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Case study

Leg weld fatigue cracks in anhydrous ammonia nurse tanks

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ABSTRACT

In an accident in southwest Iowa, USA in 2012, an anhydrous ammonia nurse tank vented its entire cargo of 5500 L (1500 gallons) of liquid ammonia to the atmosphere. Follow-up study of the failed tank revealed a through-crack along a weld used to connect the tank to its running gear. Side-angle ultrasound examinations were performed on 532 used anhydrous ammonia nurse tanks to measure the locations, sizes, and orientations of flaw indications. The tanks examined had manufacture dates ranging from 1952 to 2011. A total of 83 indications were found in or near the leg welds of 50 of these 532 tanks. Several factors suggest that these indications are fatigue cracks, not the stress corrosion cracks more commonly detected in nurse tanks. These findings suggest that roughly 9% of the 200,000 nurse tanks in the U.S. nurse tank fleet may contain leg-weld fatigue cracks. Nurse tanks are the only large, pressurized packages for hazardous cargo that do not contain manways; thus, their interior walls cannot be inspected for flaws with magnetic particle or fluorescent dye penetrant methods. Since the tank interior is inaccessible, side-angle ultrasound is the only detection method capable of detecting cracks in nurse tanks initiating at both interior and exterior tank surfaces. For this reason, the authors recommend that side-angle ultrasound be considered for use in periodic nurse tank inspections.

1. Introduction

Nurse tanks (Fig. 1) are welded steel pressure vessels used to transport anhydrous ammonia fertilizer from vendor sites to farm fields. There are hundreds of thousands of ammonia nurse tanks in use worldwide; some have been in service for more than 60 years. The steels used to manufacture nurse tanks are all low-carbon steels with mixed ferrite–pearlite microstructures (e.g., ASTM A285, ASTM A455, and ASTM A516 grade 70).

Anhydrous ammonia (NH_3) is among the most dangerous chemicals used in agriculture. Accidental NH_3 releases have caused deaths, severe injuries, and extensive property damage. NH_3 damages skin, lung, eye, and mucous membrane tissue; causes frostbite; and suffocates victims. At one atmosphere pressure, NH_3 boils at −33 °C; thus, it must be stored under pressure to remain liquid at ambient temperatures. The possibility of failure of the pressurized vessel adds explosion hazard to the other dangers. The dangers posed by either slow or explosive NH_3 releases make the safe storage and transport of anhydrous ammonia an important concern for both agricultural workers and the general public [1–3].

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Fig. 1. Anhydrous ammonia nurse tank mounted on running gear. Inset shows that the leg attachment brackets are welded directly to the tank body to connect the tank to the running gear.

Nurse tank failures most often result from stress corrosion cracking (SCC) or welding defects introduced during manufacture or repair [4–8]. In one incident [7], an exploding tank rocketed across a farmyard and struck a tractor, severing the rear wheels and cab from the engine and front wheels. In another incident [6], a weld failed while the tank was being filled, killing one worker and inflicting permanently disabling lung injuries on another.

In a 2012 incident near Casey, Iowa, USA, a nurse tank rapidly vented its entire contents from a fracture initiated at a crack on a leg weld. A nearby worker escaped injury by running to his truck and driving upwind away from the expanding ammonia cloud, which destroyed more than a hectare of corn plants. That incident occurred while the authors were performing an extensive study of SCC in nurse tanks [9–11] that included examination by side-angle ultrasound of all welds on each of 532 used nurse tanks. The great majority of the 3326 indications detected by examining those tanks appeared in or near the longitudinal and circumferential welds used to fabricate the tanks from plate (Fig. 2), but the measurements also revealed that more than 9% of the tanks showed indications in the heat-affected zones near the tanks' leg welds (Fig. 1 inset). These leg weld indications are the subject of this study.

2. Materials and methods for measuring flaw size, location, and orientation

During May–August, 2012, 532 tanks owned by farm cooperative companies in central Iowa, USA were examined by ultrasound. Only areas near welds were examined, generally in a band approximately 200 mm wide centered on the weld. Ultrasound cannot discriminate perfectly between cracks and other defects in tank steel. In recognition of this fact, the term *indications* is generally used to describe ultrasound reflections that reveal a discontinuity in the metal. Indications are usually

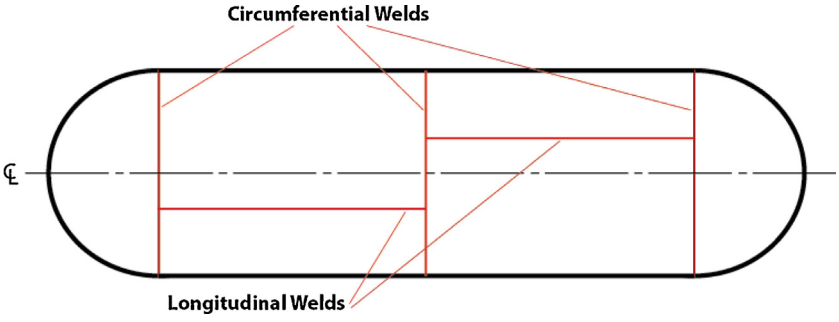

Fig. 2. Locations of circumferential and longitudinal welds in nurse tanks.