Testing and Recommended Practices to Improve Nurse Tank Safety: Phase IV

BACKGROUND

Anhydrous ammonia (NH_3), used in agriculture as a nitrogen-rich fertilizer, is a hazardous material often transported in steel nurse tanks. The Phase IV study concludes a series of efforts aimed at improving the reliability and safety of these nurse tanks.

The Phase I study found that stress corrosion cracking (SCC) was likely in nurse tanks. Phase II determined a growth rate for the cracks. During Phase III, the tanks previously surveyed were examined again to compare real crack growth rates to calculated ones, and to measure whether new cracks had initiated.

OBJECTIVES

Phase IV explores recommendations from previous studies to use a combination of phased array (PA) ultrasonic testing and acoustic emission (AE) monitoring of tanks.

Phase IV has two objectives:

- First, to see whether more accurate results could be obtained using PA ultrasonic testing, a nondestructive technique that places no stress on a tank. The lower resolution of single-beam ultrasonic testing used in previous phases may have missed or misdiagnosed stress corrosion cracking.
- Second, agribusinesses have questioned the requirement to hydrostatically pressure test ("hydro test") tanks with illegible data plates every five years. Their concern is that the hydro test could damage the tank. By instrumenting a tank for AE monitoring during the test, any changes to the tank due to the hydro test itself could be isolated.

METHODS

The Phase IV study examined 20 tanks that had been surveyed in previous phases using a lower precision single-beam ultrasonic device. Phase IV also included one relatively new tank (2017 manufacture) and one older tank (age undetermined) that was tested to failure.

Pre-hydro PA testing

The first step of the process involved using PA testing to re-examine each of the 20 tanks studied in previous phases to determine whether any new cracks had initiated, or whether existing cracks had grown.

AE monitoring during hydro testing

The second step of the process involved placing sensors around each tank at various locations to monitor AE events during a standard hydro test. Detected AE events were triangulated, revealing the approximate locations of events.

Post-hydro PA testing

The third and final step of the process was to use PA to re-examine each of the tanks showing AE events.

FINDINGS

Results from each testing phase are summarized in **Table 1**.

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Table 1. Data from Phase IV Study.

Phase	Results
Pre-hydro PA results	Out of the 20 previously tested tanks, 11 tanks showed more cracks had nucleated and grown in the intervening years; 2 tanks had the same number of indications; and 7 tanks had fewer indications than previously recorded.
AE monitoring during hydro testing	Out of the tanks that were hydro tested, 16 tanks (15 older and 1 newer) showed an AE event worthy of further examination using PA.
Post-hydro PA testing	Of the 16 tanks flagged for further examination, only 7 tanks were found to have measurable differences between the pre- and post-hydro ultrasonic examinations. Among the differences, only one new crack was thought to have occurred. None of the results suggests an increased probability of failure.

CONCLUSIONS

PA analysis is superior to single beam.

The use of multiple beams in the ultrasonic probe allowed weld geometry effects to be more easily separated from actual crack indications within the steel. This resulted in fewer indications being seen in some tanks in the pre-hydro tests. Additional indications seen in other tanks could be due to the increased precision of the PA device; however, it is likely that many are indications of new cracks or cracks that had grown to a sufficient size for detection since Phase III.

While PA analysis offers increased sensitivities, the cost of the test unit itself (approximately $30,000) is considerably more expensive than the cost of previous handheld units (approximately $5,000) used in Phases I–III and requires additional expertise to use.

AE testing is useful in detecting changes in the tank.

The sensitivity of the equipment used was adequate to tell that changes were occurring in the tank during testing. Although 16 of 21 tanks had AE events, only 7 of these tanks had measurable differences in the post-hydro PA inspection.

Changes produced by hydro testing are minimal.

While it is likely that the hydro tests cause some change to the crack structure of the tank, it is less likely that the changes are large enough to constitute actual damage. It is possible that the hydro test opened existing cracks, making them easier to spot using PA. It is equally possible that a minor amount of crack growth occurred. Of the seven tanks where differences were seen pre-hydro and post-hydro, the changes observed were not enough to render the tank significantly (or even marginally) less safe or to significantly decrease a tank's service life.

Post weld heat treatment (PWHT) is beneficial.

Tanks which had undergone PWHT were found to have fewer, smaller cracks in the pre-hydro tests and no crack growth was seen from previous examinations. They were also less likely to develop additional cracks during the hydro test. As in Phases I–III, the benefits of a PWHT seem evident.

RECOMMENDATIONS

Hydro testing of tanks does not constitute a significant threat to the safety of a tank and may serve as a safety check. While the use of PA ultrasonic technology could determine the extent of cracking and the quality of welds in older tanks, it is a costly solution that may not always be feasible to implement.

To read the complete report, please visit: https://rosap.ntl.bts.gov/view/dot/62475