GOVERNMENT & INDUSTRY PIPELINE RESEARCH & DEVELOPMENT FORUM

22-24 March 2005

Houston TX

Design, Construction, Materials and Welding Technology Track

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1.0 SESSION SUMMARY

The objective of this session, Appendix 1, was to:

- review the technology needs for design, construction, materials, and welding in the pipeline industry;
- identify significant gaps and barriers;
- recommend actions; and
- establish priorities for subsequent funding.

It was necessary to examine the entire process from basic research through commercialization in order to identify all relevant gaps and barriers. Accordingly, the session was organized around six presentations that served as spring boards for group discussion about specific technology needs, opportunities, gaps, and barriers in each topical area.

- Technology
  - Design & Construction
    - PRCI DCO Committee Priorities, Appendix 2 (Marie Quintana for Rick Gailing)
    - MMS Offshore Perspective, Appendix 3 (Mik Else)
    - OPS Initiatives, Appendix 4 (James Merritt)
    - NIST Pipeline Corrosion Studies, Appendix 5 (Richard Ricker)
  - Materials & Welding, Appendix 6 (Dave Horsley)
- Implementation & Commercialization, Appendix 7 (Yong-Yi Wang)
- Administration & Project Management, Appendix 8 (Marie Quintana)

All of the ideas from the discussions were captured and rated in terms of

- priority to the industry,
- time frame in which action is needed, and
- risk associated with achieving the desired outcome from the recommended action within the time frame.

Analysis of this data is the basis for the following discussion of gaps, opportunities and recommended actions for design, construction, materials, and welding. The ideas were also considered in the context of eleven broader focus areas:

- Design, Construction and Operation of Pipelines – Reliability and Structural Integrity,
- Strain Based Design and High Strength Steel,
- Materials Properties and Performance,
- Right of Way Management,
- Environmental Management,
- Adverse Environments and Unique Conditions,
- Offshore,
- Codes and Standards,
- Commercialization,

- Resource Management, and
- Human Factors.

The reason for taking this approach was to put the individual issues in broader context, revealing any synergies that might exist. The result of this approach can be seen in the discussions that follow. The detail notes are included in Appendix 9.

Many specific issues must be considered in the context of broader program objectives for truly effective implementation of the results. The fundamental gaps underlying the major issues in design and construction are the inadequacies of existing limit state design methodologies. Similarly, it was found that the drive to higher strength steels for performance and cost advantages is limited by inadequacies in strain based design methodologies. Since effective implementation of new materials needs relies on the availability of design tools, measurement systems, fabrication methods and welding processes, the development in these areas is interdependent and must proceed in parallel. Similarly, the need for improved coating systems cannot be satisfied effectively without parallel development of short term test methods and relationship with field performance.

Successful development and implementation of technological improvements relies on acceptance by all stakeholders. The process can be seriously hindered by administrative and/or human factors. Consequently, specific recommendations are made with regard to human factors & public awareness, codes & standards, commercialization, and program management. Many of the initial steps in these areas do not require technology development. *However, reengineering of the proposal review and project management processes is needed if the full benefits of technology development are to be realized*.

All issues elevated during the Design, Construction, Materials, and Welding Technology Track have been brought forward and presented in order of priority. The top five are summarized in the table below. All are detailed in the pages that follow.

Gaps	Potential R&D
Strain Based Design Needs • Comprehensive set of design tools • Full scale experimental tests designed for the validation of predictive methods	• Predictive methodologies • Methods for characterization of materials properties & variability • Full scale experimental program considering longitudinal tensile and compressive strains, with and without internal pressure
Codes & Standards severely lag the state of technology for materials, design criteria, inspection, risk assessment, defect acceptance criteria, etc.	• Review for gaps & opportunities to develop comprehensive action plan. • Standardization of RBDA based on consensus agreement of methods to assess acceptable risk. • Standardize AUT methodology accounting for variability of sizing, probability of detection, and strain based design requirements.
Design & Construction Needs • Methods for predicting loads, particularly for large scale movement • Limit state design methods applicable to ground movement & environmentally imposed loads	• Comprehensive program to address all associated issues. • Improved predictive tools for loading under large scale movement and adverse environmental condition.
Welding development lags materials development. Numerous opportunities for improved productivity, performance, and cost efficiency.	Use NIST/OPS Welding Workshop, planned for later in 2005, to clearly identify gaps, required actions, and research needs.
Coatings • Short term test methods to predict long term performance – wear, penetration, coating/soil interactions. • Understand requirements under adverse conditions.	Use NIST/OPS Coatings Workshop, planned for June 2005, to clearly identify gaps, required actions, and research needs.

2.0 MAJOR TECHNOLOGY GAPS, OPPORTUNITIES, AND RECOMMENDED ACTIONS

2.1 Design, Construction and Operation of Pipelines – Reliability and Structural Integrity

Problem – There has been a considerable amount of work undertaken by PRCI, OPS, and others in the development of analytical models and predictive methods to support reliability based design analysis (RBDA). While these efforts have produced some useful tools to address specific issues, they represent a rather fragmented approach to a broad problem.

Many limit state methodologies are not sufficiently developed in the context of RBDA. Specifically, work is required to more clearly predict both demand (i.e. ground movement and environmentally imposed loads) and pipeline capacity (i.e. limit state response). Further, there is insufficient material and site property data to support application of these tools.

Recommended Actions – A comprehensive program is needed to address all of the issues associated with RBDA. Individual projects within such a program must be coordinated to ensure that individual efforts can be leveraged effectively for the overall program objectives. Further, they should make full use of and build on the existing knowledge base.

Specific needs are summarized below that may be addressed as individual projects or in the context of the broader program:

1) Develop reliable methods to collect and use site data (i.e. materials properties, site properties, and their interactions) to support both current and future probabilistic design methods and limit state design tools. This may require development of more reliable measurement systems.
2) Develop improved engineering procedures to reduce the need for overly conservative simplifications in ensuring the structural integrity of buried pipelines subjected to large scale geological hazards. These procedures must establish guidance for potential remedial action and for prioritizing maintenance operations. Two parallel approaches are recommended with a global standard as the ultimate objective.
   - Implement the recommendations from the BP Conference on geological hazards held in London 2004 as a common process for mitigating the effects of geological hazards.
   - Improve procedures for evaluating the effects of significant ground movement on structural integrity of buried pipelines, with and without corrosion defects, using reliable engineering data as an interim step in the development of analytical procedures.
3) Develop predictive tools for landslides and other large displacements that
   - Identify high risk regions
   - Estimate risk of pipeline failure
   - Preclude extended damage to pipeline operation
4) Develop design and engineering tools to assess atypical loading conditions (e.g. heavy construction equipment and blast loadings from construction activities near existing pipeline installations). The objective is to replace costly full scale geotechnical tests. As a minimum, tools should address
   - shallow buried pipe,
   - influence of heavy equipment & blasting, and
   - database of physical test results including scaling factors.

2.2 Strain Based Design and High Strength Steels

Problem: Improvement and standardization of strain-based design methodologies are needed for both onshore and offshore applications. At present, the pipeline industry does not have a comprehensive set of design tools for strain based design. The problem is compounded by the increasing interest in high strength steels, where limited experimental data is available.

The successful implementation of high strength steels in the pipeline industry is dependent upon standardization of reliable strain-based design methodologies. Efforts are underway in developing numerical models to predict pipeline response to tensile loads. Limited experimental tests are under way to validate these numerical models. However, full scale experimental tests are needed to validate the numerical models for wider ranges of materials and D/t combinations.

Current efforts are fragmented and suffer from a general lack of relevant materials properties data, particularly for the higher strength steels (e.g. X80 and higher) where material performance, manufacturability and fabricability are not well-documented.

Recommended Actions: A comprehensive program is needed to address all of the issues associated with strain based design. Individual projects within such a program must be coordinated to ensure that individual efforts can be leveraged effectively for the overall program objectives. Further, they should make full use of and build on the existing knowledge base.

The overall program objective is to develop and standardize improved strain based design methodologies. This includes development of the necessary supporting data and specifications in consideration of available inspection methods, construction methods and the limitations of material performance (i.e. both pipe materials and weld metals) in the high strength regimes. Specific needs are summarized below that may be addressed as individual projects or in the context of the broader program:

1) Design Methodologies
   - Develop and standardize comprehensive design methodologies that build on existing research and utilize the results from large and small scale performance tests for validation. These should provide flexibility for accommodating variations in material properties and flaw size.
2) Materials Performance and Defect Assessment
   - Develop, validate and standardize small scale testing methodologies and sampling procedures for reporting the material properties needed for strain based designs (e.g. full stress-strain behavior, toughness transition data, welds, heat affected zones, directional pipe properties, etc.)
   - Consolidate active work on large scale performance and numerical methods and identify the gaps to determine where additional work is needed to validate design approaches.
   - Establish suitable field inspection tools for higher probability of flaw detection and reliable size determination. Implementation of existing automatic ultrasonic test methods has issues with detection, precision, and accuracy need to be resolved for. Establish consortium of stakeholders (e.g. AUT contractors and operators) and rewrite ASTM standard guideline for integration of allied AUT technologies (e.g. sectorial scan with phased array).
   - Optimize welding processes to improve productivity and reduce flaw size for strain based design. This includes welding consumable & process development for high strength pipe with equipment appropriate for environmental conditions in the field. This is contingent upon reasonable estimates for the trade-off between flaw acceptance and toughness for each strength range of interest.
     Anticipating a high level of automation or mechanization will be needed, this effort must also include welder training for reliable implementation.

2.3 Materials Properties and Performance

Improvements in materials properties performance and characterization are needed in a number of discrete areas that are not part of the larger programs already presented. Each of the following issues can be handled easily by an individual project with a clear definition.

2.3.1 Corrosion/Pitting

Problem: There is a need for improved methods for corrosion rate predictions. This applies to both pit growth and general corrosion. Industry standards should be developed for these improved methods. Further, these methods should provide a basis for industry standard practices in dealing for remediation.

Recommended Actions: Supplement the ongoing NIST study which surveyed historical data and materials to include the following, as a minimum.

- Obtain samples of contemporary pipeline steels for evaluation.
- Obtain current data on pit chemistry and environment
- Expand the study to consider the full range of environmental effects (e.g. aeration, conductivity, soil chemistry, electrical potential or degree of cathodic protection, inhomogeneity of materials, etc.)
- Correlate results with anecdotal evidence from industrial experience.

2.3.2 Materials Database for Existing Pipelines

Problem: There is a need for in situ measurements and/or materials database for existing pipeline materials to support analytical methods for predicting pipeline performance. Recent advances in web based applications make this a more viable project today than when it was first proposed several years ago.

Recommended Actions: Consolidate the available information from agencies and industry. The potential difficulty is in establishing the reliability of the data.

2.3.3 Dents

Problem: Predictive models for the influence of dents on operating pipelines need to be expanded to include dents in the girth welds.

Recommended Action: Extend existing analytical models to pipes with girth welds. Validate with field experience.

2.3.4 Offshore Materials

Problem: Properties as they relate to the structural integrity of pipe are sparse. This includes mechanical properties as well as corrosion behavior of materials with and without the use of corrosion inhibiting methods. MMS studies are ongoing, but more research is needed than the current funding levels support.

Recommended Action: A greater level of co-funding from industry and other funding agencies is one avenue to accelerate the program.

2.3.5 Welding

Problem: Welding is often the pace-limiting process in pipeline installation. Significant opportunities exist for improvements in productivity and performance to enable the move to new materials. Unfortunately, innovation in welding process and materials development lags pipeline industry needs. New materials development rarely involves welding process and materials development early enough, if at all, to be effective.

Particular challenges exist with welding of in-service pipelines, LNG/CNG, hydrogen transport, and high strength steels, which require innovative approaches for refinement of existing welding processes and adaptation of new welding processes (e.g. magnetically induced arc butt (MIAB) welding).

Recommended Action: For the future, projects that introduce new pipeline steels to the industry must be required to include development of fabrication and joining technologies to support implementation. For the present, the discussion of welding issues must be elevated to identify the major gaps and opportunities. Specific issues include:

- Identify factors critical to successful joining of high strength steels. Consideration must be given to tie-ins, double joints, and repairs (sleeves and hot taps) as well as main line construction.
- Develop processes and techniques that demonstration sufficient reliability and can be practically implemented. This requires consideration of the tradeoffs possible among allowable defect size, level of toughness, and degree of strength overmatch needed. Consideration must also be given to the type of equipment appropriate for use on right-of-way.
- Develop predictive tools for base metal and weld metal response when welding on in service pipelines

The NIST/OPS welding workshop planned for later this year will offer a forum for constructive discussion of the needs in this area.

2.3.6 Strain Aging

Problem: Thermal cycling during the life of a pipeline can result in a change in material performance due to strain aging (e.g. preheat, post heat, coatings). This has potential impact on the performance of pipelines, particularly under strain based loading, where welds are intended to overmatch the pipe strength and buckling resistance can be reduced by the new shape (Luders strain) of the stress strain curve. The relevance of wide plate test results that are conducted typically without deliberate strain aging may need to be reassessed in some instances.

Recommended Action: Characterize the strain aging behavior of pipe materials due to the thermal effects of the coating application, installation, and service of pipelines. Coordinate this work with the various pipe manufacturers.

2.3.7 Fatigue

Problem: Fatigue continues to be an issue where storage conditions result in cyclic loading. Codes and standards need updating to reflect the available offshore data. This issue is also relevant for onshore applications when the pipe is used for storage.

Recommended Action: Consolidate the available data for inclusion in API 1110. Gaining access to the data is expected to be a challenge because much of it is project driven and not easily accessible.

2.3.8 Industry Wide Database

Problem: There is a general impression that the pipeline industry expends considerable resources relearning the same lessons again and again. A central repository for data and experiences could short cut the learning curve in many cases. The idea is similar to the NIST corrosion database.

Recommended Action: A project could be funded with independent contractors where information is provided anonymously and used by the agency and industry as a whole. The Initial step should be a feasibility study to determine suitable format, access, accuracy, reconciliation of discrepancies, etc. The database should be reviewed and validated by competent and independent contractors periodically to ensure it's the reliability and accuracy.

2.3.9 Corrosion and Stress Corrosion Cracking

Problem: There is an industry wide need for improvements in corrosion rate predictions. This applies to general corrosion, stress corrosion cracking (SCC), and pitting.

Recommended Actions: Existing NIST and CANMET programs provide a solid foundation for continued effort in this area. Specific recommendations are summarized as follows:

1) Develop improved models for general corrosion rates and SCC initiation & growth rates based on NIST and CANMET data.
2) Supplement the ongoing NIST study for general corrosion and pit growth. This should include
   - Contemporary pipeline steels to augment the historical database
   - Expand the study to consider the full range of effects encountered in pipeline applications (e.g. aeration, conductivity, soil chemistry, electrical potential or degree of cathodic protection, inhomogeneity of materials, etc.)
   - Collect anecdotal evidence from industrial experience to enhance credibility of historical data analysis.

2.3.10 Coatings

Problem: The industry relies almost exclusively on coating systems for corrosion protection of pipelines. Ongoing improvement of coating systems and measurement methods is an essential part of ensuring pipeline integrity. New developments need to balance a wide range of constraints in addition to effectiveness for corrosion protection. These include cost, ease of application, survivability under field conditions, interactions of the coating and/or application methods with pipe steels and welds, etc. Recent evidence suggests that the thermal treatment used in the application of existing coating systems is responsible for strain aging in steel substrates. This unforeseen change in strength and ductility potentially is a concern for certain pipeline designs where strain based loading may occur.

Further, there is a need for more effective short term testing methods to predict long term performance under field conditions. More reliable short term measurement systems will facilitate the development of new coating systems.

Recommended Actions: A series of research programs is needed to address the gaps in the knowledge base. The workshop planned for later this year should be used as a forum to develop specific project proposals. Two specific issues that need immediate attention are:

3) development of improved short term testing methods for pipeline coating systems that more reliably predict long term performance for wear & penetration, coating and soil interactions, etc.
4) low temperature coating processes to avoid thermal affects on pipe steels and welds, which should be coordinated with pipe manufacturers.

2.4 Right of Way Management

The following two areas require technology development. Issues surrounding third party damage and encroachment detection are a bit more complicated and require a comprehensive program for maximum benefit. Extension of existing technologies in other areas to horizontal directional drilling is more appropriately managed as a discrete project.

