NASA/TM—2013-217852

Evaluation of Data-Logging Transducer to Passively Collect Pressure Vessel p/T History

Stephen P. Wnuk
Glenn Research Center, Cleveland, Ohio

Son Le
Stennis Space Center, Stennis Space Center, Mississippi

Raymond A. Loew
Sierra Lobo, Inc., Fremont, Ohio

March 2013

NASA STI Program . . . in Profile

Since its founding, NASA has been dedicated to the advancement of aeronautics and space science. The NASA Scientific and Technical Information (STI) program plays a key part in helping NASA maintain this important role.

The NASA STI Program operates under the auspices of the Agency Chief Information Officer. It collects, organizes, provides for archiving, and disseminates NASA's STI. The NASA STI program provides access to the NASA Aeronautics and Space Database and its public interface, the NASA Technical Reports Server, thus providing one of the largest collections of aeronautical and space science STI in the world. Results are published in both non-NASA channels and by NASA in the NASA STI Report Series, which includes the following report types:

- TECHNICAL PUBLICATION. Reports of completed research or a major significant phase of research that present the results of NASA programs and include extensive data or theoretical analysis. Includes compilations of significant scientific and technical data and information deemed to be of continuing reference value. NASA counterpart of peer-reviewed formal professional papers but has less stringent limitations on manuscript length and extent of graphic presentations.

- TECHNICAL MEMORANDUM. Scientific and technical findings that are preliminary or of specialized interest, e.g., quick release reports, working papers, and bibliographies that contain minimal annotation. Does not contain extensive analysis.

- CONTRACTOR REPORT. Scientific and technical findings by NASA-sponsored contractors and grantees.

- CONFERENCE PUBLICATION. Collected papers from scientific and technical conferences, symposia, seminars, or other meetings sponsored or cosponsored by NASA.

- SPECIAL PUBLICATION. Scientific, technical, or historical information from NASA programs, projects, and missions, often concerned with subjects having substantial public interest.

- TECHNICAL TRANSLATION. English-language translations of foreign scientific and technical material pertinent to NASA's mission.

Specialized services also include creating custom thesauri, building customized databases, organizing and publishing research results.

For more information about the NASA STI program, see the following:

- Access the NASA STI program home page at *http://www.sti.nasa.gov*

- E-mail your question to *help@sti.nasa.gov*

- Fax your question to the NASA STI Information Desk at 443–757–5803

- Phone the NASA STI Information Desk at 443–757–5802

- Write to:
  STI Information Desk
  NASA Center for AeroSpace Information
  7115 Standard Drive
  Hanover, MD 21076–1320

NASA/TM—2013-217852

Evaluation of Data-Logging Transducer to Passively Collect Pressure Vessel p/T History

Stephen P. Wnuk
Glenn Research Center, Cleveland, Ohio

Son Le
Stennis Space Center, Stennis Space Center, Mississippi

Raymond A. Loew
Sierra Lobo, Inc., Fremont, Ohio

Prepared for the
The Joint Machinery Failure Prevention Technology (MFPT) 2013 and 59th International Instrumentation Symposium (IIS)
cosponsored by the Society for Machinery Failure Prevention Technology and the International Society of Automation
Cleveland, Ohio, May 13–17, 2013

National Aeronautics and
Space Administration

Glenn Research Center
Cleveland, Ohio 44135

March 2013

Acknowledgments

The authors would like to acknowledge support of Rocket Propulsion Test (RPT) Program Office. RPT was an ideal sponsor in this venture. We would also like to thank the Aero-Acoustic Propulsion Laboratory (AAPL) test staff for their support in deploying the data-logging transducer within their Glenn Research Center (GRC) test facility and for covering this activity in spite of a demanding and busy facility test schedule. We also acknowledge the efforts of Stennis Space Center (SSC) installation staff/crew, the technical advocacy of Haynes Haselmaier, the facilitation of Virgil Smith, and the leadership of Cliff Arnold.

Level of Review: This material has been technically reviewed by technical management.

