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PROLONG THE INTEGRITY OF HIGH ENERGY PIPING SYSTEMS: UNIT SPECIFIC STRATEGIC PLANNING

High-energy piping systems are essential to the safe and cost-effective operation of a modern power plant. The propensity for piping and failures tends to increase with the age of the systems involved. Prolonged operation, particularly at elevated temperatures, may result in metallurgical degradation. Metallurgical degradation may increase the potential for cracking and crack propagation until a final failure stage is reached by the component. As a result, power plant operators have become increasingly cognizant of the importance of condition assessment evaluations for high-energy piping systems and boiler components.

TABLE OF CONTENTS

INTRODUCTION

High-energy piping systems are essential to the safe and cost-effective operation of a modern power plant. The propensity for piping and failures tends to increase with the age of the systems involved. Prolonged operation, particularly at elevated temperatures, may result in metallurgical degradation. Metallurgical degradation may increase the potential for cracking and crack propagation until a final failure stage is reached by the component. As a result, power plant operators have become increasingly cognizant of the importance of condition assessment evaluations for high-energy piping systems and boiler components.

Significant levels of metallurgical degradation should be detected for conservative determinations of the remaining useful life of a component or system. With this information, proper planning and budgeting or repair and replacement programs can be performed. By proper planning and the performance of engineering evaluations, excessively long plant outages or interruptions of scheduled operations can be minimized and in some cases avoided.

Some of the challenges in prolonging the integrity of high energy piping systems include reductions in plant engineering staff, an aging workforce and the need to remain competitive. Plant managers are routinely faced with the daunting task of determining the current condition of their equipment, forecasting outage budgets and schedules, planning replacement schedules, and performing risk assessments for their facilities. Furthermore, insurance companies are increasingly requiring inspection and maintenance records and new EPA Regulations have become a major issue within the industry.

The solutions to extending the life of high energy piping systems involve taking a comprehensive approach to piping management utilizing unit specific operational training, advanced data management, and strategic inspection, maintenance and replacement prioritization.

This manuscript will examine and illustrate the challenges and solutions to prolonging the integrity of high energy piping systems through the utilization of a unit specific strategic management approach.

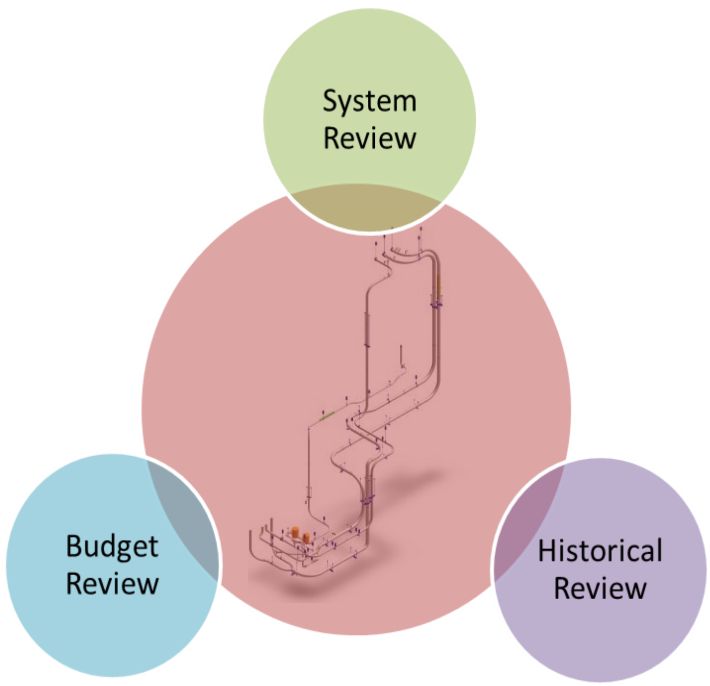
Who We Are: Industry Experts

- 32 Year Old Company
- Failure Analysis and Prevention Specialists
- Engineering Design Services
- Metallurgical Evaluation/Analyses
- Quality Assurance Programs for Repair and Retrofit Projects
- Nondestructive Examinations Field/In-House
- Inspection Protocol Development
- Specialty Welding

