

Balance-of-Plant Corrosion

Program Overview

Program Description

The Balance-of-Plant Corrosion Program conducts research and provides technical support aimed at preventing piping degradation due to corrosion mechanisms. Through the implementation of advanced materials and corrosion-control methods developed in coordination with applicable engineering code and regulatory requirements, the operating lifetimes of susceptible piping systems can be safely extended.

Industry Needs and Issues Addressed

- Advances in detecting, monitoring, and mitigating corrosion in the secondary systems of nuclear power plants, which can cost plants up to \$25 million/year
- Improved understanding of corrosion product transport in boiling water reactors, flow-accelerated corrosion (FAC) in steam and feedwater systems of all types, degradation in service water systems, and degradation in raw water heat exchangers, including the main condenser
- Inspection, repair, and replacement techniques for buried piping to facilitate life extension
- Reduced number of piping and equipment failures caused by flow-accelerated corrosion
- Chemistry improvements to reduce the rates of FAC damage, and material upgrades that eliminate damage in replaced components

Impact

- Availability of high-density polyethylene (HDPE) pipe as a replacement option for degraded metal pipe (material costs 1/5 those of metal alloys, fabrication costs 1/10 to 1/20 those of metal pipe, lower unit weight, and no tendency to corrode, foul, or form tubercles)
- Computer-based training for new and reassigned plant personnel about common forms of corrosion in plant secondary systems
- Easy-to-use "Corrosion Calculators" allowing plant personnel to predict and focus inspections on the most common forms of corrosion in plant secondary systems
- Robust inspection technology and utility guidance to assess the health of large-diameter, intermediate-diameter, and small-diameter buried piping
- Inspection technologies for difficult-to-access locations susceptible to FAC
- FAC mitigation techniques to reduce the probability of large-bore pipe ruptures and other forced power reductions
- Improved guidance, predictive software, and proactive piping replacements to reduce the number of piping inspections (by up to 25% over a 6-year period, saving \$250,000 per outage per plant)
- Identification of new FAC vulnerabilities before leaks occur
- Technical guidance and training focused on practical tools to inform FAC inspections

Key Accomplishments

- Tensile and fatigue property data of types 3408 and 4710 high-density polyethylene
- Development and approval of American Society of Mechanical Engineers (ASME) Code Case N-755 to allow high-density polyethylene to be used in buried ASME Class 3 piping systems
- Effects of boiling water reactor and pressurized water reactor chemistry changes on FAC
- Improved technology to inspect buried service water piping for corrosion damage
- Computer-based training modules and computational tools to evaluate common forms of degradation and to train plant personnel on controlling common forms of corrosion
- Updates to CHECWORKS software based on user input

- Guidance for controlling erosion in FAC-susceptible systems
- Less conservative methodologies for determining the amount of FAC-caused degradation in piping components
- Guidance on the use of material alloy analyzers to reduce the number of FAC inspections

Current Year Objectives

- Stress intensification factors for pipe fittings constructed of Type 4710 high-density polyethylene
- Long-term creep rupture and slow crack growth data for Type 4710 high-density polyethylene
- Condition assessment of large-diameter buried piping
- Pitting detection in service water piping systems with radiographic scanning systems
- Boiling water reactor bottom head drain inspection tool
- CHECWORKS Version 3.0 software
- Small-bore piping strategy for FAC mitigation
- Self-assessment guidance for FAC programs

Industry Involvement

Estimated 2009 funding: \$0.7

Program Technical Lead

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Summary of Projects

Project Number	Project Title	Value
	BOP Corrosion Technology Development (base)	A 1998 Electric Power Research Institute (EPRI)-funded study found the cost of corrosion in the secondary systems of the U.S. nuclear fleet to total approximately \$2586M/year, or an average of ~\$25M/plant/year. The largest components of these costs were associated with corrosion product transport in boiling water reactors (BWRs), flow-accelerated corrosion in steam and feedwater systems of all types of U.S. nuclear plants, degradation in service water systems, and degradation in raw water heat exchangers, including the main condenser. Without proactive intervention, these costs are expected to increase as the plants age. One of the issues for approval of plant life extension has been the health of buried piping. Inspection, repair, and replacement of these lines when required can be extremely expensive, particularly buried lines that pass underneath buildings and equipment.
	BOP Corrosion CHECWORKS Users Group (CHUG) (supplemental)	The CHECWORKS User Group (CHUG) provides experience sharing to its members (> 260 nuclear plants worldwide), provides training to new and reassigned personnel, maintains and provides updates to the CHECWORKS software, operates a dedicated website, and sponsors related research as requested by its members. This includes the development of inspection technology for the BWR bottom vessel drain line, which if ruptured would cause a small break loss of coolant accident (LOCA), and research and guidance to address detection of erosion damage in high-energy piping systems.

