Materials Reliability Program: Generic Guidance for Alloy 600 Management (MRP-126NP)

1009561

Final Report, November 2004

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REPORT SUMMARY

This report provides guidance for plants to use in developing their individual Alloy 600 management plans. It defines the key elements of an Alloy 600 management plan and directs readers to useful resources for developing and implementing a plant-specific plan.

Background

The EPRI Materials Reliability Program (MRP) Alloy 600 Issue Task Group (ITG) determined that every plant should have an overall plan for managing Alloy 600 primary water stress corrosion cracking (PWSCC) degradation. This decision was based on the need for the industry to stop reacting to each finding of Alloy 600 PWSCC degradation as an isolated event and start pro-actively managing the issue. A committee of Alloy 600 ITG members volunteered to produce a guidance document for plants to use in developing their Alloy 600 management plans. The committee worked with a contractor (EPRIsolutions) to prepare this document.

Objective

To document a standard guideline for plants to use in developing their Alloy 600 management plans that provides short- and long-term guidance for managing inspection, evaluation, mitigation, and repair/replacement of all Alloy 600 base material and Alloy 82/182 weld metal locations (with the exception of steam generator tubing—which is addressed in separate industry programs, including EPRI's Steam Generator Management Program—and reactor internals, which also are addressed in separate industry programs such as the EPRI MRP Reactor Internals program) in pressurized water reactor (PWR) primary systems.

Approach

The committee defined the objectives of an Alloy 600 management plan: 1) maintain plant safety; 2) minimize the impact of PWSCC on plant availability; and 3) develop and execute long-term strategies for Alloy 600 management. The committee outlined key elements of an Alloy 600 management plan in the introduction with more detail in later sections. The appendices of this document direct readers to existing resources that can be used in developing a plant-specific Alloy 600 management plan. The committee's scope was limited to Alloy 600 and its associated weld metals Alloy 82/182. MRP is still investigating properties of the replacement metals Alloy 690/52/152 and is not issuing guidance on managing Alloy 690/52/152 components at this time.

Results

This document establishes a mandatory requirement that "*Each plant shall develop and document an Alloy 600 management plan, defining the processes it intends to use to maintain the integrity and operability of each Alloy 600/82/182 component for the remaining life of the*

plant." All U.S. PWRs must implement this requirement within eighteen months of the document's issuance. Implementing the key elements listed in Table 1-1 of this document is considered good practice. The remainder of the document consists of background material and general information. Complete guidelines are provided for plants to use in developing their Alloy 600 management plans. The document offers comprehensive reference lists that newer staff can use to become more familiar with Alloy 600 PWSCC degradation. More experienced staff can use the document as an outline for preparing their Alloy 600 management plans.

EPRI Perspective

All plants need to develop and implement an Alloy 600 management plan defining the processes they intend to use to maintain the integrity and operability of each Alloy 600/82/182 component for the remaining life of the plant. This document outlines the key elements of a plant specific plan and includes comprehensive lists of available resources that plants should use in developing their plans.

Keywords

Alloy 600 management
Alloy 600 management plan
Primary water stress corrosion cracking (PWSCC)
PWSCC leakage
Stress corrosion
Boric acid corrosion
Alloy 600
Alloy 690
Alloy 82/182
Alloy 52/152
CRDM nozzle
CEDM nozzle
In-core instrument (ICI)
Bottom mounted nozzle (BMN)
Bottom mounted instrument (BMI)
J-groove weld
Reactor vessel head
Reactor vessel closure head
Reactor vessel upper head
Safety assessment
Circumferential cracking
Inspection
Probabilistic fracture mechanics

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1
INTRODUCTION

Throughout the nuclear industry, many reactor coolant system nozzles, welds and welded attachments such as instrument nozzles, nozzle safe ends, heater sleeves in pressurizer vessels, and control rod drive nozzles in the reactor vessel closure heads were manufactured of Alloy 600 materials. Alloy 600 and its associated weld materials, Alloys 82 and 182, are susceptible to primary water stress corrosion cracking (PWSCC). PWSCC has been observed in control rod drive mechanism nozzles, control element drive nozzles, pressurizer nozzles, hot leg nozzles, and bottom mounted instrument nozzles, and in J-groove welds and full penetration butt-welds. Pro-active identification of degradation areas is particularly important due to the impact on outage time, radiation exposure, and cost associated with inspections and repairs.

Each plant shall develop and document an Alloy 600 management plan, defining the processes it intends to use to maintain the integrity and operability of each Alloy 600/82/182 component for the remaining life of the plant. This plan should include consideration of mitigation (zinc, MSIP, etc.), inspection (type and frequency), repair (weld repair, overlay, or mechanical clamp), and replacement (substitute with stainless steel or Alloy 690/52/152) options.

The scope of this document is limited to Alloy 600 and its associated weld metals Alloy 82/182. The MRP is still investigating the properties of the replacement metals Alloy 690/52/152 and is not issuing guidance on managing Alloy 690/52/152 components at this time.

This document provides a recommended structure for plant specific Alloy 600 management plans and provides guidance to available resources to assist individual plants in developing their plans.

