# After Effects of Welding Armor Steels

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**Matt Rogers**

**Welding Engineer**

TARDEC

RDTA-EN/ Materials/Environmental

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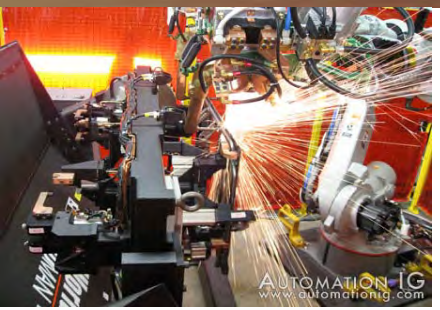
## Presenters:




# Matt Rogers

Welding Engineer

- Dec 2009 Welding Engineer @ TARDEC
- Welding Engineer, 6 years Application Engineering experience
- Bachelors of Science in Welding Engineering Technology from Ferris State University
- Associates Degree in Welding Technology
- 14 years Welding Experience

# Overview

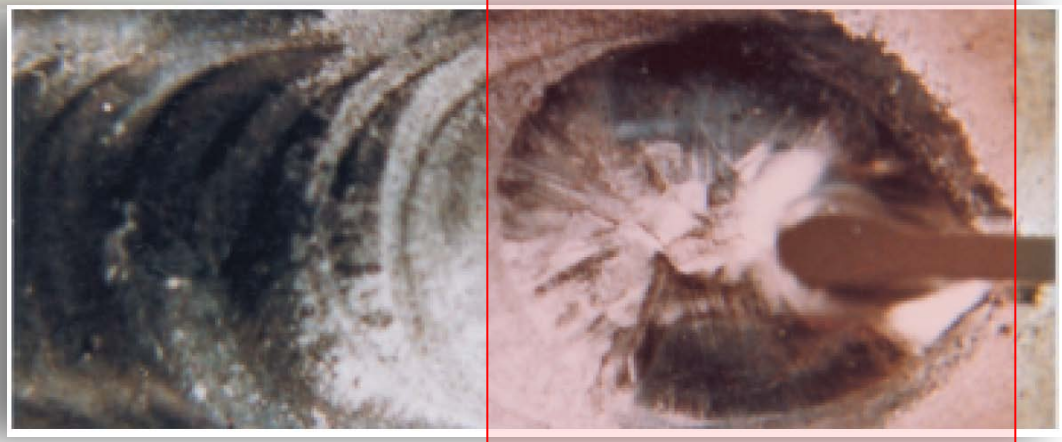
- Materials and Types for Cracking
  - Hot Cracking
  - Cold Cracking
- Types of cracks
- Causes
  - Hydrogen
  - Electrode Selection
  - Electrode Storage
- Inspection Methods
  - PT, UT, RT, MT
- Preventions
- Conclusion

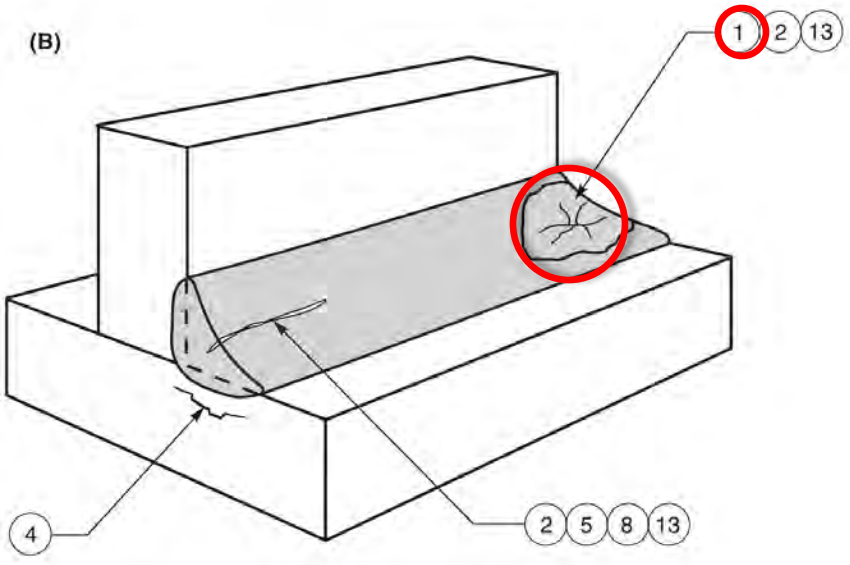
# Materials / Cracks

- MIL-DTL-46100, MIL-DTL-12560J, & MIL-DTL-32332

- Hot Cracking
  - Definition: Cracks in the weld, which results from stress in the material during solidification of the pool

- Cold Cracking
  - Definition: Cracks in the weld, which occur after the weld has solidified and cooled to ambient temperatures.