2.4.1 Third Party Damage & Encroachment

Problem: The major issues associated with right of way management involve third party damage and detection of encroachment. Gas transmission pipelines are sometimes damaged by construction equipment or encroaching vehicles not owned by the pipeline company. The resulting third-party damage is the major cause of damage to natural gas transmission pipelines. DOT reports that from 1994 to 2004, approximately 32% of all hazardous accidents involving onshore transmission pipelines were caused by third-party damage. The consequences were 9 deaths, 38 injuries, and costs totaling $91 million, or an average of $360,000 per incident. New technologies for automated and real-time monitoring of pipeline right-of-ways are needed to assure the long-term integrity, safety and security of the nation's natural gas pipeline network.

Recommended Actions:

1) Conduct a comprehensive review of the available technologies for detection of third party damage and encroachment. The objective is to identify the most promising approaches for pipeline applications. This initial effort should provide a clear and logical path forward for subsequent research activities. The focus should be on technologies already developed or under consideration by other industry sectors in order to coordinate development efforts. For example, heavy construction companies are moving toward more accurate systems which could be coordinated with right of way management.
2) Establish the feasibility of existing sensor technology for acoustic signatures and embedding sensors into smart systems for detection of third party damage. Sensors and acoustic signature must be further developed and evaluated to assess their monitoring capability with respect to pipeline encroachment.

2.4.2 Standard Practices

Problem: Industry wide and regulatory acceptance of right of way management plans is critical to establishing standard practices and guidelines.

Recommended Action: Regulatory acceptance of a standard practice is the essential first step. The optimum solution will require full engagement of a cross functional team that includes regulators at multiple levels and pipeline owners/operators. The objective is to demonstrate the feasibility of and gain acceptance for methods of right of way management that include

- real time and reliable detection of third party damage,
- viability of available technologies,
- critical safety, and
- economics.

2.4.3 Horizontal Directional Drilling

Problem: Down hole drilling techniques and the availability of better geophysical data can be used to extend the capabilities and reliability of horizontal directional drilling.

Recommended Action: Improve engineering methodologies for extended reach and horizontal directional drilling.

2.5 Environmental Management

The major environmental issue requiring technology development is the need for alternatives to hydrostatic testing of pipelines. The remaining administrative issues require more effective application of technology and technical information.

2.5.1 Alternatives to Hydrostatic Test

Problem: The environmental impact of hydrostatic test operations is a continuing point of discussion both in terms of where the water comes from and disposal of the water after test completion. Further, there is a growing speculation in the technical value of the test (e.g. defect growth that would not occur during normal operation).

Recommended Action: Review the results of current studies (e.g. OPS & MMS) to determine future focus. Consider the merits of hydrostatic testing both in terms of environmental impact and technical value of the data generated.

2.5.2 Standardized Management Plans

Problem: Environmental concerns over right of way maintenance and delays in permitting for new construction are ongoing issues for the pipeline industry. Industry standards are needed in order to mitigate the constraints associated with these issues.

Recommended Action: Establish industry wide guidelines and recommended practices for environmental management that include consideration of the following:

- Standardized design methodologies,
- Simplified information exchange,
- Disposition of hydrostatic test waters,
- Habitat fragmentation,
- Vegetation management, and
- Integration.

2.5.3 Forum for Continuous Improvement

Problem: Successful environmental management relies on continuing factual discussion of the impacts of oil and gas operations. Also, there is a sense that technologies employed in other industries may also be applicable to pipeline operations. A constructive forum does not yet exist for continuous improvement in this area.

Recommended Action: The recent reorganization of PHMSA may provide a forum for the needed discussion going forward. No other recommendations were made.

2.6 Adverse Environments and Unique Conditions

Pipeline construction and operation in adverse environments continues to present unique challenges to the industry. Arctic and offshore environments are of particular interest. There is also speculation that some in-service inspection methods may promote certain types of crack growth.

2.6.1 Arctic Environments

Problem: The influence of terrain on pipeline construction and maintenance in Arctic and Sub-Arctic regions is not well understood with regard to all of the possible loading conditions due to thermal effects. Numerical and engineering models are needed that address the specific conditions in the arctic environment.

Recommended Action: Develop design, construction and integrity analysis tools that consider

- Axial loading due to thermal effects,
- Freeze-thaw cycles of permafrost induced transverse cyclic bending, and
- Resources and information for arctic regions outside North America (e.g. Russia).

2.6.2 Hurricanes

Problem: As recent events in the Gulf of Mexico have proven, hurricanes can have a major impact on performance and operation of offshore pipelines. There is research opportunity for design tools as well as response prediction. Ongoing improvement of response time to breaks, design & operation guidelines, and cost effective methods for upgrading older installations is needed.

Recommended Action: MMS studies are ongoing, but more research is needed than the current funding levels support. Greater co-funding from users and other agencies is one avenue. It is expected that improved tools for predicting response under adverse conditions could result from the data available on recent disasters. An opportunity also exists for improved sensing and monitoring (e.g. satellites, etc.). DOE has an initiative in this area, but funding levels may not be sufficient to achieve the needed results.

2.6.3 In-Service Inspection

Problem: There is concern about the influence of magnetic fields induced with existing pigging methods on hydrogen assisted cracking. Improved methods for hydrogen monitoring, particularly for high strength steel applications, is needed.

Recommended Action: MMS studies are ongoing, but more research is needed than the current funding levels support. Greater co-funding from users and other agencies is one avenue.

2.7 Offshore

2.7.1 Environmental Influences

Problem: The impact of environmental conditions on oil and gas operations is not well documented or understood. Note that this is not a study of adverse environments, but rather a consideration of more transient environmental conditions (e.g. remote location response/repair, deep water design challenges, vessel/equipment availability, transportation, etc.).

Recommended Action: MMS studies are ongoing, but more research is needed than current funding levels support. Greater co-funding from users and other agencies may be a viable alternative to accelerate the work in this area.

2.7.2 Reeling

Problem: One of the unknowns associated with reeled pipe is the true accumulated strain and how it changes from the inside to the outside of the reel. Understanding this is the first step to understanding the fatigue life of reeled pipe. It is believed accumulated strain does not have a dramatic effect on fatigue performance, but to date this is only an assumption.

Recommended Action: Assess the effects of reeling on long term pipe performance. Develop predictive tools and simulation methods for accumulated strain and fatigue in reeling operations. This work should build on EPRG's active program on reeling.

2.8 Codes and Standards

Problem: Existing codes and standards are not up to date with the state of technology in the industry - design criteria, inspection, etc. There are two fundamental reasons:

- regulatory adoption of relevant codes and standards is inconsistent, and
- there is no industry "pull" because of the high level of frustration regarding the time and effort involved in driving new technology through the consensus standards process.

Without regulatory requirements to use industry standards, large companies put their efforts into independent, often project specific, documents. This situation accelerates the decline of industry wide codes and standards that are needed to:

- establish workmanship guidelines and facilitate welder training,
- facilitate materials and welding process development, and
- enable material and procedure qualification efforts throughout the industry.

Recommended Actions: There are several actions recommended to facilitate the improvement in industry wide codes and standards on multiple levels.

1) Fund a comprehensive review of existing standards for gaps and opportunities. The desired outcome of this review is an action plan for incorporating research results into codes and standards. This review must be conducted by a cross-functional team representing regulatory agencies, code bodies, and industry to set minimum targets and communicate the gaps to the relevant industry committees and code bodies. Funding organizations should require:
   - involvement of standards organizations up front in the development process,
   - better coordination between regulatory programs and research programs, and
   - involvement of all stakeholders in projects and processes.

   Given the industry's reluctance to participate in standards committee activities, alternative funding mechanism from government agencies that does not require industry co-funding may be necessary to jump start the standards making process.
2) Funding organizations can use the project approval process to motivate industry involved in research to engage with code committees.
3) Increase regulatory participation in the standardization process. DOT must be more proactive in code activities. If the codes are used as part of the regulatory requirements, DOT needs to be engaged and encourage their contractors to be engaged.
   It is suggested that DOT designate and fund EPC (engineering, procurement, construction) contractors to represent the agency in the code writing process.

2.9 Commercialization

Problem: There is a general need for a higher level of successful technology transfer and commercialization from the R&D efforts in the pipeline industry. This applies both to totally new technology as well as technology improvements. New technologies are slow to find their way into commercially available products and services. This is in part due to the fact that the primary R&D project deliverable is a research report rather than a practical deployment. Further, commercialization and standardization are logical partners, since the successful deployment of a new product, process or service can be hindered by antiquated standards.

Recommended Actions: The first step in correcting this situation is simply to change the expectations for R&D outcomes. This can be done in a number of ways:

1) The project proposal solicitation process should include a requirement for a commercialization plan that is monitored by the funding agencies on some level. Procedures implemented by other agencies could be used as models for process improvement.

- The National Science Foundation (NSF) follows the project commercialization plans for 4-5 years after project completion. Further, NSF uses an applicant's commercialization history to make decisions about future funding.
- MMS estimates that 80% of their R&D projects achieve successful commercialization. This level of success is attributed to the fact that they target more development than basic research and require a clearly defined set of deliverables at the outset of the projects.

2) For projects focused on support for existing infrastructure, project proposals should address the possible benefits of any new technology developed to existing installations. If applicable, commercialization plans could be included that address the specific needs of existing pipelines.

2.10 Resource Management

Problem: As available funding for technology development in the pipeline industry becomes tight, it is more important than ever to leverage the capabilities of all stakeholders in the process. This is a difficult task with pipeline technology projects being conducted by so many different organizations. At present, the project proposal review process does not consider work undertaken by all industry stakeholders when making funding decisions.

Further, effective R&D relies on collaboration among multiple stakeholders (e.g. pipeline companies & their suppliers, applied research organizations, universities and national labs). Industry participation traditionally has been limited by the difficulties in navigating the cultural and bureaucratic challenges in the various government funding and reporting processes.

Sharing of technology among the agencies could shortcut the R&D process for pipelines on many levels (e.g. strain based design approaches, materials characterization, inspection methods, etc.) Unfortunately, the connections among government agencies are weak. OPS and MMS do well; the link to DOE is developing; and the link to DOD is practically nonexistent.

If significant improvements are not made in this area, the risks are that multiple projects will be funded for essentially the same work, that the best resources will not be engaged in the projects, and that the results will not be commercialized effectively.

Recommended Actions: Project evaluation and management processes can be altered to provide incentive for the level of collaboration needed among stakeholders. This can be accomplished in a number of ways:

1) Strengthen the peer review process that is necessary at the outset of all projects. Greater effort is needed to involve the right people in the process to avoid funding work that is already in process.
2) Encourage projects that include collaborative effort at the appropriate levels in project solicitation, review and execution.
3) Ensure that industry partners have advocates in the government funding and reporting processes. Industry consortia like PRCI and INGAA are in a unique position to fill this role in order to relieve the administrative burden on industrial partners.

The technical track participants were unable to make a recommendation for better leveraging the various government agencies. It is not clear how to incent the various organizations within the government to communicate and share technology with the pipeline industry. It was suggested that OPS could provide a catalyst for the needed cross-fertilization. Further, organizations like PRCI could elevate political awareness in the industry for the purpose of influencing budget allocations and joint agency projects.

2.11 Human Factors

2.11.1 "Brain Drain"

Problem: The pipeline industry is experiencing "brain drain". Recruiting high level talent into the industry at both operational and professional levels has become very difficult. The work force is aging without a supply of new talent to replace it. All industry partners participating in the technology track report difficulties filling the HR "pipeline" with high level engineering graduates and operations personnel. There is an urgent need to elevate awareness in both the public sector and academia regarding the needs and opportunities in the pipeline industry.

Recommended Actions: Traditionally, this is a role filled by professional, technical, and trade organizations in partnership with industry. It requires a collaborative effort by the industry as a whole. The recommended approach is to educate the educators and facilitate outreach efforts.

1) Encourage and fund research projects that provide effective collaboration among the pipeline industry, research institutes, and universities.
2) The existing programs at the university level need active industry participation if they are to be effective (e.g. CSM, Penn State and Tulane). The recently formed Pipeline Engineering Center at University of Calgary is in need of "care and feeding" if it is to establish itself as a center for engineering education and research.
3) Tulane University serves as a model for an effective outreach program.
4) Push the same approaches down the education pipeline to the community college and trade school levels.

2.11.2 Public Awareness

Problem: A greater acceptance of energy policies and streamlining of the permitting process is needed. This requires influence of regulatory requirements at the regional and local levels, which starts with public awareness of energy issues, in general, and pipeline issues, in particular. One specific issue relates to building setbacks driven by special interest groups without technical foundation.

Recommended Actions: Traditionally, this is a role filled by professional, technical, and trade organizations in partnership with industry. It requires a collaborative effort by the industry as a whole and can be influenced by regulatory agencies. Ongoing programs are needed to improve public awareness of catastrophic events, energy policies, supply vs. demand, location of supply vs. location of demand, relative costs, the role of regulatory agencies, etc.

List of Appendices

Additional information that was not specifically discussed during this technical track is included in Appendices 11 and 12.

Government Industry R&D Forum
22-24 March 2005

Design, Construction, Materials & Welding Technology Track

Facilitators

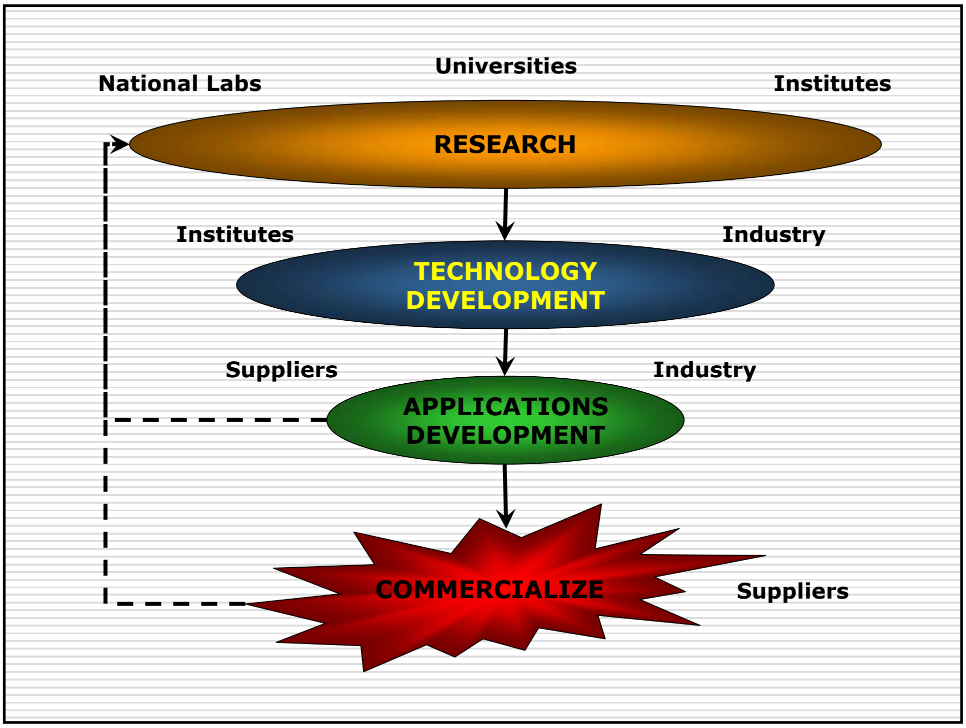
Marie Quintana, Lincoln Electric

Ashish Bhandari, General Electric

Objectives

Technology needs for design, construction, materials & welding in the pipeline industry

- Gaps & challenges
- Barriers
- Actions
  - Short term
  - Long term
- Priorities



Format

- Present topic, top five, open discussion, targets
- Technology
  - Design & Construction
    - PRCI DCO (Gailing)
    - USDOI Offshore Perspective (Else)
    - DOT OPS Initiatives (Merritt)
  - Materials & Welding (Horsley)
- Implementation (Wang)
- Administration (Quintana, Kratzenberg)

Schedule – 23 March 2005

8:30	Objectives & Format
8:45	PRCI DCO Committee
9:00	DOI Offshore Perspective
9:20	Group Discussion
10:40	DOT OPS Initiatives
11:00	Group Discussion
12:00	Lunch
1:30	Materials & Welding
2:00	Group Discussion
3:00	Break
3:15	Implementation
3:30	Group Discussion
4:10	Administration
4:30	Group Discussion

Schedule – 24 March 2005

8:00	Wrap-Up
	Review results from Day 1
	Identify actions
	Identify priorities
9:45	Summarize Report out

Government Industry R&D Forum
22-24 March 2005

Pipeline Design & Construction

Near Term Focus

Future Gaps & Opportunities

DC&O Mission Statement

Develop safe, environmentally responsible, cost-effective and reliable solutions for the design, construction, and operation of energy pipelines