PWSCC Experience

Content Deleted – MRP/EPRI Proprietary Material

Content Deleted – MRP/EPRI Proprietary Material

Guidance Document Objective

Document a standard guideline for plants to use in developing their Alloy 600 management plan that provides short and long term guidance for management of inspection, evaluation, mitigation, and repair/replacement of all Alloy 600 base material and Alloy 82/182 weld metal locations (with the exception of steam generator tubing which is addressed in separate industry programs including EPRI's Steam Generator Management Program and reactor internals which are also addressed in separate industry programs such as the EPRI MRP Reactor Internals program area) in PWR primary systems.

Materials Guidelines Implementation Protocol

This guidance document includes a mandatory requirement on page 1-1, that *Each plant shall develop and document an Alloy 600 management plan, defining the processes it intends to use to maintain the integrity and operability of each Alloy 600/82/182 component for the remaining life of the plant.* This requirement is to be implemented at all U.S. PWRs within eighteen months of issuance of this guidance document. Implementation of the key elements listed in Table 1-1 of this document is considered good practice. The remainder of this document consists of background material and general information.

Objectives of a Plant Specific Alloy 600 Management Plan

The main objectives for each plant specific Alloy 600 management plan are listed below.

- Maintain plant safety
- Minimize the impact of PWSCC on plant availability
- Develop and execute long-term strategies for Alloy 600 management

The plan should use decision analysis expertise with engineering, operational, and financial inputs to determine the optimal strategy for Alloy 600 management. The plan shall comply with specific industry and regulatory guidance for inspections and repairs.

Key Elements of a Plant Specific Alloy 600 Management Plan

The purpose of a plant specific plan is to provide guidance for administering Alloy 600/82/182 inspections, implementing preventative actions (replacement or mitigation), and developing contingent repair plans. A plant specific Alloy 600 management plan cannot rely solely on generic assessments. Detailed plant specific information is required in order to identify and rank/prioritize locations/components to be inspected, and to detect, repair, and mitigate PWSCC cracking of Alloy 600/82/182.

Most plants have addressed PWSCC of Alloy 600/82/182 in some way as part of aging management and/or license renewal activities. Important resources for these activities include NUREG-1800, Standard Review Plan for Review of License Renewal Applications for Nuclear Power Plants, July, 2001 and NUREG-1801, Generic Aging Lessons Learned (GALL) Report (Vol 1 and Vol 2), July, 2001.

The NRC outlined ten attributes for evaluation of generic aging management programs in NUREG-1801. These attributes are also suited to managing Alloy 600/82/182, and have been incorporated here. Table 1-1 lists the NRC attributes along with the associated key elements to be included in a plant specific Alloy 600 management plan document[1].

Table 1-1
Key Elements of a Plant Specific Alloy 600 Management Plan Document

	NRC Evaluation Attribute	*Alloy 600 Management Plan Document Elements*
1	Scope of Program	• Alloy 600/82/182 locations and inspection programs • Assigned responsibilities for Alloy 600 management (including individuals from multiple disciplines and departments) • Implementation plans (modification packages, budget, scheduling, etc.) with contingency planning
2	Preventative Actions	• Plan for implementation of Alloy 600/82/182 mitigation strategies • Plan for possible replacement of components as preventative action
3	Parameters Monitored/Inspected	• Detailed data (including location, component function, service history, temperature, operating environment, fabrication records, etc.) about components containing Alloy 600/82/182 to be used in inspection ranking
4	Detection of Aging Effects	• Plant specific inspection plan for detection of PWSCC cracking designed to detect any PWSCC cracking before it impacts plant safety and operability • Plant specific inspection matrix listing applicable inspection techniques for each type of Alloy 600/82/182 component/weld
5	Monitoring and Trending	• Inspection schedule that meets Code and regulatory requirements for Alloy 600/82/182 locations {In-Service Inspection (ISI), Pre-Service Inspection(PSI)} and incorporates results from previous inspections
6	Acceptance Criteria	• Reference to applicable Code and regulatory requirements for Alloy 600/82/182 locations (ASME and NRC requirements) for evaluation of inspection results
7	Corrective Actions	• Procedures for disposition of inspection findings • Plant specific repair matrix listing acceptable repair techniques for each type of Alloy 600/82/182 component/weld
8	Confirmation Process	• Reference to site quality assurance procedures and associated regulations
9	Administrative Controls	• Reference to site quality assurance procedures and associated regulations

[1] Items may be included via reference to another plant or industry document.

	NRC Evaluation Attribute	Alloy 600 Management Plan Document Elements
10	Operating Experience	• References to Industry Alloy 600/82/182 experience • Schedule for periodic review of industry data on available inspection, repair, and mitigation technologies and lessons learned from industry experience

It is recommended that each plant draw upon industry and plant specific knowledge, operational, engineering, and field service experiences when drafting a plant specific Alloy 600 management plan.[2]

[2] See Appendix A for specific examples of PWSCC of Alloy 600/82/182.

2 ASSIGNED RESPONSIBILITIES AND INTERFACES

A key element of the Alloy 600 management plan is assignment of responsibilities to the various organizations involved in managing Alloy 600. These assignments should be clearly documented and should include all organizations that have specific responsibilities in the management of Alloy 600/82/182.

