PROCEEDING OF 2008 NATIONAL HYDROGEN ASSOCIATION CONFERENCE, SACRAMENTO CALIFORNIA, MARCH 2008

HYDROGEN PIPELINE RESEARCH AT NIST*

T.A. Siewert, J.D. McColskey, and A.N. Lasseigne [+]

Abstract
In 2007, the National Institute of Standards and Technology greatly expanded its efforts in support of the use of hydrogen as a fuel. Various NIST divisions have started projects on measurement needs in meeting of flow rates, storage, and other standardization issues. Our Materials Reliability division has focused on the problems with hydrogen embrittlement of conventional pipeline and storage-vessel materials (mostly steels). Our first step was to hold a workshop to help us rank the various needs and then use these data to plan and construct an appropriate test facility.

Key Words: hydrogen; mechanical testing; permeation; pipelines; test facility; workshop

1. Introduction
The U.S. Department of Energy (DOE) is funding many activities that will enable our country to increase the use of hydrogen as fuel. Many of these were identified in the 2002 DOE workshop that developed their National Hydrogen Energy Roadmap [1]. As their efforts expanded over the years, we watched until we saw some activities that matched the scope of our Division. By 2006, we thought we had identified areas in standardization and test method development that could benefit from expertise that we had developed in our ongoing pipeline research.

To confirm that our ideas were sound, we planned a workshop at NIST that would give us input from the federal government (especially DOE and DOT (Department of Transportation)), industry and academic communities.

2. Workshop
To obtain user feedback on our plans for a facility to evaluate and develop mechanical testing procedures for hydrogen pipelines, we held a workshop in Boulder, Colorado on August 21 and 22, 2007. The workshop had 46 participants representing pipeline owners, industry and standards organizations, academic researchers, national laboratories, and government agencies. The workshop began with presentations on NIST (its mission and capabilities), the proposed NIST

[+] National Institute of Standards and Technology, Boulder, Colorado, 80305, USA

program on materials compatibility with hydrogen, activities in other government organizations (DOE and DOT), current standards activities and needs for supporting data (especially in ASME), and a description of the roadmap desired from the workshop. Next, the attendees divided into three working groups:

- Materials – chaired by Brian Somerday, Sandia National Laboratory-Livermore,
- Test Techniques and Methods – chaired by Andrew Duncan, Savannah River National Laboratory, and
- Codes, Standards, and Safety – chaired by Lou Hayden, consultant.

At the end of the first day, we heard a short report from each group (to compare approaches and the standards and data needs being identified by each group). We continued the breakout sessions on the second day, and then met to summarize the findings and develop an overall list of needs. Although the reports of each group are included in a list, the combined participants reviewed only the top three needs identified by each group and then ranked them in descending order of importance. These were:

Materials

- Develop advanced tools (measurement techniques, analytical methods, and models)
- Focus on current construction linepipe steels, with strengths under X70 (rather than other alloy types), which has a minimum yield strength of 482 MPa (70 ksi)
- Assess the performance of girth welds (and heat-affected zones)

Test Techniques and Methods

- Complete the NIST Test Facility (following detailed guidance listed in the group report)
- Conduct a round robin (to assess repeatability between various hydrogen laboratories)
- Measure the performance of components (both fiber and matrix in composite linepipe materials as well as welds and their heat affected zones in welded linepipe steel)

Codes and Standards

- Measure the performance of current pipeline construction materials (especially those in current use such as API-X52 and SA106B)
- Study the effect of pressure
- Evaluate the effect of microstructure
- Evaluate non-metallic pipe (while just outside a top-three ranking, a topic the group felt could not be overlooked)

Most participants felt that 1.5 days for the workshop was too short to complete all tasks necessary for a thorough program plan, however the recommendations made in the workshop sessions gave NIST a clear picture as to its near-term course of action with regards to pressurized hydrogen testing of linepipe steels, composite linepipes, and their associated components.

