

High Energy Piping Inspection Program

for Power Generation and Process Industries



For Regulatory Compliance, Safety, and System Longevity





POWER
ELECTRIC
POWER SERVICES



EAPC Industrial Services offers an inspection plan for assessment and monitoring the integrity of high energy piping.

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Citations

Guidelines for Controlling Flow-Accelerated Corrosion in Fossil and Combined Cycle Plants, EPRI, Palo Alto, CA: 2005. 1008082.
Fossil Plant High-Energy Piping Damage: Theory and Practice, Volume 1: Piping Fundamentals. EPRI, Palo Alto, CA: 2007. 1012201.

EAPC INDUSTRIAL SERVICES

ENGINEERING FOR HEAVY INDUSTRY

EAPC Industrial Services is a multi-disciplinary consulting firm with offices in Bismarck, Dickinson, Fargo, Grand Forks, Minot, and Williston, ND; Sioux Falls, SD; Bemidji and St. Paul, MN; and Phoenix, AZ.

The staff of EAPC has performed hundreds of power generation and process industry projects for a wide breadth of clients nationally.

HSE QUALIFICATIONS

EAPC is certified under ISNetworld (ISN# 400-217037)

NCMS NON-DOT Qualified

EAPC has 180+ employees providing services in the following areas:

Engineering: Chemical, Mechanical, Electrical, Structural

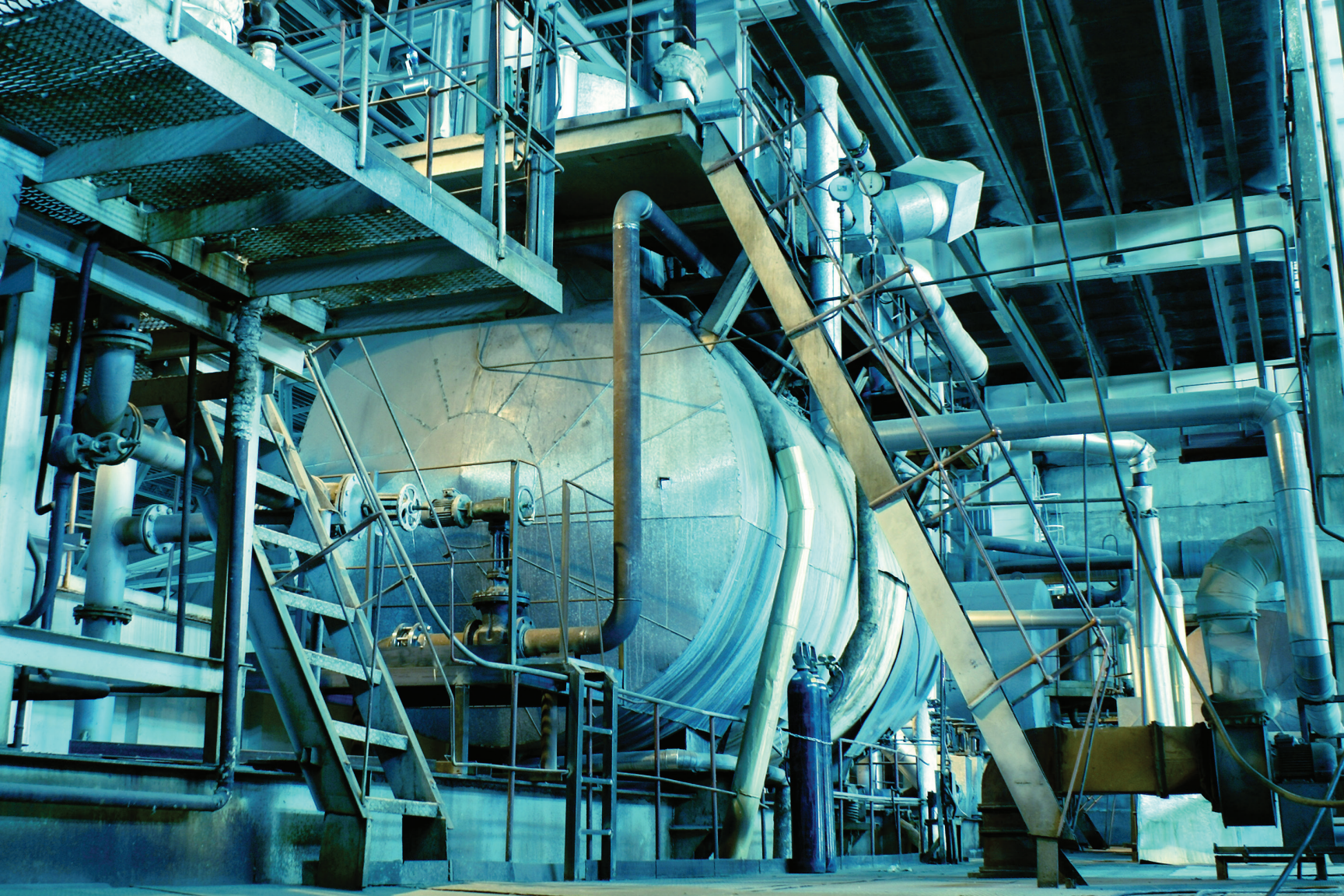
Architecture

Procurement

Construction Management

Maintenance Planning







WHAT IS HEP?

HIGH ENERGY PIPING

HEP systems are normally considered to include the main steam, reheat (both hot and cold), feedwater, and extraction steam piping. These systems can be subjected to several damage mechanisms, including creep, fatigue, thermal fatigue, microstructural instability, and flow-accelerated corrosion (FAC). An effective in-service inspection program anticipates the occurrence of damage and provides for a cost-effective program to identify this damage during an early stage of development to allow for budgeted repair or replacement. Over the past 30 years, several major failures of fossil high-energy piping have occurred.