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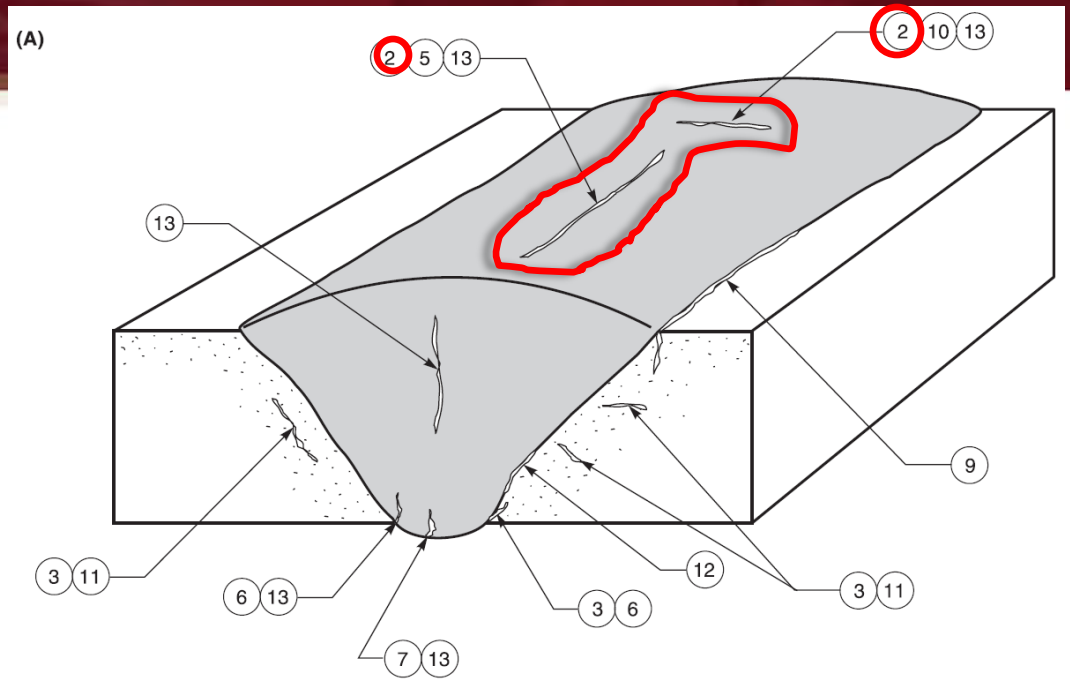


