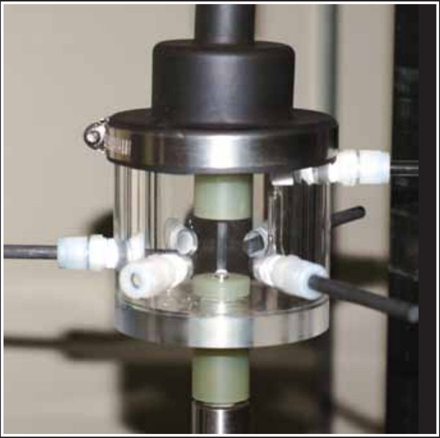
Materials Codes & Standards for H_2 Distribution

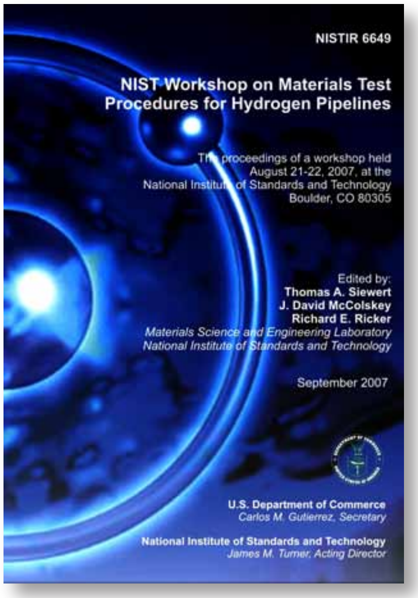


Objective

The goal of this project is to enable the development of a scientific and technical infrastructure for the safe and efficient use of hydrogen as a fuel source. We will provide the nation with reliable measurements, standards, and data for assessing the mechanical behavior of materials in hydrogen and conditions related to hydrogen production, transport, distribution, and use.

Impact and Customers

- We are developing and evaluating laboratory test methods for determining the susceptibility of metals to embrittlement by absorbed hydrogen. These methods will be validated with tests in the Materials Reliability Division's high pressure gas testing facility in Boulder to produce data for pressure vessel and pipeline codes and standards.
- In 2007, NIST hosted a workshop on test methods for hydrogen pipelines that brought together researchers from industrial, government, and academic institutions to discuss issues and identify needs for new test methods, codes, and standards.
- NIST participates in standards committees, including the ASTM committee concerned with testing materials in hydrogen environments, and the ASME committee responsible for codes and standards for hydrogen pressure vessels.
- Customers include ASME, the DoE Pipeline Working Group, the DoT Office of Pipeline Safety, and the pipeline industry.



NISTIR 6649

NIST Workshop on Materials Test Procedures for Hydrogen Pipelines

The proceedings of a workshop held August 21-22, 2007, at the National Institute of Standards and Technology Boulder, CO 80305

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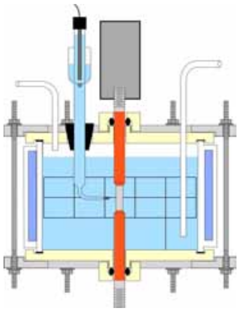
U.S. Department of Commerce
Carlos M. Gutierrez, Secretary

National Institute of Standards and Technology
James M. Turner, Acting Director

Approach

We are investigating and developing laboratory test methods for studying the influence of metallurgical variables on hydrogen embrittlement that will enable alloy development and qualification for hydrogen systems without the expense of high pressure testing facilities. Four laboratory test methods are being studied:

- mechanical tests with cathodic hydrogen charging
- electrochemical methods for measuring solubility, diffusion, and trapping
- dynamic mechanical analysis (e.g. complex modulus, internal friction)
- methods for microstructural characterization



We will validate these test methods by comparing results and predictions to tests conducted in the Materials Reliability Division's high pressure hydrogen gas testing facility in Boulder, and demonstrate to industry the effectiveness of the methods for guiding alloy and technology development. We will use our collaborations and other interactions with standards developing organizations, industry, and government agencies to guide the establishment of a national infrastructure of codes and standards for the safe distribution and use of hydrogen fuel.