WHAT IS A HEP PROGRAM?

ENGINEERED SAFETY FOR PLANT PERSONNEL & EQUIPMENT AND REDUCED UNPLANNED OUTAGES

A properly implemented program will anticipate damage associated with known damage mechanisms and will schedule periodic inspections to identify components for repair or replacement during routine scheduled maintenance outages.

The American Society of Mechanical Engineers (ASME) B31 code collection (B31.1 through B31.9) has been adopted as a legal requirement with the minimum design requirements being accepted by the power industry as a standard for all piping outside the jurisdiction of the ASME Boiler and Pressure Vessel Code.

The lifetime of any HEP component is a complex function of factors such as operating conditions (stresses, temperatures, and environment), geometry (piping layout, support placement, wall thickness), material, and damage type.



FACTORS THAT EFFECT HEP

CATASTROPHIC FAILURE IS PREVENTABLE

High pressure steam and boiler feedwater piping systems have failed catastrophically over the past 30 years. The Electric Power Research Institute (EPRI) has undertaken efforts to address corrective and preventive methods for improvements in design and inspection of HEP systems.

HEP failures in power and process plants have occurred due to:

- creep in longitudinal seam welded pipe
- corrosion fatigue
- heavily loaded pipe support welded connections and in circumferential piping welds
- flow accelerated corrosion in boiler feedwater piping

With large bore piping such as the main steam piping, creep can be one of the important detrimental factors affecting the life of the system. Creep is plastic deformation that is related by stress, time, and temperature of a material under load. Flow accelerated corrosion is common in feedwater piping systems where the water pH has been operating above or below the desired range of 9.2 to 9.6 in iron-based piping materials.

WHAT IS CREEP?

