Balance-of-Plant Corrosion

Program Overview

Program Description

Corrosion in the secondary side of nuclear power plants costs individual plants up to $25 million per year for detection, monitoring, and mitigation. Improved understanding of corrosion product transport in boiling water reactors, flow-accelerated corrosion (FAC) in steam and feedwater systems of all types, and degradation in service water systems is necessary to develop effective inspection and repair techniques. Growing regulatory attention to the condition of buried piping presents another emerging issue with industrywide technical implications, including relicensing.

The Balance-of-Plant Corrosion Program (BOPC) 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.

Research Value

Research results from the Balance-of-Plant Corrosion Program help nuclear power plants more readily identify corrosion locations, make informed run/repair/replace decisions, reduce the risk of pipe ruptures and power reductions, consider alternative piping material replacement options, and respond to emerging industry issues such as buried piping. BOPC participants gain access to the following:

- Technical results enabling the use of high-density polyethylene 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).
- 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 an estimated $250,000 per outage per plant).
- Computer-based training for new and reassigned plant personnel about common forms of corrosion in plant secondary systems.
- Robust inspection technology and guidance to assess the health of large-diameter, intermediate-diameter, and small-diameter buried piping.
- Mitigation technology to address buried pipe degradation.
- 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.

Approach

The Balance-of-Plant Corrosion Program develops the technology, tools, and software to cost-effectively address corrosion issues in the balance-of-plant (BOP) portions of nuclear power plants. The program has spearheaded the development of improved inspection technologies 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.

- Develop technologies to accurately and cost-effectively detect, monitor, and mitigate corrosion in the secondary systems of nuclear power plants.
- Improve the understanding of corrosion product transport in boiling water reactors, 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.

- Develop and demonstrate inspection, repair, and replacement techniques for buried piping to facilitate life extension.
- Develop and maintain software products such as CHECWORKS to predict plant degradation and reduce unneeded piping inspections and BPWORKS to provide a risk-ranking of buried piping systems.
- Manage user group forums focused on corrosion and buried pipe to exchange utility experience and data and identify industrywide improvement opportunities.

Accomplishments

Electric Power Research Institute's (EPRI's) Balance-of-Plant Corrosion Program supports nuclear power industry efforts to mitigate piping degradation, spanning technical guidance, software tools, technical training, and user forums.

- Collected tensile and fatigue property data to support technical justification for use of high-density polyethylene for safety and non-safety piping systems (ASME Code Case N-755).
- Analyzed the effects of boiling water reactor and pressurized water reactor chemistry changes on FAC.
- Developed improved technology to inspect buried service water piping for corrosion damage.
- Developed computer-based training modules and computational tools to evaluate common forms of degradation and to train plant personnel on controlling common forms of corrosion.
- Established less conservative methodologies for determining the amount of FAC-caused degradation in piping components.
- Formulated guidance on the use of material alloy analyzers to reduce the number of FAC inspections.

Current Year Activities

Balance-of-Plant Corrosion Program R&D for 2010 will continue research efforts related to detection and mitigation of corrosion in piping systems. Specific efforts will include the following:

- Develop stress intensification factors for pipe fittings constructed of Type 4710 high-density polyethylene.
- Acquire long-term creep rupture and slow crack growth data for Type 4710 high-density polyethylene.
- Update and improve BPWORKS software for risk-ranking of buried piping.
- Evaluate pitting detection in service water piping systems with radiographic scanning systems.

Estimated 2010 Program Funding

$2.7 million

Program Manager

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Summary of Projects

Project Number	Project Title	Description
P41.05.05.01	CHECWORKS Users Group (CHUG)(QA)	Through industry guidance for effective flow-accelerated corrosion programs, comprehensive software, and member dialogue including interactive web, industry conferences, and other communication, this project develops tools for organizing and prioritizing nuclear power plant approaches to code acceptance of degraded piping.
P41.05.05.02	Buried Pipe Integrity Group (BPIG)	Through guidance for effective buried pipe programs, risk-ranking software, and industry dialogue including interactive web, industry conferences, and other communication, this project develops tools for organizing and prioritizing nuclear power plant approaches to code acceptance of degraded piping.
P41.05.05.02a	Buried Pipe Integrity Group	Through guidance for effective buried pipe programs, risk-ranking software, and industry dialogue including interactive web, industry conferences, and other communication, this project develops tools for organizing and prioritizing nuclear power plant approaches to code acceptance of degraded piping.
P41.05.05.05	BOP Corrosion Technology Development (base)	Through guidance for effective buried pipe programs, risk-ranking software, and industry dialogue including interactive web, industry conferences, and other communication, this project develops tools for organizing and prioritizing nuclear power plant approaches to code acceptance of degraded piping. Through guidance for effective flow-accelerated corrosion programs, comprehensive software, and member dialogue including interactive web, industry conferences, and other communication, this project helps nuclear power plants to maintain strong stewardship over generation assets.

CHECWORKS Users Group (CHUG)(QA) (052460)

Key Research Question

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.

Approach

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.

Impact

- 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 estimated savings of $2,150,000 per outage per plant)
- Develop practical tools to reduce FAC risks, such as material alloy analyzers that 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. Technical guidance related to pipe alloy analyzers, erosion, and 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.

2010 Products

Product Title & Description	Planned Completion Date	Product Type
New projects will be added to address ongoing needs, as identified by the members and EPRI.	12/23/10	Technical Resource

Buried Pipe Integrity Group (BPIG) (068213)

Key Research Question

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.

Approach

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.

Impact

- 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.

2010 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, the Electric Power Research Institute (EPRI), and other experts to share buried pipe experience information, advancing efforts to extend buried pipe life and mitigate corrosion in these systems.	12/23/10	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.	12/23/10	Technical Update
Buried Pipe Reliability Products as selected by BPIG members: The members of the Buried Pipe Integrity Group (BPIG) 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.	12/23/10	Technical Resource

Buried Pipe Integrity Group (068003)

Key Research Question

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.

Approach

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.

Impact

- 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.

2010 Products

Product Title & Description	Planned Completion Date	Product Type
Buried Pipe Integrity Group Meetings, 2 per year	12/23/10	Workshop, Training, or Conference
Recommendations for an Effective Buried Pipe Program, Update	12/23/10	Technical Update
Buried Pipe Reliability Products as selected by BPIG members	12/23/10	Technical Resource

BOP Corrosion Technology Development (base) (052459)

Key Research Question

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.

Approach

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.

Impact

- 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 mitigation technologies to address buried pipe degradation.
- 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 the American Society of Mechanical Engineers (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.