**Flow Accelerated Corrosion Program**

**Procedure Contains NMM eB REFLIB Forms:** YES [ ] NO [x]

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<th>Site</th>
<th>Site Procedure Champion</th>
<th>Governance Owner</th>
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<td>James P. Miksa</td>
<td>PLP</td>
<td>Bill Greeson</td>
<td>Oscar Limpias</td>
<td>VP Engineering</td>
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**Exception Date**

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<th>Site</th>
<th>Site Procedure Champion</th>
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</tr>
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<tbody>
<tr>
<td>ANO</td>
<td>Bill Greeson</td>
<td>Manager, Programs &amp; Components</td>
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<tr>
<td>BRP</td>
<td>Linda Patterson</td>
<td>Manager, Programs &amp; Components</td>
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<td>GGNS</td>
<td>Michael Tesoriero</td>
<td>Manager, Programs &amp; Components</td>
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<td>IPEC</td>
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<td>PLP</td>
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<td>Steven Woods</td>
<td>Manager, Programs &amp; Components</td>
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<td>RBS</td>
<td>S. Charles Coleman</td>
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<td>VY</td>
<td>George Wierzbowski</td>
<td>Manager, Programs &amp; Components</td>
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<td>W3</td>
<td>Ran Gilmore</td>
<td>Manager, Programs &amp; Components</td>
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<tr>
<td>N/A</td>
<td>Luis Terrazas</td>
<td>Manager, Programs &amp; Components</td>
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</tbody>
</table>

**Site and NMM Procedures Canceled or Superseded By This Revision**

<table>
<thead>
<tr>
<th>Process Applicability Exclusion</th>
<th>All Sites: [ ]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific Sites</td>
<td>ANO [ ] BRP [ ] GGNS [ ] IPEC [ ] JAF [ ] PLP [ ] PNPS [ ] RBS [ ] VY [ ] W3 [ ]</td>
</tr>
</tbody>
</table>

**Change Statement**

Revision 6 is a non-editorial revision that incorporates enhancements and changes identified during NRC/INPO, site and Corp reviews conducted within the Entergy Fleet. The changes and enhancements include clarifications to Section 5.6 Evaluation of UT Inspection Data, prescriptive criteria for Component Evaluation Packages and the level of review required. Also part of this revision is the prescriptive minimum criteria for the Outage Summary Report (specified time for completion, and minimum content and specific Configuration Management criterion for record retention.

*Requires justification for the exception*
<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>PURPOSE</td>
<td>3</td>
</tr>
<tr>
<td>2.0</td>
<td>REFERENCES</td>
<td>3</td>
</tr>
<tr>
<td>3.0</td>
<td>DEFINITIONS</td>
<td>5</td>
</tr>
<tr>
<td>4.0</td>
<td>RESPONSIBILITIES</td>
<td>10</td>
</tr>
<tr>
<td>5.0</td>
<td>DETAILS</td>
<td>15</td>
</tr>
<tr>
<td>5.1</td>
<td>PRECAUTIONS AND LIMITATIONS</td>
<td>15</td>
</tr>
<tr>
<td>5.2</td>
<td>ANALYSIS/PRE-EXAMINATION</td>
<td>15</td>
</tr>
<tr>
<td>5.3</td>
<td>PREPARATION OF OUTAGE INSPECTION PLAN</td>
<td>17</td>
</tr>
<tr>
<td>5.4</td>
<td>GRIDDING</td>
<td>19</td>
</tr>
<tr>
<td>5.5</td>
<td>NDE TEST METHODS AND DOCUMENTATION</td>
<td>20</td>
</tr>
<tr>
<td>5.6</td>
<td>EVALUATION OF UT INSPECTION DATA</td>
<td>21</td>
</tr>
<tr>
<td>5.7</td>
<td>EVALUATION OF RT INSPECTION DATA</td>
<td>23</td>
</tr>
<tr>
<td>5.8</td>
<td>EVALUATION OF VISUAL INSPECTION DATA</td>
<td>23</td>
</tr>
<tr>
<td>5.9</td>
<td>DISPOSITION OF INSPECTION RESULTS</td>
<td>24</td>
</tr>
<tr>
<td>5.10</td>
<td>RE-INSPECTION REQUIREMENT</td>
<td>25</td>
</tr>
<tr>
<td>5.11</td>
<td>COMPONENTS FAILING TO MEET INITIAL SCREENING CRITERIA</td>
<td>25</td>
</tr>
<tr>
<td>5.12</td>
<td>SAMPLE EXPANSION</td>
<td>26</td>
</tr>
<tr>
<td>5.13</td>
<td>REPAIR / REPLACEMENT OF DEGRADED COMPONENTS</td>
<td>27</td>
</tr>
<tr>
<td>5.14</td>
<td>COMPONENT EVALUATION PACKAGES</td>
<td>27</td>
</tr>
<tr>
<td>5.15</td>
<td>POST-INSPECTION ACTIVITIES</td>
<td>28</td>
</tr>
<tr>
<td>5.16</td>
<td>LONG TERM STRATEGY</td>
<td>28</td>
</tr>
<tr>
<td>5.17</td>
<td>METHODS OF DETERMINING PLANT PERFORMANCE</td>
<td>29</td>
</tr>
<tr>
<td>6.0</td>
<td>INTERFACES</td>
<td>29</td>
</tr>
<tr>
<td>7.0</td>
<td>RECORDS</td>
<td>29</td>
</tr>
<tr>
<td>8.0</td>
<td>SITE SPECIFIC COMMITMENTS</td>
<td>30</td>
</tr>
<tr>
<td>9.0</td>
<td>ATTACHMENTS</td>
<td>31</td>
</tr>
<tr>
<td></td>
<td>ATTACHMENT 9.1 GUIDANCE ON PARAMETERS AFFECTING FAC</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td>ATTACHMENT 9.2 FLOW ACCELERATED CORROSION PROGRAM ATTRIBUTES</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>ATTACHMENT 9.3 WALL THINNING EVALUATION PROCESS MAP</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td>ATTACHMENT 9.4 FAC OUTAGE SCOPE TEMPLATE</td>
<td>37</td>
</tr>
</tbody>
</table>
1.0 PURPOSE
[P-33641 - P-33643], [P-33645], [P-33714 – P-33719], [P-33730], [P-35351], [JAFP-87-0737], [JPN-89-051], [IP-87-055Z], [IPN-89-044], [BECo-89-107], [FVY-89-66], [FVY-87-94], [FVY-87-121], [P-1079], [P-35269], [P-24444], [P-15802], [P-15803], [P-16557], [P-20303], [P-22888], [RCL 01038934-01], [CMT891015777] [LO-LAR-2009-244-58] [LO-LAR-2008-0048-40] [PNPS A-16781] [VY A-16924]

[1] The purpose of this procedure is to implement a common approach to establish programmatic control, updating, and documenting Flow-Accelerated Corrosion (FAC) programs for standardization at Entergy’s nuclear plants.

