PD621
Grade 91 and Other Creep Strength Enhanced Ferretic Steels

Day One

- Course Overview
  - History of the development of the CSEF Steels
  - The fundamental metallurgy of the CSEF Steels
  - Problems associated with poor design
  - Problems associated with improper processing
  - Problems associated with deficient chemical composition
  - Unique issues encountered in the inspection of the CSEF steels
  - Welding of the CSEF Steels
  - Life assessment of the CSEF Steels
- History of Grade 91 and the CSEF Steels
  - Evolution from carbon steels to low alloys to X-20
    - Subsequent work by Teledyne on the precursors to Grade 91
  - Development of Grade 91 as part of the LMFBR (Liquid Metal Fast Breeder Reactor) program
  - Development of new and stronger creep resistant alloys for use in advanced power generating and processing equipment
    - Ultra-Supercritical steam generators, Combined Cycle units, High Temperature nuclear steam generators, etc.
- The Metallurgy of Grade 91 and the CSEF Steels
  - The theory of meta-stable alloys
    - Importance of lower transformation products to the development of superior creep strength
    - Importance of tempering and the precipitation of stabilizing carbides, carbo/nitrides to the development of superior creep strength
  - Chemical composition and the influence of key elements on alloy performance
    - Role of nitrogen in developing good creep strength for many of the CSEF steels,
      - ⇨ Danger of certain nitride-forming elements in undermining nitrogen's effect
    - Influence of certain austenite stabilizing elements, such as nickel and manganese, on the critical transformation temperatures

- Balancing austenite and ferrite stabilizing elements to minimize the amount of delta ferrite formed
  - Effect of delta ferrite on properties
- Effect of inter-critical heat treatment on creep properties
- Vulnerability to stress-corrosion cracking
- Control of properties through the use of a tempering parameter
  - the cumulative effect of thermal treatments on properties

Day Two

- Design Advantages of the CSEF Steels and the Assessment of Long-Term Creep Strength
  - Reductions in weight
  - Reductions in thickness and resistance to thermal-fatigue damage
  - Oxidation resistance of higher chromium CSEF steels
  - General philosophy of creep testing of engineering alloys
  - Importance of level of test stress on results
  - Importance of level of test temperature on results
  - Specifying temperature intervals at stress levels to provide more accurate extrapolation
  - Differences in test “philosophy” when assessing long-term creep strength
    - Kimura’s range splitting
  - Degraded vs. “normal” Grade 91 properties
- Processing
  - Heat Treatment
    - Recommended heat treatment practice for normalizing and tempering and post weld heat treatment
    - The importance of temperature control
    - The proper use of thermocouples for effective control of local heat treatments
    - Thickness vs. temperature during local heat treatments
      - ⇨ size of heat and soak bands required to satisfy heat treating ranges
    - Use of a tempering parameter for control of microstructure
    - Problems encountered due to incorrect heat treatment

- Welding
  - Control of weld metal chemistry to optimize heat treat temperature range: the importance of CMTRs (Certified Material Test Report)
  - Dissimilar metal weld issues
  - Tempering response of weld metal
  - Control of time between welding and PWHT (postweld heat treatment)
  - The Type IV region
  - Pre-heating and interpass temperatures
  - The value of the hydrogen bake
  - Crater cracking susceptibility
  - Issues with different weld processes
  - Problems encountered due to improper control of welding

- Inspection and Assessment Issues
  - Microstructure vs. Creep Strength
    - Examination by optical vs. electron microscopy
    - Metallographic replication as an inspection tool
  - Hardness vs. Creep Strength
    - What is an appropriate maximum and minimum hardness for Grade 91 and the other CSEF steels?
    - What should be done if hardness if below desired range? Above desired range?
    - Types of hardness testers, their relative advantages and disadvantages
    - Decarburization issues
    - Intercritical heating and the limitations of hardness testing for QC (quality control)
    - Test site selection
  - Assessment Tools
    - Creep testing
      - ⇨ Miniature creep specimens
      - ⇨ Punch tests
      - ⇨ Full size creep specimens
    - High temperature strain gauges
    - Incorporation of creep results into life assessment

- The ASME Code and the CSEF Steels
  - The changing role of the ASME Code in US industry
    - The loss of technical talent in industry
    - The Code viewed as the technical resource of last resort
  - Creating rules for the CSEF steels
    - More prescriptive rules needed for the CSEF steels
    - The scarcity of needed data on which to base rules