- 4-SYTE System Strategy Program
- Expert Witness
- Outage Support
- ASME Code Design/Fabrication (U, PP, and S Stamps)
- National Board of Boiler & Pressure Vessel Inspectors Code Repairs (R Stamp)

PROLONG PIPING INTEGRITY: UNIT SPECIFIC STRATEGY

Each facility has its own unique operational history and conditions. In order to prolong the integrity and ensure the safety of your critical piping systems it's imperative to consider your facility's unique conditions to develop a strategic plan. Many plant managers and engineers never get started with an integrity program because the task is so daunting. Breaking this process into a three step approach simplifies the task.

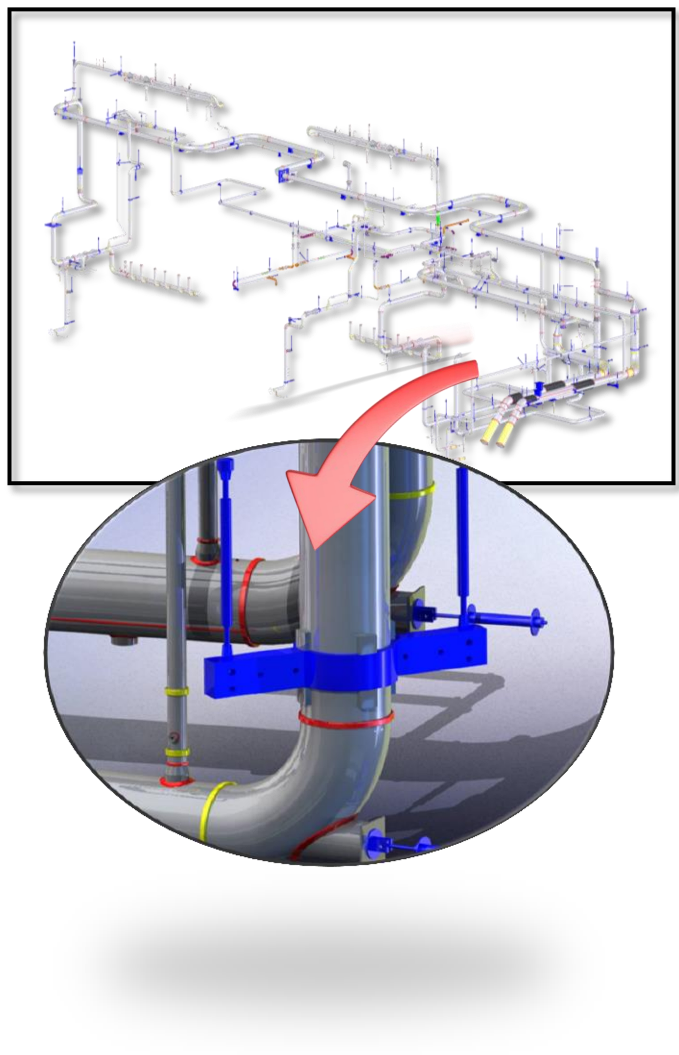


Use of an equipment management program like the 4-SYTE System Strategy Program can simplify the 3-Step review process. The program is an online, 3-dimensional, interactive equipment management program that allows plant managers and corporate planners to access their account via a secure website. The program offers key personnel the ability to manage all previous inspections, repairs, and recommendations, as well as construction, design, and operational data associated with any section of the critical components in their facilities. Using this program, our engineers apply their expertise in root cause analysis and failure prevention to develop a strategy for equipment integrity, replacement, and risk management.

The 4-SYTE program provides affordable start-up and maintenance with no requirements to purchase or install software. It also provides data access, storage and protection. In addition, it allows for customized searches and report generation.