[2] The objective of the FAC program is to predict, detect, monitor and minimize degradation in single and two-phase flow piping (safety and non-safety related systems) to prevent failures while enhancing plant safety and reliability.

[3] This procedure provides criteria and methodology for selecting components for inspection, performing inspections, evaluating inspection data and disposition of results, sample expansion requirements, piping repair /replacement criteria, program responsibilities and documentation requirements.

[4] This procedure may be used as a guide for evaluating systems and components that are not included in the FAC program.

[5] The frequency of the activities described in this document shall be on a refuel outage basis, unless otherwise noted. However, in some cases, online or mid-cycle inspection and evaluation may be performed.

2.0 REFERENCES

2.1 General References

[1] NRC Generic Letter 89-08, "Erosion/Corrosion Induced Pipe Wall Thinning".


Flow Accelerated Corrosion Program

2.1 cont.

[6] ANSI B31.1 “Power Piping”, (For applicable code year see individual plant FSAR).


2.1 cont.


[23] CHECWORKS Steam / Feedwater Application, Entergy approved version.


2.2 Site Specific References

[1] JAF-SPEC-MISC-03290 Rev. 0, “Specification for Evaluation and Acceptance of Local Areas of material, parts and components that are less than the specified thickness.” By REEDY Engineering.

[2] IP3-SPEC-UNSPEC-02996 Rev. 0, “Specification for Evaluation and Acceptance of Local Areas of material, parts and components that are less than the specified thickness.” By REEDY Engineering.

3.0 DEFINITIONS

[1] Base Line Inspection – An initial wall thickness measurement of a component taken prior to being placed in service.

[2] Basis Document – Program documents that define the scope, attributes, commitments, evaluation reports and predictive models that form the basis of the FAC program (i.e., System Susceptibility Evaluation (SSE) reports). These documents contain the basis for the plant piping in the CHECWORKS model, the Susceptible-Not-Modeled (SNM) piping and those that are non-susceptible.

[3] CHECWORKS – EPRI Computer Modeling Program used to predict rated wall thinning and remaining life of components degraded by FAC.
3.0 cont.

[4] Code Minimum Thickness ($t_{\text{min}}, t_{\text{codemin}}$) – The minimum required global wall thickness based on hoop stress.

[5] Critical Thickness ($t_{\text{crit}}$) – The minimum required wall thickness per code of construction required to meet all design-loading conditions.

[6] Deficient Component – A component identified by examination to be below $t_{\text{accept}}$ wall thickness or projected to be below $t_{\text{accept}}$ wall thickness by the next refueling outage.

[7] Degraded component – A component identified as being below the screening criteria that is acceptable for continued operation.

[8] EPRI CHUG – EPRI CHECWORKS USERS GROUP.

[9] Examination – Denotes the performance of all visual observation and nondestructive testing, such as radiography, ultrasonic, eddy current, liquid penetrant and magnetic particle methods.

[10] Examination Checklist/ Traveler – A data sheet/checklist developed for components being inspected and may contain but is not limited to the following: $t_{\text{nom}}, t_{\text{meas}}, t_{\text{min}},$ Screening criteria, component's name, system number, previous data, inspection datasheet number, grid size, examination extent, work order and affiliated minimum wall calculation.

[11] Flow Accelerated Corrosion (FAC) – Degradation and consequent wall thinning of a component by a dissolution phenomenon, which is affected by variables such as temperature, steam quality, steam/fluid velocity, water chemistry, component material composition and component geometry. Previously known as Erosion/Corrosion.

[12] Grid – A pattern of points or lines on a piping component, where UT thickness measurements will be made. Grid may be permanently marked with circumferential and longitudinal grid lines.

[13] Grid Point – A specific location on a piping component, where a UT thickness measurement will be made. Grid points are at the intersections of the circumferential and longitudinal grid lines.


[15] Grid Scan – 100% scans of the area between the grid lines. The lowest measurement in each area is to be recorded as the measured thickness.
3.0 cont.

[16] **Full Scan** – Scans of 100% of an area, circumference, nozzle, heater segments etc, measuring minimum, maximum and averages thicknesses and approximate location of minimum measured thickness.

[17] **Grid Size** – The distance between grid points in the circumferential or longitudinal direction. Also called grid space or grid spacing.

[18] **Initial Thickness** \( (t_{\text{init}}) \) – The thickness determined by ultrasonic examination prior to the component being placed into service (baseline) or the first ultrasonic examination during its service life. If an examination has not previously been performed on the component, the initial thickness shall be determined by reviewing the initial ultrasonic data for that component. The area of maximum wall thickness within the same region as the worn area (based on the method selected for evaluating wear) shall be identified and compared to \( t_{\text{nom}} \). If the thickness is greater than \( t_{\text{nom}} \), the maximum wall thickness within that region shall be used as \( t_{\text{init}} \). If that thickness is less than \( t_{\text{nom}} \), \( t_{\text{nom}} \) shall be used as \( t_{\text{init}} \).

[19] **Inspection Location** – A specific examination location, which may be an elbow, tee, reducer, straight pipe section, etc.

[20] **Inspection Outage** – The outage during which the component was inspected.

[21] **Large-bore Piping** – Piping generally greater than 2” nominal pipe size typically with butt-weld fittings. (>2” with socket welds is considered small bore piping)

[22] **Line Scans** – Piping segments broken into one-foot lengths (Small-Bore pipe).

[23] **Minimum acceptable wall thickness** \( (t_{\text{accept}}) \) – Maximum value of axial stress, hoop stress, and/or critical thickness and the piping replacement values of 0.3 \( t_{\text{nom}} \) for Class1 piping or 0.2 \( t_{\text{nom}} \) for Class 2, Class 3 and non-safety related piping.

[24] **Minimum Measured Thickness** \( (t_{\text{meas}} \text{ or } t_{\text{mm}}) \) – As identified by ultrasonic thickness examination, the present thickness at the thinnest point on a component.

[25] **Local minimum required thickness** \( (t_{\text{aloc}}) \) – Minimum acceptable local wall thickness as calculated by EN-CS-S-008-MULTI.

[26] **Minimum required thickness** \( (t_{\text{a, \min}}) \) – Minimum required pipe wall thickness based on axial stress (See EN-CS-S-008-MULTI).
Flow Accelerated Corrosion Program

3.0 cont.

[27] **Next Scheduled Inspection (NSI)** – The outage at which an inspection will be performed on a given component.

[28] **Nominal Thickness ($t_{nom}$)** – Wall thickness equal to ANSI standard thickness.

[29] **PASS 1 Analysis** – Runs modeled in CHECWORKS that either have no inspection data, an insufficient number of inspections to provide a proper calibration, or where there is no expectation of ever developing a proper calibration.


