Current and Emerging Technologies to Prevent Mechanical Damage to Natural Gas and Hazardous Liquid Transmission Pipelines

2nd QUARTERLY PUBLIC REPORT

Period: July through September 2005

Background

This objective of this project is to assist the National Association of Corrosion Engineers (NACE) in the development and balloting of a draft standard for wet gas Internal Direct Corrosion Assessment (ICDA). This includes identifying, with NACE, the key technical issues and methodology related to wet gas ICDA. The indirect assessment will include information on wet gas, assessment mechanisms, and upset conditions.

Summary of Progress this Quarter

An initial draft for the "Proposed NACE Standard Recommended Practice for Wet Gas Internal Corrosion Direct Assessment (ICDA) Methodology for Pipelines" was completed this period. The draft was written based on the committee instructions in the NACE spring 2005 meeting minutes, two teleconferences among the committee chairs and the contractors responsible for the wet gas ICDA and three public documents:

- Dry gas ICDA
- SwRI R&D report to DOT on wet gas ICDA (July, 2004)
- International Pipeline Conference paper/2004 presented by Moghissi et al.

Two teleconferences were held, respectively on July 25 and Aug. 16 to discuss the wet gas ICDA. The first meeting discussed wet gas ICDA issues raised during the NACE/05 in Houston, identified people who at NACE/05 wished to volunteer for drafting the wet gas ICDA, and determined how to proceed on drafting the wet gas ICDA. The meeting determined that the chapters in the wet gas ICDA draft skeleton would be based on the dry gas ICDA and provide DA for scenarios not covered in the draft DG-ICDA standard.

A second meeting was held Aug. 16 to discuss this skeleton outline. The skeleton and the first two of the four steps required for the wet gas ICDA were drafted based on the three documents listed above. Discussion also included determining the differences between wet gas and dry gas, and the criteria to determine locations to dig. It was suggested to draft a flowchart (see Figure 1 in Results and Conclusions section below) similar to that in the dry gas ICDA.

The draft was then sent to all volunteer members for feedback. Discussions of the draft were held at the NACE Technology Week in September in Calgary. Document revision has begun based on the discussion at the NACE Technology Week.

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Results

Based on the initial research, the wet gas ICDA will consist of four steps:

1. Pre-assessment: Collect essential historic and current operating data about the pipeline relevant to corrosion distribution, determine if Wet-ICDA is feasible and then define and bound the Wet-ICDA regions based on expected flow regime. The types of data to be collected are typically available in design and construction records, operating and maintenance histories, alignment sheets, corrosion survey records, gas and liquid analysis reports, and inspection reports from prior integrity evaluations or maintenance actions. This first step is aimed at classifying the pipeline into segments with self-similar flow regimes such that the relative corrosion behavior of these segments can be assessed.

2. Indirect Inspections: Measurements are taken or calculations are performed to prioritize locations along a particular pipeline segment by probable severity of corrosion damage.

   The factors contributing to the distribution of corrosion severity will be included and an initial assumption about corrosion distribution will be made. Wet-ICDA is sufficiently flexible to allow the use of existing wet gas models within the framework of the overall process. The corrosion rate depends primarily on product quality, liquid chemistry, pressure, and temperature. However, the likelihood of finding and prioritizing corrosion damage at a particular location along a pipeline segment is influenced by a long list of additional factors, each of which needs to be considered in terms of its overall importance and effect on safety.

   The proposed basis of a Wet-ICDA method for wet product is to separate the factors of flow effects, corrosivity, and other corrosion rate influencing factors. Flow effects include possible flow regimes and condensing water (i.e., at locations of heat loss). Expected possible flow regimes are stagnant, stratified, and slugging.

   On this basis, a pipeline with similar flow effects (e.g.., flow regime, velocity) throughout an entire segment is considered to have corrosion distribution determined only by non-flow related corrosivity factors (i.e. gas quality, inhibitors, attempts at cleaning, flow direction, etc.). However, pipelines with more than one flow regime over distance can have corrosion distributions influenced by:

   - Flow Modeling
   - Corrosion Mechanisms
   - Upsets and
   - Mitigation Effects

   Compute the probability of critical corrosion damage as a function of location along the pipeline using physical models for flow, corrosion rate, and inspection information as well as uncertainties in elevation data, pipeline geometry and flow characteristics. The probability of corrosion damage is computed as the probability that the corrosion depth exceeds a critical depth given the presence of electrolytes such as water. More than one candidate corrosion rate models are employed to reduce the chance of selecting the incorrect model. Monte Carlo simulation and the first-order reliability method (FORM) implemented in a spreadsheet model could be used to perform the probability integration.

3. Direct (or Detailed) Examinations: The pipe is excavated and examined at locations prioritized to have the highest likelihood of corrosion. The examination must have sufficient detail to determine the existence, extent, and severity of corrosion. Examination of the internal surface of a pipe can involve non-destructive examination methods sufficient to identify and characterize internal defects. Bayesian updating has been used to incorporate inspection information (e.g., in-line, excavation, etc.) and update the prediction of most probable damage location. The addition of this new performance technology provides a systematic method for focusing costly inspections on only those locations with a high probability of damage and incorporating the results of the inspection in a manner that improves confidence in future predictions.

