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Environmental Conditions Associated with Stress Corrosion Cracking on Wax Coated Pipelines

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ABSTRACT

This report investigates the environmental variables associated with stress corrosion cracking (SCC) found on multiple natural gas pipeline segments. Technicians collected environmental data at direct examination sites on eleven pipelines classified as SCC susceptible from 2015-2019. All SCC colonies observed during these direct examinations were on six pipelines with wax coatings. Two hundred seventy-nine excavations were completed on wax coated pipelines from 2015-2019. SCC was confirmed by metallurgical analysis at thirty-two of these excavations. Based on this data set, environmental variables correlated with observed SCC on wax coated lines include depressions and inclined topography, poor drainage, soil with organics and moraine depositional environments.

Key words: Coatings, Stress Corrosion Cracking, Inspections

INTRODUCTION

As an environmentally induced cracking (EIC) mechanism, stress corrosion cracking is a failure of materials exposed to a corrosive environment. This report investigates the environmental conditions surrounding multiple natural gas pipeline segments in Michigan, USA that are classified as SCC susceptible and the environment variables associated with SCC. In addition to a corrosive environment, an adequate tensile stress must be present in the material and the material must be susceptible to corrosion when exposed to the environment. This report focuses on the environmental component of the equation.

SCC is usually found at places where electrolyte is in contact with the pipe and where cathodic protection (CP) is ineffective.¹ Small areas of ineffective CP due to shielding (e.g., by rocks or

disbonded coating) will not typically be discernable in CIS data, but larger areas where ineffective CP exists are easy to see in CIS data. Anomalies are present in DCVG data where CP current flows to the pipe surface. By definition, DCVG anomalies are areas where the structure is in contact with electrolyte resulting in the ability for effective CP to exist. Therefore, DCVG anomalies should not be used to predict the location of SCC. SCC growth does not need to be continuous: growth may occur only when conditions are favorable and remain dormant otherwise. Near-neutral SCC is often found in environmental conditions that vary with time.² Such locations may be in physical transitions between different environments or in places that hold moisture from precipitation for a long time before drying out (e.g. clay soils at the bottom of hills or in shallow depressions). These are often places with low soil resistivity.

Continually or frequently wet areas are environmental conditions widely associated with SCC.³ Wet soils may promote SCC because SCC requires an electrolyte to initiate and grow. Additionally, biological, chemical, and physical conditions frequently found in wet areas can further enhance conditions for SCC. Chemically reducing conditions are often found in areas subject to long-term saturation and are problematic because sulfate reducing bacteria (SRB) can exist there. The anaerobic metabolism (does not use free oxygen) of SRB can promote hydrogen entry into the pipe steel which increases brittleness and susceptibility to SCC. Reducing conditions are also often found in low lying, clayey soils with poor drainage. These soils can cause the pipe coating to sag and allow electrolyte to contact the pipe surface. CNEB⁽¹⁾ found that locations of significant SCC are related to clay soils because of their potential to contribute to pipe coating disbondment.³

Another important aspect of some SCC predictive models is the presence of glaciofluvial alluvium. Glaciofluvial alluvium is sediment that was deposited by glacially fed rivers. Because glaciers and glacial rivers are large and can move large pieces of sediment, this sediment is frequently composed of large grains like gravel, cobbles, and boulders. King found that features like dents that cause an increase in stress are associated with near-neutral SCC.² Coarse soils may be more likely to dent the pipe, create a stress riser and become sites of near-neutral SCC. King also notes that large rocks can shield pipelines from cathodic protection current, another requirement for SCC initiation and growth. Michigan is covered in glacial landscapes and glaciofluvial alluvium may be relevant to SCC on these pipelines.

Some environmental conditions have been shown to be less suitable for SCC growth. Organic-rich wetlands are often reducing environments, but many studies have shown that contrary to what happens in reducing areas discussed previously, crack growth is limited when the pipe is surrounded by organic matter. Therefore, the effect of wetlands on SCC is mixed, but the effect appears to be linked to the presence of organic material at pipe depth.² Such conditions are identified during field surveys.

Since an electrolyte is required for SCC to form and grow, dry soils may slow SCC growth or reduce initiation rate. Coarse soils (i.e. sand and larger grain sizes) are typically well drained and dry. However, the positive effects of coarse soils may be countered by the coating damage and CP shielding that large rocks like cobbles and boulders can cause, which increase the initiation and growth of SCC. In the balance between these two concepts is sand, which can provide good drainage with little possibility for mechanical damage to the pipe. Sediment texture, topographic position, depositional environment, soil resistivity, and soil moisture measurements may all give indications about common moisture levels over time.

Much of the literature on the conditions that contribute to the development and growth of stress corrosion cracking colonies focuses on coal tar and asphalt coated pipelines. This paper addresses the observed conditions around wax coated pipelines where stress corrosion cracking has been observed. This data is intended to continue building toward a more comprehensive understanding of the

¹ Canadian National Energy Board (CNEB)

environmental conditions associated with SCC on wax coated lines. This understanding might improve dig site selection as part of integrity management programs.

PROCEDURE

Excavation sites (dig sites) were selected on SCC susceptible pipelines based on magnetic flux leakage (MFL) and electro-magnetic acoustic transducer (EMAT) in-line inspection (ILI) results. A total of 395 digs were completed on these lines from 2015-2019. Of the 395 digs, 279 were completed on pipelines with wax coatings. SCC was not the primary target of all digs. Regardless of the dig intent, data from all digs on these lines was used as a single data set to compare environmental conditions at sites with observed SCC and without observed SCC to continue building toward a more comprehensive understanding of the environmental conditions associated with SCC on Michigan pipelines.

Data collected during direct examinations included coating condition, soil resistivity, soil pH, and soil moisture percentage. This data was combined with soil and terrain data including soil texture, soil drainage, land usage, and depositional environment. When SCC was suspected, coupons were cut from the pipe and provided to the metallurgical laboratory for confirmation of SCC. When SCC was confirmed, the metallurgical laboratory classified the cracking as high pH or near neutral. Additionally, the severity of SCC was rated according to NACE⁽²⁾ SP0204-2015.⁴

RESULTS

Pipeline materials, coating and operational data were summarized from line history reports and ILI tool dig lists (Table 1). Many of the lines excavated have similar characteristics and many of the fields in this population are related. For example, all Manufacturer 1 pipe in this population has EFW welds. Nonetheless, some trends were observed:

1. SCC was only observed at digs on lines with wax coating.
2. SCC was observed more frequently on pipe from Manufacturer 1, with EFW welds, and installed in 1949 than pipe from other manufacturers, weld type and installation years.
3. The digs where SCC was observed were on pipe with high ratios of MAOP to SMYS. However, this dataset is composed mostly of digs with high % SMYS and SCC were only found at a few digs with high % SMYS.

² NACE International (NACE)