DC&O Key Emphasis Areas

- Offshore
- Onshore and Arctic
- Damage Prevention and Protection
- Reliability Based Design and Prevention
- Integrity Practice Standardization

Technical Programs (2001 – 2004)

1.	Prevention of Third Party Damage	$1,305k
2.	Implementing Integrity Standards	$3,060k
3.	Reliability-Based Design Alternatives	$918k
4.	Determination of Max. Safe Surface Loads	$994k
5.	Leak Detection and Notification	$350k
6.	Prevention of Critical Pipeline Strains	$1,363k
7.	Solutions for Adverse Crossings	$245k
		$8,235k

Future Needs

- Geological events
- Adverse environments
- Environmental impacts
- Reliable operations

Geological Events

Fault creep, landslides, settlement, earthquakes

- Traditional approach is excessive conservatism
- Reduce cost associated with overly conservative designs and maintenance protocols
- Need engineering procedures, methods and models to mitigate effect of pipe-soil interactions
  - Ground movement
  - Stresses as pipe-soil couple responds to displacement
  - Support and loading configurations
  - Material properties
  - Corrosion

Geological Events

- Continuity of service
- Mitigate life and property threatening incidents
  - Landslides & other large displacements
  - Need methodologies and tools to
    - Identify high risk regions
    - Estimate risk of pipeline failure
    - Preclude extended damage to pipeline operation

Adverse Environments

- Reliable Design, Construction and Operation
  - Arctic & Sub-Arctic Regions
    Need better understanding of terrain influence on pipeline construction & maintenance
  - Need numerical & engineering models
    - Design, construction & integrity analysis
      - Axial loading due to thermal effects
      - Freeze-thaw cycles of permafrost induce transverse cyclic bending
    - More aggressive environmental protection standards
      - Maintenance of rights of way

Environmental Impact

- Mitigate delays in permitting for new construction
- Mitigate environmental concerns over right of way maintenance
- Need for standardized design methodologies, simplified information exchange and recommended practices
  - Disposition of hydrotest waters
  - Habitat fragmentation
  - Vegetation management
  - Integration

Reliable Operation

- Third Party Damage
  - 32% of all hazardous accidents were direct result of third party damage
    - 9 deaths, 38 injuries, USD 91M
  - Need to demonstrate feasibility of and gain acceptance for feasible methods of right of way management
    - Real time reliable detection
    - Viability of available technologies
    - Critical safety
    - Economics
  - Need to commercialize viable options

Reliable Operation

- Safe Loads For Buried Pipelines
  - Need design and engineering tools to assess atypical loading conditions
  - Need validated method to replace costly full scale geotechnical tests
    - Shallow buried pipe
    - Heavy equipment & blasting
    - Database of physical test results including scaling factors

Future Needs

- Four major categories
  - Geological events
  - Adverse environments
  - Environmental impacts
  - Reliable operations

2005 Pipeline R&D Forum

Offshore Oil & Gas

Mik Else
Minerals Management Service

March 23, 2005

OCS Pipeline Design
CHALLENGES

- **Deepwater**
  - *Technology Limits*
  - *HTHP*
- **Construction**
  - *Structural Integrity*
  - *Remote Locations*
- **Environment**
  - *Operations*
  - *Repairs*
- **Aging Infrastructure**
  - *Erosion/Corrosion*
  - *Repair & Abandonment*
- **Safety**
  - *Training*
  - *Operational Hazards*
- **Hurricanes**
  - *Mudslides*
  - *Weighted Aftermath*

Pipeline & Riser Design

Strain-Based Design

Project Number	434
Date of Summary	February 4, 2005
Research Title	Strain-Based Design of Pipelines
Contractor	Edison Welding Institute
Principal Investigator	William Mohr
Contracting Agency	Minerals Management Service
Estimated Completion	May 31, 2006
Description	The majority of pipeline design codes are based on stress-based design methods. Although conventional stress-based design covers most pipeline applications, it does not cover the design of pipelines that may experience high strains like those of the deepwater GOM and Arctic regions. Similarly, high strains can occur to most any offshore pipeline due to ground movement, unsupported spanning, and seismic loading therefore an exacting site-specific analysis including loading conditions and material mechanical properties is needed to maintain the acceptable level of pipeline safety needed. This research project investigates how the use of strain-based design of pipelines can better assure safe and pollution free operations.
Progress	Phase I was completed in 2003 and developed a best practice Guidance Document on Strain Based Design of pipelines to cover design, assessment, and testing guidelines for designers of pipelines that may experience high strains in service. See AA (Final Report) to view the Final Report and Guidance Document. Phase II is scheduled to begin in the Spring of 2005 and will refine the Guidance Document by providing further analysis and guidance in the areas of pipeline material specifications, welding specifications, and engineering critical assessment. A meeting for Phase II was held on July 28, 2004, to discuss the continued scope and direction of the project. Based on that review meeting, the Phase II scope of work was revised to make the project tasks more explicit, while following the technical recommendations of the review meeting, by placing emphasis on determining local stress-strain curves, providing material and welding guidance for strain based design, and developing realistic choices in finite element models to check the effects of combinations of soft regions, internal pressure, and axial strain. Collaboration will also be established with Engineering Mechanics Corporation (Emc2) of Columbus to assess the effects of both softened HAZs and internal pressure on fracture resistance for high-strain applications. Emc2 is conducting a parallel project on fracture assessment of pipe girth welds. A meeting is planned for the Summer of 2005 to discuss the technical progress on the first year of Phase II and to give participants the opportunity to provide additional guidance for the second year of the project.

Design of Cathodic Protection

Project Number	496
Date of Summary	February 8, 2005
Research Title	Design of Cathodic Protection Systems for Deep Water Compliant Petroleum Production Risers
Contractor	Florida Atlantic University
Principal Investigator	Dr. William Hartt
Contracting Agency	Minerals Management Service
Estimated Completion	April 30, 2005

Description

Develop a cathodic protection design protocol for deep water petroleum production compliant rises. Results should provide for an Interactive software package on anode/pipeline design, final report and a presentation to industry on software demonstration and project results.

Progress

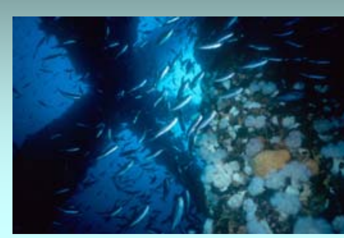
Conceptual models have been developed that are based upon a zero resistance source at one end of a riser and a non-zero resistance source at the other. The former (zero resistance source) is represented by any structure with a large number of distributed anodes, such as a production jacket, tension leg platform, or FPSO.

Four different catenary riser configurations are being considered, as listed below:

1. Riser with no suspension anodes terminating at an electrically isolated surface structure at one end and at a non-zero resistance source at the other.
2. Riser with no suspension anodes terminating at a surface structure to which it is electrically connected at one end and at a non-zero resistance source at the other.
3. Riser with one suspension anode or anode cluster terminating at an electrically isolated surface structure at one end and at a non-zero resistance source at the other.
4. Riser with one suspension anode or anode group terminating at a surface structure to which it is electrically connected at one end and at a non-zero resistance source at the other.

The critical task in cp design is to assure that potential nowhere along the riser becomes positive to the protection potential (-0.80 Vag/AgCl) during the design life. Proposed Design Procedure Options that are being evaluated for configuring the cp design protocol include 1) the equations of Morgan and Uhlig, 2) Gibson's equation, 3) the Slope parameter equations, and 4) the Inclusive Equation.

Integrity of Risers



Project Number	497
Date of Summary	February 8, 2005
Research Title	Probabilistic Reliability and Integrity Assessment of Large-Diameter Compliant Risers for Ultra-Deepwater Operations
Contractor	INTEC Engineering Partnership, Ltd.
Principal Investigator	Phase I - Dr. Sandeep Jesudasen, Phase II - Dr. Jie Fang
Contracting Agency	Minerals Management Service
Estimated Completion	April 14, 2006

Description

The objectives of this two phase study include the development of a methodology for assessment of the reliability and integrity of large-diameter SCRs for ultra-deepwater applications. Effects of fatigue, corrosion, and wear associated with terminations at the platform or at sea floor touch-down will be studied. Methods of accounting for uncertainties in structural, material, and environmental parameters will also be investigated. The outcome of the study will be database of international SCR in use and a report/guidance document that details the methodology for assessing the reliability and integrity of SCRs as developed through the following five topics.

1. SCR hang-off strategies and hull riser tie-in;
2. Effect of flexible joint aging on weld fatigue at hang off;
3. Improved stress recovery for VIV analysis;
4. Wave loading fatigue and coupled vessel/mooring/riser analysis; and
5. Soil pipe interaction and effect on SCR fatigue and extreme response.

Progress

Phase I consists primarily of the development of the SCR database with secondary efforts on the design analysis and guidance document, to be developed in Phase II. The database structure has been developed and the researcher is now soliciting data from Industry to populate the database. The database is designed to allow for both proprietary and non-proprietary management of data to serve public information requests.

SCR Seafloor Interaction

Project Number	510
Date of Summary	February 8, 2005
Research Title	Seafloor Interaction with Steel Catenary Risers
Contractor	Offshore Technology Research Center
Principal Investigator	Aubeny, Biscontine and Murff
Contracting Agency	Minerals Management Service
Estimated Completion	May 2006

Description

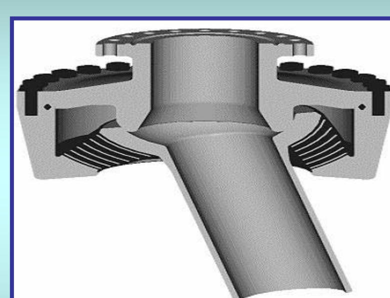
Project will develop a realistic model of seafloor stiffness boundary condition in the touchdown area that can be used with existing finite element design codes to assess the fatigue of a Steel Catenary Riser (SCR) at the touchdown point. Goals of this project will be:

- Improve the current state of understanding and descriptions of the basic mechanisms affecting the seafloor stiffness at the SCR touchdown point;
- Incorporate this knowledge in an improved method and analytical model to more realistically and completely describe seafloor stiffness and its variation over the life of the SCR; and
- Provide a framework to extrapolate laboratory and field observations and measurements to the other seafloor and SCR loading conditions.

Progress

Held KO meeting with OTRC Technical staff on September 23, 2004, including discussions of seafloor compositions and materials stiffness characteristics, SCR motion dynamics, and SCR pipe material bending characteristics.

SCR Flexjoint Design



Project Number	530
Date of Summary	February 1, 2005
Research Title	SCR Flexjoint Design and Performance
Contractor	Oil States Industries
Principal Investigator	Jim Norris
Contracting Agency	Minerals Management Service
Estimated Completion	January 2007

Description

Project will provide a complete characterization of flexjoint elastomers, visoelastic failure characterization, and stress/strain allowable definitions. The work will culminate with a fatigue assessment methodology capable of handling multiple combinations of alternating compression and shear loads.

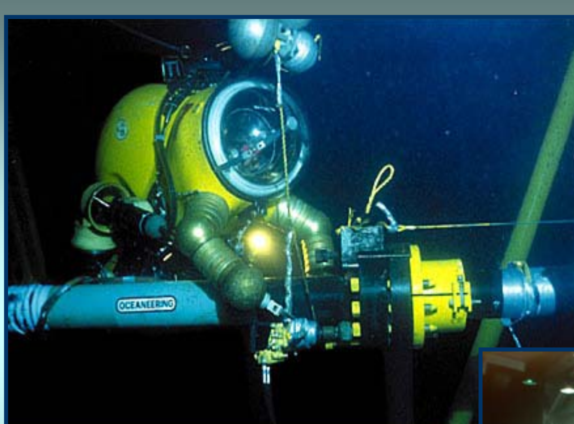
SCR Integrity Management

Project Number	531
Date of Summary	February 1, 2005
Research Title	SCR Integrity Management
Contractor	Marine Computation Services
Principal Investigator	Luiz Souza
Contracting Agency	Minerals Management Service
Estimated Completion	May 2005
Description	Project will identify emerging technologies, technology gaps, and monitoring techniques; develop SCR validations approach and integrity management methodology; and provide an industry forum for sharing of technology.

Shallow Water Repair

Underwater Wet Welding

Project Number	346
Date of Summary	February 3, 2005
Research Title	Taylor-Designed Underwater Wet Welding Process for Offshore Structures and Pipelines in the Gulf of Mexico
Contractor	Colorado School of Mines, Center for Welding, Joining and Coatings Research
Principal Investigator	Stephen Liu
Contracting Agency	Minerals Management Service
Completion	March 2006
Description	This project will lead to quality and safe operation and maintenance of offshore platforms in the Gulf of Mexico and advance the technology of underwater wet welding. Despite the significantly lower cost of wet welding, the selection of the method over other processes if limited because of limited experience with wet welding. Also there is a general lack of guidelines, recommended procedures and specifications for the qualification of underwater wet welds. This research will focus on developing solutions to material to mitigate the concerns for using wet welds on offshore oil and gas facilities.
Progress	Phase I of the project was completed in August 2004 with the final draft and appendices received in September 2004. Phase II, which began in February 2004, will use the same technology to weld three different electrode types at three separate depths ranging from 50 to 150 meters on a radial surface as opposed to the flat surface welding performed in Phase I.



Deep Water Design & Repair

DW RUPE: Pipeline Repair

Project Number	532
Date of Summary	February 1, 2005
Research Title	SDW RUPE: Deepwater Gulf of Mexico Pipelines Induced Damage Characteristics & Repair Options
Contractor	Stress Subsea, Inc.
Principal Investigator	Ray Ayers
Contracting Agency	Minerals Management Service
Estimated Completion	May 2005
Description	Project will analyze and develop pipeline repair plans and capabilities for spool piece repair and leak clamps for deepwater (1000+ ft) pipelines in he Gulf of Mexico.

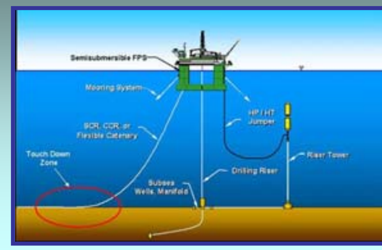
Pipeline Construction

Hydrotest Alternative

Project Number	525
Date of Summary	March 11, 2005
Research Title	Hydrotest Alternative JIP – For Deepwater Gas Export Pipelines
Contractor	Intec Engineering and Det Norske Veritas
Principal Investigator	Guillermo Hahn (Intec) and Jorn Spiten (DNV)
Contracting Agency	Minerals Management Service
Estimated Completion	May 2005
Description	To develop guidelines, conditions, and criteria required for implementations of the hydrotest alternative method for deepwater gas export pipeline systems; to illustrate the application of the alternative method by considering the representative systems; and to deliver a draft hydrotest departure “standard” to be proposed for adoption by applicable regulatory agencies.
Progress	Phase I is being managed by Intec Engineering and focuses strictly on deepwater export gas pipelines. The Phase I kick-off meeting was held in January 2005. Phase II of the JIP, if developed, will be managed by Det Norske Veritas and have a broader scope with regard to the type of pipelines, i.e., deepwater and shallow water oil and gas pipelines. The next meeting is scheduled for March 24 - 25, 2005 to discuss fundamental issues and challenges, current practices, and industry and government codes and regulations.

Materials

Touch Down Zone Solutions



Project Number	494
Date of Summary	February 7, 2005
Research Title	New Touch-Down Zone Solutions for SCRs
Contractor	Granherne - Kellogg, Brown & Root
Principal Investigator	Rajiv Aggarwal
Contracting Agency	Minerals Management Service
Estimated Completion	June 30, 2005

Description

The project will evaluate, develop, and improve project readiness of technologies for solutions for the Touch Down Zone (TDZ) region of Steel Catenary Risers (SCRs) used for deepwater development. There is often insufficient time during the system selection phase for a project team to undertake a comprehensive investigation of potential SCR performance and therefore any selection often later requires timely and costly alterations to other parts of the system in order to mitigate difficulties with the SCRs. Furthermore, design improvements during the early stages of development will lessen the chance of premature failure and any accidental discharge of oil and gas that may result. This project will help alleviate these concerns by evaluating and developing SCR system designs and therefore improve project readiness, safety and environmental protection at the TDZ region. This project will undertake two case studies with SCR applications; for a semi-submersible floating production unit in the Gulf of Mexico and for a tanker-based FPSO unit offshore West Africa during which the top two TDZ solutions will be analyzed.