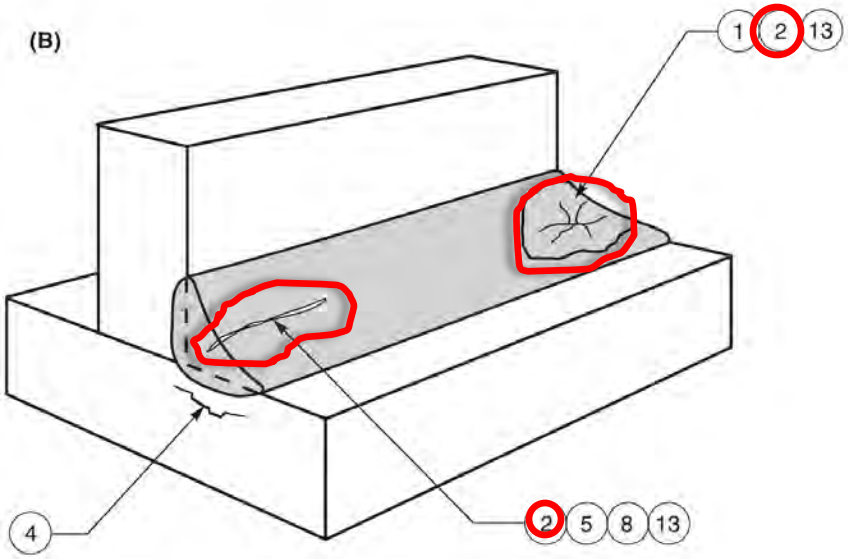


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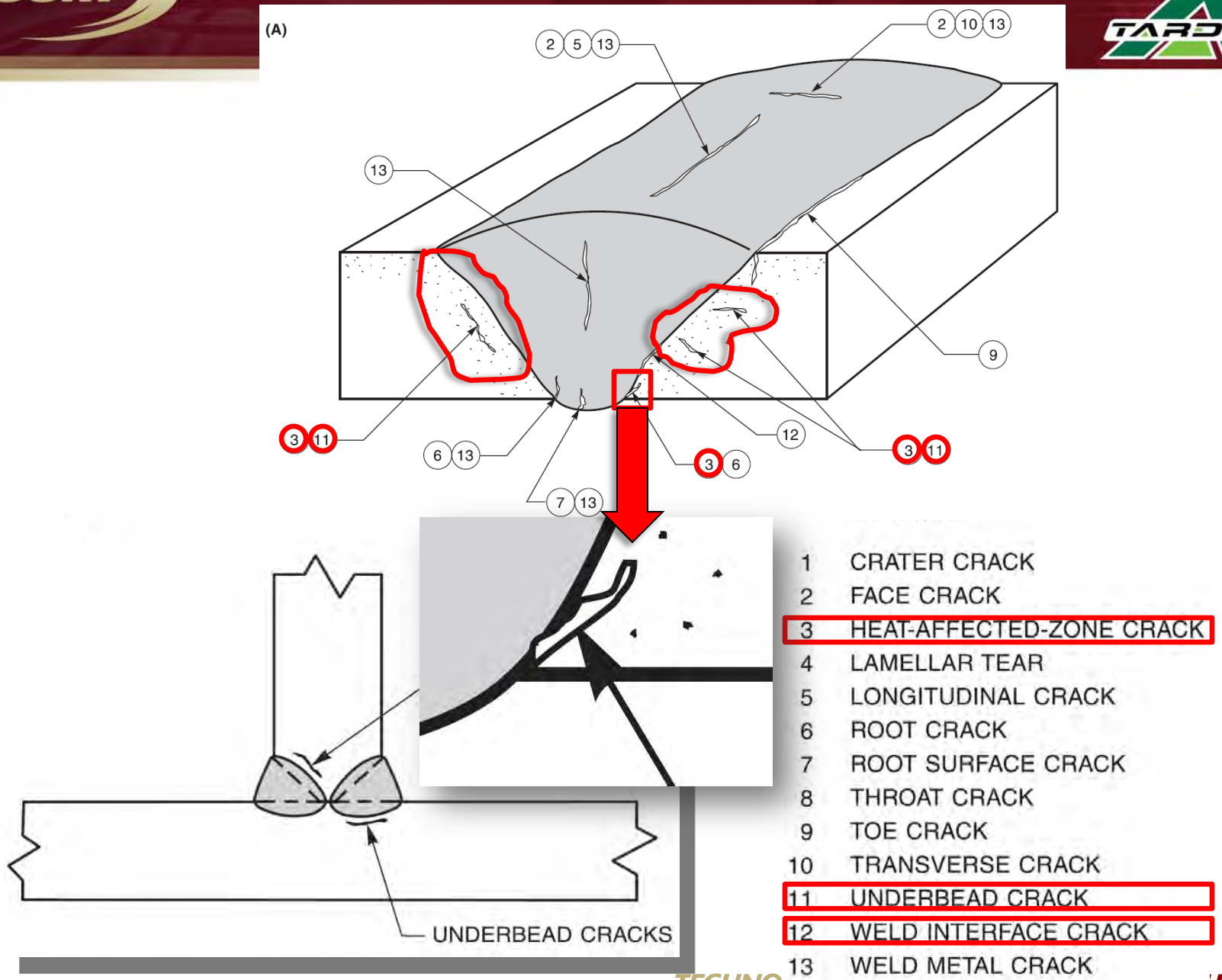

