Lecture 8: Chemistry of Service Systems

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Chemistry of Service Systems

- Low temperature, non-irradiated systems
- Service Water Systems
  - Fire Protection System
  - Recirculating Cooling Water System (RCW)
  - Water Treatment Plant
- Associated balance of plant systems
  - Generator stator cooling
  - Turbine Lubrication oil
  - Generator hydrogen cooling

Chemistry of Service Water Systems

- Fire Protection and Condenser Cooling Water systems use minimally treated water
- RCW uses demineralised water at pH 10 with added hydrazine to remove dissolved O_2 when necessary
- Water Treatment Plant produces purified water for a variety of systems

Chemistry of Service Water Systems

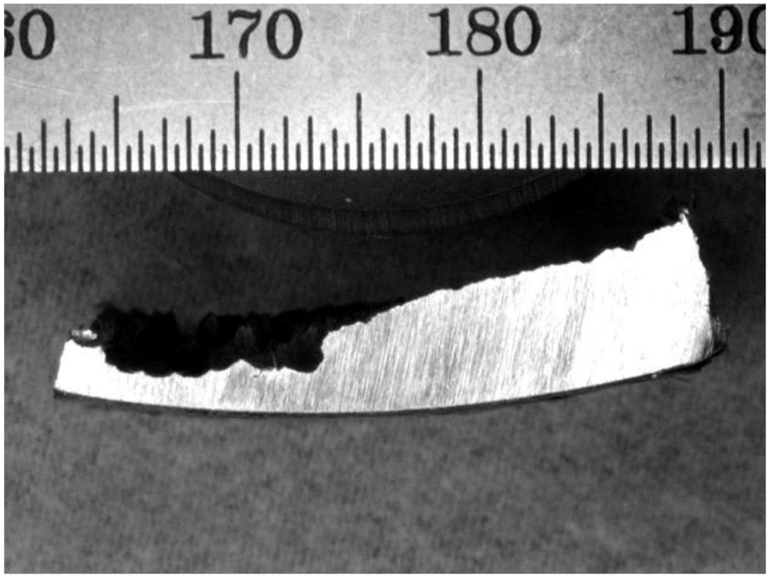
Potential chemistry control problems:

- General corrosion

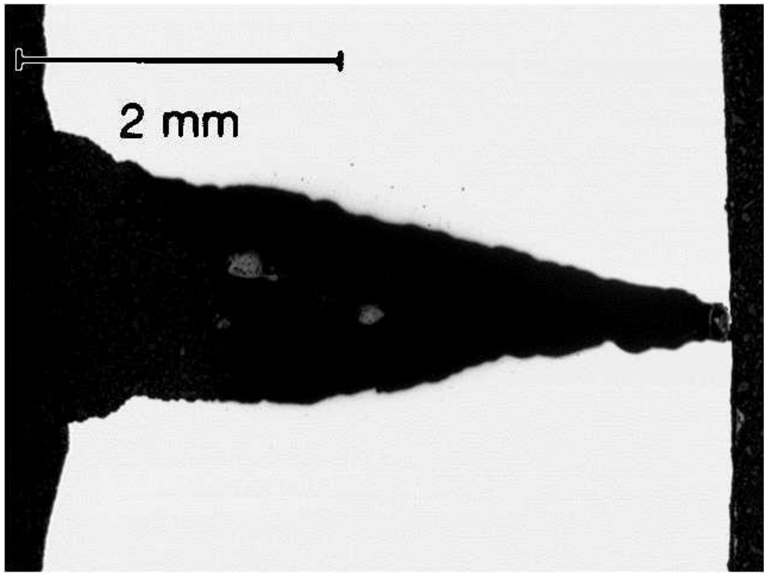
- Microbially influenced corrosion (MIC)
  - Material degradation – through-wall failures
    - Breech of containment
    - Downgrading of D_2O

- Microbial fouling
  - Loss of heat transport efficiency
    - Oversize HX – increased cost
    - Power derating
    - Forced outage