Senior Management

Senior management is ultimately responsible for the successful implementation of an Alloy 600 management plan at any site.[3]

Management Plan Ownership

The ownership of the plan should be clearly delineated; explaining which department and position is responsible for the overall implementation of the plan. For multi-site organizations, the overall plan owner may be from the corporate organization, but in this case there should be clear assignment of site ownership as well to ensure all site functions are appropriately managed and interfaced with the overall plan. There should be clear ownership for tracking and trending of inspection results with an assigned individual or group. The plan should identify a clear chain of responsibility and lines of communication.

Other Disciplines

The Alloy 600 management plan should document responsibilities of all plant and corporate organizations that are important to the success of the plan where those responsibilities are beyond their normal everyday activities. Plant and corporate organizations that may be involved include business planning, project management, plant maintenance, design engineering, systems engineering, program engineering, procurement, ALARA/radiation protection, operations, and the Non-Destructive Evaluation (NDE) team.

[3] Reactor Pressure Vessel Head Degradation at Davis Besse, LER 2002-002-00 Principles for Effective Operational Decision Making, INPO, December 2001.

Interfaces

The Alloy 600 management plan will also interface with or be a part of several existing plant and corporate programs. The Alloy 600 management plan should not duplicate processes or procedures located within Equipment Reliability, Corrosion Control, or In-service Inspection programs, but should interface with these programs where appropriate. Finally, as long as Alloy 600/82/182 is present in the plant there is some potential for cracking, leakage, and failure. The consequences of this must be understood in order to prioritize inspection, mitigation, and replacement efforts. Most component failures due to PWSCC of Alloy 600/82/182 are bounded by existing FSAR analysis in the licensing basis for operating reactors and generic safety assessments have been performed for many locations. The Alloy 600 management plan should interface with the plant analysis group (i.e. the group that understands LOCA analysis) to verify that failure at a specific location is bounded by existing analysis.[4]

[4] Any potential failure that is not bounded by existing analysis should be entered in the plant corrective action program and reported to the MRP and the associated OG for determination of the generic implications.

3
INDUSTRY EXPERIENCE

It is extremely important that personnel responsible for the Alloy 600 management plan be very familiar with the experience of the industry with respect to Alloy 600/82/182 degradation. Responsible personnel need to keep up with industry operating events and incorporate changes to their plan based on the new knowledge gained by experience. Personnel responsible for the Alloy 600 management program should participate in industry meetings and initiatives. Other resources of information on industry events include:

- Nuclear Regulatory Commission (NRC), Licensee Event Reports (LERs), Notices, etc., www.nrc.gov
- Owners Groups – Babcock & Wilcox (BWOG), Westinghouse (WOG), Combustion Engineering (CEOG, now merged with WOG)
- Institute of Nuclear Power Operators (INPO)
- World Association of Nuclear Operators, www.wano.org
- Electric Power Research Institute (EPRI), www.epri.com
- EPRI Materials Reliability Program (MRP) Alloy 600 Issue Task Group (ITG)

Appendix A of this document includes a table of key industry events. The remaining appendices of this document (with the exception of Appendix F) list reports and program initiatives that have been completed by EPRI, the NRC, and the owners groups. There are separate appendices for resources related to Alloy 600/82/182 locations, inspections, mitigation, component ranking and susceptibility, and repair/replacement. Appendix H lists assorted EPRI and NRC resources that do not fall into these specific categories, and Appendix I does the same for owners group resources.

4
DETERMINE ALL ALLOY 600/82/182 LOCATIONS

Another key element of an Alloy 600 management plan is a comprehensive list of all PWR Reactor Coolant System (RCS) components utilizing Alloy 600 base metal and Alloy 82/182 weld metal. Generic and plant specific locations have been identified in various documents prepared by the NSSS Owners Groups and EPRI. These documents should be reviewed and included or referenced in each plant's Alloy 600 management plan Alloy 600 location list.

Generic Locations

Information on generic locations is available from several sources. The data provided in this document and the reports referenced here should be reviewed in order to develop a list of generic locations applicable to each plant's design. The scope of components that are known to contain Alloy 600/82/182 in at least some plant designs[5] includes:

- Reactor Vessel Heads
- Reactor Vessel Hot Leg Nozzles
- Reactor Vessel Cold Leg Nozzles
- Reactor Vessel Bottom Mounted Nozzles
- Steam Generator Primary Nozzles
- Pressurizer
- Heat Exchangers
- Piping
- Reactor Coolant Loop Pipe Branch Connections
- Attachments and internal sub-components of any of the above noted components

The following table lists some typical locations of Alloy 600/82/182 for each NSSS type. These are generic locations; each individual plant will need to verify whether these locations are applicable. Additional references for NSSS generic and plant specific locations are included in Appendix B.

[5] This document is not intended to address Alloy 600 in steam generator tubing, the industry has a separate program for this issue, EPRI's Steam Generator Management Program.