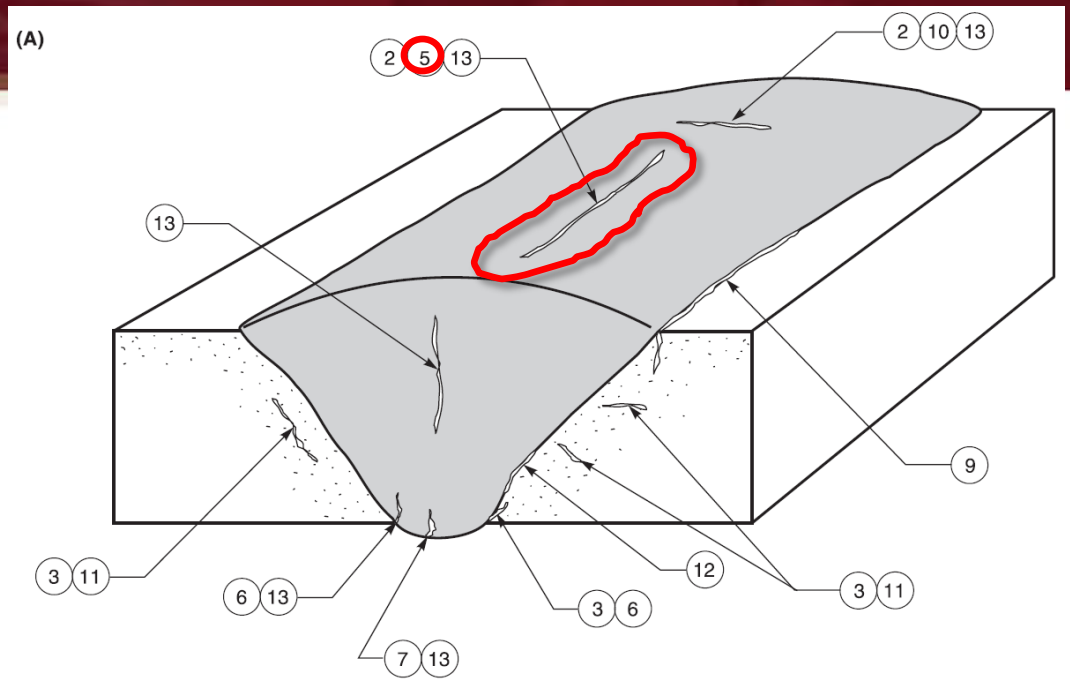


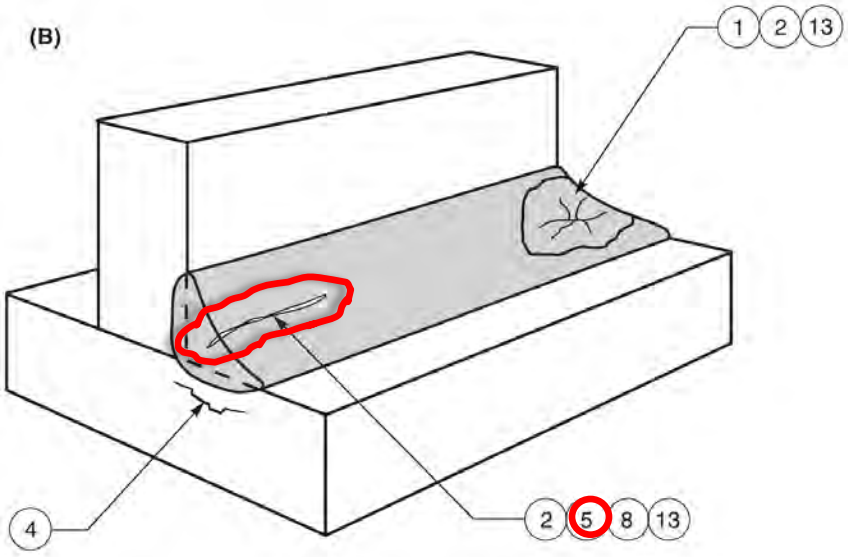


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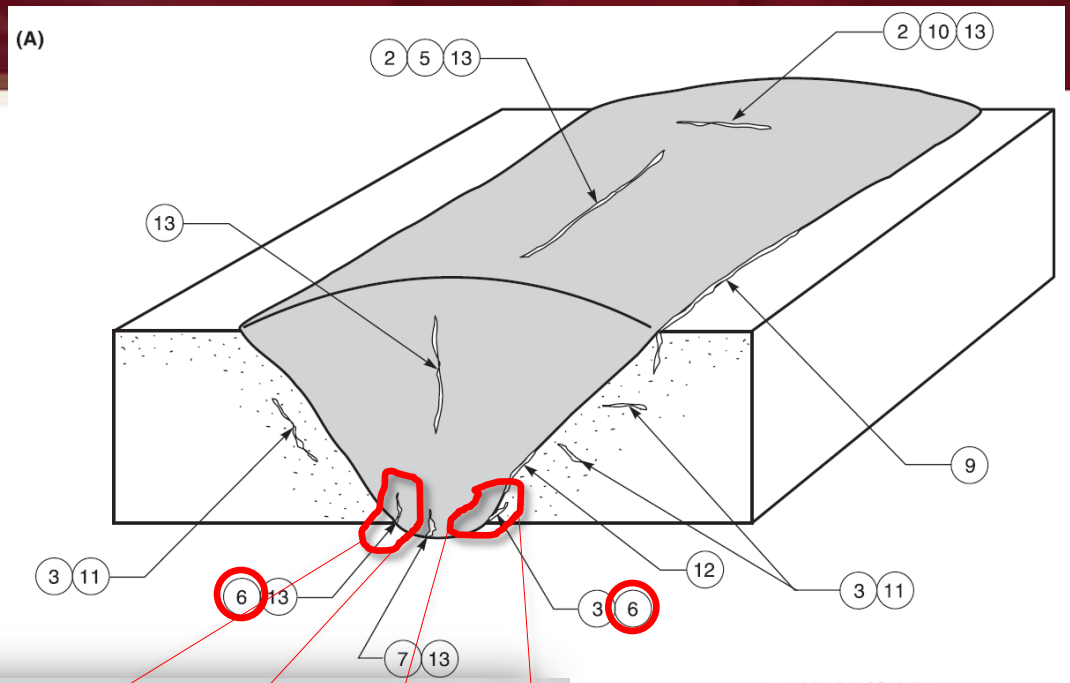