Fire Protection System and MIC



Corrosion Caused by MIC



Through-Wall Pitting of FPS

MIC in Fire Protection Systems

- Carbon Steel
  - General corrosion and tuberculation
  -
- "Raw" water
  - Microbial nutrients and high microbial population
- Intermittent flow
  - Alternate stagnant (anaerobic) and flowing conditions (aerobic)

3” Fire Protection System Riser

Fire Protection System MIC Prevention

- Design
  - Material and joints
  - Stagnant
  - Water source
- Operation
  - Water treatment
  - Call-ups – usage
- Evaluation
  - Routine water sample trending
  - Internal inspection
  - Radiography

Control of Tuberculation

- Tuberculation greatly limited through chemistry control as a result of design and operational considerations

- Tuberculation resulting in partial or complete flow blockage is only really a problem for carbon steel pipes

- Tuberculation normally the result of two processes
    - –Microbial
    - –General electrochemical processes

Control of Tuberculation

- Tuberculation worse under conditions of low oxygenation (not deaerated)
- Tends to occur either in low-flow systems, or in stagnant legs in systems past which there is a flow of oxygenated water

Control of Fouling

- Primarily control of suspended solids within systems
- Best achieved through physical removal of suspended solids using filters and screens
  - Note: fouling can lead to:
    - Physical plugging of equipment (e.g., heat exchangers)
    - Providing sites for initiation of corrosion
- Chemistry parameters considered diagnostic
  - Ensure correct operation of physical strainers and filtration systems

Control of Corrosion Demineralized Water Systems

- Fouling control in these systems primarily by controlling corrosion
- Best achieved through design and operational considerations
- Effective chemistry control of corrosion possible in these systems
- Corrosiveness of demineralized water reduced by controlling:
    - Alkalinity
    - Dissolved O_2 content

Dissolved O_2 Specification

- Pitting, crevice corrosion, general corrosion primary corrosion mechanisms considered for determining dissolved O_2 specification
- Carbon steel considered most susceptible material in terms of general corrosion
  - Carbon steel corrosion concerns used to determine dissolved O_2 specification

Dissolved O_2 Specification

- N_2H_4 generally used to remove dissolved O_2 from closed loop systems
  - N_2H_4 usage should be kept as low as possible:
    - Economic
    - Environmental
    - Degradation concerns

- Normal use of N_2H_4 to control O_2 - add N_2H_4 at 2-3 x [dissolved O_2]

Dissolved O_2 Specification

- Possible presence of Cu-bearing alloys in RCW
  - Unreacted N_2H_4 breaks down to release $NH_3 \Rightarrow$corrosion of Cu and Cu-containing alloys
  - Keep concentration of residual N_2H_4 as low as possible concentration of dissolved O_2 limited by general corrosion of carbon steel

- N_2H_4 should only be added at 2x [dissolved O_2] when latter exceeds upper control limit

Recirculated Cooling Water - Specifications

Parameter	Specification
Control	
pH	9-10
Dissolved O_2	<50 μg/kg
Diagnostic	
NH_3	<100 μg/kg
Total Cu	<50 μg/kg
Total Fe	<100 μg/kg
Cl^-	<100 μg/kg
Conductivity	<0.3 mS/m

Water Treatment Plant

- WTP provides make-up water for steam cycle and other systems
- WTP one of two major impurity sources for SG
  - other source - cooling-water in-leakage at condenser
- Rationale for WTP performance requirements:
  - Concentrations of impurities in make-up water must be significantly less than performance requirements for diagnostic parameters in SG blowdown

Performance requirements for water quality exiting WTP

Parameter	Specification	Rationale
Na	<0.5 µg/kg	Limit impurity ingress
Cl^- (inorganic + organic)	<1 µg/kg	Limit impurity ingress
SO_4^{2-}	<1 µg/kg	Limit impurity ingress
Specific conductivity	<0.01mS/m	Limit impurity ingress
Silica	<50 µg/kg	Limit impurity ingress
TOC	<200 µg/kg	Limit impurity ingress

Turbine Generator Set

- Converts useful heat energy in steam into mechanical energy
  - Generator coupled to steam turbine drive further converts mechanical energy to electric energy