Table 4-1
Typical Locations of Alloy 600/82/182 Type Materials in PWR Plants Designed by Westinghouse, Combustion Engineering, and Babcock & Wilcox

Location	Westinghouse Design Plants	Combustion Engineering Design Plants	Babcock & Wilcox Design Plants
Large Diameter (>4") Reactor Vessel Head Nozzles			
- Top Head CRDM/CEDM	Yes	Yes	Yes
- Top Head ICI	No	Yes	No
Small Diameter Nozzles (<4.0")			
- Pressurizer Steam Space Instrument	No	Yes	Yes
- Pressurizer Liquid Space Instrument	No	Yes	Yes
- Reactor Vessel Top Head Vent	Yes	Yes	No
- Reactor Vessel Top Head Thermocouple	No	No	Yes (Note 3)
- Reactor Vessel Head Leak Monitor Tubes	Yes	Yes	Yes
- Hot Leg Instrument	No (Note 6)	Yes	Yes
- Cold Leg Instrument	No	Yes	Yes
- Reactor Vessel Bottom Head Instrument	Yes	Yes(Note 5)	Yes
- Steam Generator Bowl Drain	Yes	Yes	Yes
Pressurizer Heater Sleeves	No	Yes	Yes (Note 2)
Reactor Vessels			
- Inlet & Outlet Nozzle	Yes	No (Note 1)	No
- CRDM Motor Housing	No	Yes	Yes (Note 7)
- Core Flood Nozzle	NA		Yes
Pressurizers			
- Surge Line Nozzles	Yes	Yes	Yes
- Spray Nozzles	Yes	Yes	Yes
- Safety & Relief Valve Nozzles	Yes	Yes	Yes
Main Coolant Piping Loop			
- SG Inlet & Outlet Nozzles	Yes	No	No
- RCP Suction & Discharge Nozzles	No	Yes	Yes
Branch Line Connections			
- Pipe-to-Surge Nozzle Connection	No	Yes	Yes
- Charging Inlet Nozzles	No	Yes	Yes
- Safety Injection and SDC Inlet (Note 4)	No	Yes	Yes
- Shutdown Cooling Outlet Nozzle	No	Yes	Yes
- Spray Nozzles	No	Yes	Yes
- Let-Down and Drain Nozzles	No	Yes	Yes
- Core Flood Tank Nozzle	NA		Yes
Steam Generator Divider Plate/Weld	Yes	Yes	No
Steam Generator Tube Sheet Cladding	Yes	Yes	Yes
Core Support Blocks/Alignment Lugs	Yes	Yes	Yes
Flow Element	N/A	N/A	Yes
Steam Generator Nozzle Dams	No	Yes (Note 8)	Yes
Flow Meter	N/A	N/A	Yes

1. One CE design plant has Alloy 82/182 welds and is therefore similar to the Westinghouse design plants.
2. Oconee 1 and TMI 1 only.
3. Applies only to TMI 1 since the Oconee 1 replacement head has no thermocouples.
4. B&W terminology for "safety injection" nozzle is "high pressure injection (HPI)" nozzle.
5. Palo Verde Only.
6. Some plants may have used Alloy 600 in plant modifications for RTD bypass elimination.
7. Type A and B plants have Alloy 600, type C plants do not.
8. May be removed for replacement steam generators.