Progress

This JIP was originally set for completion in November 2004, however based on the project participant's decision to increase the number of TDZ solutions from two to four, the project scope was modified and a new end date set for June 2005. The four TDZ solutions now under analysis include (1) Titanium segment, (2) Lightweight Coating (LWC), (3) Upset pipe, and (4) PDW-1 Integral Connector. A KO meeting is scheduled for April of 2005 to wrap up for the work performed under Stages I – III and as a launch meeting for Stage IV. The objective of Stage IV is to perform further analysis on the four TDZ solutions as well as perform partial and full scale laboratory testing of materials and applications.

Hydrogen Monitoring

Project Number	522
Date of Summary	September 10, 2004
Research Title	Methodologies for Measuring and Monitoring Hydrogen for Safety in Advanced High Strength Linepipe Steel Applications.
Contractor	Colorado School of Mines
Principal Investigator	Olsen and Mishra
Contracting Agency	Minerals Management Service
Estimated Completion	December 2006

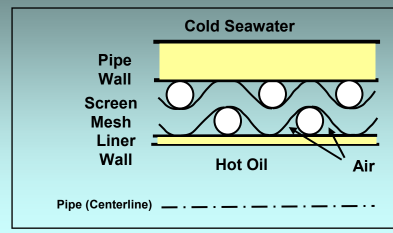
Description

Project will investigate methodologies for measuring and monitoring hydrogen for safety in advance high strength linepipe steel applications for use in offshore operations as well as onshore uses.

Progress

Based on the positive results of a MMS funded research project initiated in 2003 on the assessment of magnetism effects on hydrogen cracking for thick walled pipelines, this project was developed to continue analysis of the effects of magnetism on high density steel and develop field testing equipment. Analysis by the contractor has been initiated. A progress meeting is scheduled for June 2005.

Insulated Coaxial Pipe

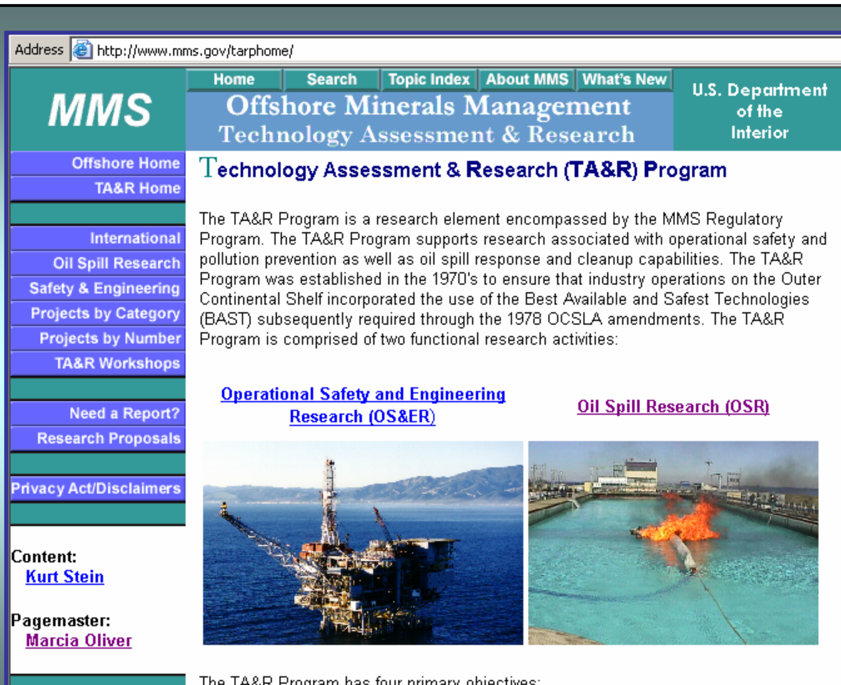


Project Number	509
Date of Summary	February 8, 2005
Research Title	Interstitially Insulated Pipe
Contractor	Offshore Technology Research Center
Principal Investigator	Marotta and Fletcher
Contracting Agency	Minerals Management Service
Estimated Completion	June 30, 2005
Description	Project will demonstrate whether an insulation system incorporating a low thermal conductivity screen mesh between a pipe and an interior liner can be an effective passive thermal insulation solution for deepwater flowlines and risers. It has been established that a thermal resistance (due to the metrology of the contacting surfaces) is created at the interface between two materials, in this case a pipe and a liner. The theory is that if the two contacting surface are separated by a screen wire or mesh at the pipe and liner interface, then a higher thermal interface resistance will result, which will significantly increase the resistance to thermal transport characteristics. The screen wire will reduce the heat transfer by restricting the path available for conduction and forms a stagnant air gap to minimize radiation and convective heat transfer. Heat transfer can be further reduced by adding a Mylar film to the exterior of the liner and the interior of the pipe.
Progress	Phase I of the experimental investigation, which consists of a test matrix where the measurement of thermal joint resistance for several size wire screens (Meshing size) and materials as a function of joint interface pressure (e.g., 10 to 500 psi) and mean interface temperature (e.g., 32oF to 175oF), is nearly complete. At present all testing for Stainless Steel wire screen have been completed with Titanium and Tungsten still to be conducted. The thermophysical properties as a function of temperature and metrology data for P110 (4140 Steel) have been measured. The results, to date, indicate that the number of contacts and wire-screen diameter, which dictates the air gap between the two surfaces; have a large influence on the measured values. The experimental data does not include the coated, reflective polymeric film, which in conjunction with the wire screen will add an additional radiation thermal barrier.

Natural Events

Hurricane-Induced Damage

Project Number	503
Date of Summary	February 8, 2005
Research Title	Evaluate and Compare Hurricane-Induced Damage to Offshore Pipelines for Hurricane Lili – Rev. A
Contractor	Stress Engineering Services, Inc.
Principal Investigator	Dr. Ayers
Contracting Agency	Minerals Management Service
Estimated Completion	March 31, 2005
Description	This project will investigate the major classes of pipeline failure that resulted to GOM OCS facilities by Hurricane Lili in the Fall of 2002. The project will have four objectives: 1) Investigate pipeline failures resulting from Hurricane Lili, including flowlines, major trunk lines and platform risers from both fixed and floating production facilities; 2) Compare and contrast these failures with those reported from Hurricane Andrew; 3) Make specific recommendations for changes in design or operations guidelines that might prevent or mitigate such failures in the future. 4) Suggest cost-effective methods for making existing pipelines designed by older guidelines less likely to fail in the future.
Progress	Preliminary findings have found that nearly 75% of the pipeline failures resulting from Hurricane Lili occurred in platform risers (similar to Hurricane Andrew) and that most of the failures occurred in smaller sized pipe (2 – 6 inch) ODs. Observations of the design data available and the degree of damage found suggests that if the pipeline riser designs were based on API 2A-WSD (for platforms), then the design wind speed is lower than that which was actually seen in either Hurricane Andrew or Lili. Further evaluation is underway however, the project has been slowed due to Hurricane Ivan hitting the Gulf of Mexico in September 2004 which caused additional damage to pipelines and facilities and has limited the time that industry representatives have to dedicate to this project.

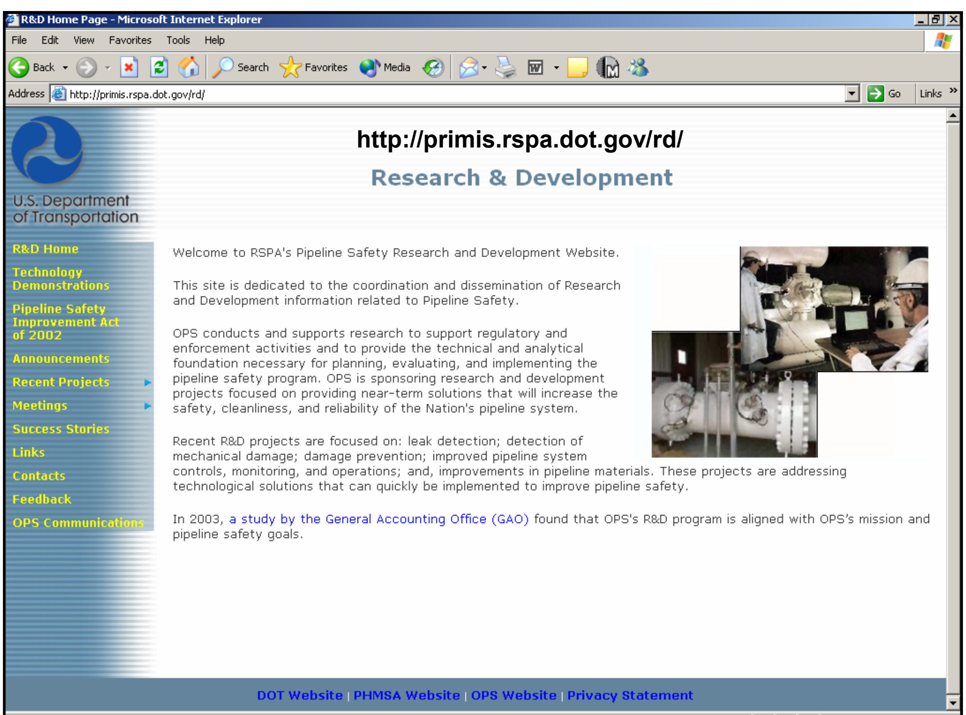


U.S. Department of Transportation

Office of Pipeline Safety Presentation on

Design-Construction Materials-Welding

Office of Pipeline Safety



Design-Construction-Materials-Welding Research

Project Title	Researcher	OPS	Co-Share	(MO)	%
Validation of Sleeve Weld Integrity and Workmanship Limit Development	BMT Fleet Technology	$45,000	$93,550	24	100
Alternate Welding Processes for In-service Welding	BMT Fleet Technology	$90,000	$265,700	24	100
High CP Potential Effects on Pipelines	CC Technologies	$80,000	$80,000	36	100
Emerging Padding and Related Pipeline Construction Practices	Battelle	$70,000	$70,000	24	85
Corrosion Assessment Criteria: Rationalizing Their Use Applied to Early vs Modern Pipelines	Battelle	$196,000	$221,000	24	73
A Comprehensive Update in the Evaluation of Pipelines Weld Defects	Engineering Mechanics Corporation	$312,309	$417,299	24	73
First Major Improvements to the Two-curve Fracture Arrest Model	Engineering Mechanics Corporation	$305,051	$263,976	24	73
An Assessment of Magnetization Effects on Hydrogen Cracking for Thick-Walled Pipelines	Colorado School of Mines	$150,000	$50,000	12	60
Fatigue Fracture and Crack Arrest in High-Strength Pipeline Steels	National Institute of Standards and Technology	$250,000		24	41
External Corrosion of Line Pipe Steels	National Institute of Standards and Technology	$250,000		24	41
Innovative Welding Processes for Small to Medium Diameter Gas Transmission Pipelines	Edison Welding Institute, Inc.	$399,989	$700,000	18	23
Strain-Based Design of Pipelines - Phase II	Edison Welding Institute	$74,881	$224,881		20
Optimizing Weld Integrity for X80 and X100 Linepipe	Edison Welding Institute	$303,956	$587,000	24	19
Evaluation of Hydrogen Cracking in Weld Metal Deposited using Cellulosic Electrodes	Edison Welding Institute	$149,968	$150,000	24	19
A New Approach to Control Running Fracture in Pipelines	Battelle	$259,855	$320,000	24	11
Integrity Management for Wrinklebends and Buckles	Battelle	$274,971	$480,000	24	11

Design-Construction-Materials-Welding Research

Portfolio Summary (16 Projects)

Total OPS Funding	$3,211,980
Total Industry Co-Funding	$3,923,406
Average Project Duration	22 months
Average % Complete	53 %

U.S. Department of Transportation

OPS R&D Projects

Project Title: Validation of Sleeve Weld Integrity and Workmanship Limit Development

Researcher: BMT Fleet Technology

Goal: The object of this project is to support current efforts towards the development of a Guidance Note for Fillet Welded Connections to pipelines.

Office of Pipeline Safety

U.S. Department of Transportation

OPS R&D Projects

Project Title: Alternate Welding Processes for In-service Welding

Researcher: BMT Fleet Technology

Goal: Project is to support efforts towards the development and application of procedures for welding on in-service pipelines using alternate welding processes.

Office of Pipeline Safety

U.S. Department of Transportation

OPS R&D Projects

Project Title: High CP Potential Effects on Pipelines

Researcher: CC Technologies Laboratories, Inc.

Goal: The objective of the proposed research is to develop a set of guidelines for operators, which would enable the users to determine the limiting cathodic protection potentials for a given steel metallurgy and coating type and thickness to mitigate possible hydrogen-induced damage and coating disbondment and/or blistering.

Office of Pipeline Safety

U.S. Department of Transportation

OPS R&D Projects

Project Title: Emerging Padding and Related Pipeline Construction Practices

Researcher: Battelle Memorial Institute

Goal: The objective of this project is to quantify the merits of modifications to existing construction practices and emerging practices related to pipeline padding. The work will assist in determining the value of such construction practices when made in the context of performance-based inspection or re-inspection plans in response to pending pipeline safety legislation. The proposed project will complement and follow an INGAA Foundation project, which acts as co-funding and which is directed primarily at a qualitative evaluation of the potential of these techniques to improve productivity and improve safety. The combined effort will involve a field evaluation of these emerging approaches for benching pipelines and for bedding and padding in areas where native soils contain rock and other debris that could damage the pipeline or degrade its integrity over time.

Office of Pipeline Safety

U.S. Department of Transportation

OPS R&D Projects

Project Title: Corrosion Assessment Criteria: Rationalizing Their Use Applied to Early vs Modern Pipelines

Researcher: Battelle Memorial Institute

Goal: Develop quantitative measures that determine which of the current corrosion assessment criteria are valid to assess corrosion defect severity and determine failure pressure.

Office of Pipeline Safety

U.S. Department of Transportation

OPS R&D Projects

Project Title: A Comprehensive Update in the Evaluation of Pipelines Weld Defects

Researcher: Engineering Mechanics Corporation

Goal: This project will provide a major update to the alternative girth weld defect acceptance criteria. The focus of the project will be in two primary areas: a) To update the alternative defect acceptance criteria to address the immediate need of pipeline construction in the USA, typically with pipeline longitudinal strains less than 0.5%; and b) To develop alternative defect acceptance criteria for ultrahigh strength pipelines (e.g., X100) in geotechnically challenging environments, such as arctic areas and deep water offshore. Update Appendix A of API Standard 1104 for girth weld defect acceptance criteria as specified in Federal regulations (49 CFR, Parts 192 and 195), to reflect the increased use of mechanized welding and automated ultrasonic testing in new pipeline construction.

Office of Pipeline Safety

U.S. Department of Transportation

OPS R&D Projects

Project Title: First Major Improvements to the Two-curve Fracture Arrest Model

Researcher: Engineering Mechanics Corporation

Goal: The proposed program is to make the first major improvements to the most commonly used ductile fracture arrest criterion.

Office of Pipeline Safety

U.S. Department of Transportation

OPS R&D Projects

Project Title: An Assessment of Magnetization Effects on Hydrogen Cracking for Thick-Walled Pipelines

Researcher: Colorado School of Mines

Goal: This research program is proposed to:

(1) Experimentally determine the role of high strength magnetization during frequent pigging on the possibility of hydrogen damage in thick-walled, high-strength steels, both in base metal and the heat affected zone of welds [HAZ]; and
(2) Determine the hydrogen damage mechanisms through polarization studies.

Office of Pipeline Safety

U.S. Department of Transportation

OPS R&D Projects

Project Title: Fatigue Fracture and Crack Arrest in High-Strength Pipeline Steels

Researcher: National Institute of Standards and Technology

Goal: To identify the steels with the necessary crack arrest toughness. Currently used tests require so much material that it is not feasible or economical to perform these tests on many steels. However, modern linepipe steels are likely to exhibit ductile tearing rather than cleavage. In this case, knowledge of the rate dependence of plastic yielding could point the industry in the right direction. NIST has an instrument (Kolsky bar) that would be ideal for studying this as it uses very small quantities of material and can probe very high rates of deformation such as those near a rapidly propagating crack. This would provide the needed understanding of how different steels achieve crack arrest.

Office of Pipeline Safety

U.S. Department of Transportation

OPS R&D Projects

Project Title: External Corrosion of Line Pipe Steels

Researcher: National Institute of Standards and Technology

Goal: Stress corrosion cracking (SCC) has become an important issue in pipeline reliability. There is increasing need for an understanding of the fundamental mechanisms involved in SCC in order to develop improved detection and monitoring technologies. In the past, NIST developed an extensive database on underground corrosion of linepipe steels, and ran the NACE Corrosion Database Program for many years. One method to transfer improved data on SCC could be an expansion of the NACE database.

