Pipeline Research Council International (PRCI) **July 2006**

STRESS CORROSION CRACKING: Roadmap to Reduce the Cost and Increase the Effectiveness of Tools for Managing Internal and External Stress Corrosion Cracking

EXECUTIVE SUMMARY *(Excerpted)*

Current methods of managing stress-corrosion cracking (SCC) in pipelines generally depend upon periodic hydrostatic testing or in-line inspection (ILI). Significant cost savings could be achieved and the safety of pipelines could be improved by optimizing intervals for hydrostatic testing and ILI, focusing those procedures on areas of high probability of SCC, developing a more reliable and cost-effective ILI technology, and discovering ways to design and operate pipelines so as to minimize the probability of SCC.

PRCI's research effort to address critical needs related to the threat of SCC is organized in the form of an integrated approach focused in three parallel topical areas as follows:

Assessment
- An in-line-inspection (ILI) technology that can reliably detect, identify, and size stress corrosion cracks in gas pipelines
- An ILI technology that can reliably detect and size stress-corrosion cracks in dents in gas or liquid pipelines
- A nondestructive method for measuring the sizes of stress-corrosion cracks in the ditch
- A method for selecting appropriate sites for SCC direct assessment (SSCDA)
- Guidelines for quantitative risk assessment for pipelines with SCC

Mitigation
- Methods for mitigating SCC through modification or control of operating practices
- Methods to determine appropriate re-assessment intervals for hydrostatic testing, ILI, and SCCDA

Prevention
- Guidelines for preventing internal SCC in ethanol pipelines
- Guidelines for preventing external SCC in future gas and liquid pipelines

Aspects of the project(s) specific to ethanol follow *(parentheses eliminated)***:**

Deliverables: The main deliverables from the projects and project areas include an improved understanding and documentation of the causes and remedial or preventative measures for Internal SCC in Ethanol pipelines. The intent is to develop guidelines for preventing internal SCC in ethanol pipelines

Current State of Knowledge: Internal SCC. Stress-corrosion cracks have been discovered on the inside of tanks and associated piping that contains denatured ethanol. Some failures have occurred in less than one year. Although SCC has not been observed in pure ethanol, research to date indicates no apparent effect of the specific denaturant or corrosion inhibitor. Oxygen level seems to be the most important environmental factor, and chlorides and methanol also may have some effect. The cracks have been observed only in high-stress areas such as near welds that have not been post-weld heat-treated or at stress concentrations due to such things as fillet welds at lap seams. Possible solutions that are being considered are post-weld stress relief, design to reduce the severity of stress raisers, ethanol-resistant coatings, and reduced aeration. (p. 35)

Status and Research Needs (pp8-12)

Prevention Until recently, only two forms of SCC had been observed on buried pipelines – high-pH SCC and near neutral-pH SCC – both of which occur at the outside surface of the pipe. However, the relatively recent discovery of SCC inside tanks containing denatured ethanol has raised concern about the possibility of internal SCC in pipelines that carry ethanol. Therefore, PRCI's SCC program of research activities has been expanded to address prevention of both external and internal SCC.

Internal SCC in Ethanol Pipelines
Currently, denatured fuel grade ethanol is transported primarily by railroad tanker cars and tanker trucks. SCC has been observed in carbon steels in contact with denatured fuel-grade ethanol in user terminals, storage tanks, and loading/unloading racks. A white paper published by the American Petroleum Institute (API) in 2003 provided an extensive survey of published literature and service experience with SCC in fuel ethanol.[*] Documented failures of equipment in storage and transportation facilities have dated back to the early 1990s. The majority of the cracking has been found at locations near welds where the primary stresses leading to SCC have been residual welding stresses. No cases of SCC were reported in manufacturer facilities, tanker trucks, railroad tanker cars or barges, or following blending of the fuel ethanol with gasoline. All occurrences of SCC were in the first major hold point (fuel ethanol distribution terminal) or in the subsequent end-user gasoline blending and distribution terminals.

The survey did not pinpoint what causes ethanol SCC, but the failure history suggests that SCC may be related to changes in the fuel ethanol as it moves through the distribution chain over a period of days, weeks, or months. PRCI and API have funded limited research to investigate the role of factors related to the chemistry of fuel grade ethanol and steel properties on ethanol SCC.

A number of factors were originally identified as possible contributors to the SCC ethanol problem. These included the source of the ethanol, the type of denaturant, the water content, pHe, sulfate and chloride concentrations, temperature, oxygen concentration, electrochemical potential, and the use of corrosion inhibitors.

The results of the API/PRCI research demonstrated that fuel grade ethanol that meets applicable API standards is a potent cracking agent. Oxygen was found to be a primary contributing factor in the occurrence of SCC, and this was reflected in the electrochemical potential dependence of the cracking behavior. Chloride contamination also was found to exacerbate the cracking. The type of denaturant did not appear to be a factor in the cracking nor did the ethanol source. Water was not shown to be an inhibitor, as it is in other anhydrous cracking environments, such as ammonia. A36 tank steel was used in the environment studies and exhibited cracking in some of the test environments. The testing was inconclusive with respect to the relative susceptibility of line-pipe steels.

Research is needed to develop a better understanding of the causes of SCC in ethanol and, based upon that understanding, to suggest and evaluate possible ways to prevent it. Causative factors and their corresponding preventive measures can be grouped into three categories: environment, stress, and steel.

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[*] R.D. Kane and J.G. Maldonado, "Stress Corrosion Cracking of Carbon Steel in Fuel Grade Ethanol: Review and Survey," API Technical Report 939-D, September 2003

Environmental Factors
Although the recent PRCI and API studies showed that oxygen is one of the most significant factors controlling ethanol SCC, the roles of other contaminants such as chlorides and water are less well understood. Such information would be important to know whether there is a wide range of potency of fuel-grade ethanol that could be in the pipeline, which, in turn, would be important with respect to establishing limits on impurity levels or developing techniques to monitor potency. Other important environmental issues relate to the feasibility of using inhibitors or deaeration to prevent ethanol SCC.

Stress
Most cases of internal SCC to date appear to be related to residual stresses from welding. It would be important to determine if hoop stresses due to internal pressure also are capable of promoting ethanol SCC and, if so, what levels of stress are necessary.

Studies of stress effects will require determining an appropriate test method. Most of the studies to date have used the slow-strain-rate test, which is not useful for studying the effect of stress level.

Steel
It is not known whether certain grades or types of steel have different levels of susceptibility to ethanol SCC. The feasibility of using surface treatments such as shot peening or coatings to prevent internal SCC also should be investigated. Both barrier coatings and galvanic coatings should be considered.

Internal SCC (p. 36)
In order for companies to know whether internal SCC could be expected in their pipelines, and, if so, what to do about it, more information is needed on environments that will support SCC, metallurgical factors that affect susceptibility to ethanol SCC, stress conditions that will promote crack initiation and growth, and the effectiveness of remedial measures.