Process Step 1 - System Review

Key components of consideration:



- Age of the System
- Design of the System
  - Temperature
  - Pressure
  - Flexibility
- Operation of the Unit
  - [baseline vs. cyclic]
- Materials
  - Extruded
  - Rolled
  - Forged
  - Cast
  - P91
  - Locations of Dissimilar Welds
  - Locations of Fabrication Defects
- Weld Type
  - Girth Weld
    - Field
    - Shop
  - Seam Weld
  - Penetration Weld
    - Sock-o-let
    - Weld-o-let
    - Threaded
  - Attachment Weld
- Weld Location
  - Boiler Connections
  - Turbine Connections
  - Forged and Cast Wye and Tee Fittings
  - Welded Lateral Type Wye Connections
  - Branch Connections
  - Nipples, Saddles, etc
  - Straight Pipes

    - Pipe Bends and Elbows
    - Valve Connections
    - Lugs
    - Radiographic Access Hole Plugs
- Hanger Types
    - Rigid
    - Constant
    - Variable
    - Snubber

Taking the above unit specific considerations into account when developing a strategic piping integrity plan is essential to targeting the specific design issues a unit may be experiencing. Utilizing an equipment management program like the 4-SYTE System Strategy program can simplify the system review process.

Process Step 2 - Historical Review

Key components of consideration:

- Service Failure/Damage Locations
- Service Failure/Damage Classifications:
    - Creep
    - FAC
    - Fatigue
        - Mechanical
        - Corrosion
        - Thermal
- Modifications
- Replacements
- Operational Changes
- Upset Conditions
- Operational Training
- Steam Circuit Piping
- Feedwater Circuit Piping
- Hanger Walkdowns/Travel Ranges
- Inspection History
- Stress Analyses

Taking the above unit specific historical considerations into account when developing a strategic piping integrity plan is essential to targeting the specific operational issues a system may be experiencing. Utilizing an equipment management program like the 4-SYTE System

Strategy program can simplify the historical review process. Having access to the design and historical data specific to a unit's critical piping systems offers managers and planners the ability to develop a strategic plan to target their specific challenges.

Process Step 3 - Budget Review

Key components of consideration:

- Remaining Useful Life Determinations
- Prioritization:
    - Inspection
    - Repairs
    - Replacement
- Outage Schedules
- Budgetary Allocation
- EPA Regulations
- Safety/Risk Management
- Plant Life Cycle Management
- Asset Management

Taking the above unit specific considerations into account when developing a strategic high energy piping integrity program is essential to targeting the specific financial challenges a unit may be experiencing. Additionally, as the high energy piping systems reach the end of their useful life, replacements will need to be allocated for. Replacing entire piping systems is not a cost effective approach, and would be unachievable during a typical outage. Strategically planning for the replacement of specific spool pieces, utilizing an equipment management program, is a more comprehensive and cost effective approach. Utilizing an equipment management program like the 4-SYTE System Strategy program can simplify the budget review process.

CASE STUDIES

The following instances of piping damage and/or failures represent a small sampling of cases that Thielsch Engineering participated in the evaluation and subsequent repairs involving high energy piping systems in the Utility industry. These cases illustrate several types of damage that can develop as a result of the harsh environments these systems are exposed to during their service life.

Mechanical Fatigue:

In April of 2010, Thielsch Engineering discovered two significant indications in the girth welds located on the legs of a wye block in the Main Steam piping system of a power station located in the Midwest.

The linear fatigue-type surface indications were discovered during the wet fluorescent magnetic particle examination. The first indication was 13" long, at the 12:00 o'clock in the toe of the weld on the north wye block. The second indication was 4" long at the 12:00 o'clock position, in the toe of the weld on the same wye block. These indications were evaluated and confirmed to require repairs.

The boiler of this facility is a radiant reheat boiler that was designed and erected by Babcock and Wilcox. The design and erection of this boiler would have been carried out in accordance with the requirements of Section I of the ASME Boiler and Pressure Vessel Code. (This Section of the Code covers "Power Boilers".) The boiler is rated to deliver 4,545,000 pounds of steam per hour and was placed into service in 1981. Since that time, it had been operated in a base-loaded manner. At the time of the evaluation, the unit had accumulated 211,875 hours of operation.