Office of Pipeline Safety

U.S. Department of Transportation

OPS R&D Projects

Project Title: Innovative Welding Processes for Small to Medium Diameter Gas Transmission Pipelines

Researcher: Edison Welding Institute, Inc.

Goal: The project aims to develop innovative welding processes and technologies for single-sided pipeline girth welding. Root pass welding techniques will be emphasized since they have the greatest potential to improve pipeline integrity and facilitate the use of new and existing GMAW fill pass techniques. Advanced automation techniques will be used to improve weld quality, process control, seam tracking, and robustness.

Office of Pipeline Safety

U.S. Department of Transportation

OPS R&D Projects

Project Title: Strain-Based Design of Pipelines - Phase II

Researcher: Edison Welding Institute, Inc.

Goal: The major objective of the proposed project is to develop design and assessment guidelines for pipelines that may experience high strains in service. This effort draws its basis from a previously concluded project which laid the groundwork to begin the framework of these guidelines. The guidelines will include:

- Recommended pipeline material specifications to minimize strain localization (soft HAZ)
- Recommended welding specifications to minimize strain localization at pipeline girth welds
- Descriptions of the range of cases where combinations of operating pressure, strain localization, and high strain affect pipeline performance.

Office of Pipeline Safety

U.S. Department of Transportation

OPS R&D Projects

Project Title: Optimizing Weld Integrity for X80 and X100 Linepipe

Researcher: Edison Welding Institute, Inc.

Goal: The major objectives of this program are as follows:

- To provide a better understanding of the factors that control strength and toughness in high strength girth welds.
- To develop optimized welding consumables and welding procedures for high strength pipelines.
- To develop best practice guidelines for the welding of high strength pipelines.
- To disseminate best practice information to the pipeline industry.
- To enable high integrity girth welds to be more reliably and economically achieved in high strength pipelines.

Office of Pipeline Safety

U.S. Department of Transportation

OPS R&D Projects

Project Title: Evaluation of Hydrogen Cracking in Weld Metal Deposited using Cellulosic Electrodes

Researcher: Edison Welding Institute, Inc.

Goal: The objectives of the proposed project can be summarized as follows:

- To determine the effect of electrode drying and arc length on weld metal chemistry, mechanical properties and hydrogen cracking susceptibility.
- To determine the effect of electrode re-hydration on weld metal chemistry, mechanical properties and hydrogen cracking susceptibility.
- To develop practical guidelines on how to prevent hydrogen cracking in welds deposited using cellulosic covered electrodes.

Office of Pipeline Safety

U.S. Department of Transportation

OPS R&D Projects

Project Title: A New Approach to Control Running Fracture in Pipelines

Researcher: Battelle Memorial Institute

Goal: (1) Develop and validate fracture arrestor design basis in reference to fracture speed, wall hoop stress and toughness, and gas properties; (2) Quantify differences in flow properties, fracture initiation formulation, and backfill coefficient today vs initial empirical calibration, reformulate arrest model accordingly, and validate in reference to trends evident in full-scale test database; (3) Characterize essential differences for modern high strength grades vs historic steels, such as elastic strain energy and dissipation near the fracture; (4) Formulate a first-principles model reflecting active sources of dissipation; (5) Establish the implications for a shift from fracture-controlled to flow-controlled running fracture as processes other than fracture become significant as toughness increases; and (6) Quantify role of grade, yield to tensile ratio, toughness, and parameters that characterize line pipe properties and those of the transported product in reference to the fifth goal, and formulate a model for fracture arrest as the deliverable.

Office of Pipeline Safety

U.S. Department of Transportation

OPS R&D Projects

Project Title: Integrity Management for Wrinkle Bends and Buckles

Researcher: Battelle Memorial Institute

Goal: (1) Broaden the utility of severity assessment criteria to cover pipelines with diameters from 12" to 36" in Grades from B thru X60, for wall thickness typical of products and natural gas transport, and operational histories for such service, and validate by full-scale test; (2) Quantify effects of corrosion pitting on the corrosion-fatigue resistance of line pipe steels, and combine with analysis of the effects of ID and OD corrosion on wrinklebends, and modify assessment criteria. (3) Quantify effects of pipe restraint applied local to the wrinkle or globally near the wrinkle, and assess implications for fieldwork on or nearby wrinklebends; (4) Quantify differences in hot-formed vs. cold-formed wrinkles in regard to fatigue resistance of line pipe and shape of the wrinkle; (5) Update severity assessment criteria to embed effects of corrosion, constraint, and forming temperature; and (6) Evaluate differences between wrinkles and large-scale buckles.

Office of Pipeline Safety

U.S. Department of Transportation

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Office of Pipeline Safety

Pipeline Corrosion R&D at NIST

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Objective:

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Starting with the results of original NBS burial studies for bare pipe in different soils;

(1) Analyze the data (new look, techniques, angles)
(2) Look for previously unrevealed relationships (new meaning)
(3) Identify R&D needs (gap analysis)
(4) Identify a path forward (experiments)
(5) Create understanding (results)
(6) Implement change (impact)

Why?

Because the bare pipe corrosion rate model underpins regulatory and repair decision making.

Objective:
Review NBS Underground corrosion studies 1910-1957

MSEL

Phases of Program

1. 1910: Congress authorized stray current corrosion study
2. 1920: Workshop convened to plan an underground corrosion study
   a) Dept of Agriculture selects sites
   b) Industry identifies and provide materials
   c) Symposia held every 5 years
4. 1922: Ferrous pipe materials at 47 sites for 12 to 17 years
5. 1924: Other materials buried at the sites during first retrieval
6. 1928: Fe alloys, Cu, Cu alloys, and Pb samples buried at new sites
6. 1932: Materials for corrosive soils study using 15 sites (coatings)
7. 1937, 1941, 1947 materials added during retrievals at the 15 sites
8. 1945: "Underground Corrosion" by K. H. Logan NBS C450
9. 1952: Last retrival - 128 sites, >36,000 samples, 333 matl types
10. 1957: Final Rpt. "Underground Corrosion" by M. Romanoff NBS C589
11. A larger number of follow-on studies from 1957 to the present:

Ductile Cast Iron, Concentric Neutrals, Steel Pilings, Offshore Pilings, Stainless Steels, Bridge Deck Corrosion, etc.

Conclusions of Old NBS Studies

MSEL

1. Some soils are very corrosive to bare pipe
2. Some soils are not very corrosive to bare pipe
3. Localized attack (pitting) is a problem in some soils
4. Large scatter was observed
5. All ferrous materials corroded at about the same rates (well within the measurement scatter)
6. Considerably less corrosion was observed in piles driven into undisturbed soil than in this study with disturbed (aerated) soils.
7. Clearly three factors stand out:
   1. Aeration (disturbed vs. undisturbed),
   2. Drainage (water in contact with surface),
   3. High statistical variation in local occlusion cells
   4. Conductivity indicates total salt content, and
   5. Conductivity is only a rough indicator of soil corrosivity.

Original Analysis

Analysis of Corrosion Kinetics

MSEL

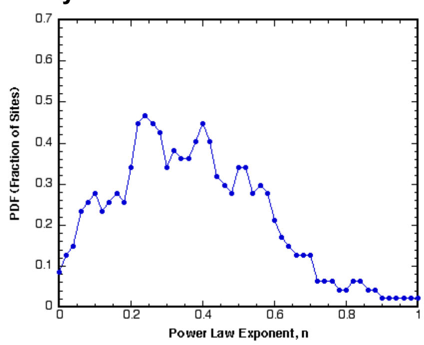
Regression analysis for relationship of the form

$$D=kt^n$$

The original NBS analysis determined an average k and n for each of the 47 soils. These were determine by linear regression of the equation

$$\text{Log}(D) = \text{Log}(k) + n\,\text{Log}(t)$$

Multiple linear regression of the k and n values as a function of soil properties met with only moderate success



Kinetic Analysis

MSEL

Bare surface with mixing

$$P=kt$$

Surface film slows transport

$$P=kt^n \quad n=1/2, 1/3, 1/4$$

Reactant consumed from environment

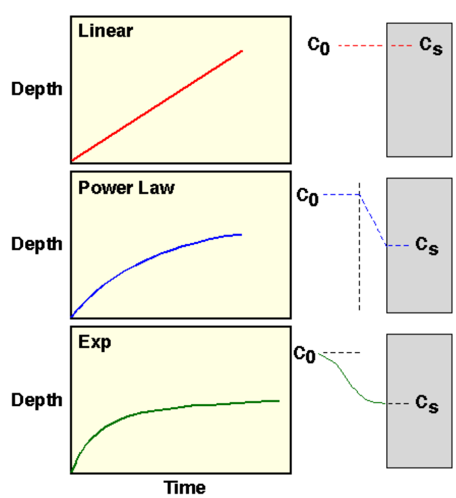
$$P=k[1-\exp(-t/b)]$$

Therefore, the slope n is an indicator of the rate determining (limiting) process

Two rates:

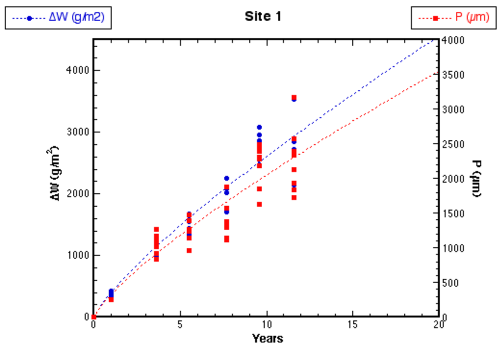
(i) corrosion rate, and
(ii) the penetration (pitting) rate

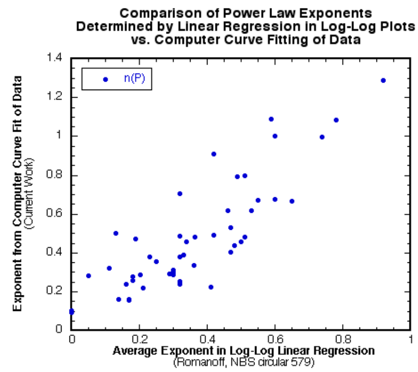
The pitting factor (PF) is the ratio of these two rates



Reevaluation of Individual Site Data

MSEL





Mass Loss

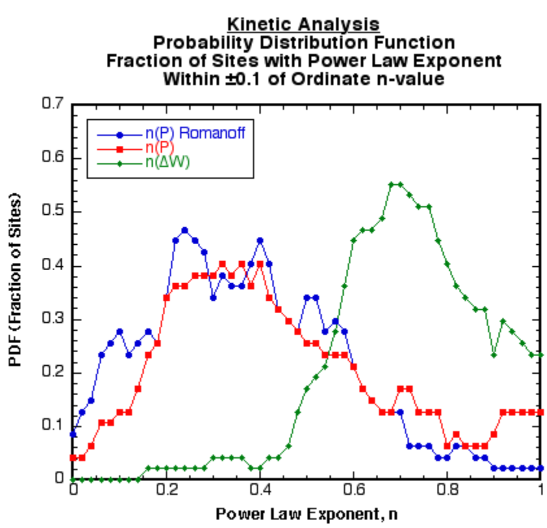
y = a*x^b		
	Value	Error
a	403.31	40.788
b	0.80955	0.046171
Chisq	2.9037e+06	NA
R	0.97535	NA

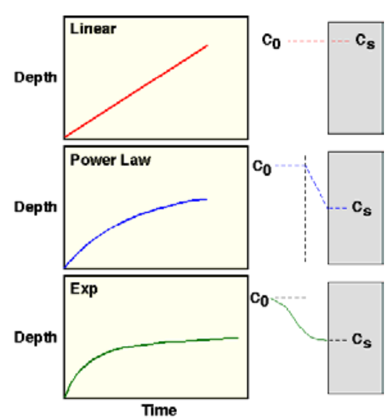
Penetration

y = a*x^b		
	Value	Error
a	328.16	49.903
b	0.79454	0.069531
Chisq	4.1868e+06	NA
R	0.94491	NA

Comparison of Exponent Distributions

MSEL





Results of Kinetic Analysis

MSEL

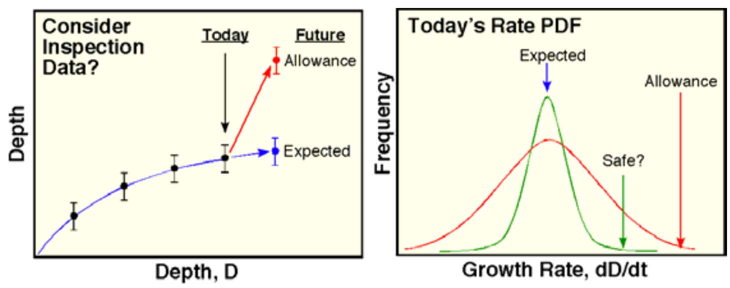
(1) Analysis of the maximum pit depth data indicates that pits grow at a rate that decreases with exposure time.

(2) For maximum pit depths, the exponent varied from about 1/4 to 1/2.

(3) Analysis of the mass lost data indicates a higher exponent or mixed rate determining kinetics (e.g. pitting and uniform attack)

(4) Multiple regression analysis for environmental factors influencing the exponent n has not yielded strong indicators.

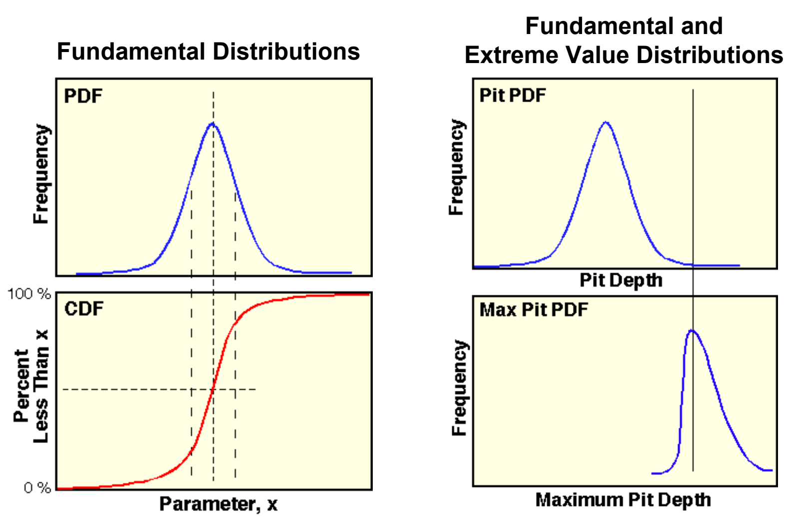
(5) Understanding the scatter in the data should help analysis.