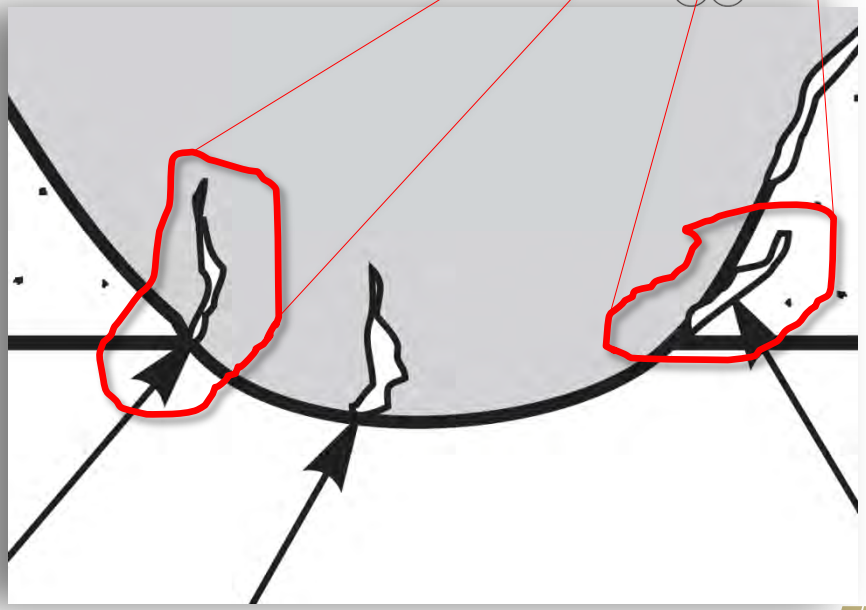

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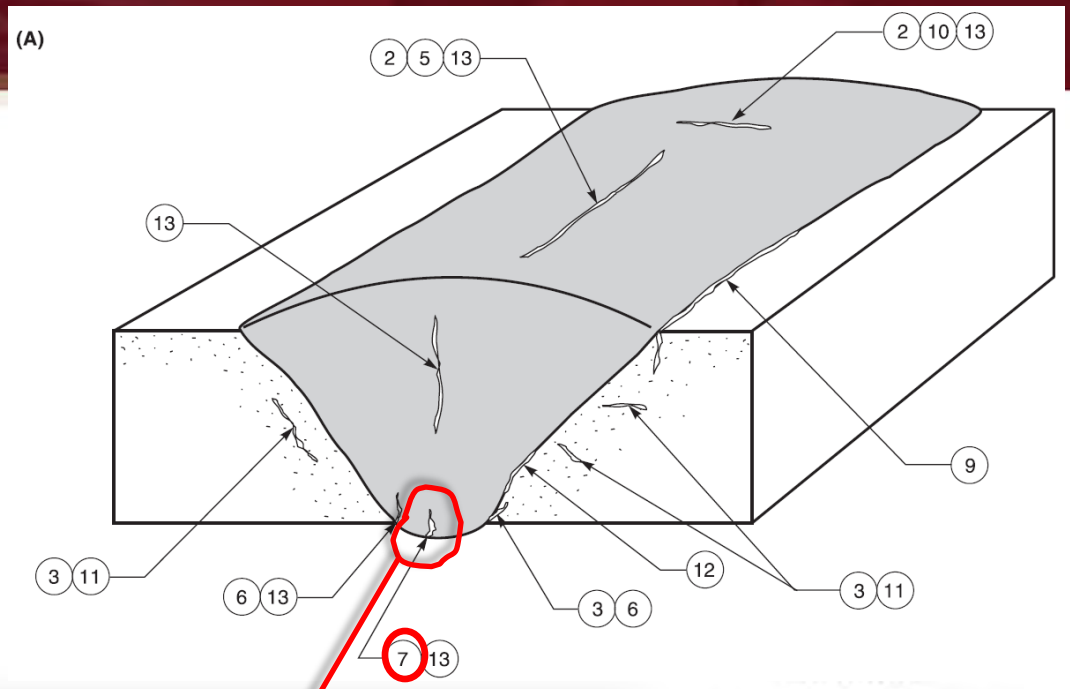