[31] **Piping Segment** – A run of piping that consists of inspection locations which have common operating parameters (i.e., temperature, pressure, flow rate, Oxygen content and pH level).

[32] **Predicted /Projected Thickness ($t_p, t_{pred}$)** – The calculated thickness of a component based upon a rate of wear to some point in time (e.g., next refueling, next scheduled examination).

[33] **Quadrant Scan** – Piping segments divided in quadrants A, B, C, D that are 90 degrees apart and broken into one-foot lengths, or as specified by the FAC engineer.

[34] **Qualified FAC Engineer** – Individual who has completed the FAC Qualification Card, who participates in the Engineering Support Personnel (ESP) training program and demonstrates knowledge required for the use of the CHECWORKS computer program.

[35] **Reference Point** – The point on a piping component where the longitudinal and circumferential grid lines originate.

[36] **Remaining Service Life (RSL)** – The amount of time remaining based upon an established rate of wear at which the component is anticipated to thin to $t_{accpt}$.

[37] **Safety Factor** – A Margin of Safety used to account for inaccuracies in wear rate evaluation.

[38] **Sample Expansion** – The addition of inspection locations based on significant or unexpected wall thinning during planned inspection(s).
3.0 cont.

[39] **Significant wall thinning** – Wall thinning to a thickness which is the largest of:

(a) A thickness less than 60% of pipe nominal wall thickness

(b) Wall thinning to a thickness that is half the remaining margin of the piping/component which is above $t_{acpt} : \left[\frac{1}{2} \left(0.875 \, t_{nom} + t_{acpt}\right)\right]

(c) $(t_{acpt} + 0.020)$ inch.

[40] **Small-bore Piping** – Piping that is generally 2” or less nominal diameter and that typically uses socket welded fittings.

[41] **Subsequent Inspection** – Inspection of components that have had a baseline inspection and/or an initial operational inspection.

[42] **Susceptible Line** – Piping determined to be susceptible to FAC using the EPRI susceptibility criteria in NSAC 202L, industry experience and as documented in the System Susceptible Evaluation.

[43] **Susceptible Non-Modeled (SNM) Piping** – A subset of the FAC susceptible lines that cannot be modeled using the EPRI CHECWORKS software.

[44] **System Susceptibility Evaluation (SSE)** – Evaluation which addresses and documents all large and small bore piping, categorizing lines by modeled, non-modeled large bore piping and small bore piping susceptible to FAC. All piping should be considered FAC susceptible unless analyzed as otherwise.

[45] **Time** – Time in service shall be actual hours on line or of operation and/or hours critical. Calendar hours may be used for conservatism.

[46] **Train** – Loops within subsystems that have similar geometries, flow rates and temperatures and which have similar FAC risk.

[47] **UT Datasheets** – Paperwork that documents the results of the ultrasonic thickness inspections.

[48] **Wear (W)** – The amount of material removed or lost from a components wall thickness since baseline or subsequent to being placed in service.

[49] **Wear Rate (WR)** – Wall loss per unit time.
4.0 RESPONSIBILITIES

4.1 MANAGER, PROGRAMS & COMPONENTS ENGINEERING (SITE)
[1] Provides a single point of accountability and responsibility for the overall health and direction of the FAC programs.

[2] Ensures that the FAC programs are effectively developed and implemented.

[3] Provides oversight for implementing the FAC programs.


4.2 SUPERVISOR, CODE PROGRAMS (SITE)

[1] Designates responsible engineer/personnel from the Code Programs engineering group for the implementation and maintenance of the FAC program.

[2] Ensures that the FAC program activities are conducted in accordance with this procedure.

[3] Ensures that repair procedures are in place to support any planned repairs or replacements.

[4] Ensures audits and surveillance of selected FAC activities is performed to verify compliance with applicable codes, procedures and drawings.

[5] Provides personnel to perform NDE during normal plant operation and unscheduled outages.

[6] Provides qualified Non-Destructive Examination personnel to perform flow accelerated corrosion inspections during scheduled refueling and maintenance outages.

[7] Provides personnel to perform reviews of all final FAC UT data sheets.

[8] Provides personnel to review vendor procedures, personnel certifications and equipment certifications.

[9] Assures adequate technical personnel are available to provide required support services prior to the outage.

[10] Allocates resources to execute the requirements of the program.
Flow Accelerated Corrosion Program

4.2 cont.

[11] Provides funding and resources to ensure FAC drawings are kept up to date and drawings reflect current plant configuration.

[12] Ensures the development of bench strength and back up personnel for the FAC program.

4.3 NDE LEVEL III OR DESIGNEE

[1] Reviews and approves FAC personnel and equipment certifications, and NDE procedures including revisions.

[2] NDE Level II or Level III reviews and signs all final NDE/UT data sheets to ensure appropriate NDE examinations have been completed in accordance with the FAC program.

[3] Provides input for resolution of anomalies found in inspection data.

[4] Identifies discrepancies or deficiencies and initiates condition report in accordance with FAC program or site protocols as appropriate.


[6] Performs functions in accordance with applicable procedures including the Entergy Quality Assurance Program.

4.4 FLOW ACCELERATED CORROSION ENGINEER

[1] Implements and maintains an effective station FAC program.

[2] Ensures all FAC Program work is performed in accordance with program procedural requirements.

[3] Prepares outage scope document prior to each outage using the criteria of this procedure, NSAC-202L, CHECWORKS (Pass 1 and Pass 2 output as a guide). Along with reviewing previous outage, inspection results and industry/site specific OE. This includes replacement scopes and initiation of paperwork as appropriate in support of replacements.


[5] Provides input to Planning for publishing schedules, work scopes, resource requirements and outage progress reports.
4.4 cont.

[6] Reviews and/or performs an engineering evaluation for all FAC inspections where pipe wall thinning has been identified and concur on any recommended action. Calculations shall be done in accordance with applicable procedures.

[7] Evaluates examination data and performs component evaluations to determine if components can remain in service.

[8] Ensures that appropriate inspections are performed in accordance with the scope of the FAC program.

[9] Reviews all inspection data and make recommendations for repair/replacement of piping materials in accordance with site protocols, if applicable.

[10] Identifies examination sample expansion scope when required.

[11] Provides NDE data for review and signature to the ANII, if requested by the ANII.

[12] Provides risk informed inspection data sheet(s) to the ANII for review and signature, if applicable.

[13] Ensures the FAC inspection program incorporates industry and in-house operating experiences and identifies tracks and trends inspection results.

[14] Maintains records of all inspection results and inspection database and transmits the approved records within 30 days in accordance with EN-AD-103.

[15] Develops a FAC examination checklist/traveler that contains \( t_{\text{nom}} \), screening criteria, \( t_{\text{accept}} \), line number, etc. for the components being inspected.

[16] Initiates request for engineering services in accordance with the Asset Suite or site specific work control process for piping replacement or engineering evaluations as required. This request should include recommended materials for replacement and configuration changes, if applicable, to reduce the effects of flow accelerated corrosion.

