Recent Natural Gas Pipeline Accidents Involving Hydrogen Induced Cracking

M. K. Budinski[1]*, F. Zakar[1]

[1]National Transportation Safety Board, Washington, DC, USA,
** Presenting Author email: michael.budinski@ntsb.gov*

Abstract

Recently, the National Transportation Safety Board (NTSB) has investigated two natural gas pipeline accidents that occurred due to hydrogen induced cracking. This presentation reviews the findings.

1. Introduction

Hydrogen induced cracking in transmission and service natural gas pipelines is relatively rare. This presentation will highlight two cases recently investigated by NTSB and will review the NTSB Materials Laboratory's approach to failure analyses involving hydrogen induced cracking.

2. Results

Case 1: On February 23, 2018, a natural gas–fueled explosion occurred at a private home in Dallas, Texas. [1,2] The residence sustained major structural damage. Four family members were injured, and one was killed in the explosion. Following the explosion, National Transportation Safety Board (NTSB) investigators located a through-wall crack in the 71-year-old 2-inch diameter steel natural gas main that served the residence. Natural gas leaking from the cracked gas main in the alley behind the home migrated through the soil and into the house where it was ignited by an unknown source. Soil absorbed and depleted the natural gas odorant, eliminating the opportunity for occupants to detect it by smell. Installed in 1946, the gas main had a maximum allowable operating pressure (MAOP) of 55 psig. The coated steel main was cathodically protected by sacrificial anodes and the natural gas was odorized. The natural gas leak rate was estimated based on NTSB's laboratory testing to be between 8 and 14 CFM at the operational pressure range of the system of 17 to 45 psig. Example images are in Figure 1.

Case 2: On August 1, 2019 a 30-inch-diameter API 5L-X52 steel natural gas transmission pipeline ruptured near Danville, Kentucky. [2,3] As a result of the rupture, 1 person was fatally injured, 6 people were hospitalized, and over 75 residents were evacuated from the Indian Camp Subdivision, a residential community. The rupture released about 101.5 million feet^3 of natural gas and ejected a 33.2-foot-long section of pipeline that landed about 481 feet southwest of the rupture site. The releasing gas ignited and burned. Five residences in the subdivision were destroyed by fires, and an additional 14 were damaged. A nearby railroad track sustained fire damage. At the time of the rupture, the pipeline was operating at 925 psig. The pipeline had a MAOP of 936 psig. The ruptured pipe segment, which was installed in 1958, was manufactured by A.O. Smith Corporation. The pipe segment in the area of the rupture was coated with coal tar enamel and was under impressed-current cathodic protection. Example images are in Figure 2.

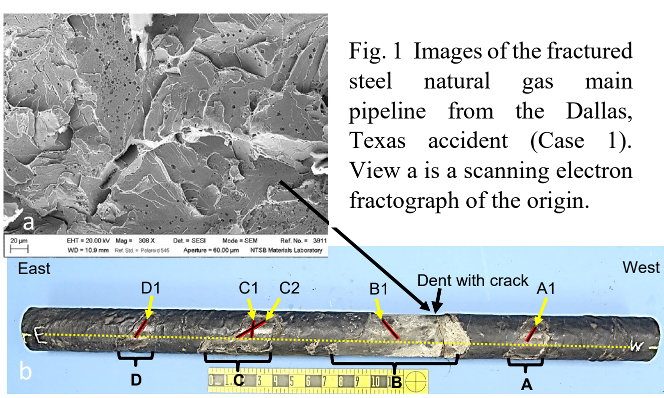

Fig. 1 Images of the fractured steel natural gas main pipeline from the Dallas, Texas accident (Case 1). View a is a scanning electron fractograph of the origin.

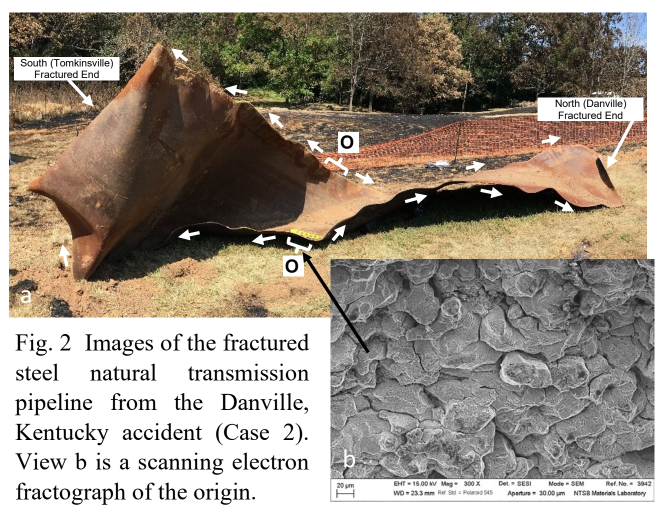

Fig. 2 Images of the fractured steel natural transmission pipeline from the Danville, Kentucky accident (Case 2). View b is a scanning electron fractograph of the origin.

In both instances the primary means for identifying hydrogen assisted cracking was by optical and scanning electron fractography, compositional analysis of hydrogen in the steel after the rupture, assessment of susceptible microstructure, evaluation of the stress state at the crack origin at the time of rupture, and investigation of sources of hydrogen charging.

3. Conclusions

Case 1: The natural gas main was damaged by mechanical excavation equipment, likely when a sanitary sewer lateral was replaced in 1995. A circumferential crack in the main propagated through the pipe wall prior to the incident, allowing natural gas to leak into the surrounding environment for an extended period. Based on the observations, the circumferential crack initiated at the bottom of the dent forming two thumbnail cracks which arrested. At a later point, the balance of the circumferential crack propagated from the thumbnail cracks, driven by a hydrogen-induced cracking mechanism. The crack most likely formed before observed calcareous deposits developed. However, given the above observations, it was not possible to further define the exact timeline of the crack formation process.

Case 2: The combination of a pre-existing hard spot (a manufacturing defect) in the pipe steel, degraded coating, and ineffective cathodic protection applied following a 2014 gas flow reversal project, resulted in hydrogen-induced cracking at the outer surface of Line 15 and the subsequent failure of the pipeline. Contributing to the accident was the 2014 gas flow reversal project that increased external corrosion and hydrogen evolution.

Acknowledgements

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