Proceedings of the ASME 2010 Pressure Vessels & Piping Division / K-PVP Conference
PVP2010
July 18-22, 2010, Bellevue, Washington, USA

PVP2010-26129

USER'S DESIGN SPECIFICATION RECOMMENDATIONS FOR ASME SECTION VIII, DIVISION 2

Trevor G. Seipp
Becht Engineering Canada Ltd.
110-259 Midpark Way, S.E.
Calgary, AB CANADA
Tel: 403-256-3575 ext 221
Fax: 403-256-3520
Email: tseipp@becht.com

Shiju V.P. George
Becht Engineering Canada Ltd.
110-259 Midpark Way, S.E.
Calgary, AB CANADA
Tel: 403-256-3575 ext 222
Fax: 403-256-3520
Email: sgeorge@becht.com

ABSTRACT

The UDS (Users Design Specification) is the design-basis document for ASME Section VIII, Division 2 pressure vessels. It defines the vessel design requirements and serves as the single point of reference for the Manufacturer's Design Report (MDR).

Despite its importance, the authors' have observed instances where insufficient attention has been paid to the creation of this baseline document. This paper discusses both requirements and recommended good practices for writing a UDS in accordance with the new Division 2 requirements. The work and information flow to arrive at the required and recommended information is discussed. In particular, the multi-disciplinary nature of a well-developed UDS and the importance of change management will be emphasized. Finally, formatting and other good practices will be discussed.

INTRODUCTION

Pressure vessel design-basis documents often take the form of a vessel datasheet, containing process and metallurgical data, and corporate specifications of the operating company or EPC company buying the vessel.

The release of ASME Section VIII, Division 2 [1] in the 1960's, with its lower allowable stresses resulted in a move towards some "certification" of the design-basis document. The Code writers took this approach to ensure that the minimum requirements and parameters of the new Code were formally defined. The recently-released ASME Section VIII, Division 2 (2007 Edition) [2] goes further and formalizes more rigorous information requirements that must be formally captured in the UDS. The new UDS requirements also acknowledge, indirectly, that proper development of the UDS is an interdisciplinary effort.

This paper presents the Pre-2007 UDS requirements for historical purposes, followed by an item-by-item discussion of the Post-2007 requirements. In the discussion of the Post-2007 requirements, the work and information flow within a typical engineering organization is discussed in the context of demonstrating the information required for the UDS. Throughout the various discussions some recommended good practices are also highlighted.

Pre-2007 UDS Requirements (2006 Edition shown)

Article AG-301.1 defined the requirements of the UDS:

> ***AG-301.1 User's Design Specification.*** *It is the responsibility of the user or an agent acting on his/her behalf, who intends that a pressure vessel designed, constructed, tested, and certified to be in compliance with these rules, to provide or cause to be provided for such vessel or vessels a User's Design Specification. This shall set forth requirements as to the intended operating conditions in such details as to constitute an adequate design basis for selecting materials and designing, fabricating, and inspecting the vessel or vessels as required to comply with these rules. The User's Design Specification shall include all of the loadings listed in AD-110, as applicable, and the method of supporting the vessel.*

Subparagraphs (a), through (e) add requirements for:

(a) Fatigue
(b) Corrosion/erosion allowance
(c) Lethal substance
(d) Effective Code Edition and Addenda
(e) No other information is required.

Significantly, with the exception of particular items such as indicating the corrosion allowance, the vessel design requirements are only generally specified in the UDS. In this context, the UDS highlights the design basis considerations while otherwise leaving the proper specification and application of the Code design to the vessel Manufacturer.

DISCUSSION OF POST-2007 UDS REQUIREMENTS

The Post-2007 UDS requirements have been extensively modified. Operating conditions must be described and process fluid properties sufficiently defined to allow the development and assessment of vessel thermal profiles. The design loads are now listed explicitly and the associated load combinations to be evaluated defined. An outline drawing showing specific nozzle elevations and orientations is required. The fatigue considerations are more explicit. Significant consideration is required for the materials selection. And all of the "additional requirements" are completely new.

In this section, all of the subparagraphs of 2.2.2.1 are detailed and discussed.

