NTSB Request:

Documentation supporting the below figure (Figure 2 - Threat Interaction Matrix, from your IM Plan Manual). Specifically, why are hard spots and atomic hydrogen embrittlement not considered interacting threats? Studies show hard spots have a high potential for hydrogen cracking when exposed to excessive cathodic protection, sour gas, and certain environmental conditions, but the threat matrix only discusses selective seam corrosion in the category of EC/MFG and marks the category of IC/MFG as non-interactive.

Response:

Three factors influence the specific susceptibility of steel pipelines to hydrogen embrittlement: applied stress, hydrogen source (coating failure, corrosion, cathodic protection), and a susceptible microstructure.

- Applied Stress – Natural gas transmission pipelines operate at sufficient hoop stress levels and therefore the applied stress condition is always assumed to be present.

- Environment – The environment that generates atomic hydrogen necessary for hydrogen embrittlement and cracking is complex. A coating fault is necessary to enable hydrogen embrittlement to occur. Furthermore, the local electrochemical environment at the coating holiday must be conducive to generate atomic hydrogen. While studies demonstrate that elevated cathodic protection will generate molecular hydrogen (H2), the dissociation to atomic hydrogen (H plus) is largely contingent upon the local water chemistry. Environments containing sulfides, phosphorous, and arsenic will promote the formation of atomic hydrogen. Cathodic protection of the pipeline is part of the environmental equation, but hydrogen charging at potentials substantially less negative than -1.25 V (off) can introduce atomic hydrogen into a susceptible material. Due to the complex electrochemical environment, Enbridge has concluded that managing hydrogen embrittlement alone by limiting cathodic protection levels is not a sufficient control measure to prevent failures. Nevertheless, it is recognized that excessive cathodic protection levels are not helpful, and Enbridge has recently placed more strict controls on cathodic potential limits for pipelines containing AO Smith pipe.

- Susceptible Microstructure - Typical pipeline steels are not considered susceptible to hydrogen embrittlement and cracking unless a localized difference in material properties with sufficiently high hardness exists. Pipeline hard spots were formed at the steel mill when the plate was at a high temperature (austenitic temperature above 1300 F) and accidently quenched, forming areas of martensite with excessively high hardness. Such hard spots are susceptible to hydrogen embrittlement and have produced past pipeline failures in the pipeline industry.

Because hydrogen embrittlement occurs at nominal CP levels, atomic hydrogen must be assumed to be present on virtually all pipeline segments (i.e., its presence is a constant) and, as such, the pipeline industry has not treated hard spots as an interactive threat. In the absence of being able to address hard spots through managing CP and hydrogen, the industry has been managing the threat by use of ILI tools capable of detecting the localized areas of high hardness. These tools can identify hard spots by a magnetic signature. Anomaly digs are then scheduled for pipeline assessment and remediation. Therefore, the industry focus has been to manage hard spots through detection and remediation rather than as an interacting environmental threat. Some deficiencies in the ILI reporting of hard spots has now been identified with the past generation of detection tools, and research with vendors is currently being performed to improve ILI detection and reliability performance.