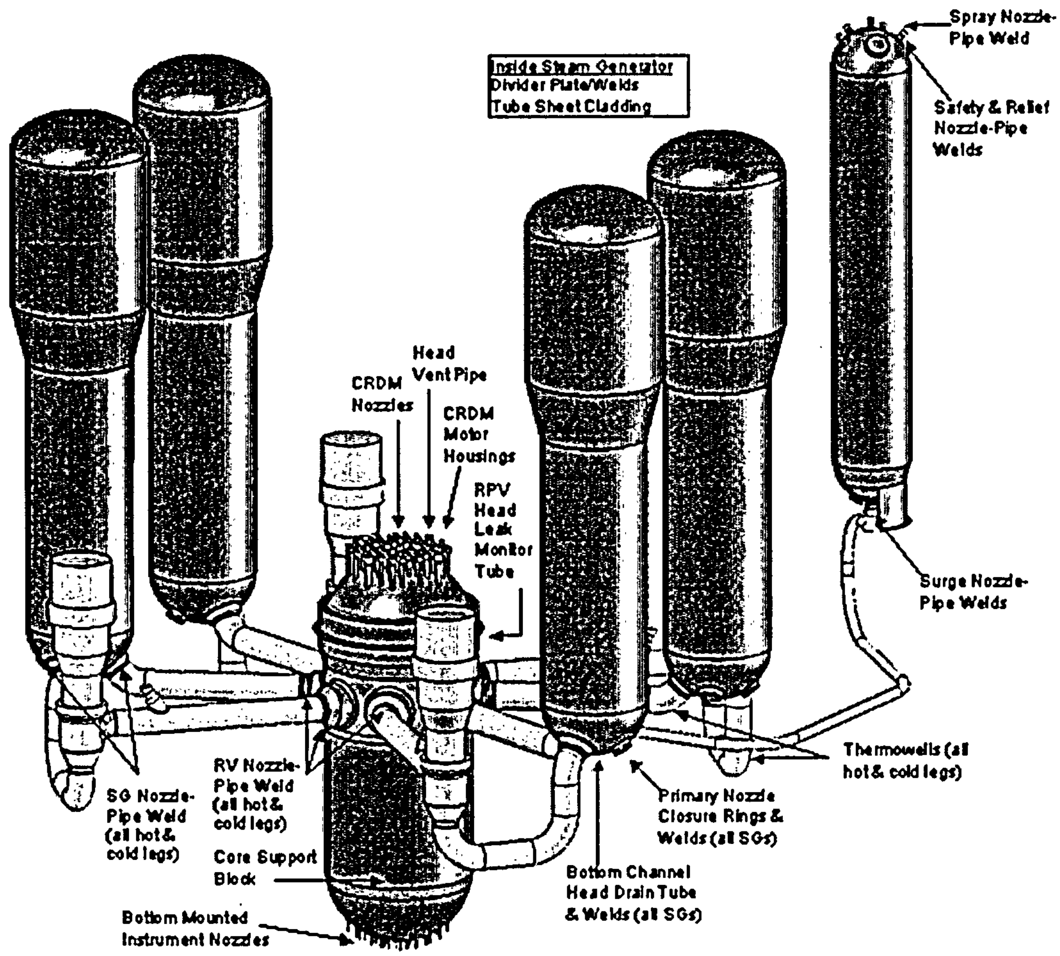

Figure 4-1
Typical Alloy 600 Locations in Westinghouse Plants

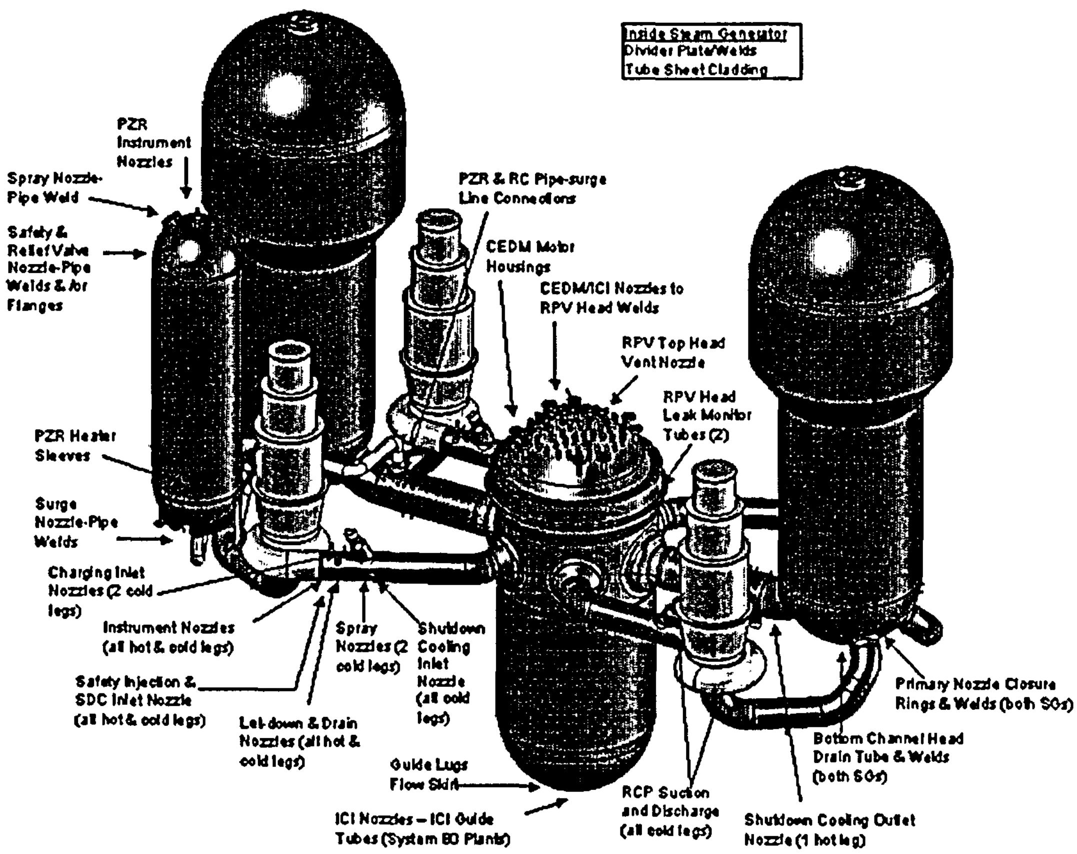

Figure 4-2
Typical Alloy 600 Locations in CE Plants

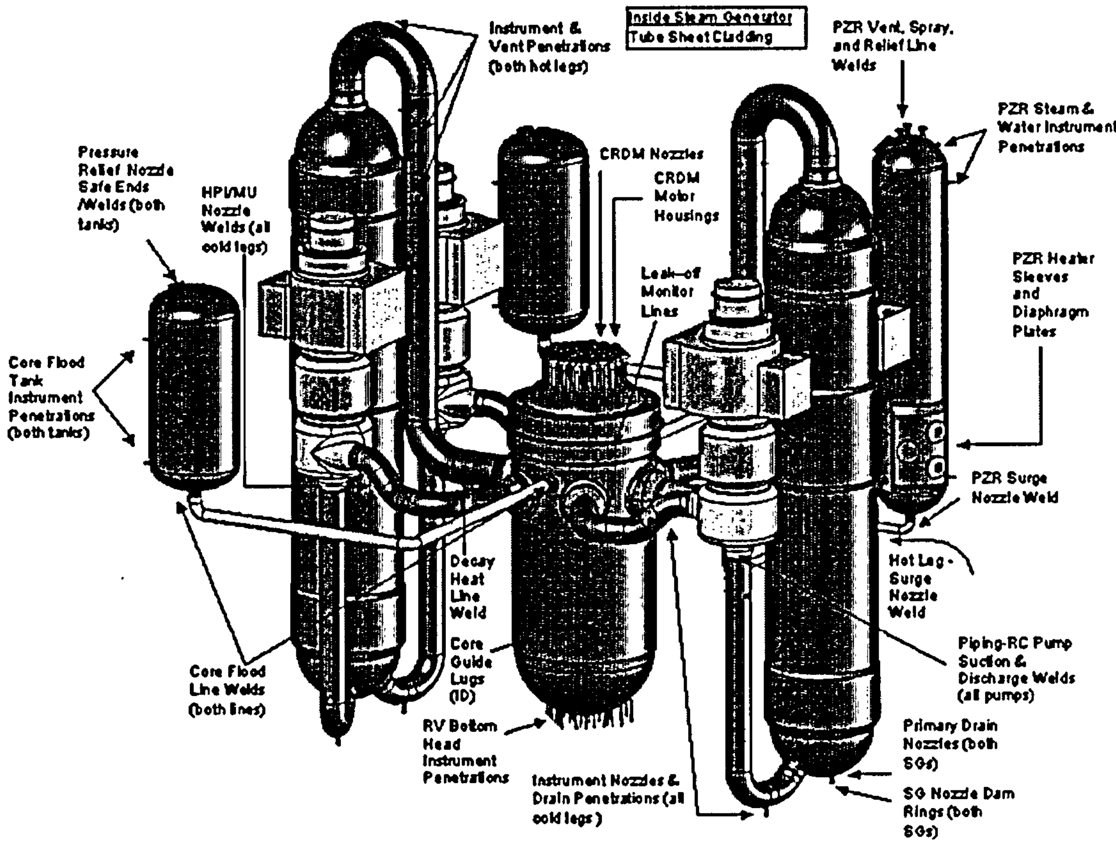

Figure 4-3
Typical Alloy 600 Locations in B&W Plants

Specific Plant Identification

Each plant's documented response to the Request for Additional Information on 60-Day Responses to NRC Bulletin 2002-01, "Reactor Pressure Vessel Head Degradation and Reactor Coolant Pressure Boundary Integrity" contains a complete list of Alloy 600/82/182 locations in their plant. This document should be reviewed and referenced by utilities for their plant specific location list in the Alloy 600 management plan. Each plant should verify and document if Alloy 600/82/182 is present at the generic locations and include other locations that may not be generic (e.g., plant specific modifications). Useful information should be available in the plant specific ISI plan. Documentation in support of license renewal activities (if applicable) also identifies all Alloy 600/82/182 locations. Other sources of information include design drawings and specifications, Certified Material Test Reports (CMTRs), weld documentation, and plant specific inquiries to NSSS vendors. Materials codes should be available from Westinghouse, CE, and B&W. The B&WOG Materials Committee has developed a comprehensive list of Alloy 600/82/182 locations for each of its members. Responsible personnel should consider that actual as built data may vary from design.

If a plant intends to use a plant specific susceptibility ranking to prioritize locations as part of their overall management plan, they will need additional information beyond simple identification of the specific locations. Material properties, fabrication history, and operating conditions can affect the susceptibility of various components. Various susceptibility models may need the following types of input:

- Service temperatures and times at temperatures
- Ranges of stress states
  - Operating and thermal stress
