

# Under Pressure: LPVs Feeling the Effects of Age

**M**ore than 300 layered pressure vessels (LPVs) are in operation at NASA facilities across the country. Gases such as helium, hydrogen, methane, nitrogen, and air are stored under high pressure in these LPVs and supply a variety of NASA test facilities like wind tunnels and engine test stands. The vessels vary widely in size and operate under a broad range of pressures and temperatures, but they all share one common denominator: age.

## Past the 50-year mark

Built in the 1950s and 1960s, many have passed the 50-year mark and are now at risk for age-related concerns. “You start to worry about things like fatigue, cracks, corrosion, environmental degradation, and embrittlement,” said Dr. William Prosser, NASA Technical Fellow for Nondestructive Evaluation (NDE). Also built prior to the inclusion of LPV construction methods in American Society of Mechanical Engineers boiler and pressure vessel codes, they are at a higher risk as “non-code” vessels.

To ensure the continued safe operation of LPVs at NASA, the NESC established a team of experts from across

NASA Centers to develop a proposal for test and analysis methods to keep age-related concerns in check, a task made more difficult by the LPV design itself. “Because of this layered structure, it’s hard to see into the layers to detect flaws in the welds,” said Prosser.

Establishing consensus on a plan forward was a top priority. “Every Center had a different level of background and understanding of the nature of the problem, had tried different methods, and had different perspectives on what should be done,” Prosser noted. See *“A Brief History of LPVs” - page 13.*

## Assessing the future of LPVs

As for the LPVs themselves, many weren’t originally built for NASA, but for the Department of Defense or other government entities, which meant little or no information existed on vessel history – how they were used, pressures they were subjected to, or materials they once contained.

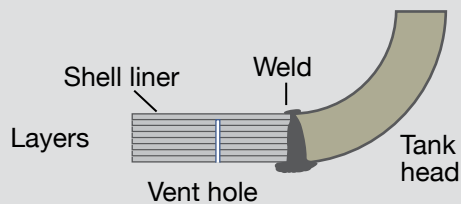
The assessment began with reviewing any available inventory information, like manufacturer, age, condition, rated and operating pressure, contents, layer thickness,



Typical large facility layered pressure vessels can be pressurized to 5,000 psi.



Section of weld between layered tank cylinder and single layer tank head (top) with cut-away illustration (bottom).



and more. NDE history and inspection methods were reviewed, as well as risk mitigation methods used by each NASA Center. Locations within government and private industry were also surveyed. The goal was to prioritize risks and determine what could be done to “buy down the most risk,” said Prosser.

The assessment also involved testing and analysis. Material evaluations of tensile strength and fracture toughness of materials and investigations of the microstructure of weld regions were performed at MSFC. The MSFC NDE team also provided acoustic emission test support. Photogrammetric techniques to measure vessel deformations on an LPV not in service were conducted at GRC. Some phased array ultrasonic technique (PAUT) NDE development was done in coordination with MSFC, SSC, and LaRC.

In the end, several near-term and long-term recommendations were identified. Near-term recommendations could be implemented immediately, such as inspecting vent holes to ensure they aren’t blocked or corroded; monitoring for product loss, which could indicate an inner shell failure; imposing service restrictions; implementing physical barriers; and developing a standard Agency process for LPV usage and centralized information database.

Long-term recommendations included extensive materials testing and the development and validation of analysis methods and NDE techniques to address high-risk conditions. The assessment revealed that the PAUT technique holds promise for inspecting specific LPV welds. See “About PAUT” - above right.

## A brief history of LPVs

The LPV fabrication method was developed in the 1930s. As the need grew to hold liquids and gases at higher pressures, thicker-walled vessels were required, but building vessels from a single, thick plate of steel became difficult. Manufacturers discovered that high-strength thin steel plates had better material properties, could be easily rolled, and were less expensive to fabricate. These thin sheets were layered together and welded, creating an LPV that could withstand pressures up to 10,000 psi. While fewer than 24,000 LPVs have been fabricated, a number of known catastrophic failures have occurred in both code and non-code vessels.

## About PAUT

Circumferential shell-to-head welds, which join the LPV domed single layer tank head to the cylindrical layered body, are of particular interest, since the area can develop cracks, which has led to catastrophic failure. PAUT inspection offers advantages over conventional ultrasonic inspection techniques. A phased array ultrasonic probe contains a number of elements that each emit an ultrasonic wave. By electronically varying the timing of the excitation of the different transducer elements, the resulting ultrasonic beam can be “steered” in different directions. This approach indicated the shell layers intersecting the shell-to-head weld region had a number of flaws in a test vessel.

While simply replacing aging LPVs would eliminate the most risk, the cost and schedule impact would soar into the billion dollar range, Prosser said. “It’s a problem we’re not going to immediately take care of by replacement. We’ve got to better understand these vessels to manage our risks effectively.” Government and industry users of LPVs are already requesting copies of the assessment results. “They were very interested in learning from our experience,” he said.

Working together with the NASA pressure systems managers as well as experts in materials, inspection, and structural analysis from the NESC Technical Discipline Teams, Prosser said the insight gained during the assessment was invaluable. “It was certainly a challenge,” he acknowledged, “but the opportunity to learn about critical engineering issues, new technologies, and applications is always fun.” □