The proceedings have been published as NIST Workshop on Materials Test Procedures for Hydrogen Pipelines, and are available for download at: http://www.boulder.nist.gov/Div853/Hydrogen_Workshop/index.htm [2].

3. Hydrogen Test Facility

We have several large test bays with load frames with capacities up to 4 MN, we decided, however, that we did not want to modify these facilities for use for very large volumes of gaseous hydrogen. Instead, we decided to refurbish some existing facilities built approximately 40 years ago for high-pressure gaseous hydrogen property measurements. Some advantages to these existing facilities (Building 8 and 12) are:

- Large separation from staff and other structures
- Sturdy construction
- Existing perimeter fencing, and
- Track record of use with hydrogen

We worked with our facilities staff to update these facilities to meet current building and fire codes for this application. The plan included:

- A new room (dimensions about 6 m x 6 m x 4 m tall) in Building 12 to house mechanical test systems and chambers to expose standard test specimens to gaseous hydrogen,
- A separate room (dimensions about 3 m x 3 m x 2 m tall) in Building 12 to house the hydraulic pumps and outside storage of gas bottles, and
- A control room (dimensions about 6 m x 6 m x 3 m tall) inside Building 8 (about 25 m away) for the personnel to operate the facility and collect the data.

Initially there will be two load frames within the test facility. The smaller one has a capacity of 100 kN, and will be fitted with a small test chamber (about 1 liter in volume) that can be pressurized to 100 MPa. This pressure exceeds those proposed for pipelines, and matches the highest pressures currently proposed for mobile storage tanks. This chamber is designed to contain standard ASTM E8 tensile compact tension C(T) specimens and will allow us to study the effect of hydrogen pressure and exposure time as we work through the materials identified in the workshop.

The larger load frame has a capacity of 500 kN, and will be fitted with a larger chamber (about 40 L in volume) that can be pressurized to 35 MPa. This pressure exceeds the maximum pressure now being discussed for pipelines. The larger volume allows us to use much larger specimens (such as full-thickness curved wide plate sections from pipelines, middle-crack tensile specimens, and crack tip opening angle specimens). Data from these larger specimens are needed by pipeline designers to estimate the performance of the full-scale structure.

Both chambers are designed using hydrogen resistant alloys and include feed-throughs for strain instrumentation on the specimens. The facility design includes multistage diaphragm compressors to reach the required pressures, evacuation pumps (to purge contaminant gases before charging specimens), and piping systems. Of course, the facility is designed for hydrogen service with once-through ventilation, hydrogen gas sensors, explosion-proof switches and lighting, etc.

As of March 2008, the facility is under construction, with a targeted completion date of June 2008. The load frames are being transferred from one of our other laboratories and are being checked for performance. The smaller chamber, compressors, and vacuum pumps are on order. A separate contract has been placed with the hydrogen safety group at Sandia National Laboratory to review the facility design.

While the facility is being completed, a number of our staff are working with the DOE Pipeline Working Group on Hydrogen to develop a test plan to reach some of the workshop goals. So far, we are helping with two round-robin studies to assess the variation in the data being produced in various laboratories and develop a standard test protocol. One round robin will be on tensile testing and one on gaseous hydrogen permeation through a thin disk of candidate pipe materials. Both round robins should be able to begin once our facility is ready. The permeation work fits well with a related collaboration with Colorado School of Mines to develop nondestructive sensors for diffusible hydrogen content determination in steel. The nondestructive sensors are based on eddy current and thermoelectric power concepts. The permeation and sensor work will be cross-correlated to validate each other.

Also, we realize that we need to supplement the staff that are currently working this project and plan to add a new staff member, several Post-Doctoral Associates, and several guest researchers. If interested, please contact Tom Siewert at siewert@boulder.nist.gov

4. References

1. National Hydrogen Energy Roadmap based on the results of the National Hydrogen Energy Workshop, Washington, D.C., April 2-3, 2002, published by USDOE, November, 2002.
2. NIST Workshop on Materials Test Procedures for Hydrogen Pipelines, NISTIR 6649, September, 2007.