Design and Application of Local Post Weld Heat Treatment

A Panel Presentation and Discussion featuring

- **Paul Kovach, P.E. - Stress Engineering Services**
- **Harvey Wilde - Thermal Solutions**
- **Prashant Parikh - Equilon**
- **Ken Fordyce - Hydril**

- Summary of WRC 452 prepared by Richard Boswell, P.E.

PWHT Key Issues

- What is PWHT and why is it necessary
- New and In-Service PWHT
- Local, Spot, and Global PWHT
- Pre-Heat and Post Heat Benefits
- Consequences of good and poor PWHT
- PWHT for different materials
- Stress Corrosion Cracking
- Residual Stress
- Metallic Phases
- Material Properties
- Thermal Gradients and Transients
- Wall thickness and thru wall gradients
- Insulation practices
- Multi Zone Heat Control
- Procedures
- Planning
- Execution
- Vertical and Horizontal vessels
- Oil Field Equipment
- Codes and Standards
- Rules of Thumb Practice
- Analytical design
- Examples
- References
- WRC Bulletin 452

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- Recommended Practices for Local Heating of Welds in Pressure Vessels
- J.W. McEnerney and P. Dong
- Based upon AWS D10/D10.10M : RP for Local Heating of Welds in Piping and Tubing
- References
  - ASME BPV Code Section VIII, Div 1 & 2 : Rules for Construction of Pressure Vessels
  - ASME BPV Code Section III, Div 1 Subsection NB Class 1 Components : Rules for Construction of Nuclear Power Plant Components
  - BS 5500 British Standard Spec for Unfired fusion welded pressure vessels
  - AS 1210 Australian Standard Unfired Pressure Vessels
  - NBIC (ANSI/NB-23) National Board Inspection Code
  - API Pressure Vessel Inspection Code (ANSI/API 510)
  - NACE RPO472-96 Methods and Controls to Prevent In-Service Environmental Cracking of Carbon Steel Weldments
  - NACE RPO296-96 Guidelines for Detection, Repair, and Mitigation of Cracking
  - ANSI/API 945Avoiding Environmental Cracking in Amine Units
  - NACE 8X194 Materials and Fabrication Practice for New Vessels in Wet H2S Refinery Service

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- Purposes for Local Heating
  - Bake Out
  - Preheat/interpass heating
  - Post heating
  - PWHT
- PWHT is performed after welding, generally at a higher temperature
- Performed below lower critical transformation temperature for Carbon and Low Alloy Steel
- Transformation above lower Critical Temperature : from body centered cubic to face centered cubic crystal structure
- Consequential Benefits
  - improved ductility
  - improved toughness
  - improved corrosion resistance
- Primary Benefits
  - tempering to specific hardness
  - relaxing of residual stress
- Other Benefit
  - hydrogen removal

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- “For PWHT to be successful, it must be based upon engineering assessment and optimization of parameters to meet the desired objectives.”

- “As a result, engineering judgement, in addition to stated code requirements, is often necessary.”

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- Terminology Section 4
  - Soak Band
  - Heated Band
  - Gradient Control Band
  - Control Zone
- Local Circumferential Heating Section 5
  - uniform around circumference
- Through Thickness Temperature Gradient
  - heating rate
  - size of band
- Induced Stresses and Distortion
  - compression during heating
  - creep relaxation during holding (soak)
  - global stress recovery on cooling
  - $4(Rt)^{1/2}$ may be adequate heated band size
- Recommended Approach for Sizing Heated Band
  - $2(Rt)^{1/2}$ on either side of the soak band if insulation not on opposite side of wall

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- Gradient Control Band
  - controls axial temperature gradient
  - minimizes heat losses
  - $8(Rt)^{1/2}$ plus width of soak band
- Axial temperature gradient
  - control is important to limit thermal stress
  - protect vessel outside of band: “not harmful”
  - limit temperature to no less than 50% soak at distance of $2(Rt)^{1/2}$ from edge of soak band
- Proximity of Pipe-Nozzle Weld or Shell or Head
  - more complicated limits (Fig 3)
- Intersection with Nozzles and Attachments
  - may require supplemental heat sources
  - maintain uniform temperature across components
  - see Fig 4 when nozzle weld does not require PWHT

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- RP for Common Welds
  - some practices not recognized by fabrication codes
  - Authorized Inspector approves for repair
  - Figs 5-6 for Shell or Heads : limits?
  - Figs 7-8 Welds connecting Nozzles or Other Attachments
  - Fig 9-10 Non-Uniform temperature across nozzle
- Heating Large or Overlapping or Entire Vessel Sections

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- Local Non Circumferential PWHT Section 6
  - typically a circular area : spot PWHT
  - major concerns:
    - thermal stress at geometric discontinuity near and outside the heated band
    - reactions of the weld region and weld residual stresses
- ASME III, VIII and BS 5500 do not provide an allowance
- AS 1210 provides requirements of local areas around nozzles or attachments on spheres or dished heads
- API 510 allows with precaution and requirements
  - review and development of a procedure by a pressure vessel engineer
  - consideration of strains/distortions, material properties, thermal gradients
  - minimum preheat of 300 ^{o}F
  - monitoring by suitable number of thermocouples
  - supplementary heating of intersected branch connections

- Each application of non-spherical surface must be evaluated on its own merit

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- Measurement of Temperature Section 7
- Insulation Section 8
- Other Considerations Section 9
  - Support during heating
  - Buckling and Distortion
  - Internal Liquids
  - Chimney Effect
  - Thermal Expansion
- Thermal Cycle Section 10
- Response to Deviations Section 11
  - TC failure
  - Heat Source failure
  - Interruption during heating
  - Interruption during holding
  - Interruption during cooling
- Considerations Related to Service Environment Section 12
  - appropriateness
  - exemption
  - tempering and stress relaxation objectives
  - hardness testing

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- Repair of Service Exposed Material Section 13
  - Root Cause of Failure
  - Select proper repair and mitigation technique but prevent harm
  - remove residue
  - bake out
  - preheat/interpass heat
  - post heat
  - PWHT
- Welding Without PWHT Section 14
- QA System Section 15
- Comparison of Heating Methods Section 16
  - electric resistance
  - high velocity gas combustion
- Case Histories Section 17
  - Shell
  - Nozzles
  - External Attachments
  - Skirt and Cone welds
- Conclusions and Recommendations Section 18

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- Conclusions and Recommendations Section 18
  - additional research warranted for
    - Detailed Assessments of thermally induced stresses resulting from local heating on cylindrical and spherical shells
    - Development of UNAMBIGUOUS criteria for controlling temperature gradients and relationship with band size, heating rate, hold time, etc
    - Development of acceptance criteria for performing local heating to avoid excessive thermal stresses and to achieve adequate weld residual stress reduction
    - Development of recommended SIMPLE analysis procedures for vessel configurations outside of the specs in codes and standards
  - PVRC joint industry project is intended to address these issues
  - Concern for effect on material properties
  - Adequate measurement of temperature during local heating is most cost effedctive means for assessment
  - Considerable differences exist between international codes
- Appendix A
  - revisions to ASME Section VIII, Div 1 Paragraph UW-40 (1998)
- Appendix B
  - revisions to ASME Section VIII, Div 2 Paragraph AF-41 & 415© (1998)