[17] Periodically reviews completed plant modifications to assess their effect on the scope of the flow accelerated corrosion program.

[18] Assists in vendor oversight as required.
4.4 cont.

[19] Maintains control of the predictive models (e.g. CHECWORKS), which includes any development, updates or revisions to the models.


[21] Initiates and/or responds to Condition Reports and Engineering Change for evaluating degraded and deficient components or other discrepancies or deficiencies within the scope of the FAC program.

[22] Develops post outage inspection summary reports.

[23] Reviews and dispositions Operating Event (OE) notices for applicability to the FAC program.

[24] Prioritizes and ranks inspection in terms of susceptibility and consequence of failure.

[25] Ensures key program elements are properly documented and program activities are controlled and performed in accordance with the applicable procedures.


[27] Maintains an up to date Program Notebook.

[28] Maintains the FAC Plant Predictive Model up to date to reflect current plant configuration.

4.5 DESIGN ENGINEERING/RESPONSIBLE ENGINEER

[1] Provides minimum acceptable wall thickness ($\t_{\text{acpt}}$) to the FAC Engineer. Responsibility may be delegated to another department or qualified personnel.

[2] Performs local wall thinning evaluations for components having UT measurements that are below or are projected to go below the minimum acceptable wall thickness ($\t_{\text{acpt}}$) or administrative wall thickness requirement. Responsibility may be delegated to another department or qualified personnel.

[3] Prepares and issues engineering change for component requiring replacement. Responsibility may be delegated to another department or qualified personnel.

[4] Performs remaining service life evaluation for components in the FAC program as required. Responsibility may be delegated to another department or qualified personnel.
4.6 MAINTENANCE SUPERVISOR/DESIGNEE

[1] Ensures that adequate craft personnel are available to support the FAC program.

[2] Ensures that scaffolding is erected, when needed, and insulation removal from components/piping segments scheduled for inspection and piping surface conditioning is performed prior to the scheduled inspection. Also ensures scaffolding erected in safety related areas is performed in accordance with applicable site procedures.

[3] Notifies the FAC engineer when an obstruction (i.e. support) requires removal for inspection, which may require an engineering evaluation.

[4] Ensures that surfaces to be inspected are free from all foreign materials that would interfere with the inspections, i.e., dirt, rust, paint, etc. If cleaning is required, this may be accomplished by power sanding (flapper wheel only), hand wire brushing, or hand sanding in accordance with site procedures/protocols.

[5] Ensures restoration of lines, i.e. insulation replacement and scaffold removal, upon completion of the FAC inspection.

4.7 FAC/ISI PROJECT COORDINATOR

[1] A FAC/ISI project coordinator may be chosen to implement the activities of the inspection plan. The duties, if applicable, may include but are not limited to the following activities:

(a) Performing component walk downs
(b) Generating NDE inspection packages
(c) Defining NDE staffing as required
(d) Scheduling of inspections
(e) Acquiring data as required
(f) Providing field coordination to ensure timely inspections are accomplished
(g) Tracking progress of the FAC inspection project
(h) Transmitting inspection results to the FAC Engineer
5.0 DETAILS

[LO-LAR-2009-244-0058] [LO-LAR-2008-0048-40] [PNPS A-16781] [VY A-16942]

5.1 PRECAUTIONS AND LIMITATIONS

None

5.2 ANALYSIS/PRE-EXAMINATION [LO-LAR-2009-244-0058]

[1] Review Data and Update Program Elements

(a) Prior to selecting components for inspection, the FAC Program Engineer shall review the FAC program by performing the following steps:


(a) Review applicable information and ensure that the scope of the FAC Program as reflected in the Basis Documents are correct AND updated in accordance with Section 5.15 [5]. The review shall include items that could affect the FAC Program from the following sources, if applicable:

(1) Design Change Packages
(2) Maintenance Work Request History
(3) Station Chemistry Reports
(4) Station Thermography Report
(5) Station Corrective Action Database
(6) Maintenance Rule Classifications of FAC Systems
(7) Plant Personnel (e.g. Operations, System Engineers, Chemistry, Mechanical/Structural Engineering, Air Operated Valves (AOV), Motor Operated Valves (MOV) and Check Valve Groups)

[3] Review CHECWORKS Model

(a) IF any changes in plant operation, configuration, OR other factors that affect FAC that have occurred since the CHECWORKS model was last updated, THEN the model should be revised to reflect that change. As a minimum, the FAC Program Engineer should review the following items:

(1) Plant power levels
(2) Operating practices. IF the plant has operated in any off-normal condition (e.g. alternate system lineups), THEN update the model accordingly.
Flow Accelerated Corrosion Program

5.2[3](a) cont.

(3) Plant chemistry. Ensure that the current conditions are represented in the model.

(4) Ensure that a Pass 2 analysis has been completed in accordance with the requirements provided in this document.

(5) Ensure the Pass 2 results are reviewed for components with negative time to Tcrit, components with operating hours that are less than one operating cycle, AND components that are greater than one cycle BUT less than operating hours for two cycles.

(b) Based on the information identified in 5.2[2] AND any inspections of SNM components since the last revision, update of the Susceptible Non-Modeled Program shall be performed in accordance with Section 5.15 [5].

(c) Ensure long term inspection schedules includes High Risk Small-Bore Piping (F1/S1) plan that has not been inspected.

(d) Ensure a basis is documented for components determined to be negative time to Tcrit during the outage scope selection process.


(a) The determination of updates, IF any, AND documenting reviews along with a peer review performed by a qualified FAC Engineer shall be captured in the FAC database, Outage Report AND the Program Notebook. IF a permanent change in the susceptibility status of a line is identified, THEN the Basis Document shall be revised to reflect that change.

[5] The criteria contained in NSAC-202L, revision 3, shall be used to perform the System Susceptibility Evaluation (SSE).


[7] Non-typical operation of systems should be taken into consideration AND IF necessary factored into the FAC program.

[8] The susceptible small-bore piping inspection priority ranking should consider personnel safety, consequence of failure AND plant unavailability.

[9] Industry AND plant experiences relating to FAC will be factored into the program.

[10] The CHECWORKS model should be used in determining inspection priority based on relative ranking for specific locations to be examined for FAC damage.
Flow Accelerated Corrosion Program

5.2 cont.

[11] Applicable FAC OE shall be reviewed and taken into consideration to ensure industry lessons learned are incorporated during the implementation and scope selection process.

5.3 PREPARATION OF OUTAGE INSPECTION PLAN [LO-LAR-2008-0048-40] [PNPS A-16781] [VY A-16924]

[1] The FAC Program Engineer shall prepare an Outage Inspection Plan prior to the outage to meet site milestones. Reference Attachment 9.4 for FAC Outage Scope Template.