Statistical Analysis of Scatter

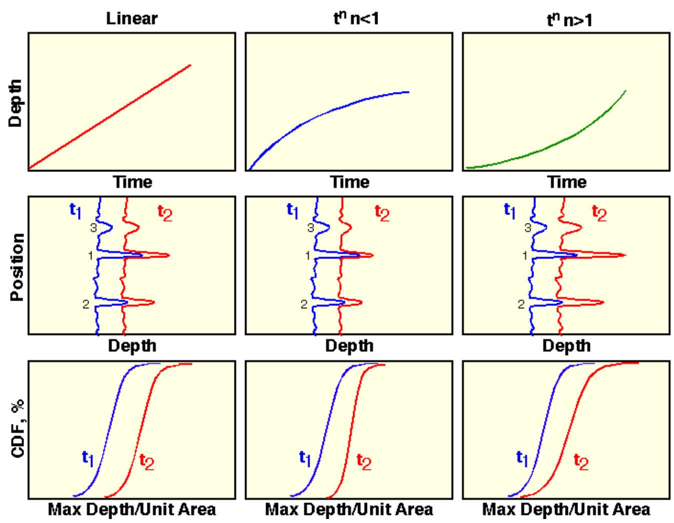
Extreme Value Statistics

MSEL



Kinetic Models and Scatter

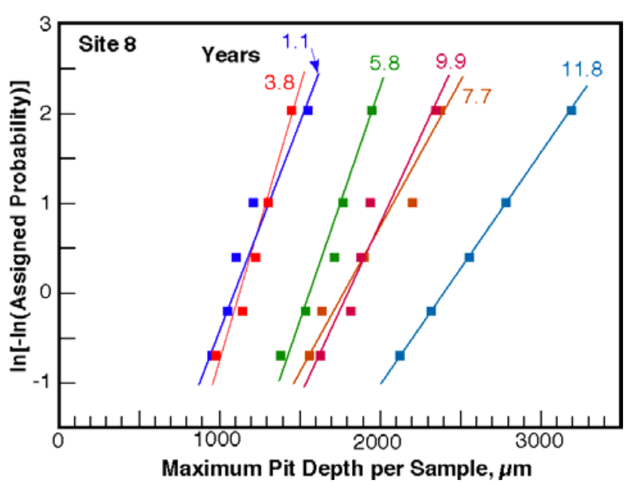
MSEL



Note, one assumes that the initial scatter is due to initiation times

Example Site Data

MSEL



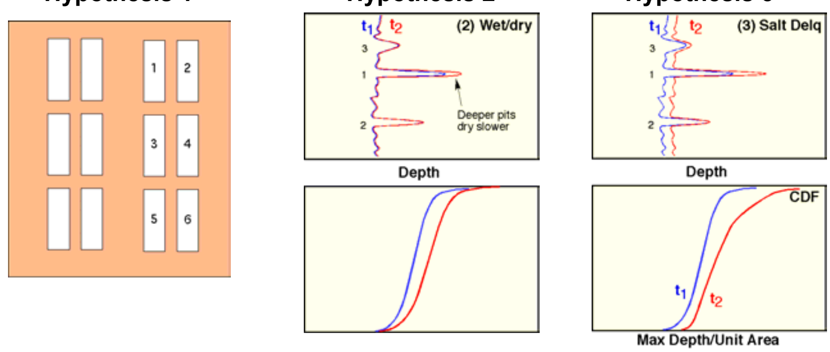
Evidence for constant, increasing, and decreasing slopes were observed

Results of Extreme Value Analysis

MSEL

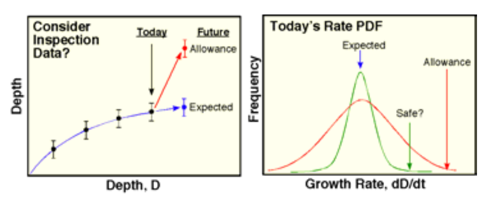
- **Scatter consistent with different kinetic models were observed.**
- **This may not be inconsistent with a decreasing rate model**
- **The source of the scatter needs to be understood.**
  1) **Variation in the environment**
  2) **Alternating wet and dry**
  3) **Salts in pit absorbing water**

Hypothesis 1 **Hypothesis 2** **Hypothesis 3**



Gap Analysis and Path Forward

MSEL



Gap:

Basic understanding of the origin of the observed scatter:

(1) Pit initiation

(2) Pit propagation

(3) Environmental variations (annual, site, irregular)

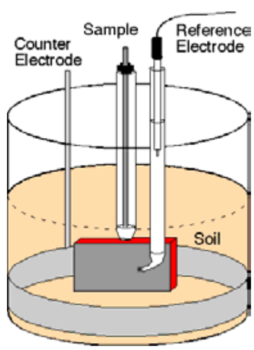
Path Forward

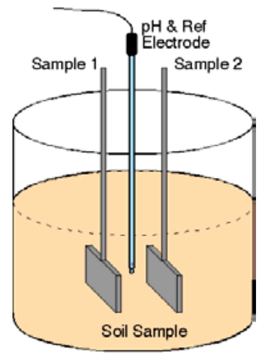
Piggable and unpiggable pipes

Laboratory Experiments designed to answer these questions

Experimental Evaluation

MSEL





Initial Focus: Rates in environments, range of rates, and transients
Followup: Pit formation and propagation rate measurement.

Conclusions

MSEL

- Assuming that corrosion rates are determined by the alloy, environment, and the conditions of exposure, then the scatter observed in the original NBS study must be due to variations in one of these factors that was not quantified sufficiently.
- Based on this analysis, and the findings of the original study, it was hypothesized that variations in ground water levels and sample wetting are the most probable explanations for the observed scatter. (other possibilities include variations in aeration, soil composition, and MIC)
- Pitting rates were found to decrease with exposure time. This was also reported in the original study. The exponent determined for this behavior is close to that reported for pitting in the literature for aqueous environments. However, this knowledge cannot be used in a rate model until the source of the scatter is better understood.
- If the origin of the scatter is understood and sufficient data for computer modeling of the rates is obtained, then prediction of the expected flaw growth rate and the expected range of rates for any particular environment and range of expected conditions should be possible.
- The objective of the laboratory experiments is to identify the source of the scatter and obtain the information required for modeling of corrosion rates.

Materials and Joining

March 2005 R&D Forum

David Horsley
TransCanada Pipelines Limited

Outline

- Background
  - Links to Design
  - Links to Construction
  - Links to Operation
- Materials and Joining Issues
- List and Prioritize

Overriding Principles

- Protection of Persons, Property and the Environment
- Compliance with Laws and Regulations
- Develop and Utilize Technologies to enhance 1 and 2, and improve Cost Effectiveness of pipeline systems

Life Cycle Costs

- Design – Construct – Operate

Links to Design

- Reliability Based Design and Assessment (RBDA)
  - Quantifies reliability for all relevant limit states
  - Reliability Optimized over life cycle
  - Higher Design Factors
- Loading Conditions
  - Seismic
  - Slope Instability
  - Frost Heave and Thaw Settlement
- Load Effects
  - Stress based design
  - Strain based design (Tensile and Compressive Limit States)
- High-Strength Pipelines
- High-Pressure/ Low Temperature/ Rich Gas Pipelines

Links to Construction

- High Productivity Welding
- Materials
- Inspection and ECA
- Alternatives to Hydrotest

Links to Operation

- RBDA
- Materials Properties database
- Corrosion

Materials and Joining

- Materials account for up to 50% of installed cost
  - Reduce steel requirements - use higher grade
- Welding is the often the pace-limiting process
  - Improve productivity by advanced automated welding systems

Materials

Materials Outline

- High Strength Materials
- Fracture Propagation and Arrest
- Inspection and ECA
- Corrosion

High Strength Materials

Increased strength → reduced WT → lower cost (for steel and construction)

- Fracture propagation and arrest
- Joining
- Stress-strain properties
- Damage Tolerance
- Response to external loads – tensile and compressive

Fracture Propagation and Arrest

Validated Fracture Control Methodology for new pipelines of high-strength steel, operating at higher pressure, lower temperature, richer gas.

- Driving force (equation of state)
- Material resistance – appropriate small scale tests
- Other resistance – backfill coefficients
- Experimental data to validate predictive models

Inspection and Engineering Critical Assessment

Define uncertainties in and suggest refinements to weld inspection and assessment methods in order to increase the level of confidence associated with their use and expand applicability to higher strength materials and other joint configurations.

- AUT
  - Sizing precision and accuracy
  - Design tools
- ECA
  - Strain based design methodologies
    - Experimental data for a wider range of materials and D and WT
  - Interaction of flaws
  - Applicability to high strength pipe materials
  - Realistic small scale fracture tests (low constraint)
  - Old and existing pipelines
  - Risk/reliability/probabilistic methods
  - Codes and Standards

Corrosion

- Comprehensive Models to predict susceptibility and rates for both General Corrossion and SCC
  - Soil type
  - Moisture content
  - pH
  - Aerobic/Anaerobic
  - Coating type
  - Pipe grade / manufacturer/ process
- Effectiveness of CP in Permafrost

Joining

Joining Outline

- Joining of Higher Strength Materials
- Welding on Pressurized Lines
- New and Improved Welding Processes

Joining of Higher Strength Materials

Identify factors critical to successful joining of high strength materials and develop welding procedures and techniques which demonstrate sufficient reliability and can be practically implemented.

- Consumable development for X-80 and X100 pipe in strain based loading design -to ensure overmatching and sufficient toughness
  - Mainline
  - Tie-ins
  - Double joints and fabrication welds
- Effects of repairs on metallurgical properties
- Hydrogen cracking susceptibility
- High productivity welding systems

New and Improved Joining Processes

Adapt new joining processes and improve or refine existing processes which show sufficient increases in productivity, efficiency or reliability.

- Enhancements to mechanized GMAW processes
  - Tandem
  - Dual tandem
  - Laser assisted
- Optimization of pipeline spread, e.g. appropriate number of shacks and welding process/equipment
- Optimization of welding procedures to reduce number and size of flaws to meet strict requirements for strain based design
- Semi-automatic process for tie-ins and repairs
- One-shot welding processes, e.g. MIAB
- Automated processes for in-service welding (full pressure and flow if possible)
  - Hot taps and stopples (design codes w.r.t structure analysis needs work too)
  - Repair sleeves
  - Direct deposition repairs

Welding on Pressurized Lines

Increase accuracy in predicting base and weld metal response when welding in-service pipelines and develop welding techniques which demonstrate sufficient safety, reliability and economy.

- Cooling rate models to account for various WT, products, flow rates, etc.
- Microstructure/hardness prediction to assess hydrogen cracking susceptibility
- Structural integrity assessment for repair sleeves and large-diameter large-ratio hot tap tees and stopples
- Special issues applicable to thin wall pipe
- Direct deposition repair methods.

Other Materials and Joining Issues (from 2003 lists)

- Inspection of CRA clad pipes
- Composite materials
- Composite Reinforced Steel (Leal/Rupture)
- Deep Water technology
- Design of SCR systems
- Plastic Pipe
- High pressure liners
- LNG/ CNG

New Issues from Alternative Pipeline Products

- High CO2 content
- Hydrogen content
- Hydrogen conversion
- Others?

Top 5 Needs

- RBDA
  - Tools / Techniques / Standards
- Strain Based Design
  - Experimental data – compressive and tensile
- AUT
  - Improved precision and accuracy
- Optimization of Welding Processes
  - Reduced flaw size to meet strain based design
  - Consumables for overmatching M/L, tie-in, dbl-joint
  - Appropriate equipment on right-of-way
- Corrosion/SCC
  - Improved models to predict growth rates

Issues and Opportunities

Identified at 2003 R&D Forum

Technology Implementation

Design, Construction, Materials, and Welding Technology Track

at R & D Forum

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What is Implementation?

- Put technology to field practice
  - Codes and standards
  - Hardware
  - Software
  - Publication
  - Internal use by operators

2Implementation by Yong-Yi Wang

Threats and Opportunities

- **Threats**
  - Outdated codes and standards
    - A code is so out-of-date that companies may not use it or participate committee activities.
    - Ductile fracture arrest model
  - Weak link among universities, national labs, research institutes, and commercial entities
  - Gap of talents and knowledge
- **Opportunities**
  - Risk-based design and maintenance
  - Computational/software tools

3Implementation by Yong-Yi Wang

Code Activities (Limited Scope)

- **ASME**
  - Reliability-based design and assessment (RBDA)
    - Based on PRCI-funded work at C-FER
    - Establish target reliability for different failure modes
    - Target reliabilities calibrated to current industry practice
    - Reliability based limit states design (ISO 16707)
  - Strain-based design
- **API**
  - 1104
- **CSA**
  - Reliability based limit states design
  - Strain based design
  - Revision of CSA Z662 Appendix K
- **OPS/MMS sponsored work**
- **Not covered: NACE, AWS, ASTM, ISO**

4Implementation by Yong-Yi Wang

DOT/PRCI Project on Weld Code Revision

- An example of code implementation
- Develop deterministic ECA procedures that would form the basis of code revisions of API 1104 Appendix A, and other ECA codes in North America as appropriate
- Incentives
  - Appendix A has not been maintained to the current understanding since its adoption.
  - It was good for the circumstances and technical understanding at the time of its adoption.
  - The safety margin of Appendix A is questionable for modern TMCP materials with high *Y/T* ratio.
  - Need to extend to strain-based design

Emc²

5Implementation by Yong-Yi Wang

DOT/PRCI Project on Weld Code Revision

- Involvement of the industry
  - PRCI
  - TransCanada
  - Lincoln Electric
  - Duke energy
- Collaboration with code committees
  - API 1104
  - CSA
  - ASME
- Status
  - Two public meetings
  - Results of the first focus area were turned over to API 1104
  - API 1104 is in the process of writing code language.
  - Work in the second focus area ongoing
    - Modeling, micro-mechanics, damage mechanics
    - Correlating small- and large-scale specimens
  - To be completed by the end of the year

Emc²

6Implementation by Yong-Yi Wang

DOE/PRCI Integration of Multi-Scale Mechanics and Welding Process Simulation

- Develop advanced weld integrity assessment procedures by integration of welding process modeling and multi-scale mechanics
- Project team members: Emc^2, Oak Ridge National Lab, MIT, and Northwestern University
- Commercial partners
  - PRCI
  - TransCanada
  - Lincoln Electric
  - Duke
  - Southern California Gas Company
  - Williams
  - ChevronTexas

7Implementation by Yong-Yi Wang

Challenges in Codes and Standards

- Outdated
- Codes and standards from overseas are becoming de facto standards
  - Offshore
  - Countries other than U.S.
- Code committees may not aware of the status.
- Lack of company support
- Gap in talent and knowledge
- Poor code maintenance, lack of continued update

8Implementation by Yong-Yi Wang

Actions, Top 5?

- Review gaps in codes and standards
- Communicate the gaps to the relevant industry committees
- Improve and maintain communication with code and standards committees
- Encourage collaborative research among industry, applied research organizations, universities and national labs
  - NIST work with industry/applied research institutions
- Require commercialization plans in proposals
- Follow up with commercialization plans
  - Monitoring
  - As a criteria for future support
- No co-funding requirements for code support?
- Support for maintenance of existing pipelines

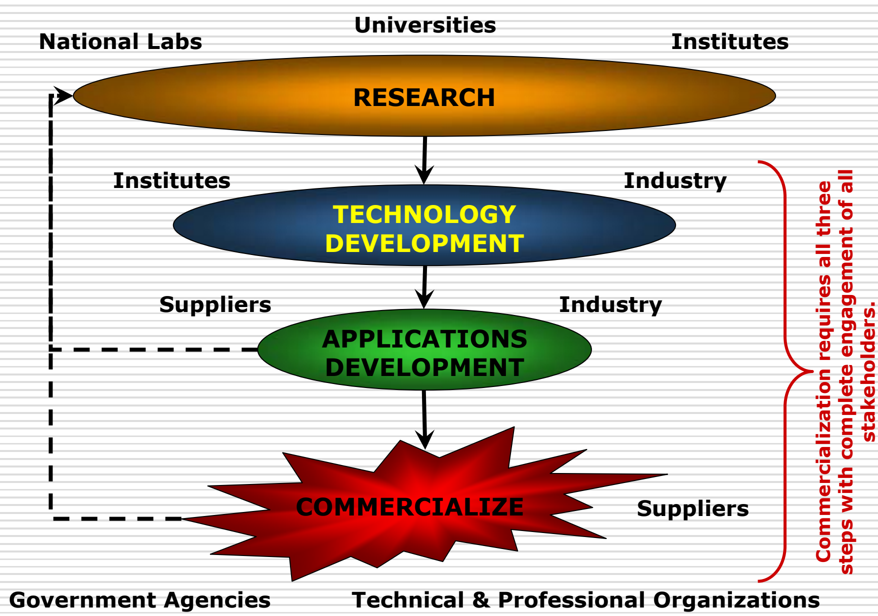
Actions, Top 5?

