ABSTRACT
The SCC (stress corrosion cracking) database was initiated by the CEPA (Canadian Energy Pipeline Association) SCC Working. The current generation of the database has a broad scope, containing detailed data for each and every colony and its associated environmental conditions. The database also includes corrosion and dents amongst other integrity concerns to identify any correlation with SCC and provide a common industry data format to investigate these other integrity issues. The intent of the current version of the database is to provide for the most detailed data entry that one could typically capture at an investigative dig. With the wide acceptance of the current version the CEPA database it is evolving into the industry standard for investigative excavation data.

The initial trending results are based on the dataset generated by CEPA member companies, which represents over a thousand investigative excavations. The trend results should only be interpreted broadly at this time, although they do generally support industry’s understanding of SCC.

The development and implementation of the CEPA SCC database is premised on the belief, developed through extensive field investigations and laboratory research, that SCC is not a random development, but it initiates and grows at specific locations susceptible to SCC. It is further premised on the belief that such susceptible sites can be generally located by appropriate prioritization techniques. Thus, the objective of the database is to explore correlation among the various operational and environmental variables to improve the current understanding of how to locate SCC, and in particular ‘significant’ SCC, in order that measures can be taken to prevent operational failures and enhance the safety of Canadian pipelines.

The need for an industry database regarding SCC was identified by the CEPA SCC working group shortly after its formation 1994. It was apparent that the various companies were collecting the field data from investigative excavations in significantly different formats, only some of which were electronic. The need for a common data structure and data repository to facilitate trending was reinforced numerous times at the Banff Conferences and by the NEB during its inquiry into SCC in 1995/96.

FIRST GENERATION
A first attempt at the database used a Visual Basic graphical front end interfacing with an Access database. This version of the data capture program was solely concerned with SCC and smeared the data over the length of a joint of pipe. Bundling of the data on a per joint basis was thought to be adequate and expedient for data entry. Subsequent application of this data structure created such a course set of data that it eliminated much of its value in supporting useful trending analysis. Additionally, it required that companies create their own proprietary databases to store the level of detail contained in the original inspection reports.

CURRENT GENERATION
The second generation of the CEPA data capture program (termed SCCdb) uses a Delphi graphical front end interfacing with a Paradox database. It was determined that to facilitate trending and to direct and validate research, detailed data would be required for each and every feature (a colony in regards to SCC) and its associated environmental conditions. The scope of SCCdb was also expanded to corrosion and dents amongst other integrity concerns to identify any correlation with SCC and to provide a common industry data format to investigate these other integrity concerns. The intent of SCCdb is to provide for the most detailed data entry that one could typically capture at an investigative dig.

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investigative excavation. Given that many companies do not capture that level of detail, but if they do, there should be a standard platform to record it in. By facilitating entry of essentially all the data from the source reports, the concept is to eliminate the need to continually reference back to the reports, thereby providing added value to the companies utilizing SCCdb.

SCCdb has thee components:

- Data entry and viewing
- Spatial Correlation
- Reporting

**Data entry and viewing**

**Coordinate Systems**

Of utmost importance is consistency in measurement, especially spatial measurements of surface and subsurface features. Above ground features are measured from a control plane axially along the centreline of the pipe with decreasing Kilometer Post (KP) measurements being negative (-) and increasing KP measurement being positive (+). Lateral distances are measured perpendicular to the centreline of the pipe with distance to the left when facing towards increasing KP measurements being negative (-) and distance to the right, positive (+).

Subsurface features are measured with respect to a reference plane within the site. Again, these are measured from a reference plane to the centre of the feature axially along the centreline of the pipe with decreasing Kilometer Post (KP) measurements being negative (-) and increasing KP measurements being positive (+).

Knowing the relationship between a control plane and a reference plane allows for the translation of surface and subsurface features with little difficulty. SCCdb can record GPS coordinates for the control and reference planes, but using chaining or other measurement techniques to find the axial separation between the two are required.

All units in SCCdb regarding spatial reference are metric.

**Geographical units**

Three geographical units used in SCCdb:

- Site
- Excavation
- Bell Hole

A Site is the largest geographical unit in SCCdb and can contain several Excavations. Any time one of the parameters for a Site changes, it necessitates the creation of a new Site. For instance, to capture two portions of an investigative dig having different predicted levels of susceptibility, two Sites would have to be created. Furthermore, a Site is defined by a single control plane.

The data associated with a Site is:

- Site and Project details
- Vegetative and Physiographic regions
- Surface Work
  - resistivity
  - Novaprobe
  - Cathodic Protection

An Excavation is a hole or a series of holes tied to a common reference plane. If multiple holes makeup an excavation then each hole is termed a Bell Hole.

Data associated with an Excavation consists of:

- Repairs and Recoating
- Pipe Properties, including bends and buoyancy control
- Coating Damage
- Soil type and Texture
- Samples of soil, liquid and corrosion deposits
- Integrity Features
  - Dents/Wrinkles
  - Metal Loss
  - Cracking
  - Manufacturing Defects
Spatial Correlation
This module allows the spatial correlation of one pipe surface or environmental feature against another either axially, radially or both within a specified distance or degree. The query can be performed on one Site, all Sites or a selected Group of Sites.