[3] The Outage Inspection Plan should consider inspection priority based on relative ranking for specific locations to be examined for FAC damage.

[4] Each identified location shall be documented in the inspection plan, along with the component number AND reason for selection AND basis for selection for inspection.

[5] The inspection plan shall be reviewed by qualified FAC personnel.


(a) The FAC engineer shall prepare a FAC Outage Inspection scope as directed by plant milestones OR as directed by Station management.

(b) Inspection selections shall be made in accordance with the requirements of this procedure AND shall be identified based on CHECWORKS results, industry/station/utility experience, required re-inspections, the non-modeled program piping AND engineering judgment.

(c) IF a selected inspection location is determined to be excessively difficult, impractical OR costly to examine due to inaccessibility, temperature, ALARA concerns, scaffolding requirements, OR other factors, THEN an equivalent alternate inspection location may be selected.

(d) Components selected shall be formally documented.

(e) The criteria for component selection should consider the following:

(1) Components selected from measured OR apparent wear found in previous inspection results.

(2) Components ranked high for susceptibility from current CHECWORKS evaluation.
Flow Accelerated Corrosion Program

5.3[6](e) cont.

(3) Components identified by industry events/experience via the Nuclear Network OR through the EPRI CHUG.

(4) Components selected to calibrate the CHECWORKS models.

(5) Components designated as negative time to Tcrit

(6) Components subjected to off normal flow conditions. Primarily isolated lines to the condenser in which leakage is indicated from the turbine performance monitoring system.

(7) Engineering judgment / Other

(8) Piping identified from Work Orders (malfunctioning equipment, downstream of leaking valves, etc.).

(9) Susceptible piping locations (groups of components) contained in the Small Bore Piping database, which have NOT received an initial inspection.

(10) Piping identified from Condition Reports/ Corrective action, Work Orders (malfunctioning equip, downstream of leaking valves, etc.).

(11) Vessel Shells – Low and High Pressure Feedwater heaters, moisture separator re-heaters, drain tanks etc. [OED 2008-02]

(12) Baseline wall thickness measurements for the nozzles AND heater shells should be completed with an average five years for high pressure heaters and 10 years for low pressure heaters. [13]

(13) Inspection of carbon steel piping downstream of FAC resistant material for indications of entrance effect (Ref. EPRI TR 1015072, “FAC Entrance Effect”, November 2007)”

[7] Inspection schedule

(a) Inspection sequence AND schedule should be developed based on priority established by the FAC engineer considering repair/scope expansion potential. Consideration will also be incorporated based on other outage work priorities, job conflict AND system window duration.

(b) The FAC outage schedule should contain sufficient time for analysis AND evaluations of the components being inspected.
Flow Accelerated Corrosion Program

5.3 cont.

[8] Drawing Preparation

(a) For each component scheduled for inspection, an isometric OR other acceptable location drawing should be prepared prior to the outage that identifies the component to be examined. WHEN applicable ensure the component number is shown on the drawing.

[9] Obtain Minimum Acceptable Wall Thickness (t_{accept})

(a) Obtain t_{accept} values for each component.

(b) The minimum acceptable wall thickness, t_{accept}, values should be obtained from EN-CS-S-008-MULTI as applicable OR from an approved site method (e.g. FAC Manager).

(c) Values for t_{accept} should be obtained from design engineering OR it may be delegated to another department OR qualified personnel. These values may be ascertained prior to OR during an outage.

[10] Component Identification

(a) Inspected components should have a unique identifier to allow for the tracking of inspection data.

(b) Component identifiers may allow for the identification of the Unit, system, sub-system, line number AND corresponding location of that component within a sub-system.

(c) Components in the CHECWORKS non-modeled piping may be identified by using line numbers.

[11] Pre-inspection Activities

(a) Review inspection schedule, inspection requirements AND sequence with appropriate plant personnel to ensure requirements for the completion of the FAC inspection are understood.

(b) The FAC engineer should participate in the preparation of FAC inspection work packages as required.

5.4 GRIDDING

[1] Gridding of components shall be performed in accordance with recommendation of NSAC 202L, CEP-FAC-001, AND applicable site approved procedures OR as specified by the FAC engineer.
Flow Accelerated Corrosion Program

5.4 cont.

[2] Griding information shall be documented on the appropriate NDE UT data sheet either by a sketch OR digital photo.

5.5 NDE TEST METHODS AND DOCUMENTATION [RC07.2029.55] [LO-LAR-2009-244-0058] [LO-LAR-2008-0048-40] [VY A-16924]

[1] Components can be inspected for FAC wear using ultrasonic testing (UT), radiography testing (RT), visual observation OR other approved methods. The inspection technique used shall be at the discretion of the FAC engineer.

[2] UT thickness measurement is the primary method of determining pipe wall thickness.

(a) Inspections will be performed by using one of the following techniques:
   (1) Grid Point Reading
   (2) Grid Scan
   (3) Quadrant Scan
   (4) Line Scan
   (5) Full Scan

(b) Ultrasonic Thickness measurement shall be performed in accordance with approved NDE, site OR vendor procedures.

(c) A data sheet for components inspected shall be prepared. The information included in the sheet should contain but is NOT limited to the following:
   (1) Plant’s name/unit
   (2) Components name
   (3) Component sketch
   (4) NDE technician signature/ date
   (5) Grid size
   (6) Axial AND radial grid boundaries
   (7) Calibration information
   (8) Level II OR Level III signature/date
   (9) Work order information
   (10) Nominal & Measured thickness
   (11) 87.5% nominal thickness screening criteria
   (12) Scanning method
5.5[2](c) cont.

(13) $t_{\text{accept}}$ or administrative limits


(a) RT (digital OR conventional) is the preferred method for inspecting socket welded fittings. The method used is at the discretion of the FAC engineer.

(b) RT can be performed during plant operations without removing insulation


(a) Visual observation/techniques may be used for examination of large components such as tanks, cross-around piping, cross-under piping, pump casings, shell walls, valves etc. (visual techniques is only applicable to two phase flow).

(b) Follow-up UT examinations, at the discretion of the FAC engineer, may be required of areas where significant damage is observed OR suspected.

5.6 EVALUATION OF UT INSPECTION DATA

NOTE

Historically, typical manufacturing practice has been to supply fittings (especially tees, elbows AND reducers) with wall thickness significantly larger than the piping nominal thickness.

NOTE


[1] The data review should consider screening for further evaluation. Factors that should be considered WHEN reviewing the inspection data include unknown initial thickness (especially fittings), counter-bore, obstructions, AND manufacturing wall thickness variations.

[2] For each component that is examined AND is below the screening criteria of 87.5% of nominal wall, the wear, wear rate, remaining service life shall be calculated prior to placing the component back in-service. Systems/Components with margins that exceed the 87.5% screening criteria or where site specific procedures impose more stringent requirements are excluded from these criteria. [LO-LAR-2009-244-41]
5.6 cont.