Available from

NASA Center for Aerospace Information
7115 Standard Drive
Hanover, MD 21076–1320

National Technical Information Service
5301 Shawnee Road
Alexandria, VA 22312

Available electronically at http://www.sti.nasa.gov

Evaluation of Data-Logging Transducer to Passively Collect Pressure Vessel p/T History

Stephen P. Wnuk
National Aeronautics and Space Administration
Glenn Research Center
Cleveland, Ohio 44135

Son Le
National Aeronautics and Space Administration
Stennis Space Center
Stennis Space Center, Mississippi 39529

Raymond A. Loew
Sierra Lobo, Inc.
Fremont, Ohio 43420

Abstract

Pressure vessels owned and operated by NASA are required to be regularly certified per agency policy. Certification requires an assessment of damage mechanisms and an estimation of vessel remaining life. Since detail service histories are not typically available for most pressure vessels, a conservative estimate of vessel pressure/temperature excursions is typically used in assessing fatigue life. This paper details trial use of a data-logging transducer to passively obtain actual pressure and temperature service histories of pressure vessels. The approach was found to have some potential for cost savings and other benefits in certain cases.

Introduction

NASA has a long history of safe pressure vessel operation that is largely attributable to a rigorous vessel certification program. Vessel certification entails inspection and analysis to assess the effect and state of damage mechanisms such as corrosion and fatigue. While damage due to corrosion is readily assessable through standard Nondestructive Evaluation (NDE) inspection techniques, the state of vessel fatigue is not readily apparent and must be inferred from vessel service history. Historically, most field vessel applications are not easily monitored. Thus the service histories of such vessels are typically estimated based on operations logs, standard operating schedules, and the like. Since some of this evidence can be anecdotal in nature, safety factors are often applied to assure that the estimate errs conservatively high of actual pressure excursions experienced by the vessel. While conservative and safe, this practice produces a shorter vessel certification life than if the fatigue assessments were based on actual pressure excursions experienced by the vessel. This ultimately results in a shorter vessel service life, or more expensive analysis/inspection than would have been necessary if the actual service history of the vessel were known. With the advent of modern data logging transducers it is conceptually feasible to collect actual service histories of field vessels and realize considerable benefits through assessing vessel fatigue condition based on actual data. Seeking to exploit this development to operational gain, the Rocket Propulsion Test Management Board (RPTMB) commissioned a trial of two data logging transducers to evaluate their effectiveness in monitoring pressure and temperature excursions of vessels under widely diverse conditions. Final test applications included a low-pressure liquid nitrogen Dewar in southern US climate, and a high-pressure/high-volume gaseous nitrogen vessel in northern US climate. These two cases provide a considerable variety of vessel service conditions (pressure and temperature), vessel commodity, and environmental conditions.

Nomenclature

AAPL	Aero-Acoustic Propulsion Laboratory
NDE	Nondestructive Evaluation
P	Pressure (psig)
RPT	Rocket Propulsion Test (NASA Program Office)
RPTMB	Rocket Propulsion Test Management Board
T	Temperature

Hardware and Installation

The transducer selected for trial was a MadgeTech Model PRTEMP1000IS. An image of the device is shown in Figure 1. This device has desirable features and characteristics including intrinsic safety, compact packaging, ambient temperature range, flexible sampling parameters, versatile software, and PC interface capability. Manufacturer specification literature is reproduced at the end of this report.

The northern trial site was high pressure gaseous nitrogen vessel located on the NASA Glenn Research Center (GRC) campus in Cleveland, Ohio. The test vessel had an internal volume of 311 ft^3 and an operating pressure range of 1500 to 2200 psig. The site experiences moderate continental climate with summer highs reaching into the lower 90s (°F) and winter lows dipping into the lower teens. Winter extremes of –20° occur on an average of once a decade. The transducer was plumbed directly into the vessel pressure sense line in parallel with the primary pressure display gauge and was mounted on the same indicator panel as the gauge. Views of the installation are shown in Figure 2. The transducer was unprotected from the elements and successfully endured over two-years of service with no problems or loss of function.

Figure 1.—MadgeTech PRTemp1000IS intrinsically safe pressure and temperature data logger.