TIME-DEPENDENT DEFORMATION

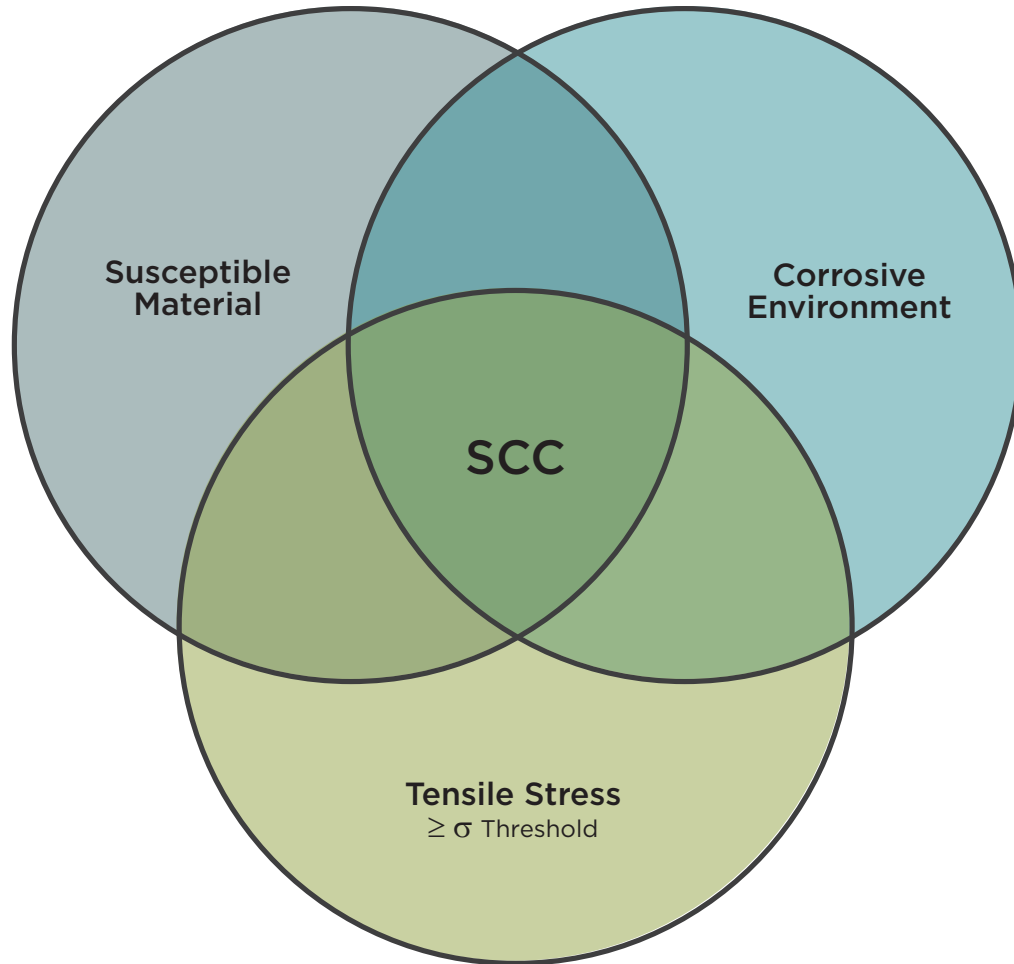
Creep may be defined as a time-dependent deformation at elevated temperature and constant stress. A failure from such a condition is referred to as a creep failure or, occasionally, a stress rupture. The temperature at which creep begins depends on the alloy composition. Actual operating stress will, in part, dictate or determine the temperature at which creep begins.

At elevated temperatures and stresses, much less than the high-temperature yield stress, metals undergo permanent plastic deformation called creep.

Creep failures are characterized by:

- Bulging or blisters in the tube
- Thick-edged fractures often with very little obvious ductility
- Longitudinal “stress cracks” in either or both ID and OD oxide scales
- External or internal oxide-scale thicknesses that suggest higher-than-expected temperatures
- Intergranular voids and cracks in the microstructure





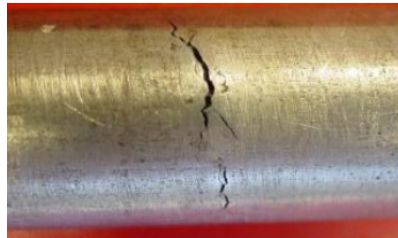
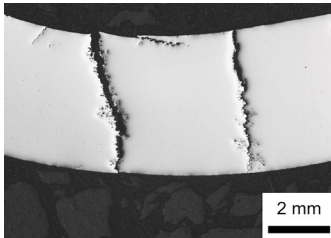
STRESS CORROSION CRACKING

THE RESULT OF A THREE FACTOR COMBO

Stress Corrosion Cracking (SCC) is the result of a combination of three factors – a susceptible material, exposure to a corrosive environment, and tensile stresses above a threshold.

