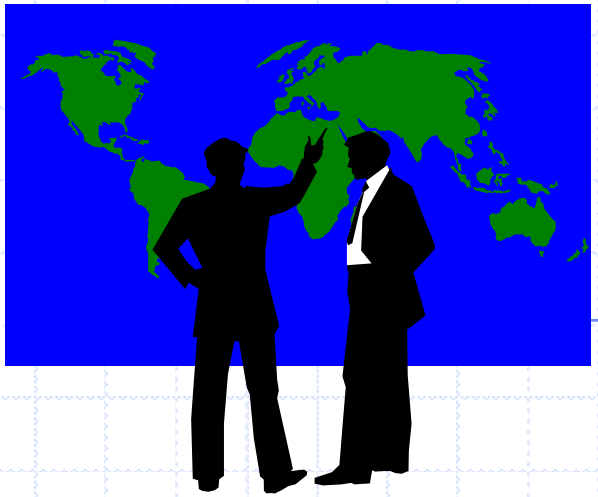
Development of a Research Roadmap Related to Safe and Reliable Transportation of Ethanol in Pipelines



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Scope

- Build upon the results of the "Safe and Reliable Transportation of Fuel-Grade Ethanol Workshop" held on October 25-26, 2007, in Dublin, Ohio
- Group and condense the list of gaps, indicating which are being addressed by current or planned research, and which require new research projects.
- Phase 1 summarizes the results and presents recommendations for new projects that could profitably be started in the near future.
- Phase 2 provides a final report that contains a roadmap of all future projects that have been identified.

Phase 1 Results
Suggested Projects for Near Future

- Safety of Transporting Blends Containing More than 10 Percent Ethanol
- Standardized Tests for SCC in Ethanol
- Technical and Economic Feasibility of Preventing SCC Through Control of Oxygen
- Feasibility of Preventing SCC by Using Inhibitors
- Compatibility of Polymeric Materials and Non-ferrous Metals with Ethanol
- Understanding of Ethanol SCC

Phase 1 Results
Other Recommendations

- API or some other suitable industry organization should establish committees to prepare
  - A recommended practice for transporting ethanol by pipeline
  - Guidelines for integrity management of pipelines for transporting ethanol.

Phase 2 Results
Roadmap of All Future Projects

- 39 distinct projects were identified and grouped into 11 categories
  1. A Standard for Safe and Reliable Transportation of Ethanol (28 projects)
  2. A Standard for Safe and Reliable Storage of Ethanol (1 project)
  3. A Phenomenological Understanding of the Factors that Cause Ethanol SCC (1 project)
  4. Guidelines for Risk Assessment (1 project)
  5. Guidelines for Fire / Spill Emergency Response (1 project)

Phase 2 Results
Roadmap of All Future Projects (cont.)

- 39 distinct projects were identified and grouped into 11 categories
  6. "Fingerprint" Test for Ethanol (2 projects)
  7. Decision Making Process for Ethanol Pipelines (1 project)
  8. Ethanol / Biofuels Handbook (1 project)
  9. Tools to Predict Residual Stresses (1 project)
  10. Committee to Coordinate Technology Transfer (1 project)
  11. Workforce Training Program (1 project)
- Total projected cost for future work is approximately $4MM over 5 years, beginning in 2009

Recommended Project 1
Safety of Transporting Blends Containing More than 10 Percent Ethanol

Gap

- Compelling evidence through slow strain rate (SSR) testing that transportation of E10 by pipeline should pose no threat of SCC.
- A different test or alternative techniques for the SSR test are needed for more realistic evaluation of environmental conditions, or a reliable correlation needs to be developed to relate the results of SSR tests to performance under realistic pipeline conditions.

Suggested Research

- Using a test that represents severe but realistic conditions, conduct SCC tests in blends from E20 through E95 to determine which blends are capable of causing SCC under service conditions. Concentrate on E20, E30, and E95, but conduct some tests with intermediate blends as well.
- Determine what products other than gasoline might be used to surround the batch of ethanol, and include blends of those as well.

