STP-PT-048

CRITERIA FOR RELIABILITY-BASED DESIGN AND ASSESSMENT FOR ASME B31.8 CODE

ASME STANDARDS TECHNOLOGY, LLC

STP-PT-048

CRITERIA FOR RELIABILITY-BASED DESIGN AND ASSESSMENT FOR ASME B31.8 CODE

Prepared by:

Maher Nessim
C-FER Technologies

ASME STANDARDS TECHNOLOGY, LLC

Date of Issuance: June 30, 2012

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

ASME Standards Technology, LLC
Three Park Avenue, New York, NY 10016-5990

ISBN No. 978-0-7918-3365-0

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

FORWORD

This Criteria Document provides guidance to potential users of the proposed ASME Appendix B31.8R on Reliability Based Design and Assessment (RBDA) by documenting the relevant background information required to fully understand the requirements of the Appendix and to apply them correctly in decision making. The need for a Criteria Document was identified during the process of voting on ASME B31.8 Ballot No. 08-905 as a requirement for further consideration of the RBDA Appendix.

Established in 1880, the American Society of Mechanical Engineers (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 that enhance public safety, and provides lifelong learning and technical exchange opportunities benefiting the engineering and technology community. Visit www.asme.org for more information.

The ASME Standards Technology, LLC (ASME ST-LLC) is a not-for-profit Limited Liability Company, with ASME as the sole member, formed in 2004 to carry out work related to newly commercialized technology. The ASME ST-LLC mission includes meeting the needs of industry and government by providing new standards-related products and services, which advance the application of emerging and newly commercialized science and technology and providing the research and technology development needed to establish and maintain the technical relevance of codes and standards. Visit www.stllc.asme.org for more information.

1. PURPOSE

This Criteria Document provides guidance to potential users of the proposed ASME Appendix B31.8R on Reliability Based Design and Assessment (RBDA) by documenting the relevant background information required to fully understand the requirements of the Appendix and to apply them correctly in decision making. The need for a Criteria Document was identified during the process of voting on ASME B31.8 Ballot No. 08-905 as a requirement for further consideration of the RBDA Appendix.

The Appendix provides requirements for the application of reliability-based methods to the design and assessment of non-sour natural gas transmission pipelines.[1] The Appendix is non-mandatory; however, Section R1.1 in the Appendix states that **"if an operator chooses to use the Appendix for designing and operating a pipeline, he must follow it until a different basis for pipeline operation is established with the regulator."** The reason for this requirement is that the RBDA approach forming the basis for the Appendix permits certain tradeoffs between initial design and planned maintenance (see Section 4.4). For example, the reliability targets may be met by using a thinner wall than would be required by the conventional design approach, combined with a more stringent integrity maintenance plan. The Appendix requires that the maintenance plan used to justify the thinner wall be followed and documented to ensure that the reliability targets are met throughout the operational life. It is therefore essential to review and establish a new comprehensive basis for continued operation in cases where this requirement is eliminated by discontinued compliance with the Appendix.

The Appendix states that **"reliability-based methods are particularly useful for pipelines involving large uncertainties...application of new materials and technologies, unique loading situations, and severe failure consequences."** This statement is based on two key features of the RBDA methodology:

1. RBDA is a rigorous methodology. While conventional design methods are mostly empirical, RBDA evaluates various design or operational choices from first principles. For example, the design factor used for wall thickness selection in conventional standards is a single safety control parameter that is used to design against a combination of threats and is assigned a single value for a range of pipe properties (i.e., diameter, grade, pressure and class). The design factor has been validated through use over the past few decades and therefore its effectiveness is established for pipeline parameters that were commonly used during that period. However, it is not necessarily adequate for pipelines made of high strength steels for which little experience exists. By contrast, RBDA addresses individual threats based on the actual structural behaviour of the pipe as derived from basic pipe properties. For example, equipment impact resistance is evaluated from a model that compares the applied pressure to the pressure required to fail a gouged dent caused by an excavator hit. This model uses the actual pipe parameters, such as diameter, wall thickness and steel grade, and can therefore be applied to the entire range of properties for which it is validated (e.g., higher strength steels) without the need for proof based on prior use. The same logic applies for unique loading conditions such as geotechnical loads.
2. RBDA explicitly acknowledges uncertainty. Safety of possible design or operational alternatives is measured by reliability (1.0 minus the failure probability). This measure explicitly incorporates the impact of uncertainty. A larger degree of uncertainty regarding pipeline behaviour or performance results in a lower calculated level of reliability and a requirement to make more conservative decisions in order to ensure adequate reliability. As such, one of the built-in features of the RBDA methodology is the ability to reflect the degree of uncertainty in the decisions made.

Other key benefits of the RBDA approach include the ability to achieve consistent safety for all pipelines. This eliminates unnecessary conservatism in individual cases, allowing more effective use of resources to

[1] The Appendix is not applicable to offshore gas transmission pipelines covered by Chapter VIII, or sour gas service covered by Chapter IX, of ASME Standard B31.8.

achieve better overall safety. The methodology also permits integration of design and operational decisions to develop more cost-effective overall solutions.