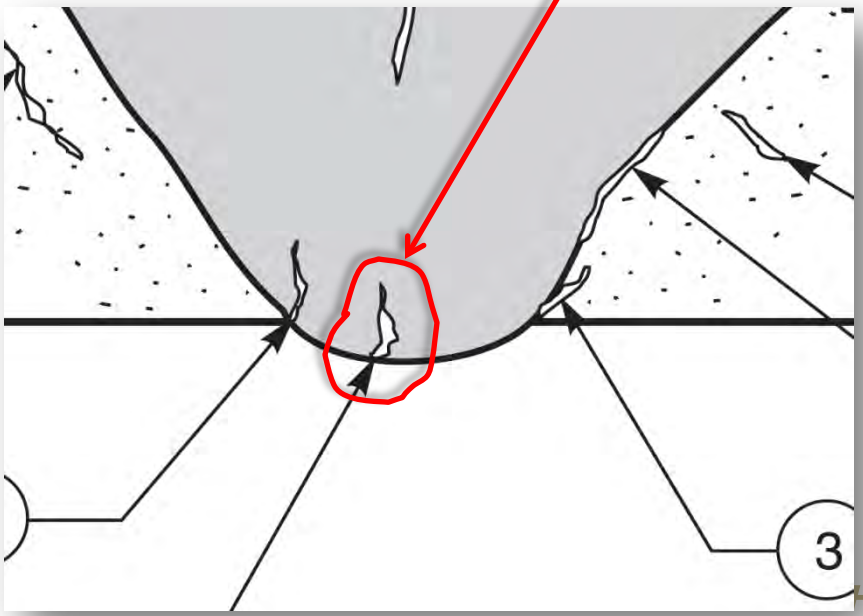


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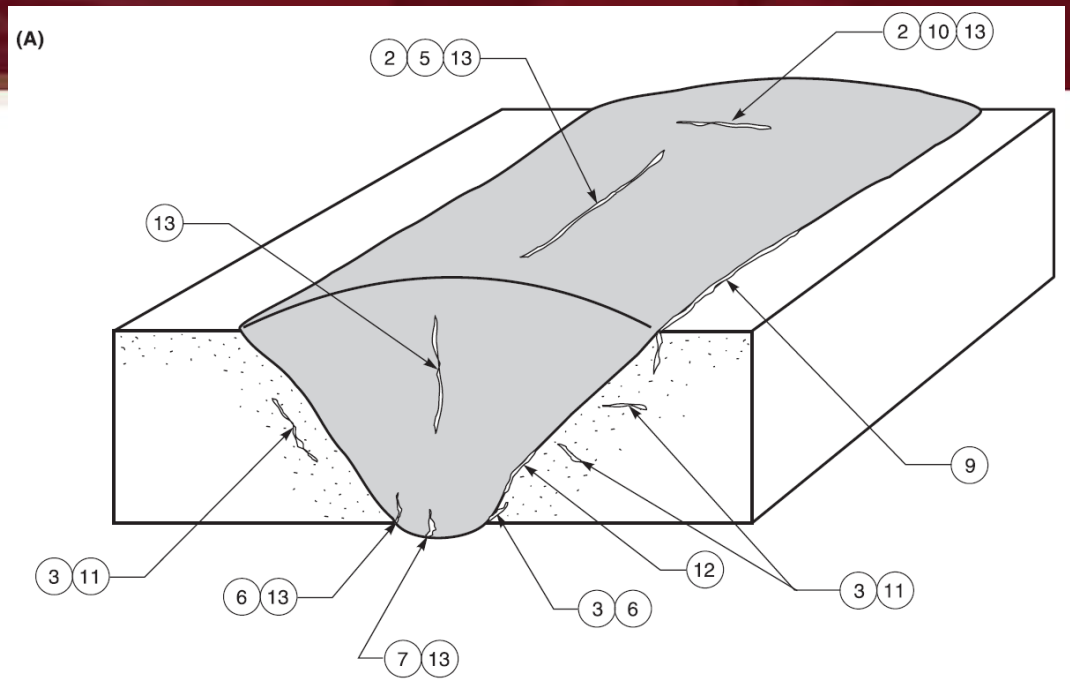