Recommended Project 3
Technical and Economic Feasibility of Preventing SCC Through Control of Oxygen

Gap

- SCC has never been produced in the laboratory if oxygen has been eliminated from the system. It might be possible to keep oxygen from ever getting into the ethanol; however technical and economic feasibility has not been established.
- One needs to be sure that there is no source of oxygen in the pipeline and that oxygen is not re-introduced during pumping or related handling in facilities terminals.

Suggested Research

- Conduct an engineering study to evaluate the technical and economic feasibility of various ways of eliminating oxygen from the ethanol. Consider ways to prevent contamination by oxygen during production and transport as well as removing oxygen before introducing the ethanol into the pipeline.
- Develop a rapid way to monitor oxygen content.
- Such research has been started under the PRCI SCC 4-3 project, but its scope may need to be extended.

Recommended Project 4
Feasibility of Preventing SCC by Using Inhibitors

Gap

- A number of inhibitors have been successful at either preventing SCC or substantially reducing the severity in aggressive lab tests. It is not known whether higher concentrations of the corrosion inhibitors would have been successful or if they would be successful in the less aggressive scenario of real pipeline operation.

Suggested Research

- Conduct a systematic study of candidate inhibitors at various concentrations in FGE with various oxygen contents. Include commercial inhibitors but avoid chemicals that are specifically not allowed in gasoline.
- Use SSR tests initially to screen inhibitors along with various electromechanical tests to evaluate the mechanisms. For chemicals that produce partial inhibition, use a less severe cracking test to evaluate their effectiveness under typical pipeline operating conditions.

Recommended Project 5
Compatibility of Non-ferrous Metals with Ethanol

Gap

- The effect of ethanol on non-ferrous metals and alloys that are in current pipeline and storage systems or might be used in future systems should not be ignored. Reportedly, pitting has been experienced with aluminum floaters.

Suggested Research.

- Conduct an inventory of non-ferrous metals that might be exposed to ethanol in storage and pipeline systems containing ethanol.
- Determine which of those materials currently are being used in ethanol storage facilities and whether the ethanol has caused any problems with them.
- For materials with no service record, conduct exposure tests in ethanol.

Recommended Project 6
Phenomenological Understanding of Ethanol SCC

Gap

- There are still many aspects of the ethanol SCC phenomenon that are not understood. A more thorough understanding of the factors that cause ethanol SCC may suggest better ways to manage the problem.

Suggested Research

- Develop a phenomenological understanding of the factors that cause ethanol SCC by conducting a systematic study of environmental, stress, and metallurgical factors.
- Determine relationships among the cracking behavior, electrochemical properties, chemical composition of the environment, stress conditions, and steel composition and properties.

Other Recommended Actions

- Results of research will be most useful if incorporated into documents such as a recommended practice for transporting ethanol by pipeline and guidelines for integrity management of pipelines for transporting ethanol.
- Integrity management guidelines should address issues such as monitoring, risk management, in-line inspection, hydrostatic testing, and direct assessment.
- It is recommended that API or some other suitable industry organization establish committees or direct existing committees to prepare those documents. For example, API might develop an overall or umbrella standard, which would refer to other standards to be developed by other organizations, such as NACE for corrosion control and monitoring, ASTM for testing, etc.