4. Post-Assessment: Analysis of the indirect and direct examination data is performed to determine overall pipeline integrity, prioritize scheduled repairs, set the interval for the next assessment and assess the effectiveness of WG-ICDA. If the results of excavations do not match the original prediction of most likely locations of internal corrosion, the corrosion distribution model is updated using a Bayesian updating procedure. The updating strategy can be operator specific and may involve adjustment of corrosion models or other parameters resulting in improved matching with excavation data.

   The notion of "likelihood" involves the mathematical considerations of uncertainties in knowledge using a probabilistic method to predict the most likely locations of corrosion. This concept and methodology is further extended in this report for wet systems by including the distribution of corrosion rates. Furthermore, based on inspection or direct examination, the probabilities may be updated, thus reprioritizing inspection locations further downstream. The approach of Bayesian updating is also discussed through an example. This standard is being prepared by Task Group (TG) 305 on Pipeline Direct Assessment Methodology. TG 305 is administered by Specific Technology Group (STG) 35 on Pipelines, Tanks, and Well Casings. This standard is expected to be issued by NACE International under the auspices of STG 35.

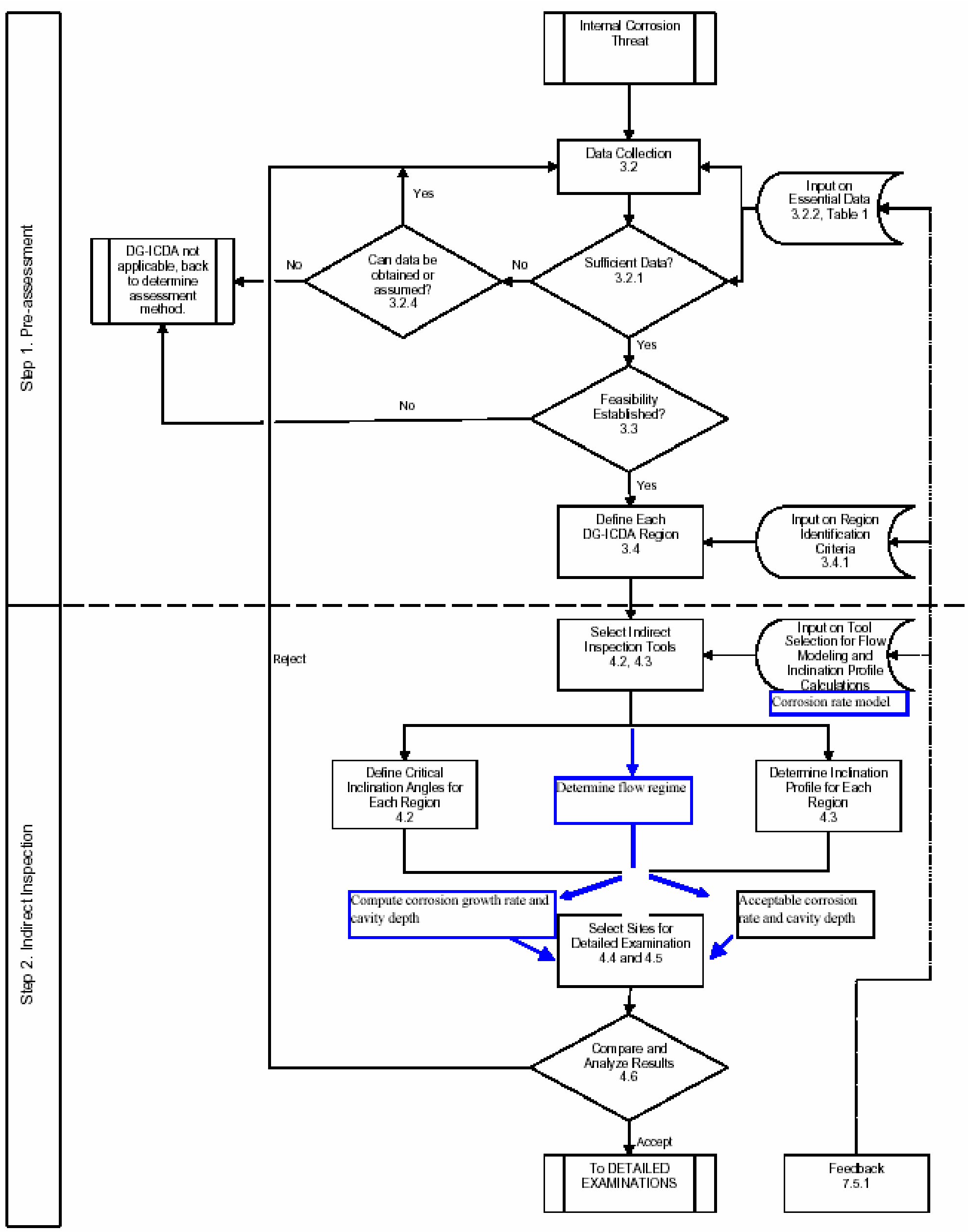

Figure 1: Draft Wet Gas Internal Corrosion Direct Assessment Flowchart

Future Activities

The future work will include:

- revise the documents based on the discussion at the NACE Technology Week meeting,
- send the revised document to all volunteers for feedback,
- teleconferences to incorporate the feedback into the new draft,
- discuss the draft again at NACE/06 in San Diego, CA,
- revise the document,
- and prepare the final report.

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