SCC process is usually divided into three stages:

1. Crack initiation and stage 1 propagation
2. Stage 2 or steady-state crack propagation
3. Stage 3 crack propagation or final failure



HEP AND WELDED COMPONENTS

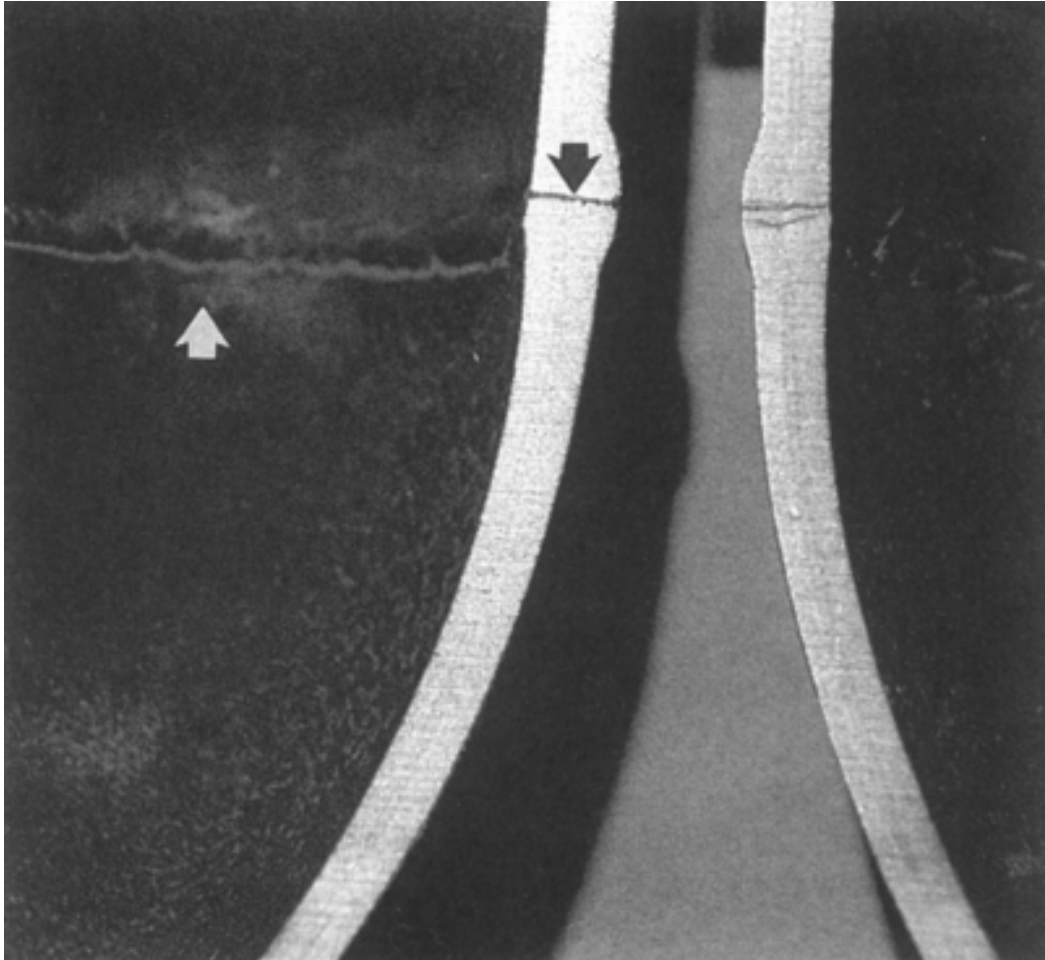
TIME-DEPENDENT DEFORMATION

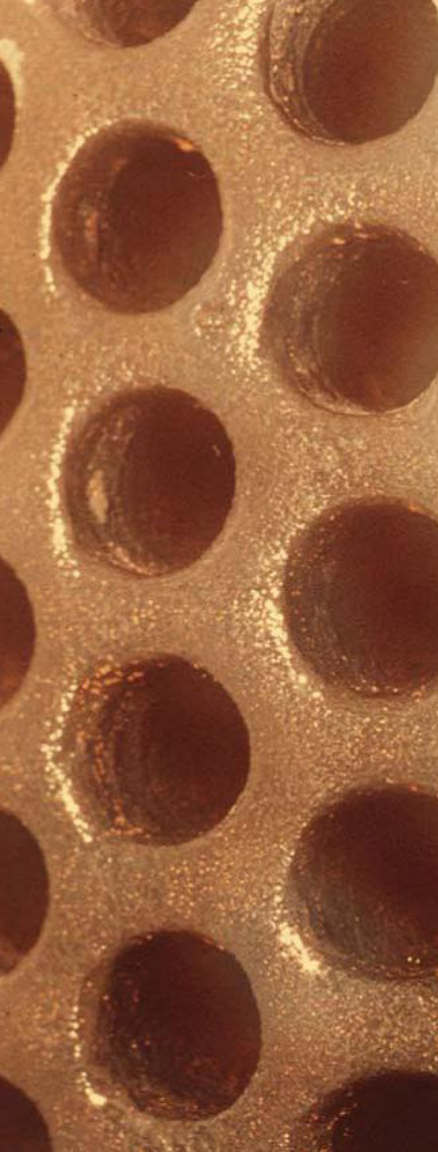
Welded joints are most critical places of steel structures due to high residual stresses and stress concentration and due to possible cracking originated from welding process. In service, cracks can easily propagate, either suddenly (brittle fracture) or gradually (fatigue, creep, or corrosion).

In such cases microfractographical analysis gives us a very useful tool.