The High-Energy piping systems would have been designed and erected in accordance with the requirements of the ASME B31.1 Code on Pressure Piping covering "Power Piping." The Main Steam piping system was reportedly fabricated using pipe manufactured in accordance with the requirements of ASTM Specification A-335, Grade P22.

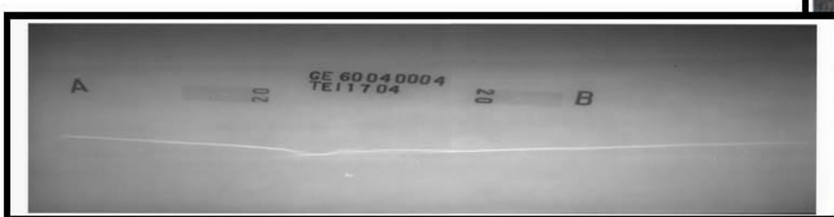
Thielsch Engineering was contracted to provide guidance and supervision to supply a weld repair program, and to perform repairs by welding on the Main Steam piping system, thus returning the

piping to a level of integrity suitable for continued service under design operating conditions. After conducting a thorough examination of the piping system, it was revealed that several hangers upstream and downstream of this weld were either damaged or bottomed out resulting in insufficient piping support and movement. A full hot and cold condition hanger walkdown and pipe stress analyses were recommended to bring the unit back to a suitable condition for continued safe and reliable operation.

P91 Piping Failure:

In January of 2004, General Electric Power Systems (GE) submitted a pipe segment to Thielsch Engineering. This pipe segment had been removed from a Hot Reheat piping system from a facility in Pennsylvania. It contained a through-wall crack that resulted in a leak during hydrostatic testing of the piping system. Thielsch Engineering was requested to perform a detailed metallurgical evaluation of the pipe segment to determine the cause of the crack.

The design, fabrication and erection of the Hot Reheat piping system were reported to have been performed in accordance with the requirements of the ASME B31.1 Code on Pressure Piping covering "Power Piping". The design of this piping system was completed by Sargent & Lundy of Chicago, Illinois. The design conditions involved a pressure of 650 psig at a temperature of 1050°F. Sargent & Lundy elected to use alloy steel pipe and fittings. The pipe was produced in accordance with the requirements of ASTM Specification A-335, Grade P91 covering "Seamless Ferritic Alloy-Steel Pipe for High-Temperature Service". (For reference purposes, Grade P91 is a modified 9 Cr - 1 Mo alloy steel material.)



The results of the metallurgical evaluation confirmed that the pipe segment had been subject to localized overheating. The localized overheating was sufficiently severe to result in reaustenitization, grain growth and cracking. The cracking and microstructural transformations introduced during the localized overheating rendered the pipe subject to brittle failure during subsequent handling.

The defect present in this pipe segment represents a localized condition. On the opposite side of the pipe segment, the microstructure and tensile properties were typical for pipe produced in accordance with ASTM Specification A-335, Grade P91. The source of the localized overheating could not be identified definitively from the results of the metallurgical evaluation. It is known, however, that the overheating occurred prior to the radiographic examination and postweld heat treatment of the affected field weld. Possible sources of localized overheating include the tempering heat treatment performed during original manufacture of the pipe, postweld heat treatment performed during fabrication of the spool piece of which this pipe was part, or some undocumented event.