Installation Site

2.2.2.1 a) Installation Site

1) Location

2) Jurisdictional authority if applicable

3) Environmental conditions

- *i) Wind design loads including relevant factors (i.e. design wind speed, exposure, gust factors)*
- *ii) Earthquake design loads*
- *iii) Snow loads*
- *iv) Lowest one day mean temperature for location*

Pressure vessels are designed and fabricated ound the world, for installation around the world. It is tal that the exact installation location be specified to nsure that the appropriate jurisdictional and environmental considerations are addressed. Furthermore, if the vessel is re-located, differences between the original and new locations can be more readily established in order to re-certify the vessel to operate at the new location.

Specifying the jurisdiction is important as some local jurisdictions may have supplemental requirements or restrictions to the use of Division 2. In the event that there are no jurisdictional requirements, it is good practice to describe how the verification/validation of the certified design will be accomplished, i.e. through a third-party or through an insurance carrier.

The specification of wind, earthquake and snow design criteria, as well as the lowest one day mean temperature, is all required for the design. Previously, this information was typically presented in operating/ engineering company specifications. Presentation of this information directly in the UDS provides the vessel designer with clear and unambiguous information to use in the development and review of the MDR calculations.

The location and environmental conditions are often obtained from the civil/structural engineers on the design team. This group typically manages this information as they are responsible for foundation and structure design throughout the site.

Jurisdictional requirements are determined by the vessel engineer. While the information can often be obtained by reviewing the jurisdiction's website, direct discussion with the authority is suggested to ensure that the jurisdictional requirements are properly captured. Given that most jurisdictions regulate both pressure vessels and piping, assistance in this endeavor may be obtained from the piping engineer responsible for registration of the piping design.

Vessel Identification

2.2.2.1 b) Vessel Identification

1) Vessel number or identification

2) Fluid properties for proprietary fluids' specific properties needed for design, e.g. gas, liquid, density, etc.

Explicitly detailing the vessel identification is useful, particularly in situations where multiple vessels are based on the same design. This approach highlights any differences that may be present in component details such as nozzle locations/orientations.

Providing proprietary fluid information relates to fluid weight calculations and also some of the more sophisticated analyses in Part 5, such as the determination of vessel temperature profiles.

The identification of the vessel is obtained from the P&ID, which in most organizations is controlled by the process engineering group. As this group is also responsible for the fluid properties their input is required to obtain this information. If applicable, the process licensor may need to be involved as well. Detailed discussions with the process engineering group and/or the process licensor are often required to ensure that the fluid properties are established for all operating scenarios experienced by the vessel. In cases where the process composition varies along the length of the vessel, such as in a distillation column or a chemical reactor vessel, the associated property changes, as appropriate, must also be specified.

Vessel Configuration and Controlling Dimensions

2.2.2.1 c) Vessel Configuration and Controlling Dimensions

1) Outline drawings

2) Vertical or horizontal

3) Openings, connections, closures including quantity, type and size, and location (i.e. elevation and orientation)

4) Principal component dimensions in sufficient detail so that volume capacities can be determined

5) Support method

The requirement to include outline drawings and a complete connection schedule is a significant change from the Pre-2007 UDS. Instead of just a narrative specification or list of design data, the user must expend some effort into developing drawings and establishing specific connection locations. This activity should highlight to the user any constructability or maintainability issues that may be present.

While some of this information may be obtained from the P&ID, detailed dimensional requirements will require input from the process engineering and piping disciplines. The process engineering group will have made the determination on whether the vessel is horizontal or vertical, based on their requirements.

The decision about the support method is a complex one involving the vessel engineer, the civil/structural and process engineering groups. The input from the process engineering group will dictate the elevation of the vessel. This will influence whether the vessel is supported from grade or in an elevated structure. If it is at grade, the choices are usually saddles or legs vs. skirt. If it is in an elevated structure an additional choice is the use of lugs which may be situated almost anywhere on the vessel. The specific support arrangement will not only influence the installed cost but also the design parameters of the vessel. The anchor bolt locations, underlying support beam details (if in a structure), and whether or not friction reducing pads beneath the support are required, are design considerations that will need to be established with the civil/structural engineering group.