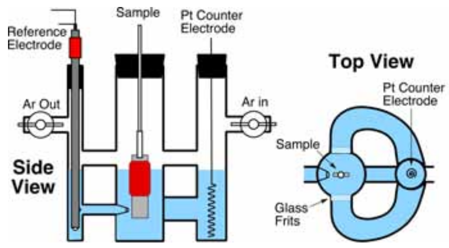
METALS

Accomplishments

This project requires close coordination and collaboration with DoE, ASME, DoT Office of Pipeline Safety, and industry. This collaboration is facilitated primarily through participation in the DoE Pipeline Working Group (PWG). NIST staff began attending meetings and workshops held by these groups before this project started and will participate in these meetings for its duration. Once funding for this project was approved, NIST immediately began planning to bring these groups to NIST for a workshop on hydrogen testing. At the NIST workshop, representatives discussed materials, testing, and standard issues. At its conclusion, the DoE PWG subgroup on testing methods met to coordinate test activities and plan round robin testing including NIST. This plan was reviewed by the entire PWG and approved at their meeting.

The key assumption of this project is that once inside a metal, the same hydrogen concentration (activity) will have the same influence on mechanical properties regardless of the actual hydrogen source. Only the thermodynamics and kinetics of hydrogen absorption differ among the various hydrogen sources.

Through the use of electrochemistry, it is theoretically possible to control hydrogen activity with potential, and measure hydrogen absorption, or desorption, with current. Experimentally, passivating surface films, corrosion reactions, and hydrogen recombination can cause large deviations from theory. Therefore, the research in this program began with electrochemical

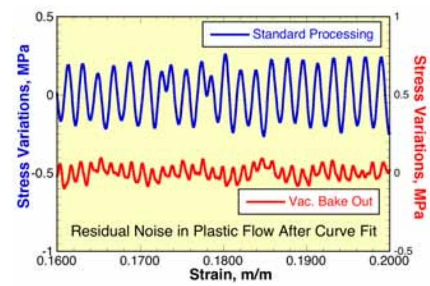


Hydrogen absorption-desorpton cell

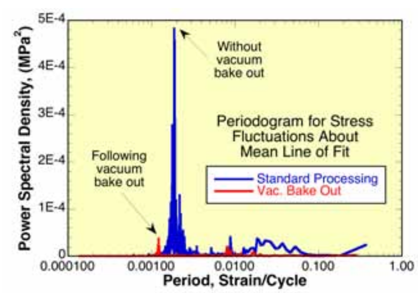
absorption and desorption experiments to identify the ideal solutions, reference electrodes, and other conditions for studying hydrogen absorption, diffusion, trapping and embrittlement. The figure above is a schematic of the electrochemical cell used for these experiments.

Prior to the start of this project, we worked with DoE's Jefferson National Accelerator Facility on "springback" of deep drawn Nb, and realized that hydrogen could explain the observed broad range of tensile and plastic flow behavior. To test the hypothesis that hydrogen absorbed during processing was responsible for these variations, samples were heat treated in vacuum and examined. The vacuum treatment lowered the yield stress, doubled the ductility, and reduced serrated yielding during plastic flow (the Portevin-Le Chatelier or PLC effect). Time series analysis techniques were used to evaluate the plastic flow curves, and dynamic mechanical analysis was used to evaluate the influence of outgassing on the elastic and anelastic behavior. The results were presented at an international conference on large grain and single crystal Nb in Brazil, and were published by AIP.

In 2008, NIST worked with DoE Sandia National Laboratories, The University of Illinois, Kyushu University, Japan, and Ecole Nationale Superieure des Mines de Saint-Etienne, France to organize an international meeting on the effects of hydrogen on the mechanical properties of materials. This meetings was held in Jackson Hole, WY with over 170 attendees from 21 different countries. At this meeting 140 papers were presented on the effects of hydrogen on mechanical properties, and hydrogen fueled vehicle research. The proceedings of this meeting will be published by ASM International.



Oscillations in plastic flow



PLC periodogram

Learn More

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Publications

Ricker RE, Pitchure DJ and Myneni GR *Interstitial Solutes and Deformation in Nb and Nb Single Crystals* AIP Conf Proc., 927: 60 (2007)

Siewert TA, McColskey JD and Ricker RE *NIST Workshop on Materials Test Procedures for Hydrogen Pipelines* NISTIR 6649 (2007)

Sommerday BP, Soforonis P, Murakami Y, Delafosse D, Jones RH and Ricker RE *Hydrogen Effects in Metals* 2008 Intl. Hydrogen Conference, ASM Intl. (in press)

Ricker RE and Pitchure DJ *The Influence of Hydrogen on the Elastic Modulus and Anelastic Response of Cold Worked Pure Iron* Proceedings of the 2008 Intl. Hydrogen Conference, ASM Intl. (in press)