell</i> .....	183
4.5.6	<i>Example E4.5.6 – Radial Nozzle in an Ellipsoidal Head with Inside Projection</i> .....	192
4.6	FLAT HEADS .....	199
4.6.1	<i>Example E4.6.1 - Flat Unstayed Circular Heads Attached by Bolts</i> .....	199
4.6.2	<i>Example E4.6.2 – Flat Un-stayed Non-Circular Heads Attached by Welding</i> .....	200
4.6.3	<i>Example E4.6.3 – Integral Flat Head with a Centrally Located Opening</i> .....	201
4.7	SPHERICALLY DISHED BOLTED COVERS .....	208
4.7.1	<i>Example E4.7.1 – Thickness Calculation for a Type D Head</i> .....	208
4.7.2	<i>Example E4.7.2 – Thickness Calculation for a Type D Head Using the Alternative Rule in VIII-2, Paragraph 4.7.5.3</i> .....	219
4.8	QUICK-ACTUATING (QUICK OPENING) CLOSURES .....	228
4.8.1	<i>Example E4.8.1 – Review of Requirements for Quick-Actuating Closures</i> .....	228
4.9	BRACED AND STAYED SURFACES .....	230
4.9.1	<i>Example E4.9.1 - Braced and Stayed Surfaces</i> .....	230
4.10	LIGAMENTS .....	233
4.10.1	<i>Example E4.10.1 - Ligaments</i> .....	233
4.11	JACKETED VESSELS .....	235
4.11.1	<i>Example E4.11.1 - Partial Jacket</i> .....	235
4.11.2	<i>Example E4.11.2 - Half-Pipe Jacket</i> .....	237
4.12	NONCIRCULAR VESSELS.....	240
4.12.1	<i>Example E4.12.1 - Type 1</i> .....	240
4.12.2	<i>Example E4.12.2 - Type 4</i> .....	244
4.13	LAYERED VESSELS .....	255
4.13.1	<i>Example E4.13.1 – Layered Cylindrical Shell</i> .....	255
4.13.2	<i>Example E4.13.2 – Layered Hemispherical Head</i> .....	256
4.13.3	<i>Example E4.13.3 – Maximum Permissible Gap in a Layered Cylindrical Shell</i> .....	257
4.14	EVALUATION OF VESSELS OUTSIDE OF TOLERANCE.....	258
4.14.1	<i>Example E4.14.1 – Shell Tolerances</i> .....	258
4.14.2	<i>Example E4.14.2 – Shell Tolerances and Fatigue Evaluation</i> .....	258
4.14.3	<i>Example E4.14.3 - Local Thin Area</i> .....	259
4.15	SUPPORTS AND ATTACHMENTS .....	260
4.15.1	<i>Example E4.15.1 - Horizontal Vessel with Zick’s Analysis</i> .....	260
4.15.2	<i>Example E4.15.2 – Vertical Vessel, Skirt Design</i> .....	268
4.16	FLANGED JOINTS .....	278
4.16.1	<i>Example E4.16.1 - Integral Type</i> .....	278
4.16.2	<i>Example E4.16.2 - Loose Type</i> .....	288
4.17	CLAMPED CONNECTIONS .....	297
4.17.1	<i>Example E4.17.1 - Flange and Clamp Design Procedure</i> .....	297