Design Conditions

2.2.2.1 d) Design Conditions

1) Specified design pressure. The specified design pressure is the design pressure required at the top of the vessel in its operating position. It shall include suitable margin required above the maximum anticipated operating pressure to ensure proper operation of the pressure relief devices. The MAWP of the vessel may be set equal to this specified design pressure. If the actual MAWP of the vessel is calculated, it shall not be less than the specified design pressure.

2) Design temperature and coincident specified design pressure

3) Minimum Design metal Temperature (MDMT) and coincident specified design pressure

4) Dead loads, live loads, and other loads required to perform the load case combinations required in Parts 4 and 5.

Specification of the vessel design conditions is a fundamental requirement. The coincident design temperature must also be supplied. It is permissible for a pressure vessel to have multiple coincident pressure/temperature combinations, and in certain circumstances, it may even be desirable to have multiple design conditions. The UDS must also present the MDMT and coincident pressure.

Finally, loads experienced by the vessel must be provided. This statement requires the vessel engineer to have read and understood all of Part 4 (and Part 5 as applicable) to know which dead and live loads need to be provided and the load case combinations that must be evaluated.

The specified design pressure and design temperature are usually provided on the process P&ID. However, experience has shown that only one set of conditions is typically presented on the P&ID. Additional discussions with the process engineering group will be necessary to determine if other pressure/temperature combinations apply and if there are gradients along the vessel that must be considered. The selection of the MDMT is usually a multi-disciplinary task, with the process engineering group, the civil structural group, the materials/metallurgy group, and the vessel engineer making the appropriate determination. Factors such as auto-refrigeration (at a specified design pressure) require input from the process engineering group. The civil/structural engineering group provides the environmental conditions that could impact the MDMT. Finally, the materials/metallurgy group provides feedback to ensure that the material selection is appropriate for a particular MDMT.

The dead/live loads may be generated from a variety of sources. Wind and earthquake loads are addressed in 2.2.2.1.a) 3). However, attached piping loads need to be provided by the piping engineering group. If there are platforms attached to the vessel a significant effort may be necessary to obtain those dead and live loads. Since the platforms are typically used for operations and maintenance access to the vessel either during operation or during maintenance, the input of these groups is vital. For example, if a large piece of equipment such as a welding machine is required at or near a manway during a maintenance activity, it will need to be determined if it will be in-place when the vessel is de-pressurized or in operation.

Operating Conditions

> 2.2.2.1 e) Operating Conditions
> 1) *Operating pressure*
> 2) *Operating temperature*
> 3) *Fluid transients and flow and sufficient properties for determination of steady state and transient thermal gradients across the vessel sections*

Further to 2.2.2.1 b)2), additional emphasis is placed here on obtaining the process fluid properties. In this context, sufficient information is required to allow the development of the expected operating temperature profiles in the vessel. The process information is necessary to determine appropriate heat transfer coefficients. The heat transfer coefficients should be specified in the UDS as they will likely be used in a finite element analysis to determine the vessel thermal profiles. Thermal transients or gradients affecting the design must be presented in the UDS along with the coincident operating conditions.

This information is rarely if ever obtained directly from the P&ID. Discussions with the process engineering group are more typically required to define these conditions and obtain the necessary fluid property and flow information. The vessel engineer should understand the consequences of fluid and/or thermal transients so that the end result of these discussions is the determination of all necessary information for inclusion in the UDS.