There are four basic crack types which occur in the welded joint of steels: hot cracks, cold cracks, lamellar tearing and reheat cracks. The cracks can be found in the weld metal or in the heat affected zone from where they can propagate to parent metal or remain in the weld dependent on metallurgical factors or stresses.

The cracks were both longitudinal and transverse in the welds and in the heat-affected zones ▶





MECHANISM OF FAC

HOW CORROSION HAPPENS IN FOSSIL PLANTS AND COMBINED CYCLE PLANTS

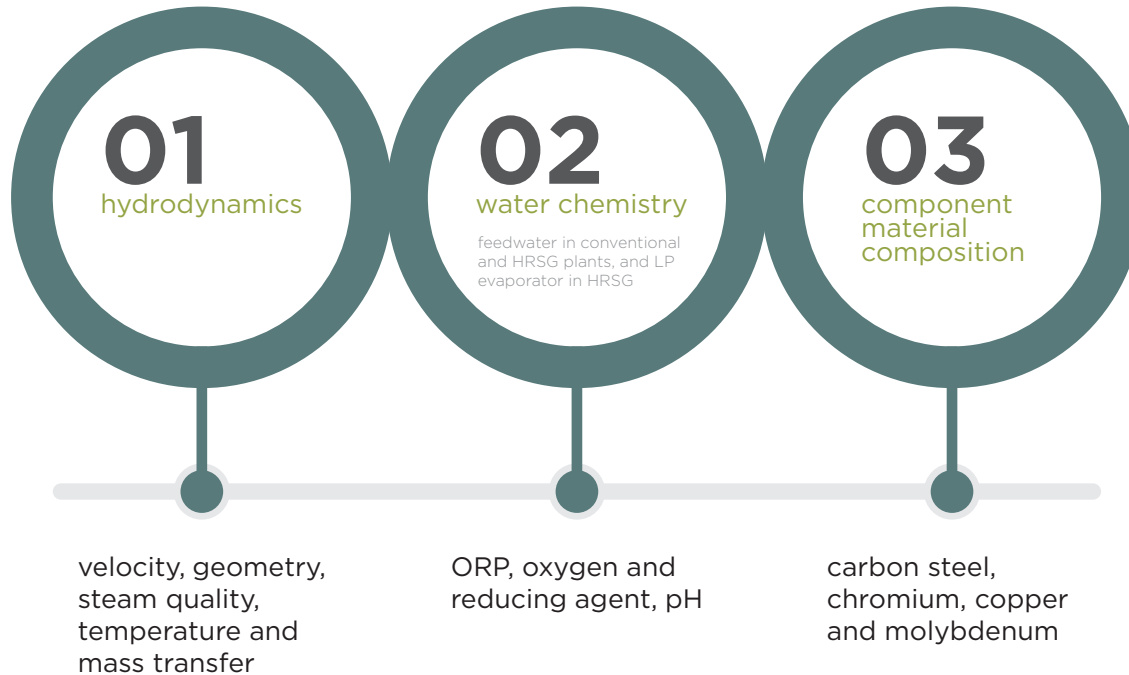
The phenomenon of FAC is a process whereby the normally protective magnetite (Fe_3O_4) layer on carbon steel dissolves in a stream of flowing water (single-phase) or wet steam (two-phase). This process reduces or eliminates the protective oxide (magnetite) layer and leads to a rapid removal of the base material until, in the worst cases, the pipe or tube bursts.