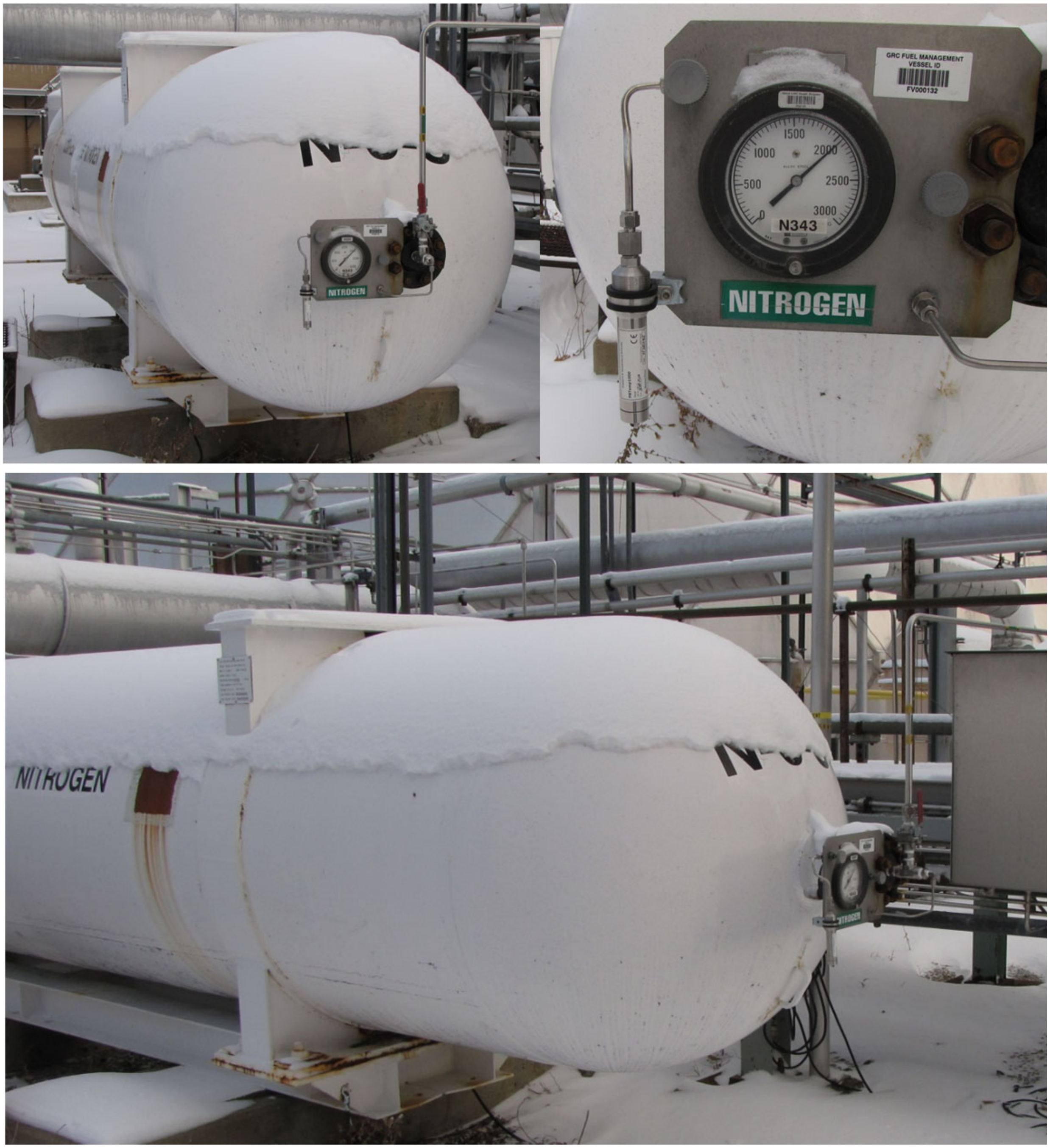

Figure 2.—Views of data logging transducer installation at Glenn Research Center, Cleveland, Ohio. Clockwise from top left: End view of the vessel and pressure indicating panel, close up of transducer mounting, profile view of vessel (only half of vessel is seen in this view).