Reporting
Due to the number of tables (30) that make up SCCdb and the numerous fields in each table, a simple print command would be inappropriate to generate a hard copy. In this regard a simple query tool/report writer is supplied to facilitate building a report of reasonable size and relevance.

UTILIZATION OF SCCdb
Gas Research International (GRI) has adopted the data fields utilized in CEPA’s SCCdb in their Integrated Spatial Analysis Techniques (ISAT) program. Recently, the Line Pipe Research Supervisory Committee of the Pipeline Research Committee International (PRCI) adopted the SCCdb program and is currently funding modifications to facilitate international usage.

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INITIAL TRENDING
Performing the data trending was more challenging than expected. Through the course of performing the initial trending various shortcomings were identified with the data entry:
• Inconsistent units and out of range values
• Inconsistent nomenclature
• Over utilization of non-trendable values (e.g. “other” in reference to coating type)
• Inconsistent coordinate systems

Following a manual quality control review to enhance trendability of the data some of these problems were quickly repaired; other problems were more involved which necessitated the removal of the data, from the dataset, for the initial trend analysis.

To address these problems a quality control (QC) module will be added to the program. This module will be automatically run as part of the process of the company compiling the data for submission to CEPA. The QC module will review the data and summarize for each parameter the number of Sites and features that have invalid and non-trendable values. This will provide the contributing companies the opportunity to revise their data to ensure its suitability for trending.

TREND INTERPRETATION
Notwithstanding the fact that the database is currently incomplete with respect to the volume of data collected to date, a first trending has been attempted. The dataset at the time of this trending was obtained from ten CEPA member companies and consists of approximately 2500 Sites representing almost 70,000 meters of pipe inspected for SCC. This dataset is associated with low-pH SCC and has been specifically screened of the few Sites identified as high-pH SCC. While it is believed that the trend results should only be interpreted broadly at this time, the initial trending exercise is considered useful in the evolution towards relevant and useful trends.

A number of trends were developed by conducting single-variable correlations between design and environmental factors, and the presence of SCC. Trends are presented in terms of the following categories:
• Number of SCC colonies with depth less than 10% of wall thickness;
• Number of SCC colonies with depth greater than 10% of wall thickness; and,
• Number of ‘significant’ SCC colonies detected.

A challenge to interpretation of the database trends results from data skewing. Skewing is a natural and expected phenomenon that, depending on the relative amounts of data from the various member companies will result in bias in terms of the trends. Skewing will result from:
• the relative volumes of data pertaining to particular circumstances;
• data from different geographic regions;
• data pertaining to different pipe coatings;
• pipelines with a variety of susceptibilities;
• susceptibility or prioritization models employed;
• inspection dates, relative to model development; and
• conventions used by different companies.

Given such considerations, it is important to exercise caution in the interpretation of the apparent trends. It is suggested that validity may be best for the highest level trends involving the greatest volume of data, and would diminish for the lower level trends involving less data per category.

It is CEPA’s expectation that the database will improve with time, as it becomes more populated and as trending is performed. For this reason, results of trending are expected to be refined as the database is populated and as analysis capabilities evolve.

Note: There is one particular asphalt coated portion of TCPL’s system (Youngstown Line 100-1) which has exhibited a far greater susceptibility to SCC than other asphalt and coal tar enamel coated pipe and would extremely skew the results. Consequently, this particular low frequency ERW longitudinal weld seam pipe has been removed from the data set to provide realistic and meaningful results for the asphalt and coal tar enamel coated pipe in general.

TRENDS

Coating Type
At the time of the 1995 Inquiry, CEPA reported that SCC was significantly more prevalent and severe in polyethylene tape coated pipe than in asphalt and coal tar enamel coated pipe. This was evidenced by the relative frequency of in-service incidents, the number of deleterious defects removed during hydrostatic retesting, the average number of SCC colonies and in particular the number of ‘significant’ SCC colonies detected per metre of pipe inspected.

Figure 3 illustrates a trend for the frequency and severity of SCC on tape and asphalt/coal tar-coated pipelines.
Based upon the data, it would seem prudent for pipeline companies to continue focusing their SCC mitigation programs on polyethylene tape coated pipe while at the same time continue monitoring asphalt/coal tar enamel coated pipe to assess the SCC if such pipe is becoming 'significant' with time.

Pipe Manufacturing Process
Figures 4 and 5 present trends for SCC on long seam and spiral welded pipe for tape and asphalt/coal tar enamel coated pipe, respectively. With respect to the pipe manufacturing process, it is apparent based on Figure 4 and 5 that pipe manufactured with a longitudinal weld seam is more susceptible to 'significant' SCC than is pipe manufactured with a spiral weld seam. This is likely a result of the orientation of both the weld seam tenting and the heat affected zone in spirally weld pipe. The apparent trend in Figure 4 toward higher SCC initiation susceptibility for spiral welded pipe is believed to be skewing, relating to a disproportionately high detection rate from the utilization of refined predictive models in the last few years. It is believed that the susceptibility to SCC initiation is similar for both long seam and spiral welded pipe.