  - Fabrication history (stress relief, hot work, cold work, repair)
- Metallurgical characteristics
- Fatigue history of the component
- Industry experience

This information may also be found in resources such as:

- System or component drawings with dimensions, materials, weld preps, and weld process
- ASME material designations for base material and weld material
- Construction and fabrication records, CMTRs, and post weld treatment records
- Original manufacturing details such as sequence of manufacturing steps, PWHT time and temperature, pre-service NDE performed, any deviation reports or repairs
- NDE, PSI, and ISI schedules and results
- ISI identification number if in plan, ISI planned inspections, ISI past inspections
- Installed location information regarding ease of access, type of insulation, dose rate, a picture of the component, etc.

Once the plant specific Alloy 600/82/182 locations and associated parameters have been established, this data should be maintained in an easily retrievable form for future use.

5
INSPECTION PLAN

Inspection is a key component of Alloy 600 management. Alloy 600/82/182 inspection requirements from regulations, ASME Section XI, and recommendations and guidelines issued by industry groups, such as EPRI MRP or Owners Groups, shall be incorporated into each plant's overall Alloy 600 Inspection Plan. Plants may choose to perform inspections beyond those required or recommended by industry organizations in order to better assess the condition of the plant or to assist in future planning for mitigation or repair and replacement activities. For many plants, the most convenient place to document the Alloy 600/82/182 Inspection Plan will be as either "required " or "augmented' inspections in their normal Section XI ISI plan. Periodic review of such plans should be conducted to ensure continued alignment with the overall Alloy 600 management plan and to capture industry experience. A sampling of reports and other documents containing industry recommendations is provided in Appendix C. Inspection results should be made available to the industry through the EPRI MRP.