Project Number	Project Title	Value
	BOP Services	Balance of Plant Corrosion (BOPC) services support individual member needs for technical assistance or technology implementation to address mitigation of piping degradation.
	Buried Pipe Integrity Group (BPIG)	Buried pipes in nuclear power plants are susceptible to leaks and failures. Small leaks can be difficult to locate and all types of leaks can be expensive to repair due to accessibility issues. Many leaks also can require a plant shutdown to repair. A broad based and comprehensive program is needed to support plants effort to reduce the probability and consequences of failure to an acceptable level. The BPIG will provide a forum for exchange of utility experience data and effective program activities.

Project Descriptions

BOP Corrosion Technology Development (base) (052459)

Issue

Corrosion in the secondary systems of nuclear plants can result in annual costs of up to \$25 million per plant. These costs are primarily associated with corrosion product transport in boiling water reactors, flow-accelerated corrosion in steam and feedwater systems of all types of nuclear plants, degradation in service water systems, and degradation in raw water heat exchangers, including the main condenser. Without intervention, these costs will increase as plants age. A specific issue impacting plants considering life extension is the health of buried piping. Inspection, repair, and replacement of these lines can be extremely expensive, particularly in buried lines that pass beneath buildings and equipment.

Description

The Balance of Plant Corrosion (BOP Corrosion) Program develops the technology, tools, and software to cost-effectively address corrosion issues in the BOP portions of nuclear power plants. BOP Corrosion has spearheaded the development of improved inspection technology to assess the health of secondary systems and the use of alternate materials to reduce cost and improve the service life of BOP piping and components.

Value

- Provide the data and methodology to allow use of high-density polyethylene as an option to repair or replace corroding steel piping systems in American Society of Mechanical Engineers (ASME) Class 3 service water systems.
- Develop computer-based modules to train new and reassigned plant personnel on the most common forms of corrosion in the secondary systems of nuclear plants.
- Develop easy-to-use "Corrosion Calculators" to allow predictions and focused inspections of the most common forms of corrosion found in plant secondary systems.
- Develop robust inspection technology and guidance to assess the health of large-diameter, intermediate-diameter, and small-diameter buried piping.
- Develop inspection technology to assess the health of the bottom head drain line of boiling water reactor plants. Technology to inspect this line does not currently exist, and a leak or rupture of this line would constitute a small-break loss of coolant accident.

How to Apply Results

Data supporting the use of high-density polyethylene as a repair and replacement option for corroded steel service water systems has been provided to ASME and is available for members to incorporate into code cases. Computer-based training modules are available to members and can be modified for plant-specific information. Corrosion Calculators can be accessed on EPRIweb, eliminating the need for plant owners to install and support such software, and inspection tools for buried piping are being tested at host sites.