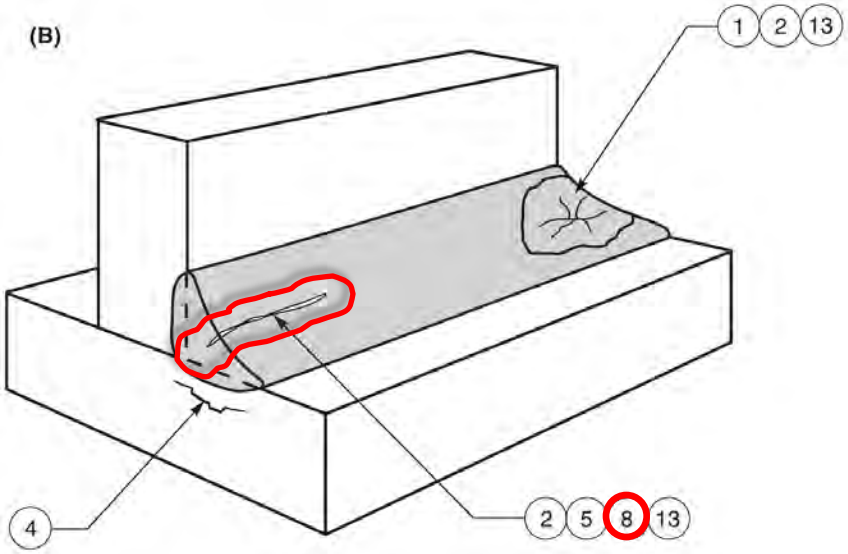


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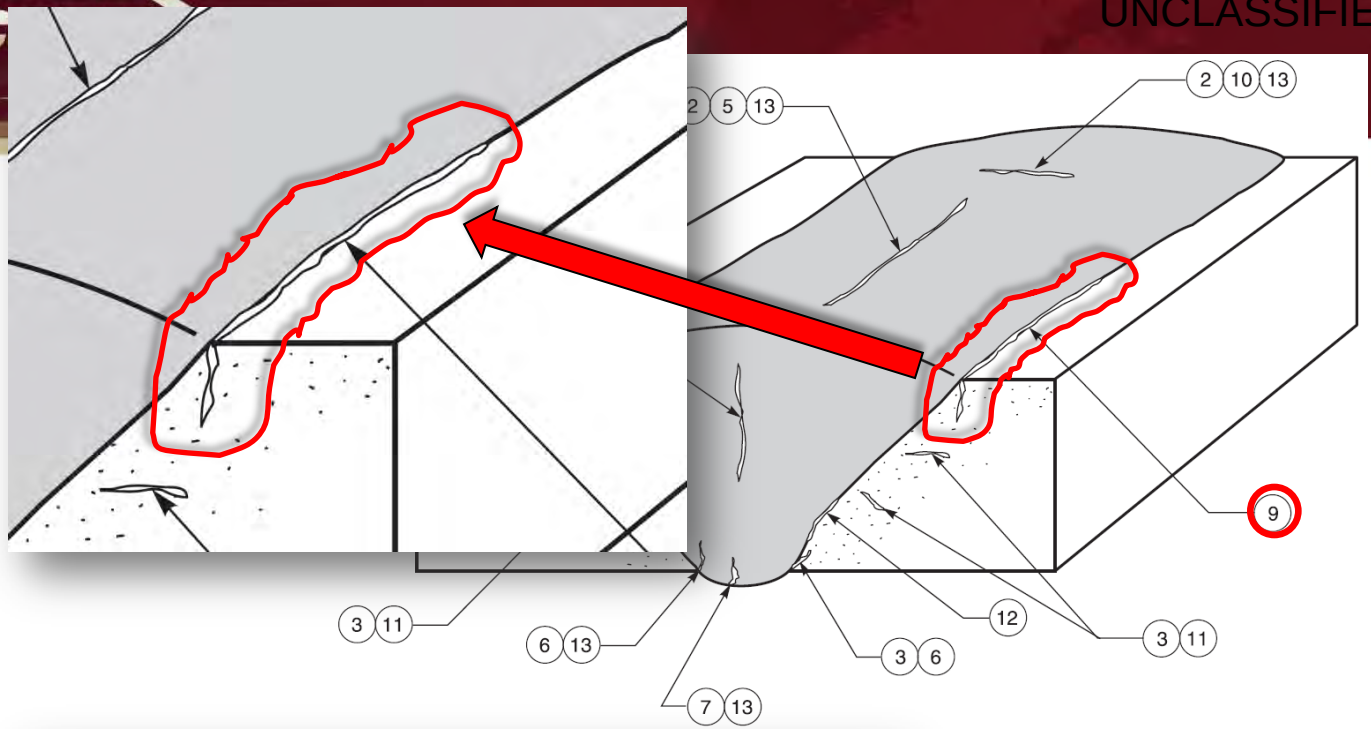