A plan for monitoring each Alloy 600/82/182 location should account for susceptibility and safety and economic consequences of degradation/failure. An inspection plan should optimize inspection intervals and techniques to maximize the likelihood of detecting a flaw prior to any impact on plant safety and reliability and to properly delegate resources.

Technique and Frequency of Inspection

The techniques and frequency of inspection should be determined with the following in mind:

- Nuclear safety
- Regulatory compliance
- Economic impact
- Component ranking
- Integration with outage and ISI schedules
  - Extended outage should be recognized as an opportunity for inspection.
  - Determine optimum outage
    - Activities required in outages prior to inspection outage
    - Other planned outage activities
- Define windows within an outage
- Anticipate scope expansion

- Configuration required for one inspection versus another
- Method capabilities
- Availability of qualified inspectors and equipment
- Radiation exposure As Low As Reasonably Achievable (ALARA)

A plant specific matrix with inspection techniques applicable to specific plant locations should be included in the Alloy 600 management plan document. Appendix F includes an example of a plant specific inspection and repair matrix.

Disposition

Defects found during inspection shall be dispositioned in accordance with applicable regulatory requirements. It may be possible to apply a mitigation technique in order to prevent further growth of a flaw.

A decision tree or matrix may be helpful to guide plant staff in determining whether analysis, mitigation of defect growth, defect repair, or replacement of the degraded component is appropriate. The factors used in this decision should include the type of component, the location of the component in the plant, the size and orientation of the defect.

Any corrective actions should be reviewed and approved in accordance with site quality assurance procedures and associated regulations to ensure that these actions have been completed and are effective.

6
COMPONENT RANKING

A ranking system may be used to prioritize the expenditure of resources for mitigation, replacement, and additional inspection beyond requirements. The ranking system should account for susceptibility and safety and economic consequences of degradation/failure.

Generic work may be available to evaluate susceptibility, analyze safety and economic consequences, and devise a ranking system that considers both safety and economic risk. Individual utilities will be ultimately responsible for any plant specific ranking used in their Alloy 600 management plan.

If a ranking system is used, the model should be documented in the plant's Alloy 600 management plan.

Susceptibility

Susceptibility models can be used to evaluate the likelihood of PWSCC initiation at various Alloy 600/82/182 locations in a plant. The susceptibility of a specific component or weld is dependent on multiple factors such as:

- Materials Factors
  - Material properties
  - Metallurgical characteristics
  - Material processing history (cold work, heat treat, etc.)
  - Welding method/process
  - Repair history
- Temperature Factors
  - Time-temperature history
- Applied Stresses
  - Fabrication residual stress
  - Operational stress
  - Operational environment
  - Industry and plant experience with a particular component type

Plant staff should be aware that written records may not include all repair/in-process information and the uncertainty this introduces into any susceptibility models should be recognized and accounted for when using susceptibility as part of a ranking system.

More than one susceptibility model exists. It is important to consider whether or not the model is appropriate for the Alloy 600/82/182 location being evaluated. Reports on susceptibility are listed in Appendix D.

Consequences

Component ranking should be based not just on susceptibility to cracking, but also on the consequences associated with a crack or leak at each location. Failure could impact plant safety, personnel safety, and operations. Inspections required for regulatory compliance are designed to prevent any safety consequence.

The economic consequences of flaws should be evaluated as appropriate. A crack or leak may lead to a forced outage or an outage extension. Some plants have a risk informed in-service inspection program that identifies the consequences of failure for many locations in the plant.

7 MITIGATION

Mitigation activities are important to assure the long term operability of certain components containing Alloy 600/82/182. Without appropriate mitigative actions, it is possible that a significant number of components, especially those with high susceptibility, will develop cracks from PWSCC during the remaining life of the plants. Stress Corrosion Cracking (SCC) requires the confluence of a susceptible material, a chemical environment conducive to cracking, and sufficiently high tensile stresses on the material in contact with the coolant. Mitigation is intended to extend the life of components by altering one or more of the conditions necessary for SCC to occur in PWRs. Removing the susceptible material would appropriately be called a replacement activity, such as replacement of the reactor vessel top heads with new heads containing no Alloy 600/82/182. However cladding over the susceptible material with a material less susceptible would also remove the material from contact with reactor coolant and therefore be a mitigative action. There are a number of mitigative actions that address the stresses on the material in contact with reactor coolant, some already developed and implemented in the field, such as Mechanical Stress Improvement Process (MSIP), and some still under development, such as cavitation peening. In addition, approaches to modify the environment to reduce the likelihood of PWSCC are under investigation. Laboratory results and limited field experience indicate that Zinc injection can play a role in reducing the probability of crack initiation and may help reduce crack growth, although results on growth are mixed to date. Other mitigation processes are under investigation in the industry and their development should be followed to ensure the latest available information is utilized.