## TABLE OF CONTENTS

4.18	TUBESHEETS IN SHELL AND TUBE HEAT EXCHANGERS.....	307
4.18.1	Example E4.18.1 - U-Tube Tubesheet Integral with Shell and Channel .....	307
4.18.2	Example E4.18.2 - U-Tube Tubesheet Gasketed With Shell and Channel .....	310
4.18.3	Example E4.18.3 - U-Tube Tubesheet Gasketed With Shell and Channel .....	313
4.18.4	Example E.4.18.4 - U-Tube Tubesheet Gasketed With Shell and Integral with Channel, Extended as a Flange .....	315
4.18.5	Example E.4.18.5 - Fixed Tubesheet Exchanger, Configuration b, Tubesheet Integral with Shell, Extended as a Flange and Gasketed on the Channel Side .....	319
4.18.6	Example E.4.18.6 - Fixed Tubesheet Exchanger, Configuration b, Tubesheet Integral with Shell, Extended as a Flange and Gasketed on the Channel Side .....	330
4.18.7	Example E.14.7 - Fixed Tubesheet Exchanger, Configuration a.....	341
4.18.8	Example E4.18.8 - Stationary Tubesheet Gasketed With Shell and Channel; Floating Tubesheet Gasketed, Not Extended as a Flange.....	352
4.18.9	Example E.14.18.9 - Stationary Tubesheet Gasketed With Shell and Channel; Floating Tubesheet Integral.....	359
4.18.10	Example E.14.18.10 - Stationary Tubesheet Gasketed With Shell and Channel; Floating Tubesheet Internally Sealed .....	368
4.19	BELLOWS EXPANSION JOINTS.....	376
4.19.1	Example E4.19.1 – U-Shaped Un-reinforced Bellows Expansion Joint and Fatigue Evaluation .....	376
4.19.2	Example E4.19.2 - Toroidal Bellows Expansion Joint and Fatigue Evaluation .....	382
<b>PART 5</b>	.....	<b>389</b>
5.1	DESIGN-BY-ANALYSIS FOR SECTION VIII, DIVISION 1 .....	389
5.2	PARAGRAPH U-2(G) – DESIGN-BY-ANALYSIS PROVISION WITHOUT PROCEDURES .....	389
<b>PART 6</b>	.....	<b>393</b>
6.1	EXAMPLE E6.1 – POSTWELD HEAT TREATMENT OF A PRESSURE VESSEL .....	393
6.2	EXAMPLE E6.2 – OUT-OF-ROUNDNESS OF A CYLINDRICAL FORGED VESSEL.....	396
<b>PART 7</b>	.....	<b>399</b>
7.1	INSPECTION AND EXAMINATION RULES COMMENTARY .....	399
7.2	EXAMPLE E7.1 – NDE: ESTABLISH JOINT EFFICIENCIES, RT-1.....	406
7.3	EXAMPLE E7.2 – NDE: ESTABLISH JOINT EFFICIENCIES, RT-2.....	408
7.4	EXAMPLE E7.3 – NDE: ESTABLISH JOINT EFFICIENCIES, RT-4.....	410
7.5	EXAMPLE E7.4 – NDE: ESTABLISH JOINT EFFICIENCIES, RT-3.....	412
<b>PART 8</b>	.....	<b>415</b>
8.1	EXAMPLE E8.1 – DETERMINATION OF A HYDROSTATIC TEST PRESSURE.....	415
8.2	EXAMPLE E8.2 – DETERMINATION OF A PNEUMATIC TEST PRESSURE .....	416



INTENTIONALLY LEFT BLANK



## FOREWORD

This document is the Division 1 example problem manual. In this manual, example problems are solved using both the Division 1 and Division 2 rules. When the design rule is the same, the example problem is solved using the Division 2 rules with the Division 1 allowable stress and weld joint efficiency. With this approach, users of Division 1 will become familiar and adept at using Division 2, and this will also provide a significant training benefit to the Division 1 user in that Division 2 has been designed as the home for the common rules initiative being undertaken by the ASME Section VIII Committee.

In 2007, ASME released a new version of the ASME B&PV Code, Section VIII, Division 2. This new version of Division 2 incorporated the latest technologies to enhance competitiveness and is structured in a way to make it more user-friendly for both users and the committees that maintain it. In addition to updating many of the design-by-analysis technologies, the design-by-rule technologies, many adopted from the Division 1 rules, were modernized. ASME has issued *ASME Section VIII – Division 2 Criteria and Commentary, PTB-1-2009* that provides background and insight into design-by-analysis and design-by-rule technologies.

The ASME Section VIII Committee is currently undertaking an effort to review and identify common rules contained in the Section VIII Division 1, Division 2, and Division 3 B&PV Codes. In this context, common rules are defined as those rules in the Section VIII, Division 1, Division 2, and Division 3 Codes that are identical and difficult to maintain because they are computationally or editorially complex, or they require frequent updating because of the introduction of new technologies. Common rules typically occur in the design-by-rule and design-by-analysis parts of the code; but also exist in material, fabrication, and examination requirements. A plan has been developed to coordinate common rules with the following objectives.