[3] The FAC Program Engineer **OR** designee shall review the UT data to ensure that the data is complete **AND** corresponds to the requirements specified on the inspection data sheet (i.e., grid size, spacing, flow direction, starting **AND** ending locations, obstructions, missing data, suspect readings **AND** orientation).

[4] **IF** low readings are encountered from repeat inspections that are due to counter-bore, **THEN** those areas shall be noted **AND** additional inspections are **NOT** required.


(a) A grid reduction / refinement may be used **IF** the minimum measured thickness is less than the minimum required wall thickness, severe wall thinning is detected, engineering judgment, **OR** the projected thickness is less than the minimum required wall thickness **OR** as directed by the FAC engineer.

(b) The results of the grid refinement **OR** scan shall be documented on an inspection data sheet.


(a) **IF** measurement indicates wall loss at any edge of the grid, **THEN** the grid should be extended until the entire wear pattern is mapped.

[7] Determination of Initial Wall Thickness

(a) Initial Thickness \( t_{\text{init}} \): The thickness determined by ultrasonic examination prior to the component being placed into service (baseline) **OR** the first ultrasonic examination during its service life. **IF** an examination has **NOT** previously been performed on the component, the initial thickness shall be determined by reviewing the initial ultrasonic data for that component. The area of maximum wall thickness within the same region as the worn area (based on the method selected for evaluating wear) shall be identified **AND** compared to \( t_{\text{nom}} \). **IF** the thickness is greater than \( t_{\text{nom}} \), the maximum wall thickness within that region shall be used as \( t_{\text{init}} \). **IF** that thickness is less than \( t_{\text{nom}} \), \( t_{\text{nom}} \) shall be used as \( t_{\text{init}} \).

[8] Determination of Wear

(a) Wear of piping components may be evaluated using the band, area, **AND** blanket **OR** point-to-point method as defined in NSAC-202 L, latest revision **OR** any other approved method.

(b) Evaluation of inspection data that is determined to require wear evaluation shall be documented **AND** reviewed.
5.6 cont.

[9] Wear rate Determination

(a) Wear rate is determined by wear/ unit time (Units to be consistent with thickness evaluation).

(b) A reasonable safety factor should be applied to the wear rates to account for inaccuracies in the FAC wear rate calculations.

(c) Wear rate evaluation should be evaluated on a component evaluation sheet.

[10] Predicted Thickness ($t_p$, $t_{pred}$)

(a) The projected OR predicted thickness to the next schedule refueling outage.

$$t_{pred} = t_{meas} - \text{Safety factor} \times \text{Wear Rate} \times \text{Time}$$

A safety factor of 1.1 should be applied to all Entergy nuclear plants. IF a value less than 1.1 is used the reason shall be documented.


(a) Remaining service life (RSL) shall be evaluated as follows, units to be consistent with thickness evaluation:

$$RSL = \frac{(t_{meas} - t_{accept})}{(\text{Safety Factor} \times \text{Wear Rate})}$$

5.7 EVALUATION OF RT INSPECTION DATA

[1] Qualified NDE personnel shall interpret the film AND report the examination result to the FAC engineer.

[2] Appropriate conservatism should be used to determine IF a component requires replacement OR re-inspection as a consequence of qualitative nature of RT.

[3] RT inspection shall be recorded on a data sheet.

5.8 EVALUATION OF VISUAL INSPECTION DATA

[1] Where accessible, visual inspections may be performed on two-phase flow lines.

[2] Follow-up UT inspection is required for locations where significant damage is observed OR suspected.
Flow Accelerated Corrosion Program

5.8 cont.

Due to the qualitative nature of visual inspections, appropriate conservatism should be used WHEN determining whether a component is acceptable to return to service AND WHEN establishing a re-inspection frequency.

5.9 DISPOSITION OF INSPECTION RESULTS [LO-LAR-2009-244-0058] [LO-LAR-2008-0048-40] [PNPS A-16781] [VY A-16924]

The following are used to disposition component inspection results. Reference attachment 9.3 for logic diagram.

NOTE

Certain components may have very little margin remaining as a consequence of high stresses in the line even though \( t_{\text{pred}} \geq 0.875 \ t_{\text{nom}} \) AND therefore may require evaluation, for example Feedwater, Condensate, RHR, etc.

IF \( t_{\text{pred}} \) is \( \geq 0.875 \ t_{\text{nom}} \), the component is acceptable as is AND may be returned to service.

IF \( t_{\text{pred}} \) is \( < 0.875 \ t_{\text{nom}} \), evaluate for sample expansion (Reference section 5.12).

IF \( t_{\text{pred}} \) is \( \leq 0.3 \ t_{\text{nom}} \), for ISI Class 1 piping repair OR replacement is required in accordance with the requirements of ASME Section XI Repair and Replacement Program.

IF \( t_{\text{pred}} \) is \( \leq 0.2 \ t_{\text{nom}} \), for ISI Class 2, Class 3 AND non-safety related, repair, replace OR evaluate as warranted in accordance with applicable site programs OR as directed by the FAC engineer.

IF \( t_{\text{pred}} \) is \( \geq t_{\text{accpt}} \) and the remaining service life of the component is greater than or equal to the number of hours in the next operating cycle the component is acceptable for continued operation; however monitoring is required in accordance with program requirements.

IF \( t_{\text{pred}} \) is \( < t_{\text{accpt}} \), a structural evaluation is required in accordance with site approved procedures OR engineering standards. Also a sample expansion evaluation is required. Repair or replacement in accordance with the requirements of ASME Section XI Repair and Replacement Program OR other site approved process may also be required.
5.9 cont.

[8] IF \( t_{\text{meas}} < t_{\text{accpi}} \), generate a condition report. A structural evaluation is also required in accordance with applicable site procedures OR engineering standards.

5.10 RE-INSPECTION REQUIREMENT

[1] IF the remaining service life (RSL) of a component is greater than OR equal to the number of hours in the next operating cycle, THEN the component may be returned to service.

[2] IF the component's remaining service life (RSL) is greater than the number of hours in the next operating cycle but is less than the number of hours in the next two operating cycles, THEN the component should be considered for re-inspection, repair or replacement during the next scheduled outage.

[3] IF the component is acceptable for continued service, THEN it shall be re-examined before OR during the outage immediately prior to the cycle during which it is projected to wear to the minimum allowable wall thickness.

5.11 COMPONENTS FAILING TO MEET INITIAL SCREENING CRITERIA

[LO-LAR-2009-244-0058]

[1] IF the results of the remaining life evaluation are shorter than the amount of time until the next scheduled inspection, there are several options for disposition of the component, as follows: [LO-LAR-2009-244-0058]

(a) Shorten the inspection interval (for components that can be inspected online)

(b) Refine the \( t_{\text{accpi}} \) value through a detailed stress analysis, which should be provided by Design Engineering OR designee.