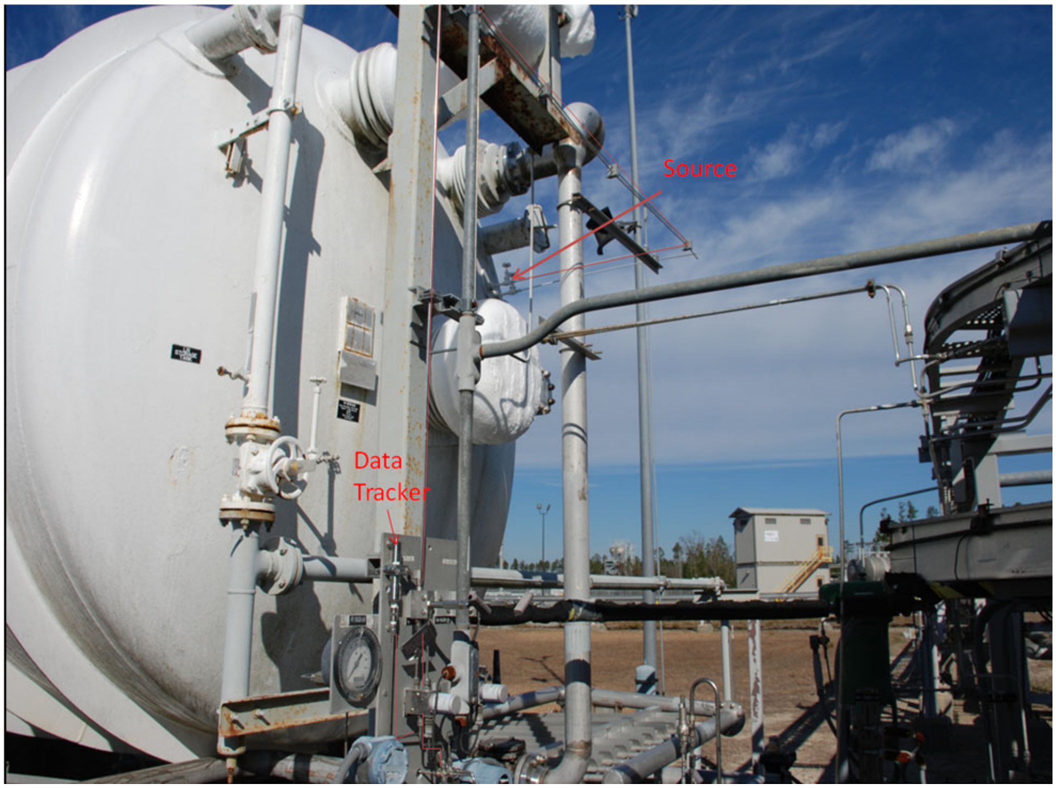

Figure 3.—View of data logging transducer installed on 28,000 gal Dewar at Stennis Space Center (SSC), Mississippi (only end of vessel is seen in this view).

The southern trial site was a 28,000 gal liquid Nitrogen Dewar located at Stennis Space Center (SSC) near the Mississippi state coast. The test Dewar was in service providing LN to the E-Complex Test Facility. This vessel has been used in several tests related to the Taurus project but not while the data tracker has been mounted. The vessel is pressurized to satisfy test requirement then it is depressurized. A view of the installation is shown in Figure 3.

Results

At GRC a high range transducer (0 to 5000 psig) was received, initiated, and installed without significant problem. There were some software compatibility and PC Operating System issues that had to be resolved with factory assistance, yet in retrospect these device setup issues were minor. Mounting and connection of the transducer into the vessel pressure sense panel was accomplished with very little effort in roughly an hour. The device was set to collect data at the default rate of once every 30-min (48 points per day). The transducer began service directly monitoring vessel gaseous nitrogen pressure in September 2010. An initial data download was successfully acquired in January 2011. This initial 4-month data set is summarized in Figure 4. The transducer remained in service for two more years until January 2013. A download of the data acquired at that time indicated that transducer memory had reached full capacity in August 2011, and that no subsequent data points were recorded by the transducer. Due to unfamiliarity with the device, technicians had not known to reset the buffer. There was no visual indication that the device was at full capacity. The test trial was terminated at this time and the transducer was retired from the trial as well. Over its two year trial period the device easily tolerated climate extremes (rain, snow, and sleet) without any special protection. The initial battery also lasted the entire two year period, which is twice the advertised limit.

