Development and Implementation of a High Energy Piping Program

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Specialize in:
- High Energy Piping Evaluations
- Critical Boiler Component Evolutions
- Specialty Repairs
High Energy Piping Background

- In the early 1980’s several catastrophic failures in HEP systems
  - Mohave and Monroe
- At the time limited understanding of the damage mechanism, inspection tools and life assessment
- Significant work by several organizations, EPRI and MPC to develop many of the tools we are using today
High Energy Piping Today

- Failures continue to happen
  - Since 1980’s 60+ seam weld failures
  - In just the last 3 years 30+ girth weld failures
- The combined cycle plants represent a whole new set of challenges
  - We are dealing with “infant mortality” issues
  - Complexity of the new alloys Gr 91/92
  - Seeing “end of life failure” much sooner
Problem Definition: The Challenge

- Operate HEP systems in a Safe and Reliable manner
  - Failures represent serious personnel safety Risk
  - Failures represent potentially catastrophic financial loss
- Clients have diminishing internal resources
  - Staff
  - $$$
- Requires a wide array of technologies and technical expertise
- Most Effective When Proactive - not Reactive
Overview of the Solution

- Programmatic Engineering Approach
  - Multi disciplined
  - Integrated
- Need to Prioritize the Inspection location.
  - *Where* should I look first
- Need to develop an appropriate inspection protocol
  - *How* should I look
- Need to develop methodologies to analyze the results
  - *What* do I do now
Program Flow Chart

1. Develop Overall Program Document
   - Collect and Review Existing Data
   - Perform Baseline Life Calculations
   - Perform Pipe Stress Analysis as Needed
   - Perform Risk Assessment/Prioritized Evaluation List

2. Perform Site Evaluations of Top Priority Components/Test Sites
   - VT, MT, LPA, TOFD, Hardness, Replication,

3. Analyze Results and Provide Recommendations
   - 1) Additional NDE
   - 2) Sample removal/analysis
   - 3) FE/FM

4. Perform Updated Risk Ranking
   - 1) Suitable for Service
   - 2) Repair immediately
   - 3) Define Re-inspection interval

5. Continue Monitoring Program

Information Management Program
Primary Disciplines/Capabilities

- Program Development/Risk Assessment
- Materials/Metallurgical Engineering
- Stress analysis
- Advanced Non-Destructive Examination
- Finite Element/Fracture Mechanics
- Cycle chemistry
- Remaining Life Assessment
- Data Management
- Repair Technology
- QA
High Energy Piping (HEP) Program

High Energy Piping Program
  - Sometimes referred to as Covered Piping Systems (CPS)

Step 1: Establish an overarching Program Document

Step 2: Develop a Risk-based prioritization of inspection locations

Step 3: Perform appropriate inspections of critical locations

Step 5: Perform life assessment/Repair-Replace, if required

Step 6: Develop re-inspection plan

Step 6: Maintain database of inspection results

Step 7: Raise the Program’s IQ by incorporating inspection and analysis results for guidance during subsequent outages
HEP Program Document

- Program document establishes the overall goals and objectives of the Program
- Defines roles and responsibilities
- The most effective Programs are:
  - Supported by upper management
  - Under the direction of a central engineering group
Risk Based Prioritizations

+ Most plants have limited budgets, time and personnel to perform their own HEP evaluations

+ The question is always:
  - “I can only evaluate 20 welds which ones should I inspect and when should I inspect them?”

+ Historically this has been based on the perceived level of stress acting on a weld

+ Stress is a key contributor in damage development, but it is not the only factor
Risk Base Prioritization

✿ Risk is defined as the Probability of Failure Multiplied by the Consequence of the Failure
  - Risk = Prob_f x Consequence_f

✿ For the purposes of Risk ranking a *relative* probability of damage accumulation analysis is adequate
  - Which welds are most likely to have damage

✿ For HEP the consequence is based on personnel safety
  - A relative man pass frequency serves as the basis for assigning a Consequence value
What are the things that *Influence* damage accumulation?