Full Project Plan

Deliverable	Project	Pre-2007	2007	2008	2009	2010	2011	2012	2013	2014
1. Standard for Safe and Reliable Transport of Ethanol by Pipeline										
	1.1 API 939-D Part 2: Survey of Industry Experience									
	1.2 Develop Lab Tests Relatable to Service Conditions									
	1.3 Develop Rapid Field Test for Quality Assurance									
	1.4 PRCI SCC-4-5 Requirements for New Pipeline Systems									
	1.5 GRI-04/0128, SCC Avoidance in Ethanol Pipelines									
	1.6 PRCI SCC-4-1 Prevention of Internal SCC in Ethanol P/Ls									
	1.7 PRCI SCC-4-3 Identify Environmental and Stress Factors that Produce SCC in Existing Ethanol Pipelines and Terminals									
	1.8 PHMSA new start: Effect of Ethanol Source on SCC of Carbon Steel									
	1.9 PRCI SCC-4-4. Determine the Requirements for Existing Pipeline, Tank and Terminal Systems to Transport Ethanol without Cracking									
	1.10 PHMSA new start. Effect of Ethanol Blends and Batching Operations on SCC of Carbon Steels									
	1.11 API/SwRI SCC in Fuel Ethanol									
	1.12 Feasibility of Preventing SCC by Using Inhibitors									
	1.13 Technical and Economic Feasibility of Preventing SCC Through Control of Oxygen									
	1.14 Test Modern, Low-Carbon Steels to Determine if They are Less Susceptible to Ethanol SCC									
	1.15 Determine Compatibility of Aluminum, Brass, and Any Other Non-Ferrous Metals That Might be Used in Ethanol Pipelines									
	1.16 Evaluate Effectiveness of, and Effect on, Internal Coatings									
	1.17 Evaluate Effect of Pressure on SCC									
	1.18 DNV Internal Project to Develop Probes to Measure Corrosion Potential and Oxygen Content									
	1.19 PHMSA new start. Monitoring of Conditions Leading to SCC/Corrosion									

Full Project Plan (cont.)

Deliverable	Project	Pre-2007	2007	2008	2009	2010	2011	2012	2013	2014
	1.20 Fundamental Study to Determine How SCC Relates to Corrosion Potential, Polarization Curve, and Other Basic Electrochemical parameters									
	1.21 Develop Guidelines for ILI for Internal SCC									
	1.22 Develop Method for Predicting Where Internal Ethanol SCC is Most Likely									
	1.23 Develop NDE Method to Detect and Measure Cracks from Outside									
	1.24 Develop Method to Detect Ethanol Leaks									
	1.25 Repair Criteria and Methods									
	1.26 Develop Welding Guidelines for Avoiding Harmful Residual Stresses									
	1.27 Develop Guidelines for Avoiding Pitting or General Corrosion									
	1.28 Evaluate Proposed SCC Solutions for Compatibility with Automotive Requirements									
2. Standard for Safe and Reliable Storage of Ethanol										
	2.1 Determine Any Differences in Guidelines for Storage Versus Transportation									
3. Phenomenological Understanding of the Factors that Cause Ethanol SCC										
	3.1 Determine the Relationships Among Cracking Behavior and Environmental, Stress, and Metallurgical Factors									
4. Guidelines for Risk Assessment										
	4.1 Develop Guidelines for Risk Assessment									
5. Guidelines for Fire/Spill Emergency Response										
	5.1 Develop Guidelines for Fire/Spill Emergency Response									
6. "Fingerprint" Test for Ethanol										
	6.1 Develop Method to Characterize Critical Differences in Ethanol from Different Sources in Terms of SCC Propensity (Included in Project 1.8)									

Full Project Plan (cont.)

Deliverable	Project	Pre-2007	2007	2008	2009	2010	2011	2012	2013	2014
	6.2 Refine Method to Characterize Critical Differences in Ethanol from Different Sources							—		
7. Decision-Making Process for Specific Pipelines										
	7.1 Develop List of Issues to be Considered by a Company Regarding Transport of Ethanol							—		
8. Ethanol (Biofuels) Handbook										
	8.1 Write a Handbook on Transportation and Storage of Ethanol and Other Biofuels									—
9. Tools to Predict Residual Stresses										
	9.1 Develop Tools to Predict Residual Stresses					—	—	—		
10. Committee to Coordinate Tech Transfer										
	10.1 Support Participation of Technical Expert in Committee Activities				—	—	—	—	—	—
11. Workforce Training Program										
	11.1 Develop Workforce Training Program						—	—		