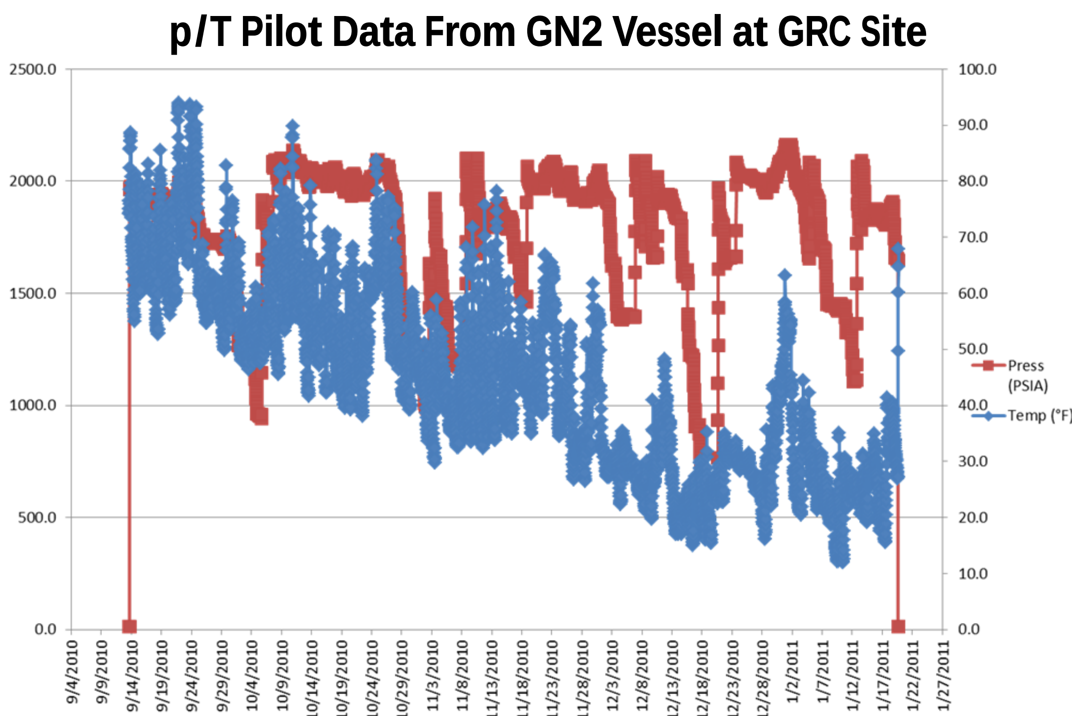

Figure 4.—Information collected by data logging transducer at GRC site over the period September 2010 to January 2011. Vessel pressure data is shown in red (square icons, scale on left). Note zero pressure points at start and end of interval are due to transducer being removed for inspection at end of initial period. Vessel temperature data is shown in blue (diamond icons, scale on right). Temperature data captures summer highs in the 90s (°F.) and winter lows in the teens. Every known pressure excursion of the vessel was accurately captured in the detail data.

At the SSC site a low range transducer (0 to 100 psig) was likewise received, initiated, and installed without significant problem. A challenge was inherent in the installed location for this transducer, since contact with the cryogen would damage the transducer. The installed location is shown pictorially in Figure 3 and schematically in Figure 5. The transducer was installed on a 1/4 in. pressure sense line that measures the static head pressure at the bottom of the Dewar. The Dewar’s vent line is normally open to facilitate boil-off. The transducer was first activated around December 27, 2010. As with GRC, some factory assistance was required to resolve initial setup problems, and the transducer was set to collect data at a rate of once every 15-min. At the end of the first week (around January 3, 2011), staff pulled a sample to see if it was capturing data. It had in fact been capturing data however; the data did not make sense. The pressure and temperature readings were inverse to one another. As the temperature would rise the pressure would drop (relatively proportional amounts, degrees to pounds in both directions). This outcome was unexpected. The memory was cleared and the transducer was reinstalled in February 2011. The transducer was removed in October 2011. The data is summarized in Figure 6. The data was reviewed with engineers from SSC Engineering & Test Directorate. It is determined that the temperature measurement does not reflect the skin temperature of the inner vessel. The recorded temperature shows a trend that is consistent with ambient condition throughout the day. Given that the vessel vent valve is normally opened and the transducer is measuring the static head pressure, it is reasonable to attribute the decrease in pressure due to a reduction in static head as the ambient temperature increases throughout the day.

