STP-PT-006

DESIGN GUIDELINES FOR HYDROGEN PIPING AND PIPELINES

ASME STANDARDS TECHNOLOGY, LLC

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FOREWORD

Commercialization of hydrogen fuel cells, in particular fuel cell vehicles, will require development of an extensive hydrogen infrastructure comparable to that which exists today for petroleum. This infrastructure must include the means to safely and efficiently generate, transport, distribute, store, and use hydrogen as a fuel. Standardization of pressure retaining components, such as tanks, piping and pipelines, will enable hydrogen infrastructure development by establishing confidence in the technical integrity of products.

Since 1884, the American Society of Mechanical Engineers (ASME) has been developing codes and standards (C&S) that protect public health and safety. The traditional approach to standards development involved writing prescriptive standards only after technology has been established and commercialized. With the push toward a hydrogen economy, government and industry have realized that they cannot afford a hydrogen-related safety incident that may undermine consumer confidence. As a result, ASME has adopted a more anticipatory approach to standardization for hydrogen infrastructure which involves writing standards with more performance-based requirements in parallel with technology development and before commercialization has begun.

The ASME B31 Standards Committee has established a new Section Committee, B31.12, to develop new Code rules for piping and pipelines in hydrogen infrastructure applications. Research activities are being coordinated to develop data and technical reports concurrent with standards development and have been prioritized per B31.12 Section Committee needs.

The Technical Reports to be developed will establish data and other information to be used to support and facilitate separate initiatives to develop ASME standards for the hydrogen infrastructure. An initial report, developed under the sponsorship of the National Renewable Energy Laboratory (NREL), Hydrogen Standardization Interim Report for Tanks, Piping and Pipelines was, issued on May 3, 2005. This interim report addressed priority topical areas within each of the four pressure technology applications for hydrogen infrastructure development: storage (stationary) tanks, transport tanks, piping and pipelines and vehicle fuel tanks.

The present report builds on the work of the interim report to develop specific recommendations for design guidelines for hydrogen piping and pipelines.

Established in 1880, the American Society of Mechanical Engineers (ASME) is a 127,000-member professional not-for-profit organization focused on technical, educational and research issues of the engineering and technology community. ASME conducts one of the world's largest technical publishing operations, holds numerous technical conferences worldwide, and offers hundreds of professional development courses each year. ASME maintains and distributes 600 Codes and Standards used around the world for the design, manufacturing and installation of mechanical devices. Visit www.asme.org for more information.

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ABSTRACT

This report provides recommendations and guidance to the ASME B31.12 Hydrogen Piping and Pipelines Section Committee for design factors for metallic and nonmetallic pipe materials when used in a dry hydrogen gas environment; design life considerations; nondestructive examination (NDE) recommendations; in-service inspection (integrity management) recommendations; research needs and recommendations. The scope of this report includes all common metallic piping and pipeline materials used in the construction of piping and pipeline systems, of seamless and welded construction; composite reinforced welded or seamless metallic-lined piping and pipelines that are currently commercially manufactured and for which technical design data is available; composite reinforced plastic-lined piping and pipelines that are currently commercially manufactured and for which technical design data are available. Design factors are developed considering the operating conditions, internal hydrogen environment within the piping and pipeline systems and the effect of dry hydrogen gas on the material of construction. Composite piping and pipeline line pipe are considered as hoop-wrapped construction with liners capable of withstanding longitudinal loads. Other examination and inspection recommendations are made using similar considerations. Research recommendations are made based on lack or vagueness of existing data or where the research results were not readily adaptable to engineering use.

1 INTRODUCTION

Depletion of fossil fuels and the search for other sources of energy has been a current endeavor of mankind. Gaseous hydrogen is believed to play an important role in this endeavor and a “hydrogen economy” is a strong possibility within the next 50 years. In such a scenario, large scale production, storage, and transportation of hydrogen gas will become necessary. The objective of this work is to provide design guidelines for piping and pipelines transporting hydrogen gas under pressure. It is well documented that the hydrogen has no beneficial effects on steels but only detrimental effects. The term “hydrogen damage” represents a number of processes by which the load-carrying properties of metals, often in combination with applied and residual stresses, are reduced due to the presence of hydrogen. Hydrogen damage occurs most frequently in carbon and low-alloy steels while many metals and alloys are susceptible to it. Hydrogen damage can severely restrict the use of certain materials.

The containment and pressurization of hydrogen gas within metallic pipes is not a new concept or process. Hydrogen has been used in chemical processes for many years and industrial gas companies have produced, stored and transported hydrogen in its gaseous and liquid forms in the United States, Europe, and in other parts of the world. It is believed that piping and pipeline systems will need to be operated at pressures with possible cyclic pressure loading in excess of our current operating regimes. It is expected that hydrogen piping systems will have to be operated up to 15,000 psig (100 MPa) and that transport pipelines will operate up to 3000 psig (20 MPa) and both piping and pipeline systems will be operating at or below 300˚F (150˚C). In doing so, the metallic pipe materials in use today could be placed in an operating environment for which we have little or no data on their mechanical properties and behavior in a dry hydrogen environment. This report deals primarily with the bulk properties of the material, however localized properties have been considered. Components’ mechanical strength may be reduced for materials susceptible to hydrogen embrittlement in the presence of stress concentrations, such as weld reinforcements, threads, etc. [29].

This report provides recommendations to the ASME B31.12 Hydrogen Piping and Pipelines Section Committee for design factors for commonly used metallic piping materials. The use of nonmetallic materials has also been considered and where design information is available, guidance has been provided. These factors are to be applied to the design process information contained within ASME B31.12 Hydrogen Piping and Pipeline Code. In developing design factors industry standards, technical references, research reports and technical presentations were reviewed.

A discussion is presented to establish the major concerns with hydrogen gas embrittlement of currently used pipe materials and how the material properties of these alloys are affected. With these effects in mind the rationale for the design factors and the method used to derive them is provided.