Summary of Activities on Ethanol
SCC – Tanks and Facilities

Failure Documentation, Survey Results, Guidelines Development

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Organization

- API Efforts on Ethanol SCC
- Experience Documented from Survey Information
  - Example Failures
  - What crack and what does not
  - Where does cracking occur in distribution system for fuel ethanol
  - What about E10 and E85 blends?
  - How does US compare with others (Europe and Brasil)?
  - Monitoring?
- Guidelines development
  - Identification
  - Mitigation
  - Remediation
- Ethanol SCC Resources
Prior to 2003, there was only minimum understanding of the extent and consequences of ethanol SCC.

The American Petroleum Institute (Refining Committee) with assistance of the Renewable Fuels Association initiated a program to investigate this phenomenon.

Initially, this involved the development of a white paper (survey) document (API 939D) to better understand:

- Put ethanol SCC in context with other commonly observed SCC mechanisms in petroleum operations
- Survey of failure experiences, handling practices; remediation methods
- Establish a basis for a more involved research investigation; provide “linkage”.

Stress Corrosion Cracking

Material

Environment

Tensile Stress
Fuel Ethanol Survey at a Glance

- It involved a survey of companies in manufacturing, distribution and blending of fuel ethanol. Included:
  - Eight (8) ethanol processing facilities.
  - Two (2) fuel ethanol distribution terminals
  - Ten (10) end-user storage & blending facilities
  - One (1) methanol handling facility
  - Five (5) companies also provided reports and documents on SCC failures and inspections.
  - Eight (8) on-site visits were conducted
  - Review of published literature on corrosion and SCC in alcoholic environments.
  - Surveys and data gathering in EU and Brasil.
  - Survey of E85 sites

- Currently, more than 20 known cases of SCC have been documented through the survey efforts covering the period 1990-2005.

- Failures have been reported in steel – tank bottoms, wall and roofs; facilities piping, fittings and components and at least one pipeline.
Examples of Recent SCC Events

- **End user storage and gasoline blending facilities**
  - Three cases at one Great Lakes facility in loading rack piping used for blending ethanol into gasoline.
    - Cracks in sock-o-let welds, pipe butt weld, and fillet weld on pipe shoe.
  - Two cases on West Coast at two facilities
    - Cracks in roof plate welds
    - Cracks in rack piping/fittings
  - One case in Mid-Continent blending facility
    - Cracks in rack piping

- **Fuel ethanol tank at liquids distribution terminal**
  - Gulf Coast
    - Cracks in tank floor with subsidence – cracks at multiple ring wall locations.
  - Ethanol pipeline
    - Terminal to refinery blending facility
## Example Failure Data and Format

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Location</th>
<th>Equipment Description</th>
<th>Service Period</th>
<th>Source of Ethanol</th>
<th>Inhibitor</th>
<th>Steel</th>
<th>Description</th>
</tr>
</thead>
</table>
| A1      | W. Coast Terminal| EU (End-User) Tank: Built in 1940; bottom replaced in 1991; 78’ dia. steel pan; internal floating roof | 10 yrs         | During the past 4 years: *89% reported to be domestic sources* *6% one source unknown* *<5% from additional 10 suppliers* | Dependant on source / not consistent           | ASTM A36 | • Double bottom tank  
  • WMPT identified 18 cracks in or near bottom fillet welds  
  • Plate/plate lap seams & corner welds  
  • Floating roof springs also failed  
  • First course butt weld seam check but no cracks found  
  • Cracks found in one nozzle weld  
  • Metallurgical analysis performed  
  • Repairs: cut out cracks in bottom, corner welds ground out  
  • Remedial: Tank bottom and lower 3 feet of shell were epoxy coated. |
| E12-13  | Two West Coast Locations | Two tanks – one at each location Evidence suggests SCC but no investigation documentation | Leaks reported in 5 mo. to 1 year | Not known                                                                       | Not known                                      | Not known | • Found cracking near welds of newly installed patch plates and striker plates, near the corners.  
  • Did not find any cracking in the shell or corner welds  
  • Remedial: Lining all tank bottoms |
What We Know from Survey

- SCC appears to be related to conditions of:
  - Steel construction with high local tensile stresses, concentration of bending and/or hardness
  - Non-PWHT welds (basically everything), but particularly those welds where very high stress/strain concentration points are present - lap-seam welds (tank roof or bottom), low heat input (tack welds in supports)
  - Residual stresses or cold work – fabrication, forming, fit-up & subsidence
  - Flexing components (tank bottoms, roof plates & spring components)
  - More than one episode of cracking at a facility likely.
  - Experience indicates that steel grade alone is not an issue for piping and tank applications but stress, fit-up, welding and PWHT are very important.
Based on survey results, the occurrence of SCC appears limited to only a portion of the supply chain:

- SCC does not appear to be a problem for storage tanks and piping at the point of ethanol manufacture.
- SCC does not appear to be a problem in the first tier distribution system (i.e. barges, tanker cars, tank trucks),
- SCC has appeared at or after the first major hold point in the field (e.g. at either a liquids distribution terminal, storage tank, and gasoline blending facilities).
- No reported SCC from the field:
  - after ethanol is blended with conventional gasoline (E10)
  - in E85 blends
  - outside the USA
    - including Europe - little use until recently
    - Brasil – for decades but mainly hydrated ethanol with higher water content.
No major differences in handling and operating practices were observed between manufacturers and downstream storage/blending facilities.

Fuel ethanol is exposed to air, moisture and other potential contaminants many times during its path through the distribution system.

This suggests time and opportunities are available for changes to occur in the condition of the product.

Preventative methods used to alleviate SCC problem:
- Coating of tank bottoms and some floating roofs
- Post weld heat treatment of piping
Ethanol SCC: Lab versus Field

- Fuel ethanol under aerated and still air conditions showed susceptibility to SCC. Similar to field experience.

- Fractography shows similar fracture features in laboratory tests as in field failures; but can be different (impurities).

- Effect of water content: only within 0-1 percent (no effect) in lab but hydrated ethanol low susceptibility; consistent with field experience.

- E-85 ethanol/gasoline samples demonstrated SCC susceptibility in lab. But, no field failure reported to date.
Starting in 2006, API has been developing a guidelines document (API 939E) to present results and experience gain thru studies on SCC.

Focus has been SCC identification, prevention and remediation methods.

Emphasis is on practical information for operations personnel (i.e. the corrosion non-specialists).

This effort has produced a draft document that has been balloted within the API refining committee.

Revised document is in progress for balloting with hopeful finalization by May 2007.

This document focuses on:
- Facilities piping and tanks
- Lessons learned through survey and research effort in API
- Ancillary information on inspection, stress relief and coating
- Limited suggestions for monitoring (based on electrochemical methods for corrosion rate, pitting and potential monitoring).
Available Resources on Ethanol SCC

  - API 939D has been updated to include the results of research, survey and monitoring through 2006.


Available Resources on Ethanol SCC - 2

- Other API Publications:
Summary

- SCC failures have been experienced in systems handling, storing and transporting fuel ethanol.
- Lab research has confirmed this phenomenon.
- Lab and field work has identified certain conditions as causal effects, i.e. aeration, chlorides (but chlorides not required).
- Failures appear to be limited to mid-stream distribution of fuel ethanol up to mixing in conventional gasoline blends (E10).
- SCC has been recently observed in lab tests of E85, but no failures reported.
- SCC mitigation methods reported are coating of tanks (novolac, epoxy phenolics) and post weld heat treatment of piping (reduce residual stress).
API has developed a data form for documentation of SCC failures.

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