Design Fatigue Life

> *2.2.2.1 f) Design Fatigue Life*
> 1) *Cyclic operating conditions and whether or not a fatigue analysis is required shall be determined in accordance with paragraph 4.1.1.4. When a fatigue analysis is required, provide information in sufficient detail so that an analysis of the cyclic operation can be carried out in accordance with paragraph 5.5.*
> 2) *When the vessel is designed for cyclic conditions, the number of design cycles per year and the required vessel design life in years shall be stated*
> 3) *When cyclic operating conditions exist and a fatigue analysis is not required based on comparable equipment experience, the possible harmful effects of the design features listed in 5.5.2.2.a) through f) shall be evaluated when contemplating comparable equipment experience.*

This paragraph is similar to the fatigue paragraph in the Pre-2007 edition with some notable exceptions. Here, sub-paragraph f).1) refers the user to 4.1.1.4. That paragraph states:

> *4.1.1.4. A screening criterion shall be applied to all vessel parts designed in accordance with this Division to determine if a fatigue analysis is required. The fatigue screening criterion shall be performed in accordance with paragraph 5.5.2. If the results of this screening indicate that a fatigue analysis is required, then the analysis shall be performed in accordance with paragraph 5.5.2. If the allowable stress at the design temperature is governed by time-dependant properties, then a fatigue screening analysis based on experience with comparable equipment shall be satisfied (see paragraph 5.5.2.2).*

It is the authors' opinion that the fatigue screening analysis itself should be attached as an annex to the UDS with the results of the screening listed directly in the body of the UDS. In this way, an engineer certifying the UDS will have complete access to the fatigue screening analysis to appropriately specify design features suitable for fatigue service, as applicable.

Similarly, the caution in subparagraph f).3) is significant. It is the authors' opinion that, if this paragraph is applicable, the harmful effects listed in 5.5.2.2.a) through f) should be explicitly detailed and addressed in the UDS.

In order to perform the fatigue screening analysis, the vessel engineer must interface with the process engineering group. As with the establishment of the process fluid properties and associated operating scenarios, these discussions must go to some depth to ensure that the actual cycles experienced by the vessel are accurately detailed for use in the fatigue screening analysis.

A final point: although it is common industry practice to apply 5.5.2.2. to many vessels, it is imperative that the vessel engineer fully question the "comparable equipment experience" rationale. Was the equipment the same size? Was it the same metallurgy? Was it operated identically? How has the identical operation been verified/validated? Has it been operated long enough to satisfy the desired design life of this vessel? When due consideration is given to these questions it may become apparent that 5.5.2.2. is in fact not applicable.

Materials of Construction

2.2.2.1 g) Materials of Construction

1) Material specification requirements shall be in accordance with one or more of the following criteria:

i) Specification of materials of construction in accordance with Part 3

ii) Generic material type (i.e. carbon steel or Type 304 Stainless Steel). The user shall specify requirements that provide an adequate basis for selecting materials to be used for the construction of the vessel. The Manufacturer shall select the appropriate material from Part 3, considering information provided by the user per paragraph 2.2.2.1.g.3.

2) The user shall specify the corrosion and/or erosion allowance

3) The user, when selecting the materials of construction, shall consider the following:

i) Damage mechanisms associated with the service fluid at design conditions. Informative and man-mandatory guidance regarding metallurgical phenomena is provided in Section II, Part D, Appendix A, API RP 571, and WRC Bulletins 488, 489, and 490.

ii) Minimum Design Metal Temperature and any additional toughness requirements.

iii) The need for specific weld filler material to meet corrosion resistance requirements, see paragraph 6.2.5.8.

While it is sufficient to indicate a general material type, such as carbon steel, 2.2.2.1.g)3) clearly requires the user to fully address the process and its effects on the vessel material. Significant interaction with the materials/metallurgy group and the process engineering group is mandatory to ensure this. While the responsibility for this sub-paragraph is typically delegated to the materials/metallurgy group, the vessel engineer should ensure that the recommended guidance is followed.

Loads and Load Cases

2.2.2.1 h) Loads and Load Cases

1) The user shall specify all expected loads and load case combinations as listed in paragraph 4.1.5.3.

2) These loading data may be established by:

i) Calculation

ii) Experimental Methods

iii) Actual experience measurement from similar units

iv) Computer analysis

v) Published data

In this section, the user is required to explicitly specify all expected loads and load case combinations from the recommended set in paragraph 4.1.5.3. There are a few cautions from 4.1.5.3 that are worth repeating in this context. First, the loads and load case combinations that are to be considered shall include ***but not be limited to*** those shown in Tables 4.1.1 and 4.1.2 (emphasis added). If there are any other loads or load case combinations that are applicable to the vessel, then these must be included in the UDS. Also, in any combination of loads that involve the pressure, the effects of the pressure being equal to zero also need to be evaluated. It is the opinion of the authors that these zero-pressure load case combinations should be explicitly detailed in the UDS.