The Appendix in its entirety is explicitly applicable to onshore pipelines transporting non-sour lean natural gas. This statement is not intended to convey that any of the content is inapplicable to other types of pipelines, but rather that there are certain aspects of the document that are specific to non-sour lean natural gas pipelines. Specifically, **"the reliability targets in Section R1.6 are based on a model that evaluates the consequences of an ignited lean natural gas release at pressures consistent with the assumption of ideal gas behaviour."** These targets should therefore not be used directly for other gas compositions or ultra-high pressures that may have significantly different release consequences than those of lean natural gas. For rich gas (depending on the particular composition), it may be possible to demonstrate that the underlying release consequence model just mentioned is applicable, and in such cases, the targets can be applied directly. If the model does not apply directly, the Appendix may be used with case-specific reliability targets that meet the risk criteria underlying the Appendix. Such targets can be developed by adjusting the targets in the Appendix based on the relative magnitude of the release consequences associated with the rich gas composition and/or ultra-high pressure (as calculated from a suitable model) and those calculated from the model underlying the Appendix for the same pipeline. Details of this process can be inferred from the original methodology used in developing the reliability targets in the Appendix (Nessim et al.) [1], [2]. It may also be possible to extend applicability of the Appendix to other fluids, such as sour gas, by making similar adjustments to the reliability targets, as long as the release consequences associated with these fluids are dominated by human safety considerations.

Apart from the reliability targets and the specific procedure used in demonstrating compliance with them, much of the content of the Appendix is applicable to a wide variety of pipelines. This includes all requirements and other information related to the calculation of reliability with respect to different integrity threats.

Users are advised **"to consult the Commentary and the reference material that support the provisions of this Appendix to ensure that the parameters to be used in the design are within the range of applicability of the consequence models used for reliability target calibration."** The targets were developed based on a safety benchmark that was calculated from a set of pipeline designs represented by different combinations of diameter, pressure, grade and class location (Nessim et al.) [1], [2]. As required by the calibration approach, these cases were selected to cover the range of pipeline parameters that existed at the time of target development. The calculation involved use of a specific consequence model, which is built into the targets. The intent is to state that if use of the Appendix is considered for pipelines that have design parameters outside the range of the test cases used in the calibration, a check must be carried out to ensure that the *consequence model* used in the calibration can be reasonably applied to these pipelines. The intent is not to impose a limitation on the application of the targets for pipelines that are outside the range defined by the test cases, as long as the consequence model is shown to apply. For example, the test cases used in target calibration covered a pressure range of 600 to 1400 psig (4.16 to 9.66 MPa). To apply the targets to a pipeline that has an internal pressure of 1500 psig (10.35 MPa), the user should ensure that the release consequence model is applicable to a pipeline operating at 1500 psig (10.35 MPa). If this is the case, then the targets can be used for the pipeline even though the pressure is outside the range of pressures considered in the test cases used in the target calibration.

The restriction described in the previous paragraph does not apply to probability models because failure probabilities must be calculated explicitly. The only requirement in that regard is that the probability model used must be appropriate for the pipeline being considered.

2. SCOPE

The ASME B31.8R RBDA Appendix consists of two main sections:

Section R1.0 – Requirements: This section states all requirements associated with the application of the RBDA approach, including the reliability targets and the process that must be followed to demonstrate compliance with them. It also includes a set of requirements that specify the essential characteristics of a valid reliability estimation approach, but leaves it up to the user to select specific calculation models and procedures.

Section R2.0 – Commentary: This section provides supplementary technical information to assist the user in applying the Appendix. It contains background information on the approach that was used to develop the reliability targets and provides more detailed information on the reliability calculation models and input data.

While some overlap may exist between this document and the Commentary Section (Section R2.0) of the Appendix, the two documents have distinct purposes. The Commentary Section R2.0 provides additional technical information to assist users in carrying out the calculations and implementing the procedures required to apply the Appendix. This document provides additional information on the rationale behind the requirements and the implications of using them.

The outline of this Criteria Document is identical to the outline of the Requirements Section of the Appendix (Section R1.0). For each section, the Criteria Document provides additional information in some or all of the following areas (as applicable).

1. Explanation of the intent and rationale behind the Requirements (e.g., why the Appendix includes separate reliability targets for location-specific threats such as known corrosion features).
2. Description of key concepts (e.g., definition of the “evaluation length” or the “evaluation period” and why these concepts are required).
3. Elaboration on the underlying concepts (e.g., differences in the types of decisions made and information required when the Appendix is applied to new versus existing pipelines).
4. Presentation of relevant background information (e.g., basic reliability concepts and definitions).
5. Explanation of deviations from previous work (e.g., an explanation of why the document does not treat fatigue and accidental loading as separate limit state types).
6. Presentation of illustrative examples for unique or unfamiliar requirements (e.g., an example of pipeline segmentation based on population density using the minimum population density calculated from two different evaluation lengths).
7. Discussion of the impact of using RBDA as compared to conventional design methods (e.g., a description of the impact of using the reliability targets on the relative safety levels for different pipelines).
8. Explanation of judgment-based provisions (e.g., why the minimum evaluation length is set to 1 mile or 1600 m).