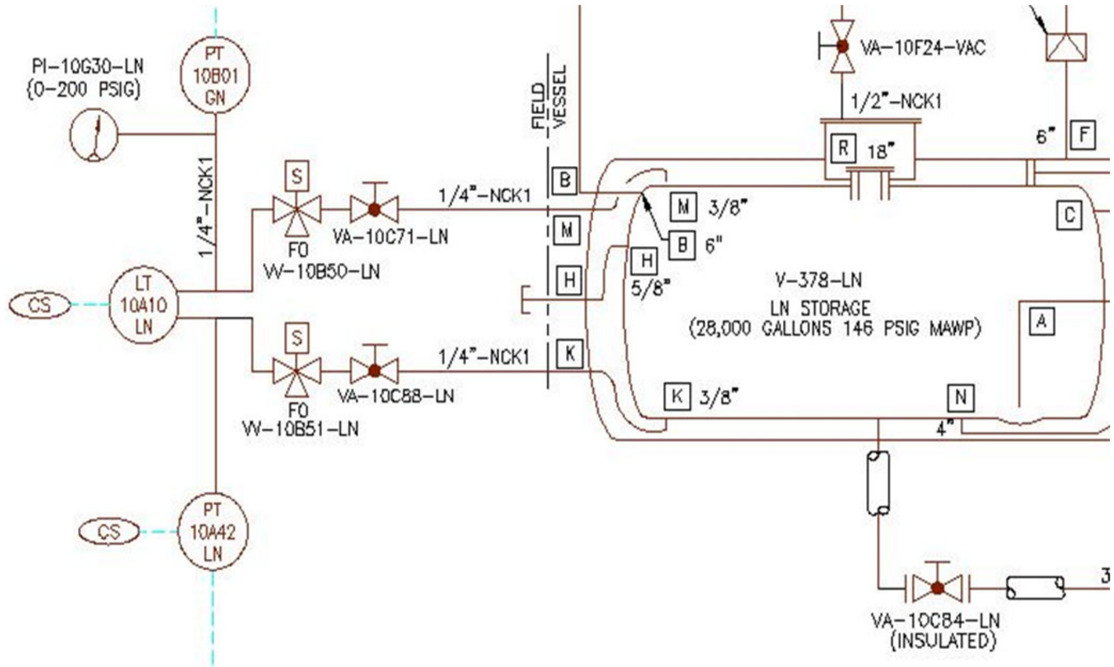

Figure 5.—The transducer was installed in parallel with PT-10A42-LN.

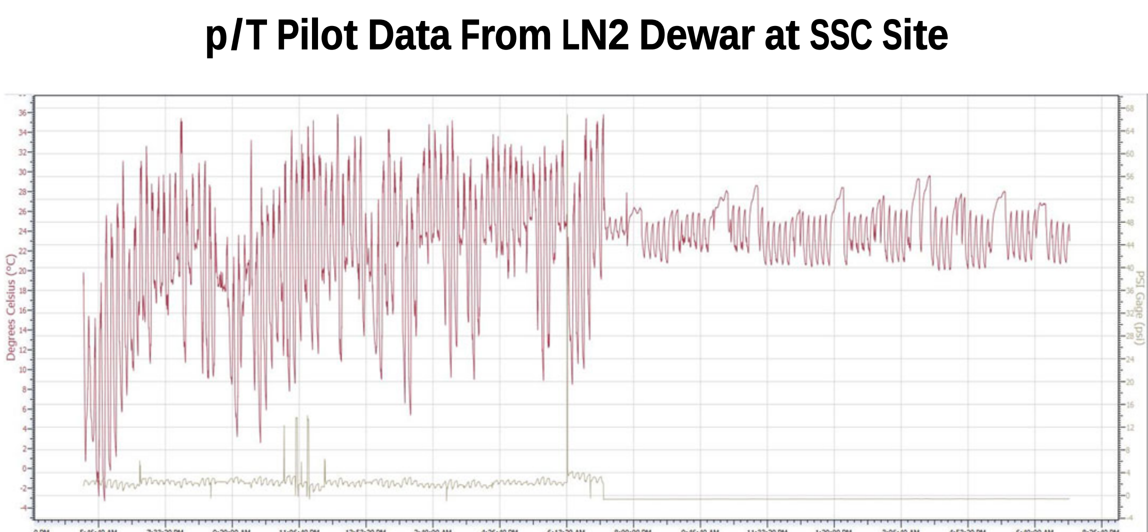

Figure 6.—Information collected by data logging transducer at SSC site from February to October 2011. Pressure data is shown in grey and temperature data is shown in red. Data indicate the transducer's pressure sensing element became nonfunctional and the temperature sensing element was no longer accurate on May 5, 2011. The battery life was expended on July 29, 2011.