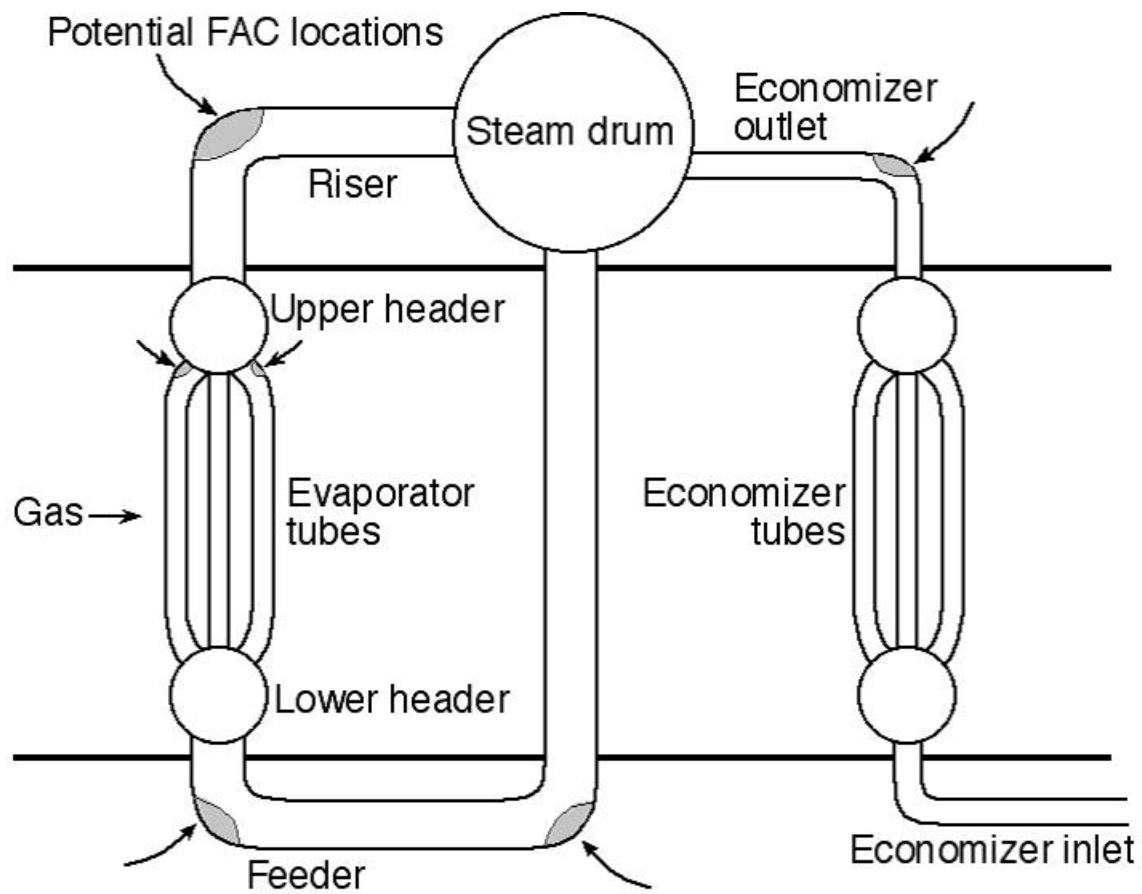
The FAC process can become rapid: wall thinning rates as high as 0.120 inch/yr (3 mm/yr) have occurred. The rate of metal loss depends on a complex interplay of many parameters including the feedwater chemistry, the material composition, the other materials in the feedwater systems, and the fluid hydrodynamics.