(c) Repair or replace the component

(d) ISI Class1 components that are less than OR equal to 0.3 \( t_{\text{nom}} \) must be repaired OR replaced unless further structural evaluation permits continued service.

[2] Wall thinning resulting in less than \( t_{\text{accpi}} \) shall be reported immediately to the FAC engineer by verbal OR written communications.

[3] A condition report shall be generated WHEN significant wall thinning OR unexpected wear is detected in a system OR component.
Flow Accelerated Corrosion Program

5.11 cont.

[4] A condition report shall be generated for wall thinning below $t_{\text{accpt}}$ OR other site established limit AND a subsequent structural evaluation performed to disposition the line for continued service.

[5] IF a previous condition report was generated for a component with wall thinning THEN no new condition report is required provided that the associated structural evaluation is current AND applicable.

5.12 SAMPLE EXPANSION [LO-LAR-2009-244-0058]

[1] IF a component is discovered that has a current OR projected wall thickness less than the minimum acceptable wall thickness ($t_{\text{accpt}}$), THEN additional inspections of identical OR similar piping components in a parallel OR alternate train shall be performed to bound the extent of thinning except as provided below. Reference section 5.12[2].

[2] WHEN inspections of components detects significant wall thinning AND it is determined that sample expansion is required, the sample size for that line should be increased to include the following:

(a) Components within two diameters downstream of the component displaying significant wear OR within two diameters upstream IF the component is an expander OR expanding elbow.

(b) A minimum of the next two most susceptible components from the relative wear ranking in the same train as the piping component displaying significant wall thinning.

(c) Corresponding components in each other train of a multi-train line with a configuration similar to that of the piping component displaying significant wall thinning.

[3] IF the expanded inspection scope detects additional degradation, the sample expansion should continue until no additional components with significant wear are detected.

[4] Sample expansion is NOT required IF the thinning was expected OR IF the thinning is unique to that component (e.g., degradation downstream of a leaking valve).

[5] Inspections of components from the current OR past outages may satisfy the sample expansion criteria, therefore, some of the sample expansion requirements can be met without performing additional inspections.
Flow Accelerated Corrosion Program

5.12 cont.

[6] Sample expansion is **NOT** required for components that are being re-inspected **IF** normal **OR** expected wear is detected **OR** wear unique to that component. All other wear patterns encountered shall be evaluated by the FAC Engineer to determine **IF** sample expansion is required.

5.13 REPAIR / REPLACEMENT OF DEGRADED COMPONENTS

[NRC Generic Letter 90-05] [LO-LAR-2009-244-0058]

[1] The FAC engineer shall generate applicable documents to facilitate repair or replacement of degraded **OR** deficient components.

[2] Components experiencing severe **OR** unacceptable wear should be replaced with corrosion resistant material. However like in kind replacement may be appropriate **IF** procurement of a resistant material would delay plant restart.

[3] Replacing components **OR** fitting-by-fitting that have experienced significant wear is a satisfactory approach to reducing wear **IF** the wear is very localized (i.e., wear is concentrated downstream of a flow control valve **OR** orifice).

[4] Repairs and replacements to piping **AND** components within the scope of Class 1, 2, 3 shall be performed in accordance with the requirements of ASME Section XI Repair and Replacement Program.

[5] All temporary non-code repairs to ISI Class 1, 2, 3 shall comply with NRC Generic Letter 90-05.

5.14 COMPONENT EVALUATION PACKAGES

[1] The FAC Engineer **OR** designee shall assemble a component evaluation package for each examined component which shall at a minimum contain the following:

(a) UT DATA Sheet

(b) Shall include all **OR** one of the following when available Isometric drawing(s), sketches, flow diagram **AND** digital photo(s).

(c) Reference to Structural /Minimum wall evaluation (Calculation #, EC #, Site Administration Screening #)

(d) Component evaluation data sheet.

(e) Applicable pipe specification data
5.15 POST- INSPECTION ACTIVITIES [LO-LAR-2009-244-0058] [CR-RBS-2011-360]

[1] The FAC Program Engineer shall prepare an Outage Report to document FAC outage activities AND submit to records for retention, within 60 days after outage completion, in accordance with applicable procedures. The Outage Report shall include as a minimum:

(a) Outage Scope Document
(b) Executive summary includes outage scope, any deferred exams, CR(s), listing of WR(s), screening criteria, disposition of adverse conditions, evaluations, calculations, repairs/replacements and/or any issues impacting the FAC Program
(c) FAC Scope Checklist for examinations schedule and inspections performed
(d) Examinations Results
(e) Component Evaluation Packages


[3] Update small bore susceptible report as applicable

[4] Update all applicable FAC reports.


5.16 LONG TERM STRATEGY [LO-LAR-2008-0048-40] [PNPS A-16781] [VY A-16924]

[1] Entergy’s fleet long-term strategy shall focus on reducing the plant's FAC susceptibility. Optimization of the inspection planning process is an important factor. However, the reduction of FAC wear rates is necessary IF both the number of inspections AND the probability of failure are to be reduced. Subsequently the fleet’s long term strategy will include the following elements:

(a) The use of improved materials for replaced components OR proactive replacement of piping with corrosion resistant material.
(b) Utilization of improved water chemistry
(c) Incorporation of local design changes.
(d) Optimization of the inspection planning process,
(e) Industry participation in meetings for technology and information transfer (e.g. EPRI CHUG).
Flow Accelerated Corrosion Program

5.16[1] cont.

(f) Maintaining up-to-date predictive software AND incorporating the latest inspection data in the models.

5.17 METHODS OF DETERMINING PLANT PERFORMANCE


6.0 INTERFACES

[5] CEP-NDE-0505, "Ultrasonic Thickness Examination"
[8] Site ASME XI Repair / Replacement Program as applicable.

7.0 RECORDS

Inspection records shall be transmitted to Administrative Services to ensure retention as quality related records, EN-AD-103, “Document Control and Records Management Programs”.
## 8.0 SITE SPECIFIC COMMITMENTS

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### 9.0 ATTACHMENTS

9.1 GUIDANCE ON PARAMETERS AFFECTING FAC.

9.2 FLOW ACCELERATED CORROSION PROGRAM ATTRIBUTES.

9.3 WALL THINNING EVALUATION PROCESS MAP.

9.4 FAC OUTAGE SCOPE TEMPLATE
GUIDANCE ON PARAMETERS AFFECTING FAC

Listed below are factors to be considered when reviewing work requests, component replacements and modification packages for possible impact on the content of the FAC Program governed by EN-DC-315. All Design Change Packages (DCP’s) are required to be evaluated for impact to the FAC Program. This list is not intended to be all-inclusive or to limit the number of items an individual would consider when performing this impact assessment. It is intended as a reasonable list of items to consider for potential program content updates.