2009 Products

Product Title & Description	Planned Completion Date	Product Type
Seismic Damping Values for Type 4710 High density Polyethylene: Products include a technical report containing the raw test data along with data analysis and interpretation.	12/31/2009	Technical Report
Workshop: Design, Fabrication, Installation, and Inspection of High Density Polyethylene Piping Systems: Workshop proceedings provide information on HDPE installation and application.	12/31/2009	Technical Resource
Recommendations for an Effective Program to Control the Degradation of Buried Pipe: This guideline document provides members with information supporting the life assessment of buried pipe and application of mitigation technology. This document should be viewed as a living document and subject to periodic revision as more data, application experience, and technology become available.	12/23/2009	Technical Update
Use of Instrumented Vehicles for Condition Assessment of Intermediate Diameter Buried Pipe: This product supports below-ground condition assessment using an advanced inspection vehicle for intermediate-sized piping.	12/23/2009	Technical Update
Capacity Testing of Cured-in-Place Pipe: This product supports the development of technical basis information to promote the acceptance of ASME Code Case N-589 for implementation of cured-in-place pipe for safety class systems.	12/23/2009	Technical Update
Crack Growth Testing of HDPE Pipe: This product summarizes performance testing of high-density polyethylene pipe in severe conditions (high-strain rates with existing cracking) to demonstrate the suitability of this material for safety class systems.	12/23/2009	Technical Update
Calculator for Risk Ranking of Buried Pipe: This software product enables members to rank the susceptibility of buried pipe systems to degradation and assess the mitigation needs for these systems.	12/23/2009	Software

BOP Corrosion CHECWORKS Users Group (CHUG) (supplemental) (052460)

Issue

Although industry efforts have been effective in reducing the number of piping and equipment failures caused by flow-accelerated corrosion (FAC), piping and components will continue to degrade as plants age. Refined guidance on where to inspect, chemistry improvements to reduce damage rates, and material upgrades for replaced components is challenged by economic considerations, short outages, and personnel turnover.

Mechanical pipe degradation caused by cavitation, liquid droplet impingement, flashing, and solid particle erosion can affect personnel safety and cause power losses. Damage caused by these mechanisms is nonlinear with time and often results from off-normal operations.

Description

The CHECWORKS User Group (CHUG) applies experience from about 260 nuclear plants worldwide to address existing and emerging issues related to flow-accelerated corrosion. CHUG provides training to new and reassigned personnel, maintains and provides updates to the CHECWORKS software, operates a dedicated website, and sponsors related research as requested by members. This includes research and guidance to address detection of erosion damage in high-energy piping systems.

Value

- Minimize risk to personnel by reducing the probability of large-bore pipe ruptures
- Reduce forced power reductions through FAC mitigation
- Reduce the number of piping inspections through improved guidance, predictive software, and piping replacements (some plants have observed a 25% reduction over a six-year period with average savings of ~\$150,000 per outage per plant)
- Develop practical tools to reduce FAC risks; for example, material alloy analyzers can be used to reduce the number of inspections
- Identify new FAC vulnerabilities before leaks occur
- Train new and reassigned plant engineers on FAC identification, monitoring and mitigation
- Facilitate interaction with industry peers and ease access to reports and other information

How to Apply Results

Members use CHECWORKS to predict plant degradation and reduce unneeded piping inspections. Results of related research such as guidance for use of pipe alloy analyzers, guidance on erosion, and investigations into low-temperature FAC provide members with information to optimize inspection locations. Members can access training for new and reassigned personnel and can use the CHUG website to facilitate communications between FAC personnel at member plants.

2009 Products

Product Title & Description	Planned Completion Date	Product Type
<ul style="list-style-type: none"> • CHEC WORKS Users Group (CHUG) Meetings: Membership in CHUG includes the following: <ul style="list-style-type: none"> • User group meetings (twice per year) to exchange FAC experiences and obtain the latest industry information • Attendance at training courses at a reduced fee • Technical support • Access to a dedicated web site • Updates to the Plants Experience Reports Database, which documents recent plant FAC experiences • Results of technical investigation into high priority technical issues as directed by the membership • Updates to the CHECWORKS Steam/Feedwater Application and related documentation. • Software distribution 	12/18/2009	Workshop, Training, or Conference
<p>Method for evaluating Multiple Inspection Data sets: Develop a method for examining multiple sets of similar inspection data. The approach uses a combination of the Fast Delta Method (currently used in CHECWORKS) with a least squares curve fit. The project would examine the suitability of this method by comparing results of multiple inspection data sets with current methods.</p>	12/8/2009	Technical Report
<p>Optimization of BWR FW FAC Inspections: Depending on factors including specific station chemistry, some boiling water reactor stations have found negligible wear in the feedwater system. This project will determine when FAC inspections could be deferred or eliminated, provided that plant conditions are not impacted by changes from power uprates, configuration alignment, chemistry, and other factors.</p>	11/18/2009	Technical Update

Future Year Products

Product Title & Description	Planned Completion Date	Product Type
<p>New projects will be added to address ongoing needs, as identified by the members and EPRI.</p>	2010	Technical Resource

BOP Services (065828)

Issue

Implementation of new and advanced technology for buried piping applications may require technical support and coordination with member plants and vendors.

