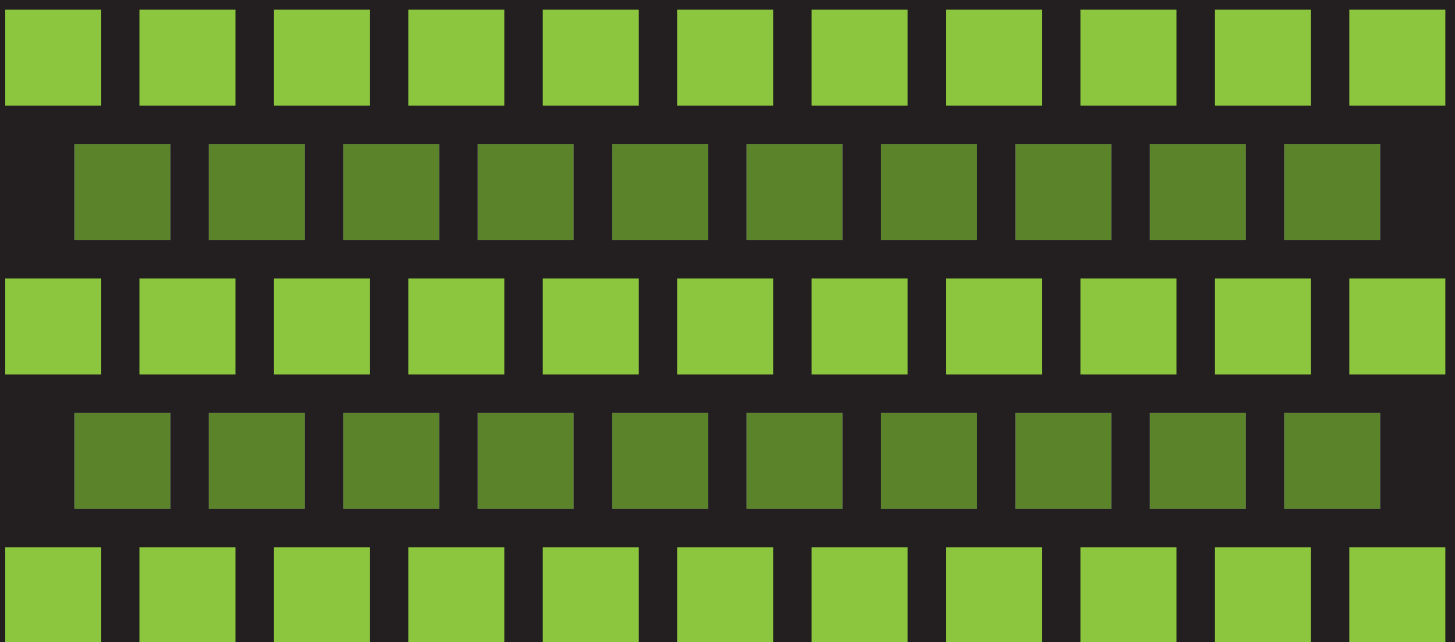


STP-PT-006

# DESIGN GUIDELINES FOR HYDROGEN PIPING AND PIPELINES



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Date of Issuance: December 7, 2007

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

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

ISBN No. 0-7918-3137-x

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## TABLE OF CONTENTS

FOREWORD.....	v
ABSTRACT .....	vi
1 INTRODUCTION .....	1
2 DEFINITIONS.....	2
3 REVIEW OF HYDROGEN EFFECTS ON PIPING AND PIPELINE MATERIALS.....	3
3.1 Overview of Metallic Pipe Materials .....	3
3.1.1 Hydrogen Damage and the Influence of Pressure .....	3
3.1.2 Hydrogen Stress Cracking.....	5
3.2 Overview of Nonmetallic Pipe Materials .....	5
3.2.1 Thermoplastic Pipe Considerations .....	5
3.2.2 Fiber-Reinforced Lined Pipe .....	6
4 DISCUSSION OF DESIGN FACTOR RATIONALE.....	8
4.1 Metallic Pipe Materials .....	8
4.1.1 Carbon Steels.....	8
4.1.2 Low-Alloy Carbon Steels.....	9
4.1.3 Austenitic Stainless Steels.....	9
4.1.4 Martensitic, Ferritic and Duplex Stainless Steels.....	10
4.1.5 Aluminum Alloys.....	10
4.1.6 Copper and Copper Alloys.....	10
4.1.7 Titanium Alloys.....	10
4.1.8 Cast Irons.....	10
5 DESIGN LIFE .....	11
5.1 Piping Systems .....	11
5.2 Pipeline Systems.....	11
6 NONDESTRUCTIVE EXAMINATION (NDE) .....	12
6.1 Piping Systems .....	12
6.1.1 Industrial Piping Systems.....	12
6.1.2 Commercial and Residential Piping Systems.....	12
6.2 Pipeline Systems.....	12
6.2.1 Pipelines Whose Design Pressure is $\leq 2200$ psi and Pipe Material has a SMYS $\leq 52$ ksi .....	13
6.2.2 Pipelines Whose Design Pressure is Larger than 2200 psi (15 MPa) or Pipe Material Has a SMYS Larger than 52 ksi (358 MPa) .....	13
7 IN-SERVICE INSPECTION RECOMMENDATIONS FOR PIPING AND PIPELINE SYSTEMS .....	14
7.1 In-service Inspection/Integrity Management of Industrial, Commercial and Residential Piping Systems .....	14
7.1.1 Industrial Piping Systems.....	14
7.1.2 Commercial and Residential Piping Systems.....	16
7.2 Pipeline Systems.....	16
8 RECOMMENDATIONS FOR RESEARCH ON MATERIALS IN DRY HYDROGEN GAS SERVICE.....	18
8.1 Carbon Steels.....	18

8.2	Stainless Steels.....	19
8.3	Other Metals .....	19
8.4	Plastics .....	19
9	TABLES OF DESIGN FACTORS FOR METALLIC PIPE MATERIALS .....	21
9.1	Design Factor Table Population Methodology .....	23
9.1.1	First or Base Row Population .....	23
9.1.2	Population of Columns .....	23
	REFERENCES .....	26
	ACKNOWLEDGMENTS .....	29

## LIST OF TABLES

Table 1	Design Factors for Piping, Carbon Steel.....	21
Table 2	Design Factors for Piping, Low-and Intermediate-Alloy Steels.....	21
Table 3	Design Factors for Pipeline, Carbon Steel Location Class 3 .....	22
Table 4	Design Factors for Pipeline, Carbon Steel Location Class 4 .....	22

## LIST OF FIGURES

Figure 1	Reduction of Tensile Properties in Hydrogen from those in Helium as a Function of Hydrogen Pressure for ASTM A-302 .....	4
Figure 2	Schematic of a Cross Section of a Pipeline .....	24

## LIST OF EQUATIONS

Equation 1	Steady State Lattice Hydrogen Concentration.....	23
Equation 2	Lattice Hydrogen Concentration—Functions.....	24
Equation 3	Lattice Hydrogen Concentration—Experimentally Measured Safe .....	24
Equation 4	Stresses in Cylindrical Vessel under Internal Pressure.....	24
Equation 5	Hydrostatic Stress .....	24
Equation 6	Safety Condition—Hoop Stress.....	25
Equation 7	Safety Condition—Design Stress .....	25
Equation 8	Tensile and Yield Stress .....	25

## 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.

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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.