FAC occurs across the temperature range 70° to around 300°C (160°–570°F) with a maximum near 150°C (300°F).

◀ FAC on an HP Feedwater Heater Tube Sheet. All HP and LP heater tubing in this unit was stainless steel. The feedwater was AVT(R).

FACTORS INFLUENCING FAC IN FOSSIL AND HRSG PLANTS





FEEDWATER CHEMISTRY OPTIONS

Reducing All-Volatile Treatment, which uses ammonia and a reducing agent. Here the Oxidizing-Reducing Potential (ORP), should be in the range -300 to -350 mV

- 1 [Ag/AgCl/sat, KCl]. It should be noted that this range of ORP is not always achieved, because ORP is a careful balance between the levels of oxygen and reducing agent, and because ORP is a function of pH, temperature, materials, and the sensor characteristics. Sometimes a reducing ORP can be as high as -80 to -100 mV.
- 2 Oxidizing All-Volatile Treatment, where the reducing agent has been eliminated. Here the ORP will be around 0 mV but could be slightly positive or negative.
- 3 Oxygenated Treatment where oxygen and ammonia are added to the feedwater. Here the ORP can be as high as +100 to +150 mV.

INSPECTION-BASED ACTIVITIES

- Performing FAC Analysis
- Selecting and Scheduling Components for Inspection
- CHECUP™ Summary. EPRI Based Software Program
- Perform NDE Inspections
- Evaluating Inspection Data
- Identifying and Confirming the Cause of Damage
- Evaluating Worn Components, Repair or Replace as Necessary

◀ Schematic of Typical FAC Locations in an HRSG



EPRI HEP INSPECTION GUIDELINES

A THREE PHASE PROCESS

EPRI publication, “Fossil Plant High Energy Piping Damage: Theory and Practice”, June 2007 outlines a three phased approach to HEP assessment. The following paragraphs outline each phase, or level of inspection.

Level I

is the least detailed level of inspection but is intended to provide a baseline for assessing the remaining life of the piping system. At this level, the design conditions of the pipe and supports are usually modeled in a computer pipe stress analysis program. With all design parameters modeled, the results of the pipe stress analysis should indicate high stress areas. The areas of high stress (as a minimum) would be targeted for non-destructive examination in Level II.

Level II

requires field measurements be taken of pipe wall thickness, pipe support loads (both hot and cold), temperature, pressure, and equipment nozzle movements (both hot and cold). The nondestructive testing usually consists of ultrasonic thickness testing, pulsed eddy current testing, dye penetrant, magnetic particle, and acoustical emissions monitoring for testing creep. After careful measurements are obtained in the field, the data is fed back into the computer pipe stress analysis program. The results from the computer model now give accurate stress values in the piping. It can now be accurately determined whether or not the pipe is overstressed. In other words, as the pipe wall thins the remaining life can be predicted.

Level III

is the most detailed phase of analysis and requires that piping material samples be cut and analyzed to assess metallurgical properties. A detailed evaluation of microstructure would be conducted by replication and electron microscopy. Results from the metallurgical analysis can then be assessed for remaining life of the component or system. If desired by the Owner, very detailed computer analysis involving creep and creep-fatigue calculations can be used to predict remaining life. This step is costly and usually employed only in isolated cases.





CASE IN POINT

HEP INSPECTION EXAMPLE PROJECT

EAPC Industrial Services provided a High Energy Pipe inspection program at Black Hills Power, Inc.'s Neil Simpson Complex to ensure safe, reliable operation. The inspection plan was for assessment and monitoring the integrity of the main steam piping and boiler feedwater piping in all four units. For regulatory reasons, personnel safety, and system longevity, it was necessary to inspect piping containing high energy fluids. This inspection program was developed in accordance with ASME B31.1 Power Piping Code and EPRI guidelines.

The inspection program included:

- pipe wall thinning, cracking, and/or degraded material properties
- periodic non-destructive testing which can be accomplished without outage
- periodic non-destructive testing in which an outage is required
- periodic destructive testing if required
- testing results and their limits with action items



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