Description

This project supports individual member needs for technical assistance or technology implementation to mitigate piping degradation.

Value

- Assist members in implementing new technology

How to Apply Results

Members secure service support outside of the base-funded program. Project activities in this area are selected by members to meet emerging issues/needs.

2009 Products

Product Title & Description	Planned Completion Date	Product Type
Project selected by individual funding utility: Products will be based on member input and requirements.	12/23/2009	Technical Resource

Buried Pipe Integrity Group (BPIG) ()

Issue

Buried pipes in nuclear power plants are susceptible to leaks and failures. Small leaks can be difficult to locate and all types of leaks can be expensive to repair due to accessibility issues. Many leaks will require a plant shutdown for repair. A broad-based and comprehensive program is needed to support plant efforts to reduce the probability and consequences of failure to an acceptable level. Buried piping has become a more visible issue with regulatory emphasis on material aging issues and plant life extension requirements.

Description

The Buried Pipe Integrity Group (BPIG) provides a forum for exchanging plant experience and supporting the implementation of advanced buried pipe assessment and mitigation technology.

Value

- Assess the health of existing piping and determine remaining service life
- Develop methods to repair buried piping in situ
- Select and qualify alternate materials and service environments (for example, high-density polyethylene, water treatment, and cathodic protection)

How to Apply Results

Members will apply the results of this project in developing effective buried pipe integrity programs and in assessing and maintaining existing buried piping systems.

2009 Products

Product Title & Description	Planned Completion Date	Product Type
Buried Pipe Integrity Group Meetings: The Buried Pipe Integrity Group (BPIG) workshops/meetings will provide an interactive forum for members, vendors, EPRI, and other experts to share buried pipe experience information, advancing efforts to extend buried pipe life and mitigate corrosion in these systems.	12/23/2009	Workshop, Training, or Conference
Buried Pipe Integrity Group Meetings: The Buried Pipe Integrity Group (BPIG) workshops/meetings will provide an interactive forum for members, vendors, EPRI, and other experts to share buried pipe experience information, advancing efforts to extend buried pipe life and mitigate corrosion in these systems.	12/23/2009	Workshop, Training, or Conference

Product Title & Description	Planned Completion Date	Product Type
Buried Pipe Reliability Products as selected by BPIG members: The members of the Buried Pipe Integrity Group will meet twice a year and, through a consensus process, select supplementally funded projects to address emerging buried pipe issues. The products resulting from these research and development activities will be available to the BPIG members.	12/23/2009	Technical Resource
Future Year Products		
Product Title & Description	Planned Completion Date	Product Type
Buried Pipe Integrity Group Meetings, 2 per year: The Buried Pipe Integrity Group (BPIG) workshops/meetings will provide an interactive forum for members, vendors, EPRI, and other experts to share buried pipe experience information, advancing efforts to extend buried pipe life and mitigate corrosion in these systems.	2010	Workshop, Training, or Conference
Recommendations for an Effective Buried Pipe Program, Update: This product provides information on assessment, repair, mitigation, materials, and life extension technology for buried piping.	2010	Technical Update
Buried Pipe Integrity Group Meetings, 2 per year: The Buried Pipe Integrity Group workshops/meetings will provide an interactive forum for members, vendors, EPRI, and other experts to share buried pipe experience information, advancing efforts to extend buried pipe life and mitigate corrosion in these systems.	2010	Workshop, Training, or Conference
Recommendations for an Effective Buried Pipe Program, Update: This product provides information on assessment, repair, mitigation, materials, and life extension technology for buried piping.	2010	Technical Update
Buried Pipe Reliability Products as selected by BPIG members: The members of the Buried Pipe Integrity Group will meet twice a year and, through a consensus process, select supplementally funded projects to address emerging buried pipe issues. The products resulting from these research and development activities will be available to the BPIG members.	2010	Technical Resource