Mitigation techniques that are currently available or under evaluation include the following:

- Zinc Addition
- Mechanical Stress Improvement Process (MSIP)
- Waterjet Peening
- Outer Diameter (OD) Weld Overlay to put Inner Diameter (ID) in compression
- Clad with Alloy 690/52/152 material

Additional information on some of these technologies can be found in the reports listed in Appendix E.

8 REPAIR/REPLACEMENT

Prior to each inspection outage the plant should evaluate the level of contingency for repairs. Some considerations and suggested pre-outage actions include:

- Gather design information (i.e., code stress report)
- Review prior inspection records
- Material, personnel, and equipment availability
- NDE support, personnel, and procedures
- Vendor selection
- Code review/possible relief requests
- Personnel/Vendor readiness
- In-house repair capabilities (small bore hot and cold leg nozzles)
- Relief requests
  - MNSA2 currently requires ASME Code relief per the NRC
  - Ambient temper bead is an option for weld repairs attaching nozzles to vessel material without preheat requirements

Repair techniques that are currently in use include:

- Mechanical Nozzle Seal Assembly (MNSA)
- Embedded Flaw Repair
- Excavate crack & weld repair
- Half nozzle repair
- ID Weld Inlay
- Replace with Alloy 690/52/152 material
- Sleeving
- Weld overlay on OD/Structural weld overlay
- Mechanical Stress Improvement Process (MSIP) (where applicable in accordance with flaw acceptance criteria)
- Relocate attachment weld to the OD or mid-wall of the vessel or pipe

In some cases, component replacement may be the best option. Example of components that have been replaced at some U.S. plants include:

- Reactor Vessel Head
- Steam Generator
- Alloy 600 pipe sections with stainless steel

Some other considerations that may impact repair and mitigation techniques include:

- Containment hatch size
- Outage length
- Synergies with other actions (10 year ISI, MSIP at multiple locations, head assembly upgrades)
- Contingencies when performing inspections
- Regulatory drivers (mandated inspections)

Plant Specific Repair Matrix

Plants should identify repair options for each location in order to effectively respond to inspection findings. Appendix F includes an example of a plant specific inspection and repair matrix.

The plant specific matrix may be organized by location and flaw type. Fields could include the primary inspection technique for detecting the flaw, the probability that a repair is required, the recommended repair method(s), and the specific actions to be taken by plant staff. The plant specific matrix may indicate the status of any on-going analysis related to the flaw, any known limitations in repair technique, and references to procedures related to repair and testing.

Several reports that are available to assist plant staff in selecting Alloy 600/82/182 repair techniques are listed in Appendix G.

9
MAINTAINING THE ALLOY 600 MANAGEMENT PLAN

The Alloy 600 Management plan should be reviewed and updated on a periodic basis to address:

- Industry events
  - Inspection history/results both plant specific and industry wide
  - Operating Experience
- Developing technologies
  - Inspection
  - Mitigation
  - Repair
  - Replacement
- Plant changes
  - Operational
  - Hardware
- Implementation issues
  - Lessons learned

This periodic plan review should be documented to capture the results of the review.

A
SUMMARY OF KEY INDUSTRY EVENTS INVOLVING PWSCC OF ALLOY 600/82/182

Content Deleted – MRP/EPRI Proprietary Material

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Content Deleted – MRP/EPRI Proprietary Material

B
RESOURCES – LOCATIONS OF ALLOY 600/82/182

Content Deleted – MRP/EPRI Proprietary Material

C
RESOURCES – INSPECTION PLANNING

Content Deleted – MRP/EPRI Proprietary Material

Content Deleted – MRP/EPRI Proprietary Material

D
RESOURCES – COMPONENT RANKING AND SUSCEPTIBILITY

Content Deleted – MRP/EPRI Proprietary Material

E
RESOURCES – MITIGATION

Content Deleted – MRP/EPRI Proprietary Material

F
EXAMPLE INSPECTION AND REPAIR MATRIX

Content Deleted – MRP/EPRI Proprietary Material

Content Deleted – MRP/EPRI Proprietary Material

Content Deleted – MRP/EPRI Proprietary Material

G
RESOURCES – REPAIR/REPLACEMENT

Content Deleted – MRP/EPRI Proprietary Material

H
ASSORTED EPRI AND NRC ALLOY 600/82/182 RESOURCES

Assorted EPRI Reports on Alloy 600/82/182

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Content Deleted – MRP/EPRI Proprietary Material

Content Deleted – MRP/EPRI Proprietary Material

Assorted NRC Resources Related to PWSCC of Alloy 600/82/182

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Content Deleted – MRP/EPRI Proprietary Material

I

ASSORTED OWNERS GROUP ALLOY 600/82/182 RESOURCES

Assorted B&WOG Developed Alloy 600 PWSCC Resources

Content Deleted – MRP/EPRI Proprietary Material

Assorted CEOG Tasks and Products Related to Alloy 600

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Content Deleted – MRP/EPRI Proprietary Material

Content Deleted – MRP/EPRI Proprietary Material

Assorted Westinghouse Owners Group Alloy 600 Issue Program Deliverables

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Content Deleted – MRP/EPRI Proprietary Material