- Includes:
  - Turbine Lubricating Oil System
  - Generator Hydrogen Cooling System
  - Stator Water Cooling System

Turbine Lubricating Oil System

- Oil acts as:
  - Lubricant to reduce wear
  - Coolant for some bearings to maintain constant bearing temperature
- Bearing failure is very serious, can cause extensive damage
- Steam Turbine Oil Purification System removes water and solid particles
  - 10-20% of oil passed through purifiers and back into reservoir
  - Use in-line particulate filter

Turbine Lubricating Oil System

- Oil used in main steam turbine-generators expected to have long service life

- Conditions can:
  - Accelerate oil deterioration rates
  - Lower oil quality
  - Increase the risk of damage to other components

- Purpose of chemistry control:
  - Ensure oil is of sufficient cleanliness for use
  - Ensure oil has chemistry properties required by turbine manufacturer.

Turbine Lubricating Oil System

Parameters Monitored Include

- Appearance
- ASTM Color
- Water Content
- Viscosity and Viscosity Index
- Oxidation Stability
- Neutralization Number
- Pour Point
- A.P.I. Gravity

➢ Required monitoring and specifications from turbine manufacturer.

Generator Hydrogen Cooling System

- Removes heat produced by:
  - Electrical heating due to:
    - Current resistance in windings of both rotor and stator
    - Current induced in structural material of rotor and stator
  - Windage (gas friction) between rotor and circulating cooling gas
- Use $H_2 \Rightarrow$ compared with air, H_2 has the advantages of:
  - Better thermal conductivity
  - Less damaging to insulation
  - Less dense, thus less friction and windage loss

Generator Hydrogen Cooling System – Chemistry Control

- Disadvantage: H_2 explosive when mixed with air
- Chemistry control of this system required to:
  - Prevent formation of explosive H_2-air mixtures
  - Maintain acceptably low level of moisture and oil for electrical efficiency

Generator Hydrogen Cooling System - Hydrogen Purity

- H_2 explosive when mixed with air
  - Upper explosion limit is 75 vol %
  - H_2 purity must be maintained well above this limit

- Increase in air concentration:
  - Enhances insulation degradation
  - Reduces cooling efficiency
  - Increases friction and windage loss

∴ H_2 purity must be maintained > 96 vol %

- Purging of system performed before operation

- Supply of high purity H_2 is required

Generator Hydrogen Cooling System

- O_2 in this system may:
  - Cause fire or explosion
  - Enhance degradation of insulation materials
- Limit O_2 concentration in H_2 to 0.5 vol %
  - O_2 concentration diagnostic for air in-leakage
- Dew Point - avoid moisture in H_2 gas
  - Mostly carbon steel system
  - Moisture can decrease interwinding resistance
    - Increased possibility of shorting
  - Dew point recommended to be < -18^oC
    - Gas dryers remove moisture

Stator Water Cooling System

- Generator Hydrogen Cooling System unable to remove all heat from generator
  - Stator Water Cooling System is also provided
  - Components manufactured of stainless steel and copper
- Stator conductors are hollow
  - Cooling water flows through hollow conductor
  - This water must be exceptionally pure to prevent leakage of current from stator conductors to ground

Stator Water Cooling System

- Chemistry control of this system is required to:
  - Maintain cooling water purity specifications,
  - Remove corrosion products and prevent their build-up in circuit.

Stator Water Cooling System

- ~20% of flow continuously directed into IX resin column
- During normal operation, water flows continuously through closed loop
  - Very little make-up
  - Make-up water is from station-demineralized water system
    - Passes through IX resin to remove impurities before going to storage tank
- Conductivity used as measure of ionic impurities
- Heat exchanger plates made of copper
  - Maintain O_2 concentrations <50 μg/kg

Stator Water Cooling System

- Corrosion Products
  - Cu deposition on stainless steel surfaces detrimental
  - Magnetic iron corrosion products collect in areas of high potential and cause electrical leakage
  - Cu concentration used as diagnostic to indicate Cu corrosion and corrosion product formation
    - Cu concentration should be <20 μg/kg