Conclusions and Recommendations

The set of trials described herein demonstrated the capability of data logging transducers to passively capture vessel service histories. Data acquired via these devices has potential to reduce vessel certification costs, improve safety, and extend the useful life of select vessels. Transducers could be used on a sampling basis to collect validation data underlying previous estimates. While not demonstrated in this trial, data from these devices could also be used to evaluate the actual severity of vessel pressure excursions. Such analysis may find, for example, that average pressure excursions for any particular vessel are much smaller (or larger) than previously thought, with obvious effects on assessed fatigue life. The devices could also be used to track rough or peak pressure excursions that might otherwise go undetected. The rugged and self-contained nature of these transducers makes them ideal for field or mobile applications where local power and control systems may not be readily available or reliable.

These trails also demonstrated that deployment of data logging transducers is not quite as straightforward as previously imagined. Also, the devices have characteristics and limitations that make them unsuitable for some applications. For example, per unit purchase price with accessories can exceed $1000 (CY2010 data) which makes them uneconomical for widespread application to smaller vessels. Limited battery life and lack of visual health/status indicators could also frustrate some applications. The devices are not readily calibrated and are unsuitable for high precision test data collection. Recommendations for future application and study of data logging transducers include the following:

- Application should involve vessels in the type of service where fatigue is a credible damage mechanism and where extending fatigue life can produce tangible savings.
- Applications must involve service commodities that are compatible with the device. Cryogenic fluids, gaseous hydrogen, or highly reactive commodities may not be suitable for these transducers.
- For any application, a formal monitoring program should be established and personnel should be specifically trained in use and operation of the transducers. These are not set and forget devices. They must be regularly checked and maintained.
- Seek devices with some visual health/status indicators integral to the device. Having to plug into the device to determine low memory or low battery status can contribute to loss of data. Devices with wireless data transfer capability may be desirable in some applications.
- These devices should be considered in circumstances where vessels are subject to potential out of tolerance conditions due to process control instabilities or such. They could provide an attractive monitoring alternative for capturing rogue excursion events.

REPORT DOCUMENTATION PAGE	*Form Approved* *OMB No. 0704-0188*

1. REPORT DATE *(DD-MM-YYYY)* 01-03-2013	**2. REPORT TYPE** Technical Memorandum	**3. DATES COVERED** *(From - To)*

4. TITLE AND SUBTITLE
Evaluation of Data-Logging Transducer to Passively Collect Pressure Vessel p/T History

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Wnuk, Stephen, P.; Le, Son; Loew, Raymond, A.

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER
WBS 736466.06.08.03.03.05

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
National Aeronautics and Space Administration
John H. Glenn Research Center at Lewis Field
Cleveland, Ohio 44135-3191

8. PERFORMING ORGANIZATION REPORT NUMBER
E-18640

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
National Aeronautics and Space Administration
Washington, DC 20546-0001

10. SPONSORING/MONITOR'S ACRONYM(S)
NASA

11. SPONSORING/MONITORING REPORT NUMBER
NASA/TM-2013-217852

12. DISTRIBUTION/AVAILABILITY STATEMENT
Unclassified-Unlimited
Subject Category: 38
Available electronically at http://www.sti.nasa.gov
This publication is available from the NASA Center for AeroSpace Information, 443-757-5802

13. SUPPLEMENTARY NOTES

14. ABSTRACT
Pressure vessels owned and operated by NASA are required to be regularly certified per agency policy. Certification requires an assessment of damage mechanisms and an estimation of vessel remaining life. Since detail service histories are not typically available for most pressure vessels, a conservative estimate of vessel pressure/temperature excursions is typically used in assessing fatigue life. This paper details trial use of a data-logging transducer to passively obtain actual pressure and temperature service histories of pressure vessels. The approach was found to have some potential for cost savings and other benefits in certain cases.

15. SUBJECT TERMS
Nondestructive evaluation (NDE); Transducer; Pressure vessel; Pressure temperature monitoring; Equipment health monitoring

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
a. REPORT U	**b. ABSTRACT** U	**c. THIS PAGE** U	UU	14	STI Help Desk (email:help@sti.nasa.gov) **19b. TELEPHONE NUMBER** ***(include area code)*** 443-757-5802