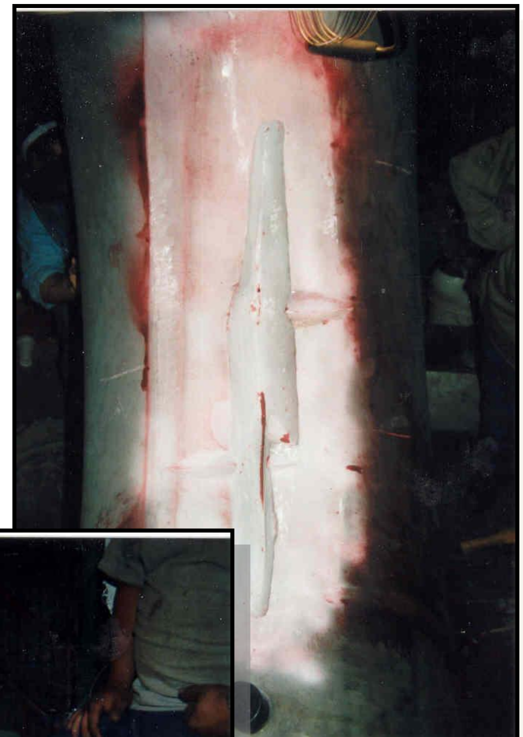
Fatigue-Creep Piping Failure:

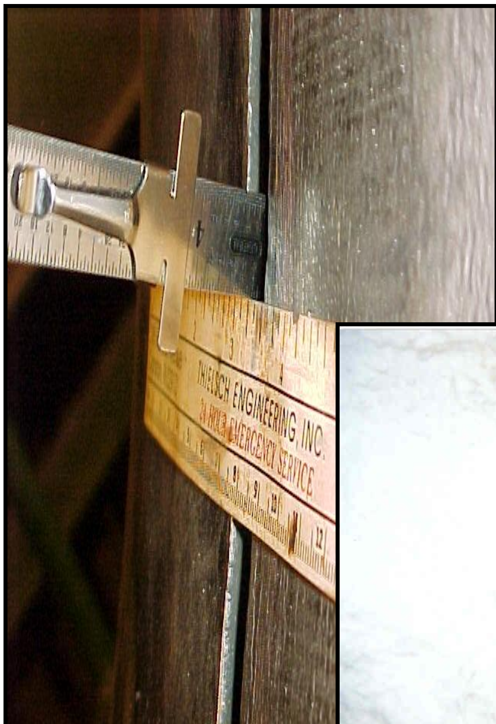
In May of 2002, a leak occurred in a Main Steam piping system at a facility located in the Midwest. This leak was the result of through-wall cracking that developed in the intrados of a clamshell elbow. Thielsch Engineering performed a metallurgical evaluation of two boat samples removed from this elbow to determine the cause of the cracking. The results of this metallurgical evaluation confirmed that the cracking in these boat samples was caused by fatigue acting in conjunction with creep. The cracking is the result of an applied bending stress. (The condition of the elbow, which had been welded with a low carbon filler material, contained at least one original weld defect, and had been heavily ground subsequent to welding, rendered it susceptible to failure by fatigue and/or creep.)

This piping system was designed and erected in accordance with the requirements of the ANSI (now ASME) 831.1 Code on Pressure Piping covering "Power Piping". The Main Steam piping system was designed to withstand a pressure of 2,650 psig at a temperature of 1015°F. (The operating conditions for this piping system involve a pressure of 2,400 psig at a temperature of 1000°F.)

The Main Steam piping system was erected using low-alloy steel pipe and fittings. The pipe was produced to the requirements of ASTM Specification A-335 covering "Seamless Ferritic Alloy Steel Pipe for High-Temperature Service". It involved Grade P22, a low-alloy steel material with a nominal composition of 2-1/4% chromium and 1% molybdenum, i.e., a 2-1/4 Cr- 1 Mo low-alloy steel. The fittings were produced to the requirements of ASTM Specification A-217, Grade WC9 covering "Alloy Steel Castings for Pressure-Containing Parts Suitable for High-Temperature Service".

Thielsch Engineering developed and instituted a repair welding program to address the cracking that had developed in the intrados of the elbow. This program, which complied with the requirements of all applicable Codes has restored the replacement elbow to a level of integrity suitable for continued service for at least five additional years.





STRATEGIC APPROACH – SOLUTIONS

In summary, implementing a unit specific, targeted strategic plan to improve safety and prolong integrity enables utility owners and operators to succeed in today's competitive market by increasing the unit's reliability and availability without sacrificing safety or environmental standards.