As with many of the UDS development efforts, determination of the vessel loads and load cases will likely be a multi-disciplinary activity. The vessel engineer must have a clear understanding of the loads and load case combinations in Part 4 and Part 5. Additionally, the failure modes described in Part 5 must be carefully considered in evaluating the specific load case combinations. As a final point, it is important to understand that the vessel designer is under no obligation to evaluate any loads or load case combinations that are not explicitly detailed in the UDS and as such it is important that all loads experienced by the vessel are considered and captured in the UDS as appropriate.

Overpressure Protection

2.2.2.1 i) Overpressure Protection

1) The user shall be responsible for the design, construction and installation of the overpressure protection system unless it is delegated to the Manufacturer. This system shall meet the requirements of Part 9.

2) The type of overpressure protection intended for the vessel shall be documented in the UDS as follows (see paragraph 9.1):

i) Type of overpressure protection system (e.g., type of pressure relief valve, rupture disc, etc.)

ii) System design (see paragraph 9.7)

3) The user shall state if jurisdictional acceptance is required prior to operation of the vessel.

The type of overpressure protection for the vessel must be explicitly stated in this section. Typically, this information will be provided in the P&ID, however discussions between the vessel engineer and the user may be required to formally capture 2.2.2.1.i)2) in the UDS. The user is ultimately responsible for ensuring that the overpressure protection provided complies with the requirements of Part 9.

Additional Requirements

Article 2.2.2.2 goes on to say that the user shall state the additional requirements as appropriate for the intended vessel service such as:

a) Additional requirements such as NDE, restricted chemistry, or heat treatments

b) Type of weld joints and the extent of NDE

c) Non-mandatory or optional provisions of the Code that are to be mandatory for the vessel

d) Special requirements for markings and their location (see paragraph 4.1 and Annex 2.F)

e) Requirements for seals and/or bolting for closures and covers

f) Additional requirements related to erection loadings

g) Any agreements which resolve the problems of operation and maintenance control unique to the vessel

h) Additional requirements related to pressure testing such as:

1) Fluid properties and test temperature limits

2) Position of vessel and support / foundation adequacy if field hydrostatic testing is required

3) Location: Manufacturer's facility or on-site

4) Cleaning and drying

5) Selection of pressure test method, see paragraph 8.1.1

6) Application of paints, coatings and lining, see paragraph 8.1.2.e

These items were deemed by the Code writers to be significant enough to be listed. Therefore, good engineering practice would be to include all of these items in the UDS. Furthermore, it is the opinion of the authors that the UDS should also state which points are not applicable. The user of the UDS is then assured that all points were considered and addressed if applicable.

Most of these issues will not be found on a P&ID, but rather through discussion with all of the appropriate engineering groups.

Of specific interest are the erection loadings. The majority of vessels are shop-fabricated and field installed. Therefore, properly defining the erection loading is critical to ensuring that the vessel will not be permanently damaged during erection. Although not specifically noted here, the authors would also recommend the inclusion of transportation loads. There have been situations that the authors are aware of where the transportation loads have been the governing case for the thickness of certain vessel parts.

CHANGE MANAGEMENT OF THE UDS

As is evident in the discussions presented throughout this paper, a properly developed UDS requires a multi-disciplinary approach for successful determination of the vessel design basis. In addition to obtaining the required information for the UDS, the vessel engineer must ensure that the various disciplines, from the civil/structural, process, materials, and piping engineering groups, among others, have provided the latest information respectively as relates to their roles in the vessel design.

The UDS, as with many design documents, may be subject to design development changes provided the revisions are properly justified and noted through a suitable revision management system. It is the responsibility of the vessel engineer to co-ordinate and incorporate all applicable changes to the UDS and to ensure that the various disciplines and the vessel manufacturer are made aware of all changes.

