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Foreword

The purpose of this document is to provide materials and inspection guidelines to the corrosion engineer on the use of carbon and low-alloy steel vessels in anhydrous ammonia service. This also serves as a state-of-the-art report on stress corrosion cracking (SCC) of these materials in liquid ammonia storage operations.

Background

Ammonia stress corrosion cracking (NH_3-SCC) in carbon steel vessels was first reported in the mid-1950s in agricultural service tanks.[1] Cracking occurred in areas of high residual stress such as welds and cold-formed dished heads. Hot forming or stress relieving the heads considerably reduced the occurrence of cracking as did the addition of a slight amount of water to the ammonia.[2] Throughout the l960s and early l970s, cracking problems appeared to be mainly associated with high-strength quenched and tempered steels, with air being the primary contaminant for inducing NH_3-SCC.[2] In the mid-1970s, SCC was also found on electric resistance welded (ERW) pipes with different strength levels and in the fully normalized condition that were exposed to air-contaminated metallurgical grade ammonia; cracking was detected in the heat affected zone (HAZ), weld metal, and certain sections of the base metal.[3] It was also found that addition of 0.2 wt% water to air-contaminated ammonia completely prevented SCC of these materials.[3] However, for cooled tank vapor spaces, the inhibitive properties of water additions were limited and SCC of ammonia storage tanks was observed at temperature ranges where rapid condensation took place.[4] The late 1970s brought reports of cracking occurring in spheres containing anhydrous ammonia with water additions and also in spheres that had been stress relieved after cracks were found and repaired.[5]

Research in the 1980s and beyond has complemented previous work, confirming a minimum of 0.2 wt.% water along with a maximum of 0.5 ppm oxygen to mitigate against NH_3-SCC.[6-9] In 1999, Loginow summarized experiences with NH_3-SCC over 30 years since the problem was firstly identified.[8] He outlined preventive measures to combat NH_3-SCC including purging to prevent air ingress or contamination, addition of at least 0.2 wt.% water for applications where water could be tolerated, preventing ammonia condensation from the vapor phase, fabricate pressure vessels that are either fully stress relieved by post-weld heat treatment (PWHT) or fabricated with heads that are hot-formed or stress relieved, using lower-strength steels when possible, and implementing frequent and periodic inspection programs.[8] In the late 1990s, it was also reported that stress relieving PWHT performed before service significantly reduces the susceptibility to cracking; however, it was mentioned that its application was sometimes impractical considering the large size of the ammonia storage tanks.[10-11] To mitigate this, more recent studies recommend conducting heat treatment of several workpieces of the tank before assembling followed by a mechanical stress relieving process of the entire tank. SCC failures in anhydrous ammonia nurse tanks in the U.S. have been reported by the Federal Motor Carrier Safety Administration (FMCSA), with four major nurse tank ruptures in Calamus, Iowa (2003), Morris, Minnesota (2005), Silver Lake, Minnesota (2007), and Middletown, Ohio (2003).[12] PWHT is now a federal requirement in the U.S. per Occupational Safety and Health Administration[(1)] (OSHA) 29 CFR 1910.111.[13]

In recent years, wet fluorescent magnetic particle testing (WFMT) for internal inspection and acoustic emission technique (AET) for non-intrusive inspection have gained acceptance as means to detect NH_3-SCC.[14-15] The purpose of these techniques is to detect and remove cracks. From a proactive standpoint, the field signature method (FSM), has been developed to monitor existing crack growth in a continuous and non-intrusive manner.[7,9,16] However, there has been limited success in implementing this monitoring technique in the field.

(1) Occupational Safety and Health Administration (OSHA), U.S. Department of Labor, 200 Constitution Ave. NW, Washington, DC 20210, www.osha.gov.