STP/PT-005

DESIGN FACTOR GUIDELINES FOR HIGH PRESSURE COMPOSITE HYDROGEN TANKS

ASME STANDARDS TECHNOLOGY, LLC

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DESIGN FACTOR GUIDELINES FOR HIGH-PRESSURE COMPOSITE HYDROGEN TANKS

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Date of Issuance: August 1, 2006

This report was prepared as an account of work sponsored by the National Renewable Energy Laboratory (NREL) and the ASME Standards Technology, LLC (ASME ST-LLC).

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ISBN No. 0-7918-3038-1

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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.

Today, ASME codes and standards are used for hydrogen storage, transmission, and distribution. The anticipated requirements of the hydrogen economy will require local refueling stations with the capability to fill gaseous hydrogen vehicle tanks rapidly, to pressures as high as 15,000 psig (100 MPa). Although current standards could be used to build pressure tanks, piping, and pipelines meeting these operating requirements, it is likely that the resulting components would not, as a practical matter, enable commercialization of the technology.

ASME has worked closely with the Department of Energy (DOE), national laboratories, and other standards developing organizations (SDOs) to identify lead organizations to address the need for standards for hydrogen applications. ASME was selected to lead the efforts for pressure tanks, piping, and pipelines for storage, transportation, and distribution of hydrogen. Initial work of the ASME's Hydrogen Steering Committee led to the formation of volunteer task forces under the ASME Board on Pressure Technology Codes and Standards (BPTCS) to explore the standardization requirements for storage tanks, transportation tanks, portable tanks, piping, and pipelines for hydrogen-specific applications. The task forces submitted their recommendations at the end of 2003, and these recommendations led to initiation of standards actions, formation of project teams, and commencement of supporting research.

The ASME Boiler and Pressure Vessel (BPV) Standards Committee appointed a project team to develop new Code rules in the Boiler and Pressure Vessel Code Section VIII (pressure vessels) and Section XII (transport tanks) for hydrogen storage and transport tanks to be used in the storage and transport of liquid and gaseous hydrogen and metal hydrides. Rules for gaseous storage tanks with maximum allowable working pressures (MAWPs) up to 15,000 psig (100 MPa) will be needed. Research activities are being coordinated to develop data and technical reports concurrent with standards development and have been prioritized per Project Team needs. The Project Team may identify additional needs and gaps as drafts are developed.

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. These reports will target specific disciplines and fill the gaps identified by ASME's hydrogen task forces. 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 factors for composite stationary tanks and transport tanks.

Established in 1880, the American Society of Mechanical Engineers (ASME) is a 120,000 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.

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, expanding upon the former role of ASME's Codes and Standards Technology Institute (CSTI). 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.

ABSTRACT

This report provides recommendations to the ASME Hydrogen Project Team for design factors for composite hydrogen tanks. The scope of this study included stationary (e.g., storage) and transport tanks; it does not include vehicle fuel tanks. The report provides recommended design factors relative to short-term burst pressure and interim margins for long-term stress rupture based on a fixed 15-year design life for fully wrapped and hoop wrapped composite tanks with metal liners. These recommended margins are based on the proven experience with existing standards for composite reinforced tanks. Recommendations for further research are also provided, in particular for development of rules that would provide design life dependent design factors relative to stress rupture that would provide a means to design for longer or shorter lives than 15 years, and to provide a method for the manufacturer to determine, by testing, the stress ratio for their fiber reinforcement system.

1 INTRODUCTION

This report provides recommendations to the ASME Hydrogen Project Team for design factors for composite hydrogen tanks. The scope of this study included stationary (e.g., storage) and transport tanks; it does not include vehicle fuel tanks. The report provides recommended design factors relative to short-term burst pressure and interim margins for long-term stress rupture based on a fixed 15-year design life for fully wrapped and hoop wrapped composite tanks with metal liners. These recommended margins are based on the proven experience with existing standards for composite reinforced tanks. Recommendations for further research are also provided, in particular for development of rules that would provide design life dependent design factors relative to stress rupture that would provide a means to design for longer or shorter lives than 15 years, and to provide a method for the manufacturer to determine, by testing, the stress ratio for their fiber reinforcement system.

Because different terms are used in different standards for the same condition, this report starts by establishing a consistent set of definitions in section 2. Terms such as Working Pressure and Maximum Permissible Operating Pressure are adopted in this report, to be consistent with a draft ISO standard, ISO/DIS 10286:2004, *Gas Cylinders - Terminology*.

In making the recommendations for margins relative to short-term and long-term burst, a clear decision as to what is included in those margins, or what is not, is required. There may be an interrelationship between the appropriate burst margin and other Code rules. Section 3 documents the assumptions made that led to the recommended margins.

Sections 4 and 5 review design factors for short-term burst and long-term stress rupture in existing, related codes and standards. The evaluation of relevant existing codes is the basis for the recommended margins for the initial draft of the codes for hydrogen storage and transport tanks. Section 6 compares transport tanks with stationary tanks.

The recommended margins, both for the initial draft of the standards, and a recommended approach for the future, are outlined in section 7. Research and development is required to establish the technology necessary to implement the recommended approach for the future. Recommendations for this research are provided in section 8.