It is strongly recommended that the UDS be formally maintained in a document control system. A "squad check" review procedure is recommended to allow the disciplines to make comments and for the vessel engineer to accurately capture and assimilate the required information and changes. As with any document that drives the fabrication of the vessel, it is important to keep in mind that changes to the UDS may impact the vessel cost and schedule for delivery and this should be considered before making any changes.

THE UDS AS A LEGAL DOCUMENT

In jurisdictions where the use of the Code is mandatory, the UDS takes the force of law. All mandatory requirements listed in the UDS therefore become binding with the force of law. The vessel engineer writing the UDS is well advised to keep this consideration foremost when writing the UDS and further when referencing documents from within the UDS

REFERENCING OTHER SPECIFICATIONS AND DATASHEETS IN THE UDS

In the context of the previous section, it should be noted that any specifications, datasheets, etc, referenced in the UDS also take the force of law. Therefore, the authors recommend the following:

- Judicious selection of referenced documents such as datasheets and specifications.
- Keep the referencing to a minimum. This will reduce the potential for conflicting requirements that can result in confusion and an incorrect design. Additionally, reference document revisions must be tracked and UDS updates may be required on this basis alone.
- A section in the UDS should be provided that describes a mechanism to adjudicate conflicts between the reference specifications/datasheet and

the UDS. Again, keeping the referencing to a minimum will reduce the effort required to understand and address these conflicts.

- Every effort should be made to ensure that conflicts do not exist between the referenced specifications and the requirements explicitly detailed in the UDS – do not rely on the manufacturer to find these conflicts.

CERTIFICATION OF THE UDS

The UDS must be certified prior to being issued. Annex 2.A provides a Guide for Certifying the UDS. In particular there is a specific paragraph that requires additional discussion:

2.A.2.4. When more than one Engineer certifies and signs the User's Design Specification the area of expertise shall be noted next to their signature under "areas of responsibility" (e.g., design, metallurgy, pressure relief, fabrication, etc). In addition, one of the Engineers signing the User's Design Specification shall certify that all elements required by this Division are included in the Specification.

The successful development of an accurate UDS is a multi-disciplinary effort that requires detailed communication and discussions. In this context, it would be good engineering practice to have a representative from each discipline sign the UDS certification indicating that they are responsible for providing the information specific to their respective discipline and as required by the Code.

FORMAT OF THE UDS

The final section in this discussion of the UDS is the format. The vessel engineer is presented with several options:

- Spreadsheet / checklist
- Narrative
- Combination

The authors highly recommend the narrative format for the UDS. As can be seen throughout this paper, the issues contained in the UDS are complex and involve communicating and coordinating with a multi-disciplinary team. A well developed UDS in this context does not lend itself to a spreadsheet / checklist approach.

REVIEW AND RECOMMENDATIONS

This paper has discussed the UDS requirements and associated rationale of the Post-2007 ASME Section VIII, Division 2. The successful development of an accurate UDS is a multi-disciplinary effort based on detailed communication and team discussions. The vessel engineer preparing the UDS should not be working alone but as a coordinating member of a multi-disciplinary engineering team.

It would be good engineering practice to have a representative from each Discipline sign the UDS certification indicating that they are responsible for providing the information specific to their respective disciplines and as required by the Code.

Keep the referencing within the UDS to a minimum. This will reduce the potential for confusion, an incorrect design, conflicting requirements and the associated resolution effort.

In jurisdictions where the use of the Code is mandatory, the UDS takes the force of law. In this context, the development of the UDS should be approached with the care afforded to the creation of a legal document.

The UDS may be subject to design development changes provided the revisions are captured through a suitable revision management system. In this context it is strongly recommended that the UDS is formally maintained in the Project's document control system and further that a squad check procedure is applied to capture and correctly incorporate discipline comments.

REFERENCES

1. ASME, 2006, *ASME Boiler and Pressure Vessel Code, Section VIII – Division 2*, American Society of Mechanical Engineers, New York, NY

2. ASME, 2009, *ASME Boiler and Pressure Vessel Code, Section VIII – Division 2*, American Society of Mechanical Engineers, New York, NY