- Standards
  - Tensile tests
    - What to test
    - How to test
  - Charpy vs. CTOD
  - Relevance of CTOD

Government Industry R&D Forum
22-24 March 2005

Design, Construction, Materials & Welding Technology Track

Project Selection and Management



Gaps & Opportunities

- Leverage
  - Capabilities, resources, funding among all stakeholders
  - Review process that minimizes duplication of effort
- Project Management
  - Alignment of reporting methods and schedules could save 5-10% of R&D cost
  - Advocate within government system to promote greater industry participation
- Forum to facilitate communication among stakeholder groups

Appendix 9
2005 R&D Forum Issues & Opportunities

				A - Highest B - Intermediate C - Lowest	A - <2 yr. B - 2-5 yr. C - >5 yr.	A - Low Risk B - Med Risk C - High Risk
Focus Area	**2003**	**2005 Gaps and Opportunities**	**Status and/or Recommended Action**	**Priority**	**When**	**Feasibility**
Right of Way Issues		**Third Party Damage & Earth Movement** Gas transmission pipelines are sometimes damaged by construction equipment or encroaching vehicles not owned by the pipeline company. The resulting third-party damage is the major cause of damage to natural gas transmission pipelines. DOT reports that from 1994 to 2004, approximately 32% of all hazardous accidents involving onshore transmission pipelines were caused by third-party damage. The consequences were 9 deaths, 38 injuries, and costs totaling $91 million, or an average of $360,000 per incident. New technologies for automated and real-time monitoring of pipeline right-of ways are needed to assure the long-term integrity, safety and security of the nation's natural gas pipeline network.	A comprehensive review of the available technologies is needed to identify the most promising technologies to be pursued and providing a clear and logical path forward for subsequent research activities. The initial focus should be on technologies already developed or under consideration by other industry sectors in order to coordinate development efforts. For example, heavy construction companies are moving toward more accurate systems which could be coordinated with right of way management. Caterpillar is key player in this regard.	C	A	A
			Technology exists today which can be deployed selectively for building the into piping systems. Some effort is warranted to validate a broader use of the relevant technologies such as acoustic monitoring, unmanned aerial vehicles, global position sensor equipment and fiber optics.	C	A	A
			Application of sensor technology for acoustic signatures and embedding sensors into smart systems.	B	A	A
	X	**Detection of encroachment**	Sensors and acoustic signature must be further developed and evaluated to assess their monitoring capability with respect to pipeline encroachment.	B	A	A
	X	**Horizontal Directional Drilling** Extend capability and reliability of horizontal drilling based on down hole drilling and better usage of geophysical technical data.	Improve engineering methodologies for extended reach and HDD.	A	A	C
		Political Pressures Building setbacks imposed by special interest groups without technical foundation.	This is related to the public awareness issues discussed as a separate line item.			
		Standard Practices Industry wide and regulatory acceptance of right of way management plans.	Demonstrate the feasibility of and gain acceptance for feasible methods of right of way management that include: Real time reliable detection of third party damage Viability of available technologies Critical safety Economics	B	A	B
Environmental Impacts		**Forum for Continuous Improvement** Continuing factual discussion of the impacts of oil and gas operation in the onshore environment is needed.	Recent reorganization of PHMSA may provide a forum for the needed discussion going forward.	C	B	A
			Look at existing technology in other areas to facilitate environmental management efforts.	C	B	B
	X	**Alternatives to Hydro test** The environmental impact of hydro test operations is a continuing point of discussion both in terms of where the water comes from and disposal of the water after test completion.	OPS and MMS working collaboratively with industry to study possible alternatives. Review results of current studies to determine future focus. Consider the merits of hydro testing both in terms of environmental impact and the technical value of the data generated.	A	A	A
		Standardized Management Plans Mitigate delays in permitting for new construction Mitigate environmental concerns over right of way maintenance.	Need standardized design methodologies, simplified information exchange and recommended practices. Major considerations include: 1) Disposition of hydro test waters 2) Habitat fragmentation 3) Vegetation management 4) Integration	B	B	B

Appendix 9
2005 R&D Forum Issues & Opportunities

				A - Highest B - Intermediate C - Lowest	A - <2 yr. B - 2-5 yr. C - >5 yr.	A - Low Risk B - Med Risk C - High Risk
Focus Area	**2003**	**2005 Gaps and Opportunities**	**Status and/or Recommended Action**	**Priority**	**When**	**Feasibility**
Offshore		**Deep Water Environment** Technology Limits and HTHP	MMS studies ongoing, but more research needed than current funding levels support. Greater co-funding from users and other agencies is one avenue.	B	B	B
		Aging Infrastructure Erosion/Corrosion and Repair/Abandonment	MMS studies ongoing, but more research needed than current funding levels support. Greater co-funding from users and other agencies is one avenue.	B	B	B
		Construction/Installation Structural Integrity and Remote Locations	MMS studies ongoing, but more research needed than current funding levels support. Greater co-funding from users and other agencies is one avenue.	B	B	B
Design, Construction & Operation	X	**Reliability & Reliable Operations** Existing probabilistic methods are limited in their ability to predict loads. There us insufficient baseline data for prediction of both pipe response and loads.	Gather enough data to use probabilistic design methods to account for loads and responses of pipe.	A	A	A
	X	**Geological Hazards** Current methods for accommodating large scale ground movements in pipeline design involve overly conservative estimates and simplifications because it is difficult to quantify multiple soil parameters, pipe support, loading, and even pipe material properties. Further, the interaction of the pipe with the soil and its effect on stresses developed in the pipe as it responds to such displacement is not wholly understood.	Develop improved engineering procedures for evaluating the effects of significant ground movement on the structural integrity of buried pipelines, with or without corrosion defects, and establish guidance for potential remedial action and for prioritizing maintenance operations. Implement the recommendations from a conference last year in London sponsored by BP on geo-hazards. The outcome from this conference was common process for mitigating geo-hazards. Long term goals is an international standard.			
		Landslides Large earth movements are highly disruptive to pipeline operations putting both life and property at risk. Previous effort in this area provides a solid background for additional work to refine predictive methods.	Need improved predictive tools for landslides and other large displacements that 1) Identify high risk regions 2) Estimate risk of pipeline failure 3) Preclude extended damage to pipeline operation			
		Surface Loading Traditional design and evaluation guidelines do not address adequately certain atypical conditions that lead to higher than anticipated stress in pipe. These include shallow buried pipes subjected to very large surface loads (e.g. heavy construction equipment and blast loadings from construction activities near existing pipeline installations). The lack of guidance for such conditions is further complicated by the age of existing infrastructure in many locations subject to these conditions.	Need design and engineering tools to assess atypical loading conditions. Need validated method to replace costly full scale geotechnical tests. Methods should include consideration of 1) Shallow buried pipe 2) Heavy equipment & blasting 3) Database of physical test results including scaling factors			
		Environmental Influences on Operation Focus is on impacts of environment on oil and gas operations.	MMS studies ongoing, but more research needed than current funding levels support. Greater co-funding from users and other agencies is one avenue.	B	B	B
		Reeling Simulation of reeling for accumulated strain and fatigue. One of the unknowns associated with reeled pipe is the true accumulated strain and how it changes from the inside to the outside of the reel. Understanding this is the first step to understanding the fatigue life of reeled pipe. It is believed accumulated strain does not have a dramatic effect on fatigue performance, but to date this is only an assumption.	There is a need for research directed at assessing the effects of reeling on long term pipe performance. Could build on EPRG's active program on reeling.	B	B	B

Appendix 9
2005 R&D Forum Issues & Opportunities

				Priority	When	Feasibility
				A - Highest B - Intermediate C - Lowest	A - <2 yr. B - 2-5 yr. C - >5 yr.	A - Low Risk B - Med Risk C - High Risk
Focus Area	**2003**	**2005 Gaps and Opportunities**	**Status and/or Recommended Action**	**Priority**	**When**	**Feasibility**
General Material Properties & Performance Issues	X	**Corrosion/SCC** Improved models for corrosion/SCC flaw initiation and growth rates.	NIST program link. Also, some CANMET work on initiation that would provide basis.	A	A	A
		Corrosion/Pitting Improvements in corrosion rate predictions pit growth & general corrosion Provide recommendations for standards	Supplement the ongoing NIST study. Obtain samples of contemporary pipeline steels Obtain current data on pit chemistry & environment Ultimately, need to expand study to consider full range of effects (e.g. aeration, conductivity, soil chemistry, electrical potential or degree of cathodic protection, inhomogeneity of materials, etc.) Collect anecdotal evidence from industrial experience.	A	B	A
		Coatings Direct assessment of installed coatings. Coatings are relied upon for corrosion protection of pipelines. There is a need for more effective short term testing methods to predict long term performance under field conditions- wear & penetration, coating soil interactions, etc.	A series of research programs is needed to address the gaps in the knowledge base. The NIST/OPS workshop planned for later this year should be used as a forum to develop specific project proposals.	A	A	A
		Alternative Coating Processes Low temperature application of coatings to avoid thermal affects on pipe material and welds.	Address this issue at the R&D forum planned by OPS on coating technologies later this year.	A	B	C
		Existing pipelines In situ measurement and/or material database of existing properties. Web based applications make this a more viable project today than when it was first proposed several years ago.	The proposed action is to consolidate the available information from agencies and industry. The potential difficulty is in establishing the reliability of the data. Definitely an opportunity for data mining.	A	A	B
		Strain Aging Better documentation of strain aging of steel resulting from thermal cycling during the life of the pipe (e.g. preheat, post heat, coating). This has potential impact on industry reliance on wide plate test results that are typically conducted without coatings.	Characterize the strain aging behavior of pipe materials resulting from thermal processes used during initial manufacture, installation and service.	B	B	A
		Dents For operating pipeline, predictive models for dents with girth welds.	Extend existing models to pipe with girth welds.	A	B	A
		Fatigue The available offshore data should be fed into codes/standards. This issue is also relevant for onshore applications when the pipe is used for storage.	Consolidate the available data for inclusion in API1110. Gaining access to the data is expected to be difficult because much of it is project driven and generally inaccessible.	A	B	C
	X	**Industry Wide Database** Central repository for data and experience to prevent recreating the wheel.	DOT could fund this with an independent contractor where the information could be provided anonymously and used by the agency and industry as a whole. Same idea as NIST corrosion database. Initial step should be a feasibility study to determine format, access, accuracy, reconciliation of discrepancies, etc.	A	B	C
	X	**Offshore Materials** Properties as they relate to structural integrity of pipe. Also, consider corrosion behavior of materials and the use of corrosion inhibiting methods.	MMS studies are ongoing, but more research needed than current funding levels support. Greater co-funding from users and other agencies is one avenue.	A	B	A
	X	**Welding** In general, innovation in welding process and materials lag pipeline industry needs.	Elevate the discussion of welding issues to identify the major gaps an opportunities. The NIST/OPS welding workshop planned for later this year will offer a forum for initial discussion.	A	B	A

Appendix 9
2005 R&D Forum Issues & Opportunities

Priority	When	Feasibility
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B - Intermediate	B - 2-5 yr.	B - Med Risk
C - Lowest	C - >5 yr.	C - High Risk

Focus Area	2003	2005 Gaps and Opportunities	Status and/or Recommended Action	Priority	When	Feasibility
Strain Based Design & High Strength Steels	X	**Design Methodologies** Improvement and standardization of strain-based design methodologies are needed for both onshore and offshore applications. Existing efforts are fragmented and suffer from a lack of relevant materials properties data (e.g. full stress-strain behavior, toughness transition data, welds, heat affected zones, directional pipe properties, etc.)	Need comprehensive methodologies that use existing research as a basis and link with the work on large and small scale test methods. MMS studies are ongoing for offshore applications, but more research needed than current funding levels support. Greater co-funding from users and other agencies is one avenue.	A	B	A
	X	**Material Properties & Performance** Material properties based on small scale tests that ensure large scale performance. Generate large scale experimental data to validate numerical models for strain based design.	Validate and standardize small scale test methods and sampling procedures.	A	A	A
			Consolidate active work on large scale performance and numerical methods. Supplement with OPS project to fill in the gaps.	A	A	B
	X	**Reliable Characterization of Flaws** Suitable field inspection tools for higher probability of flaw detection and reliable size determination. Existing implementation of AUT has issues with detection, precision, accuracy that have not been resolved.	Establish consortium of stakeholders (e.g. AUT contractors and operators) and rewrite ASTM standard guideline for integration of allied AUT technologies (e.g. sectorial scan with phased array).	A	A	C
		Welding Processes for Improved Quality Optimized welding processes to reduce flaw size for strain based design, consumables for high strength pipe, appropriate equipment on ROW	This is an applications development more appropriately done by the contractor and supplier base provided that the design targets for flaw acceptance and toughness can be established.	A	B	A
	X	**Welding Processes for Improved Productivity** High productivity joining processes - flaw size, speed & number of staff/equipment needed on ROW Such processes are likely to involve high levels of automation/mechanization that will require more specialized operator training and qualification.	This is an applications development more appropriately done by the contractor and supplier base provided that the design targets for flaw acceptance and toughness can be established.	A	B	A
Adverse Environments		**Offshore - Hurricanes** Research opportunity for design tools as well as response prediction Improvement of response time to breaks. Ongoing improvement of design & operation guidelines as well as cost effective methods for upgrading older installations.	MMS studies ongoing, but more research needed than current funding levels support. Greater co-funding from users and other agencies is one avenue. Need better tools for predicting response under adverse conditions resulting from recent disasters. Opportunity exists for improved sensing and monitoring (e.g. satellites, etc.). DOE has an initiative in this regard, but funding levels are questionable.	B	B	B
		In-service Inspection Improved methods for hydrogen monitoring for high strength steel applications. There is concern about the influence of magnetic fields induced with existing pigging methods on hydrogen assisted cracking.	MMS studies ongoing, but more research needed than current funding levels support. Greater co-funding from users and other agencies is one avenue.	B	B	B
	X	**Arctic Environments** Need better understanding of terrain influence in Arctic and Sub-Arctic regions on pipeline construction & maintenance.	Need numerical & engineering models Design, construction & integrity analysis Axial loading due to thermal effects Freeze-thaw cycles of permafrost induce transverse cyclic bending	A	A	C
			Leverage resources and information from outside North America (e.g. former Soviet Union).	B	A	A

Appendix 9
2005 R&D Forum Issues & Opportunities

Priority	When	Feasibility
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Focus Area	2003	2005 Gaps and Opportunities	Status and/or Recommended Action	Priority	When	Feasibility
Codes & Standards		**Obsolete Standards** Streamline regulatory adoption of relevant codes and standards. There is a high level of frustration about the length of time it takes technology to be implemented. In general, codes and standards have not kept up with research and technology in the oil and gas industries. Where there are no regulatory requirements to use such codes and standards, individual companies write independent, often project specific, documents.	Fund a comprehensive review of existing standards for gaps and opportunities. Should be a cross-functional team. Need regulators, code bodies and industrial sector to set minimum targets. Communicate the gaps to the relevant industry committees Where is Gaz d'France? Some existing codes still require product qualification, but there is no longer an agency that performs the service.	A	A	A
			Funding agencies (e.g. DOT) should require 1) Involvement of standards organizations up front in the development process. 2) Better coordination between regulatory program and research program. 3) Ensure all stakeholders are involved in the project and process. API 1104 should change its name to API 401k.	A	A	C
			Improve and maintain communication with code and standards committees. Funding agencies can also motivate industry involved in research to higher levels of participation on code committees.	A	A	A
		Regulatory Participation DOT support for code activities.	DOT must be more proactive in code activities. If the codes are used as part of the regulatory requirements, they need to be engaged and encourage their contractors to be engaged. Suggestion is that DOT can designate and fund an EPC contractor to represent the agency in the code writing process.	B	B	A
Commercialization		**New Technology** Generally, need higher level of successful technology transfer and commercialization. Need more standards development to deploy the knowledge in a meaningful way.	Proposal solicitation process should include a requirement for a commercialization plan that is monitored on some level. For example, NSF follows commercialization plan 5 years after closure of project and uses commercialization history to make decisions about future funding. Also, see what we can learn from MMS operating model, which has a good track record for commercialization of research and technology development. Approximately 80% of the MMS projects achieve commercialization. Clear set of deliverables at outset of the programs.	A	A	A
		Support for Existing Infrastructure Similar issues exist regarding upgrading methodologies and tools for operation and maintenance of existing pipelines.	Require project proposals to address the possible benefits of any new technology developed to existing installations. If applicable, commercialization plans could be included that address the specific needs of existing pipelines.	B	B	A
Human Factors		**Dwindling Pool of Talent** Recruiting high level talent into the industry at both operational and professional levels is very difficult. The work force is aging without a supply of new blood to replace it. Pipelines are not glitzy like IT. All industry partners are having difficulty filling the pipeline with high level engineering graduates and operations personnel. Need to get academia to understand the current needs of the industry.	This requires a collaborative effort within the industry. Need to educate the educators. The existing programs at the university level need active industry participation if they are to be effective (e.g. CSM, Penn State and Tulane). The recently formed Pipeline Engineering Center at University of Calgary is in need of "care and feeding" if it is to establish itself as a center for engineering education and research. Tulane University serves as a model for an effective outreach program. These approaches should be extended down to trade school level. This issue is also related to the Public Perception issue.	A	B	C
	X	**Public Perception** Public awareness of the impact of catastrophic events, energy policies, supply vs. demand, location of supply vs. location of demand, relative costs, etc.	Effort here could make it easier to gain public acceptance of energy policies, permitting, etc. The expectation is that this will have a positive effect on local and regional officials.	A	B	C

Appendix 9
2005 R&D Forum Issues & Opportunities

				Priority	When	Feasibility
				A - Highest B - Intermediate C - Lowest	A - <2 yr. B - 2-5 yr. C - >5 yr.	A - Low Risk B - Med Risk C - High Risk

Focus Area	2003	2005 Gaps and Opportunities	Status and/or Recommended Action	Priority	When	Feasibility
Program Management		**Leverage** Effective management of resources is key to leveraging capabilities, resources and funding among all stakeholders. Want to avoid recreating the wheel. Effective R&D relies on collaboration among multiple stakeholders (e.g. pipeline companies & their suppliers, applied research organizations, universities and national labs). The connections among government agencies is weak. OPS and MMS do well, link to DOE is developing, link to DOD is practically non-existent. Sharing of technology among the agencies could shortcut the R&D process for pipelines on many levels (e.g. strain based design approaches, materials characterization, inspection methods, etc.)	A peer review process is necessary at outset of all projects. Greater effort may be needed to involve the right people in the process to avoid funding work that is already in process.	A	A	A
			Encourage projects that include collaborative effort at the appropriate level in project solicitation and review process.	A	B	A
			The group was not able to make a recommendation on this last point. It is not clear how to motivate the various organizations within the government to communicate and share technology.			
		Industry Participation Greater industry participation in R&D projects is needed to facilitate implementation and commercialization. Navigating the cultural and bureaucratic challenges in the various government funding and reporting processes is a deterrent to many potential industry participants.	Organizations like EWI, PRCI, TWI can serve as advocates to reduce the administrative burden on industrial partners.	A	B	C
		R&D Budget Influence the congressional budgeting process with grass roots effort out of the industry. Note that funding is not restricted to domestic efforts. Industry needs to become more politically aware.	PRCI could coordinate this effort. Use positive reinforcement approach for support of DOT, MMS, etc. programs for the pipeline industry.	A	A	A

Design, Construction, Materials & Welding

Report Out

Top Five Priorities

Strain Based Design

Issue

- Industry does not have a comprehensive set of design tools for strain based design

Action Required

- Develop reliable predictive methodologies, including
  - Material characterization, inspection, construction methods and standards

Codes & Standards

Issue

- Existing code and standards are not up to date with the state of technology in the industry – design criteria, inspection, etc.