1. **Water Chemistry.** Many water chemistry parameters have been shown to contribute to FAC.
   
   a. **pH Control Amine** – pH is the primary chemistry parameter affecting FAC rates in PWRs. However, the amine used to control pH also plays an important role. Amines such as ammonia tend to separate more into the steam phase in two-phase flow conditions, and therefore provide less protection in the drains. Amines such as morpholine and especially ethanolamine have better partitioning characteristics for FAC.
   
   b. In a BWR, pH has much less of a role since the pH is stable and there are no amine’s added to control the pH. FAC rates decrease as pH level increases. FAC rates seem to drop considerably at pH values of greater than 9.3 - 9.5.
   
   c. **Oxygen Content** - FAC rates decrease as oxygen concentration increases. Values that typically result in minimum FAC rates are approximately 15 to 20 ppb.
   
   d. **Hydrogen Water Chemistry** – BWR Plants that do not have hydrogen addition normally have a main steam oxygen content near 18 ppm. Plants with hydrogen water chemistry typically have an oxygen content from 3 to 12 ppm. This has a potential to impact the corrosion rates in the LP steam systems; mainly the first and second stage reheater drains based on industry experience.
   
   e. **Hydrazine Injection** - Hydrazine is added to the feed train of PWRs as an oxygen scavenger and to maintain a reducing environment in the steam generators. From zero to approximately 150 ppb, an increase in hydrazine concentrations seems to increase rates of FAC. Higher concentrations seem to result in no further increase in FAC rates. EPRI recommends the use of high levels of hydrazine (>100 ppb) to protect steam generator tubes; however, this can result in accelerated rates of FAC in the feed train. Although CHECWORKS does not currently model high hydrazine conditions, any model updates performed after the release of version 1.0F should carefully consider hydrazine concentrations.
   
   f. **Zinc Injection** - Industry experience has shown that zinc injection decreases corrosion and FAC wear rates due to the concentration of zinc at the oxide surface. The amount of reduction depends on the amount of zinc at the surface.
2. **Piping Geometry** - Piping geometry is one of the most important factors in FAC. Generally, geometries that produce the greatest turbulence also produce the highest FAC rates. Listed below are examples of obvious items that should be considered in any assessment:

   a. Addition or replacement of fittings, bends and branch connections.
   
   b. Like for like replacement of any fitting in a system that is susceptible to FAC damage or is part of system that is already part of the FAC Program.
   
   c. Alterations or repairs encountered in the nozzles or walls of FW heaters, MSR, Drain Tanks, FW Pumps, HD Pumps or CD/CB Pumps.
   
   d. Throttled Valves.

3. **Piping Material Composition** - Alloying elements improve the resistance of piping systems to FAC. Periodic testing and inspection of Carbon Steel piping downstream of resistance material shall be performed for indications of entrance effect Ref. EPRI TR 1015072, “FAC Entrance Effect”, November 2007. In ascending order of resistance, the following table presents the degree of improvement over carbon steel:

<table>
<thead>
<tr>
<th>Material</th>
<th>Nominal Composition</th>
<th>Rate (carbon steel) / Rate (alloy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P11</td>
<td>1.25% Cr, 0.50% Mo</td>
<td>34</td>
</tr>
<tr>
<td>P22</td>
<td>2.25% Cr, 1.00% Mo</td>
<td>65</td>
</tr>
<tr>
<td>304</td>
<td>18% Cr</td>
<td>&gt;250</td>
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</table>

4. **In-Line Components** - Addition or replacement of such components as thermowells, flow elements and pressure-reducing orifices should be evaluated. The local effects caused by these components can generate FAC damage in areas where overall conditions don't indicate the need for inspections.

5. **Component Supports** - Additions or deletions of components supports which could result in the need for a review of the existing code minimum wall value or a new code minimum wall calculation.

6. **Operational Changes** - System operational changes such as the normal operation of emergency heater drains, switching of spare components, extended use of normal start-up or by-pass lines, etc.
7. **Component Replacements** – Records should be updated for like for like replacement of fittings already in the program including new baseline data, changing next scheduled inspection due date, etc. Note and track whether the replacement components have had surface preparation and a UT grid applied for future outage planning.

8. **External Sources** – Information concerning FAC Inspection results from other stations and Nuclear Plants operated by others. General information distributed by EPRI Reports, INPO & NRC Bulletins, etc. should also be considered.

9. **Maintenance History** – A review of the maintenance performed on valves, orifices, steam traps, etc. should be considered. Valves that have had seat leakage can cause very localized wear in systems normally exempted. Plugged traps create water pockets in steam systems that accelerate metal loss. Eroded orifices can cause increased metal loss due to decrease in back pressure and increase in flow rates.
PROGRAM ATTRIBUTES

Attributes:

Program Infrastructure
(a) Program Structure: Roles & Responsibilities, Program Ownership, Organizational Interfaces, etc.
(b) Configuration management
(c) Program Bases
(d) Engineering Documentation
(f) CHECWORKS models
(g) Change processes

Program Staffing and Experience
(a) Background and Expertise.
(b) Qualification and training.
(c) Bench Strength
(d) Time Allotment
(e) Industry Participation

Program Implementation
(a) Work control
(b) Inspections
(c) Maintenance and Repairs
(d) Control of Changes and Deferrals
(e) Review of INPO Operating Experience documents, CHUG operating experience, NRC notices.

Health Monitoring:
(a) System Engineering Health reports.
(b) FAC Quarterly Health Reports.

Effective Assessment:
(a) Perform FAC Self-Assessment on a periodic basis or as defined by applicable procedures.

Oversight:
(a) Effective assessment, Benchmarking or Audits.
Logic Diagram - Evaluation of Pipe Wall Thinning

Start

$ t_{\text{pred}} \geq 0.875 \times t_{\text{thcm}}$ for required thickness

$ t_{\text{ pred}} \geq 0.3 \times t_{\text{thcm}}$ for Class 1 piping or $0.2 \times t_{\text{thcm}}$ for Class 2, Class 3 and non-safety related piping

No

Repair or Replacement Required.

Additional Inspection Required

Sample Expansion

Determine need for expanded inspection scope and for future inspections of component

Yes

Yes

Structural evaluation required Per EN-CS-S-008-MULTI

Acceptable As Is

Acceptable for Continued Operation, Future Inspection Required

Acceptable for Continued Operation, inspect or Repair/Replace Next Outage

Repair or Replace Component per Plant Procedures

$ t_{\text{ pred}} > t_{\text{accept}}$

$ t_{\text{ pred}} \geq t_{\text{loc}}$
# Flow Accelerated Corrosion Program

## ATTACHMENT 9.4

**FAC OUTAGE SCOPE TEMPLATE**

Sheet 1 of 1

<table>
<thead>
<tr>
<th>Sheet</th>
<th>Name</th>
<th>Description</th>
<th>Location</th>
<th>Media Flow</th>
<th>Media Flow</th>
<th>Pad Flow</th>
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