SCC on Natural Gas and Liquid Hydrocarbon Pipelines
Figure 6 shows the current trend based on the database. As illustrated, SCC on natural gas pipelines appears to be approximately double the frequency on liquid hydrocarbon lines, a significant decrease from a 12:1 trend at the time of the 1995 Inquiry. This trend also demonstrates the effect of skewing. While the frequency of SCC found on liquid lines may have risen based on the increased inspections conducted on liquid lines since the Inquiry, the high frequency shown for liquid lines is not believed to reflect reality. One reason for this relates to the inspection results of a single CEPA member, which involved short inspections at tape-wrapped girth welds. In terms of cumulative length of inspected pipe the total was relatively low, whereas the SCC detection rate was high. Combining this with the remainder of the asphalt/coal tar coated data has skewed the general result to the high side.

Design Stress
Based upon the data collected by CEPA member companies it is apparent that there was no absolute threshold operating stress value for SCC initiation or propagation. This is supported by CEPA's failure record where ruptures had occurred down to operating hoop stress levels of between 55 and 77 % of the pipe's SMYS and between 49 and 73% of the pipe's SMYS.
trends are available, no correlation between the pipe grade and the extent and severity of SCC can be determined at this time.

**Drainage**

As indicated in the CEPA SCC Recommended Practices, tape-coated lines display the highest frequency of cracks in Imperfect to Very Poorly drained soils. Asphalt-coated lines display the highest SCC frequency in Well drained conditions. The current trends for tape and asphalt-coated pipelines are shown in Figures 9 and 10.

The trend for tape coatings, Figure 9, reflects experience in terms of both shallow and significant SCC: as drainage degrades towards Imperfect and Very Poor the frequency of SCC increases. The frequency of deep and significant SCC, however, peaks under Imperfect drainage and continues to be present, albeit at lower frequencies, at the wettest conditions.

**SCC by Pipe Grade**

Figure 8 indicates SCC has been observed in grades ranging from Gr. 290 to Gr. 483. The presence of SCC down to Gr. 290 in Canada is consistent with the experience of the pipeline industry in the United States where SCC has been detected in pipe of Grades A and B and Grade 290.

As was the case with design stress, the peak frequencies shown in fig. 8 are not interpreted to be proportional to relative susceptibility. Rather the variation is believed to reflect skewing in the data by another parameter that will hopefully be normalized in future multivariable trending. Until results from more rigorous multivariable
**Under-Coating Electrolyte pH in Proximity to SCC**

A measure (pH) of the acidity or alkalinity of the electrolyte present of the pipe’s surface provides useful information about the processes associated with SCC. To characterize the electrolyte beneath the disbonded coating, pH readings are commonly taken and recorded with respect to the location on the pipe.

The pH range of trapped electrolytes associated with low-pH SCC has been reported in the literature and is stated by CEPA as a range of 6-8. Figures 11 and 12 show the pH trends from the database for measurements taken 0mm to 50mm and 0mm to 100mm from colonies.

**Figure 11: Under Coating Electrolyte pH within 50 mm of SCC Colonies**

**Figure 12: Under Coating Electrolyte pH within 100 mm of SCC Colonies**

It is readily apparent from these trends that the pH associated with the neutral-pH SCC is in fact in the range of 5.5 to 8.5, in close agreement to what has been reported, and that ‘significant’ SCC occurs at pH 6 - 6.5, just slightly acidic with respect to neutral. By comparing Figures 11 and 12 it can also be concluded that pH measurements taken within 100mm of the colony will accurately characterize the electrolyte pH associated with the SCC.

**SCCdb DISTRIBUTION**

CEPA is making the SCCdb available to pipeline owner/operators. An application for access to SCCdb can be obtained from CEPA’s web site at www.cepa.com. Users will be notified by email of any future modifications to SCCdb.

**DATA CONTRIBUTIONS FROM NON-CEPA MEMBERS**

CEPA is currently developing a mechanism to address non-CEPA member participation in the trending analysis. The key issues are confidentiality, cost sharing and participation in the trend selection and review process.

**CONCLUSIONS**

The successful development and population of this database on SCC by CEPA marks a first in the pipeline industry. GRI’s and PRCI’s adoption of CEPA’s SCCdb and its data structure is a significant step towards reaching a unified industry database to validate and direct integrity research as well as provide operating companies with valuable insight as to where to focus their efforts. Notwithstanding this great success, CEPA recognizes the need to address the challenges relating to improved data collection and trending.

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ii Canadian Energy Pipeline Association Submission to the National Energy Board, Public Inquiry Concerning Stress Corrosion Cracking (SCC) on Canadian Oil and Gas Pipelines, Proceeding MH-2-95, Volume 1, Issue 3

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