Action Required

- Fund a comprehensive review of existing standards for gaps and opportunities. The desired outcome of this review is an action plan for incorporating research results into codes and standards

Design & Construction

Issue

- Current methodologies for predicting loads on pipelines is not sufficient, particularly with regard to large scale movements.
- Many limit state methodologies are not sufficiently developed, particularly for ground movement and environmentally imposed loads. Further, there is insufficient material and site property data to support application of

Action Required

- Comprehensive program to address all associated issues
- Improve predictive tools for pipeline loading under large scale movement and adverse environmental conditions

Coatings

Issue

- Coatings are relied upon for corrosion protection of pipelines. There is a need for more effective short term testing methods to predict long term performance – wear and penetration, coating soil interactions, etc.

Action Required

- Series of research programs relating to gaps in knowledge. Workshop planned for later this year should be used as forum for establishing specific project needs.

Other Considerations

- Coordinate with existing programs already underway
- Human factors

Appendix 11
2003 R&D Forum Issues & Opportunities
Estimated Status as of 22 March 2005

Complete	In Progress	Needed	
			New Opportunities (From 2003 R&D Forum)
	x	x	Research in Mechanical Properties and Performance of High Strength Steels and Welds
			Research on High Pressure Large Diameter Plastic Pipe (Joining and non-uniform Materials)
	x	x	Research on Alternative Design Methodology
			Fracture Mechanics of Composites (Performance, Inspection)
	x	x	Technology Assessment of high strength steel and composites
			Construction and operations of composites (Bending or Alternatives, joining, CP, Inspection, Repair, Degradation)
		x	Technology Assessment of SCC
		x	Crack Growth Model for SCC and Remediation
			HTHP Service, Design, Fabrication, Testing
	x	x	NDT for Welds and Inspection
			NDT for inspection of Plastic Pipe Fusions
	x	x	Evaluation of High Productivity Welding Technologies
			High Pressure Liners for cross-country (Assess Off-Shore Approaches)
	x	x	Innovative Approaches in Pipe Joining
			New Approaches for Cheaper, Faster, Better Construction and Fabrication of PipeNew Techniques to lessen Costs of Wetland Crossings and Erosion during Construction
			New Methods of Transporting LNG and CNG other than Pipelines (Off-Shore Regasification)
		x	New Approaches to Communicating Risk (Communication with Public and Local Officials) Proactive vs Reactive
		x	New Approaches to Communicating the Value and Merit of Pipeline Systems to Local and Regional officials and public
		x	Approaches to Dealing with Encroachment Issues
	x	x	Cross-Industry Research regarding Materials

			Issues – Construction, Materials, Welding (From 2003 R&D Forum)
			Pipeline materials resistant to SCC
	x	x	Flaw Tolerance /Determine Critical Flaw Size – Fracture Initiation Models for High Strength Steel
		x	Local Buckling (High Strength Steel)
		x	Quality Control of Materials
		x	Keeping Costs Down while meeting requirements of new materials
	x	x	Yield Strength vs. Tensile Strength. Uniform Elongation

Appendix 11
2003 R&D Forum Issues & Opportunities
Estimated Status as of 22 March 2005

Complete	In Progress	Needed	
	x	x	Standardized Tensile Tests applicable to High Strength pipe
			Non-destructive equipment for testing plastic pipe joining
			X-rays – Improved imaging and interpretation of film (films or other automated processes, ultrasonics)
	x	x	Field Construction practices including welding consumables
			How to inspect CRA clad pipe
			Large/thick walled plastic – testing with different temperatures instead of just room temperature. Fracture susceptibility.
		x	Standards and Tests
			Composite materials, and composite over steel for a safer pipe (leak before rupture)
		x	Education and Communication to Public, Press and State regulators regarding new sitings
		x	Focus on Safety by examining all new projects and informing the public
		x	Better Data Collection for Communication of Risk to the Public
			Deep water technology, light weight materials for pipe systems
			Design procedures for SCR systems
			Consideration of pipelines as an integrated engineering system
			Hydrogen Economy
		x	Cross-Industry R&D Information sharing (intra-company – offshore vs onshore & liquid vs gas)
	x	x	Welding Issues in high strength steel
			Materials that are resistant to outside force
			CP in high strength steel
			Hydrogen imbrittlement in high strength pipe
		x	Mechanical properties of heat affected zone & how to measure
			Residual magnetization from pipe making and coatings (affects ILI)
	x	x	Alternative-Based Design
		x	Trenching in Artic Regions
		x	External Loads – Frost Heave
			Restoration, one-step pavement,etc.
		x	Alternatives to Pressure Testing (when water not available or cold, Water Disposal Issues)
			Locating Plastic Pipe without Tracer Wire
			Issues of re-grind material in extrusions in plastic pipe
		x	HDD in permafrost or protected marsh, protected inland areas

Appendix 12
Edison Welding Institute Technical Track Input

GOVERNMENT / INDUSTRY PIPELINE R&D FORUM
HOUSTON, TX – MARCH 22-24, 2005

Edison Welding Institute, Inc. (EWI)
Technical Track Session Input

Track 3 – Inspection / Repair / Leak Detection

Inspection – Technical Gaps and Challenges

- ***Improved Inspection Methods (AUT using Next Generation Matrix Phased Array Transducers)***

  High probability of detection and accuracy sizing of small defects with unknown orientation in pipeline girth weld is still a challenge for the current automated ultrasonic testing systems using focused multi-probes or linear phased array transducers. It is believed that the next generation of matrix phased array probes will improve detectability and sizing accuracy by manipulation of the beam in the vertical and horizontal directions and compensating for defect mis-orientation and defects interaction. There is a need for research to investigate and validate the capabilities of the next generation matrix phased array probes.

- ***Inspection of Internal Pipe Repairs using Electromagnetic and UT Techniques***

  Currently the effectives of internal pipe repairs using adhesively bonding patches onto the inside surface of a gas transmission pipeline has been demonstrated through destructive testing. There is need for research to investigate electromagnetic and acoustic nondestructive techniques as a potential solution for nondestructive validation of the integrity of internal pipe repairs.

- ***Inspection of Solid State ("Single Shot") Welding Techniques***

  With the continuous push to reduce the total life cycle cost of an 'oil well', every manufacturing step is under constant scrutiny. Solid state welding processes such as friction stir, inertia friction, flash butt, DC butt welding, etc. all offer improved productivity and quality. Unfortunately current inspection technology does not offer an acceptable technique for the highly compressive residual stress joints. There exists a need to develop an inspection technique capable of finding flaws in weldments with compressive residual stresses.

- ***Inspection of Clad Piping***

  There are inaccuracies in the determination of defect position and size in Inconel and stainless steel clad piping welds due to ultrasonic velocity variations in the weld microstructure and variations of wave propagation direction (beam skew) through the weld metal and dissimilar metal interfaces. There is a need for research to investigate, validate and qualify the capabilities of automated ultrasonic techniques for reliable inspection of dissimilar metal cladded piping welds.

For further information please contact either Nate Ames (614) 688-5135, nate_ames@ewi.org or Bob Kratzenberg (614) 688-5157, bob_kratzenberg@ewi.org

- ***POD Mapping***

  Automated Ultrasonic Testing (AUT) is gaining acceptance and implementation for critical applications. AUT offers benefits in the areas of safety, productivity and quality over radiography and other conventional inspection techniques. Unfortunately, there has been little comprehensive data generated to date that could be utilized for design and construction purposes. There is a specific need for development of a master AUT-probability of detection (POD) and –sizing accuracy study taking into account equipment type (Phased Array, Focus Probe, Frequency, etc), operator skill level, joint configuration. These data sets would allow design engineers, pipeline engineers, drilling engineers, etc. to better predict the likelihood of detecting a range of flaw sizes in pipe and plate welds. This data is critical to the correct assessment of system life and the accurate prediction of fatigue affects.

Repair – Technical Gaps and Challenges

- ***In-Service Repair of Pipelines (Sleeve Repair, Direct Deposition, Hot Tap)***

  The repair and remediation of in-service pipelines is a safety critical process that must be closely controlled, but which must nevertheless be performed using cost-effective techniques. For large diameter pipelines, the use of manual welding is time-consuming and there is a greater risk of operator error due to long welding times. Similarly, higher strength pipelines require precise weld bead placement to ensure correct tempering of previous weld runs and the electrodes conventionally used will not provide adequate weld metal properties on pipe grades above X80. There is, therefore, a need to develop advanced welding repair and remediation methods for in-service pipelines.

- ***Internal Repair of Pipelines (Carbon Fiber-Reinforced Liners)***

  The standard method for repairing a pipeline is to excavate the damaged area to permit access and repair the damage by one for the following methods: 1) Cutting out the damaged section and adding a replacement section, 2) Adding a full encirclement sleeve or clock spring, and 3) welding directly onto the pipe. The latter two repair techniques can be undertaken while the line remains in-service. While standard repair technology works well in situations where the pipe can be readily excavated, it is not applicable in cases where the pipe cannot be easily excavated. The development of Internal Pipeline Repair Technology is needed. An ongoing study funded by DOE NETL indicates that the Carbon Fiber-Reinforced Liner Repair Process exhibits benefits over both glass fiber-reinforced liners and weld deposition repairs. The project team has identified new material properties for the desired carbon fiber-reinforced liner, which are not yet commercially available. Manufacturers are currently developing raw materials that meet these requirements and a demonstration of the technology is planned. Nevertheless, there exists a need to accelerate process optimization and equipment development for the commercial introduction of this repair technology into the market.

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Appendix 12
Edison Welding Institute Technical Track Input

<u>Leak Detection – Technical Gaps and Challenges</u>

- ***Sub-Sea Connector Test***

  As oil and gas looks to deeper water and more severe environments, the ability to design pipe connectors becomes more difficult. Design engineers are pushing the limits of material properties, making environmental and fatigue affects more critical than ever before. Currently, pipe connectors are designed and tested in accordance with API and ISO specifications. However, these specifications only require singular mechanical properties. They do not attempt to combine and/or evaluate the effects of external pressure from deepwater, corrosion effects from a variety of PH levels in seawater, the abrasive and corrosion interaction of the drilling mud and crude/sand mixtures, or the inevitable combined loading situations induced by the hanging weight of the system and the fatigue typically found in subsea and above ground pipelines. <u>There is a need to develop a test sequence that would capture all this information and allow for appropriate accept/reject criteria for pipeline connectors. It is critical to the environment and pipeline/flowline integrity that such a test be developed and validated</u>.

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Appendix 12
Edison Welding Institute Technical Track Input

GOVERNMENT / INDUSTRY PIPELINE R&D FORUM
HOUSTON, TX – MARCH 22-24, 2005

Edison Welding Institute, Inc. (EWI)
Technical Track Session Input

Track 4 – Design / Construction / Materials / Welding

Design – Technical Gaps and Challenges

- ***Strain-Based Design of Pipelines***

  The majority of pipeline design codes are based on stress-based design methods. Although conventional stress-based design covers most pipeline applications, it does not cover the design of pipelines that may experience high strains in service. High strains can occur in service due to ground movement, bending over and unsupported span, and seismic loading. In such cases, pipelines should be designed based on strain capacity. The rigors of strain-based analyses pose a number of challenges, particularly related to pipeline girth welds and general materials behavior. Ongoing studies jointly funded by DOI and DOT seek to develop design and assessment guidelines for pipelines that may experience high strains in service. However, there remains a need to develop fitness for service assessment methods for strain based loading as an alternative to full scale demonstrations as a qualification methodology.

Construction – Technical Gaps and Challenges

- ***Simulation of Reeled Pipelines for Accumulated Strain and Fatigue Resistance***

  One of the unknowns associated with reeled pipe is the true accumulated strain and how it changes from the inside to the outside of the reel. Understanding this is the first step to understanding the fatigue life of reeled pipe. It is believed accumulated strain does not have a dramatic effect on fatigue performance, but to date this is only an assumption. There is a need for research directed at assessing the effects of reeling on long term pipe performance.

Welding – Technical Gaps and Challenges

- ***Cost Effective Processes for Welding / Joining High Strength Pipe (X80 and X100)***

  As material strength requirements increase the weldability of these materials proportionally decreases. It is clear that in order to meet the demands of future pipelines and flow-lines, materials such as X80 and X100 will be a necessity. Aside from the obvious switch to more advanced filler metals, it is believed that more advanced welding techniques and processes will be needed to weld these materials cost effectively. Industry is in need of a large scale program to fully characterize the welding processes with the highest probability of success for these advanced high strength alloys. Industry is quickly approaching the point where the alloys required to meet the increasingly stringent demands are considered un-weldable and thus not feasible for implementation.

- ***Application of MIAB Welding for Oil and Gas Pipelines***

  Magnetically Impelled Arc Butt (MIAB) Welding is a "single shot" method of joining pipe and tube which is capable of making finished welds in pipe up to DN450 and 10 mm wall thickness in 15 seconds, and of achieving a joint to joint cycle time of as little as 1 minute. MIAB welding has the potential of reducing production costs by as much as 15% or more. Further evaluation of the MIAB process is warranted.

- ***Friction Stir Welding of Pipe and Tubing***

  As the operators work to manage the technology gap for future programs, one of the key areas causing significant trouble is deepwater riser fatigue resistance. FSW results in a weld with compressive residual stresses which inherently improves fatigue resistance. There is a need to develop a friction stir welding technique capable of completing girth welds on pipe and tubulars.

- ***Hybrid Laser Arc Welding of Pipelines***

  In recent years the use of high strength steels has substantially reduced the cost of pipeline materials. However, alignment, welding, NDT and coating costs typically represent around 20% of the total pipeline cost and there has been little technical progress in this area since mechanized GMAW was developed and introduced in 1969. Mechanized GMAW has been successfully used for pipeline applications for over thirty years and is currently the most widely used welding process for large diameter pipelines on and offshore. As a result, mechanized GMAW has become the benchmark against which other welding processes are assessed. Over the last 20 years there has been significant interest in laser welding of pipelines and a number of programs have been undertaken to develop and evaluate laser pipeline girth welding systems. These projects have highlighted that laser welding by itself has a number of drawbacks including precise joint fit-up requirements, tight tolerance to Hi-Lo, material weldability and poor toughness properties. These drawbacks can be overcome by combining laser welding and GMAW into a single process: Hybrid Laser Arc Welding (HLAW). Further evaluation of the HLAW process is warranted.

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GOVERNMENT / INDUSTRY PIPELINE R&D FORUM
HOUSTON, TX – MARCH 22-24, 2005

Edison Welding Institute, Inc. (EWI)
Technical Track Session Input

Track 5 – Facilities / Compression / LNG

LNG – Technical Gaps and Challenges

- ***Development and Welding of Cryogenic Materials for LNG Pipelines***

  Operators are aligning their resources for focus on LNG systems. One of the industry known's is that the options are very limited as far a material are concerned. The leading alloys are currently 9Ni alloys and Invar. Most operators openly admit that there is likely a better alloy out there it just hasn't been developed yet. There is a need to develop these next generation materials and the cost effective processes required to produce high quality weld joints.

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