- Common rules in the Section VIII Division 1, 2, and 3 codes should be identical and updated at the same time to ensure consistency.
- Common rules will be identified and published in a single document and referenced by other documents to; promote user-friendliness, minimize volunteer time on maintenance activities, and increase volunteer time for incorporation of new technologies to keep the Section VIII codes competitive and to facilitate publication.
- Core rules for basic vessel design such as wall thickness for shells and formed heads, nozzle design, etc. will be maintained in Division 1; although different from Division 2 these rules are time-proven and should remain in Division 1 because they provide sufficient design requirements for many vessels.
- ASME Section VIII Committee recognizes that Division 2 is the most technically advanced and best organized for referencing from the other Divisions and recommends that, with the exception of overpressure protection requirements, common rules identified by the committee shall reside in Division 2 and be referenced from Division 1 and Division 3, as applicable.

As a starting point for the common rules initiative, the ASME Section VIII Committee has developed Code Case 2695 to permit the use of some the design-by-rule procedures in Division 2 to be used for Division 1 construction.

As part of the common rules initiative, the ASME Section VIII Committee is working with ASME LLC to create separate example problem manuals for each Division. These manuals will contain problem examples that illustrate the proper use of code rules in design. The *ASME Section VIII - Division 2 Example Problem Manual, PTB-3 2009* has been completed and issued.



## ACKNOWLEDGEMENTS

We wish to acknowledge the review performed by the following members of the BPV VIII Committee: Chris Hinnant, Jay Vattappilly, Tom Barsh, Mike Clark, Urey Miller, Ken Tam, Gabriel Auriolles, George Rawls, Steve Roberts, Kam Mohktarian, Maan Jawad, Scott Mayeux, Ramsey Mahadeen, Mahendra Rana, Richard Basile and Lou Hayden.

Finally, we would also like to commend the efforts of Tiffany Shaughnessy for her editing and document preparation skills in the publication of this manual.



# PART 1

## GENERAL REQUIREMENTS

### 1.1 Introduction

ASME B&PV Code, Section VIII, Division 1 contains mandatory requirements, specific prohibitions, and non-mandatory guidance for the design, materials, fabrication, examination, inspection, testing, and certification of pressure vessels and their associated pressure relief devices.

### 1.2 Scope

Example problems illustrating the use of the design-by-rule methods in ASME B&PV Code, Section VIII, Division 1 are provided in this document. Example problems are provided for most of the calculation procedures in either SI or US Customary units.

### 1.3 Definitions

The following definitions are used in this manual.

**VIII-1** – ASME B&PV Code, Section VIII, Division 1, 2010 Edition, 2011 Addenda

**VIII-2** – ASME B&PV Code, Section VIII, Division 2, 2010 Edition, 2011 Addenda

### 1.4 Organization and Use

An introduction to the example problems in this document is described in Part 2 of this document. The remaining Parts of this document contain the example problems. All paragraph references without a code designation, i.e. VIII-1 or VIII-2, see Definitions, are to the ASME B&PV Code, Section VIII, Division 1, 2010 with the 2011 Addenda [1].

The example problems in this manual follow the design by rule methods in ASME B&PV Code, Section VIII, Division 1. Many of the example problems are also solved using ASME B&PV Code, Section VIII, Division 2 design-by-rule procedures contained in Part 4 of this Code using the allowable stress from VIII-1. In addition, where the design rules are the same, the VIII-2 format has been used in this example problem manual because of the user-friendliness of these rules.

### 1.5 Comparison of VIII-1 and VIII-2 Design Rules

Since many of the design rules in VIII-2 were developed using the principles of VIII-1, it is recommended that users of this manual obtain a copy of ASME PTB-1-2009 [2] that contains the VIII-2 criteria and commentary on the technical background to these rules. A comparison of the design-by-rule procedures in VIII-2 compared with VIII-1 is shown in Table E1.1.

### 1.6 ASME Code Case 2695

In recognition of the similarities and the use of the latest technology in developing the design-by-rule part of VIII-2, ASME has issued Code Case 2695 that permits the use of VIII-2 design rules with VIII-1 allowable stresses with some limitations. Code Case 2695 is shown in Table E1.2.