- Stress
- Material properties
- Embedded fabrication flaws
- Field vs shop weld
- Heat treating process
- Local influences

For each weld relative values are assigned for each influence.
Probability Analysis

- All *Influences* are not equal
- Weighting factors are developed for each *Influence*
Consequence Analysis

- A relative consequence value is assigned to each weld
- This is based on a man pass frequency estimate
- The highest man pass location is assigned a value of 10
- The lowest man pass location is assigned a value of 1
Risk Analysis

The data is collected from:

- Document review
  - Drawings
  - Prior stress analysis
  - Prior inspection reports
  - Fabrication records
- Site walkdowns
- Interviews with plant personnel

Data is entered into analysis program

A Relative Risk value is calculated for each weld
Results

- The program provides a Road Map for each outage
  - Used to develop the scope of the inspections
  - Helps to obtain cost estimates
  - Helps make scope adjustment decisions
- The program is updated after each outage to make it “smarter,” so that future prioritizations are made with the improved knowledge of the condition of those components that have been inspected/analyzed
  - This is a living document
Inspection Protocol

- Match the inspection technique to the damage mechanism
  - Creep
  - Fatigue
  - Wall loss
- Match the inspection technique to the damage location
  - ID
  - OD
  - Mid wall
- Detect damage early
  - Proactive vs reactive
Creep Damage can initiate at the OD, ID or mid wall, depending upon the weldment structure and the type of loading to which the weld is subjected.

<table>
<thead>
<tr>
<th>Inspection Technique</th>
<th>Inspection Zone</th>
<th>Sensitivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magnetic particle</td>
<td>Surface</td>
<td>Macro</td>
</tr>
<tr>
<td>Replication</td>
<td>Surface</td>
<td>Micro</td>
</tr>
<tr>
<td>Radiography</td>
<td>Volume</td>
<td>Macro</td>
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<td>Linear Phased Array</td>
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<td>Heavily Aligned Cavities</td>
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<tr>
<td>TOFD</td>
<td>Volume</td>
<td>Heavily Aligned Cavities</td>
</tr>
</tbody>
</table>
Life Assessment

- Perform Life assessment
- Evaluate macro defects
  - FEA/FM
- Estimate Remaining Life
- Develop re-inspection intervals
- Run-Repair-Replace Decision
Repair as Needed

- Only repair what needs to be repaired
  - “sometimes the best repair is no repair”
- Fully understand the damage mechanism
- Fully quantify the extent of the damage
- Develop detailed weld procedure and technical specification
- Provide experienced on site technical direction
What About Grade 91 and Other CSEF Steels?

- The inspection process for existing piping systems must be modified when the material of construction is Grade 91 or one of the other Creep-Strength Enhanced Ferritic (CSEF) steels,

- This is because errors in processing during manufacturing or during erection of components fabricated from these steels can severely degrade the material’s creep strength, leaving the material vulnerable to failure well before the end of the design life of the component.
For piping systems containing Grades 91/92 the prioritization process is modified to incorporate essential information reflected in industry-wide Grade 91 inspections results/trends and generated as part of the EPRI Grade 91 Research Project:

- Weighting factors have been adjusted to reflect increased risk for fittings, elbows, multiple attachments, etc.
- New factors have been added to capture risk associated with deficient chemical compositions, improper heat treatments, poor weld design, etc.
Summary

- The effective management of High Energy Piping Systems must be an integral part of a plant’s overall Inspection & Maintenance activities.
- Kiefner’s HEP Program is designed to assist clients in managing inspection activities to insure the most cost effective use of O&M dollars.
- Where the piping system has been constructed using Grade 91/92, management of the system is more complex.
  - Kiefner has developed rigorous inspection and assessment protocols for the management of pressure parts fabricated from Grade 91/92, both for systems already in operation as well as for systems that are in the process of being designed and built.