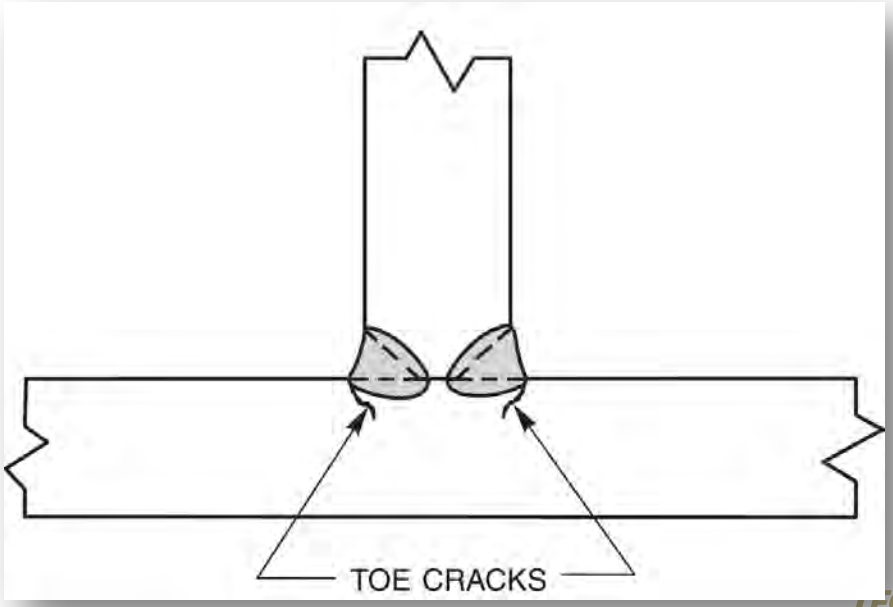


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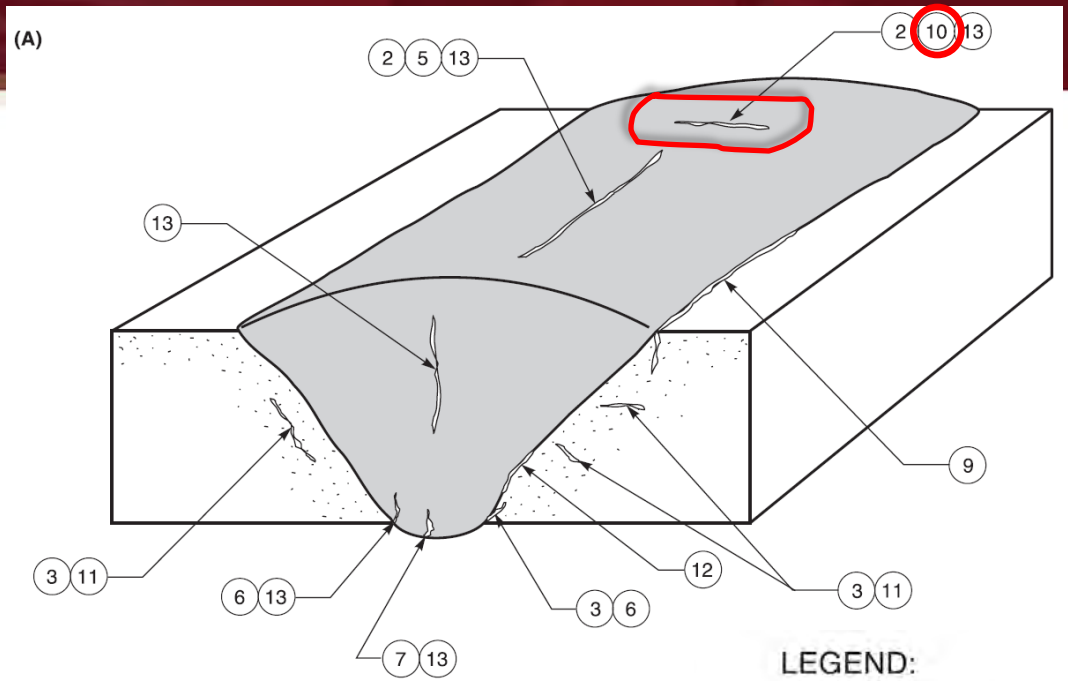


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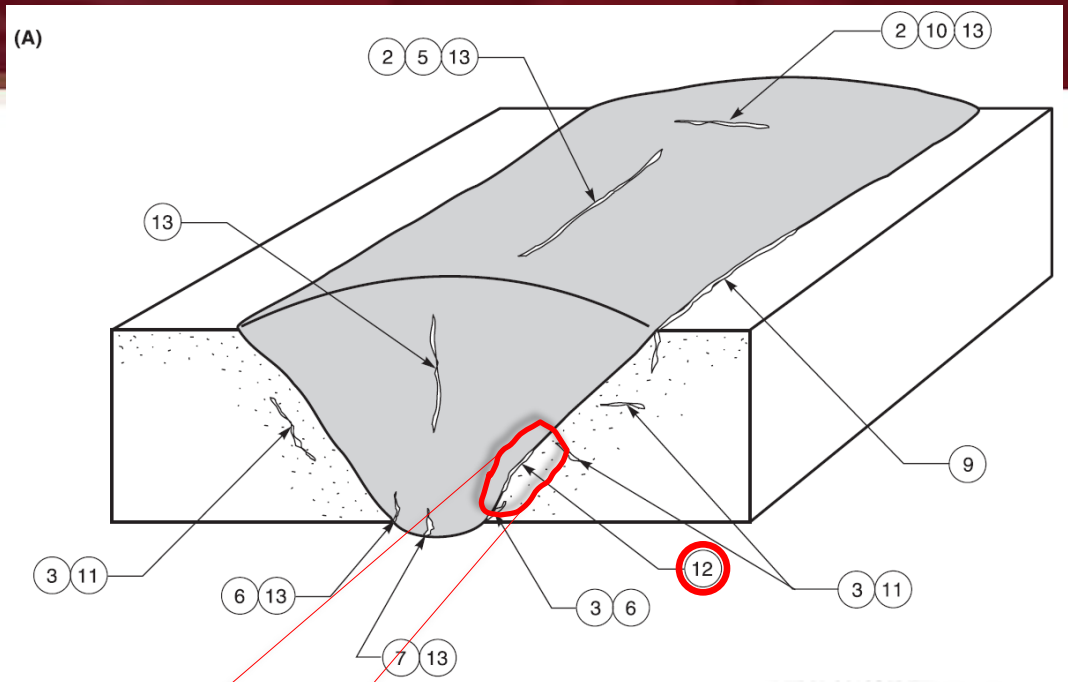


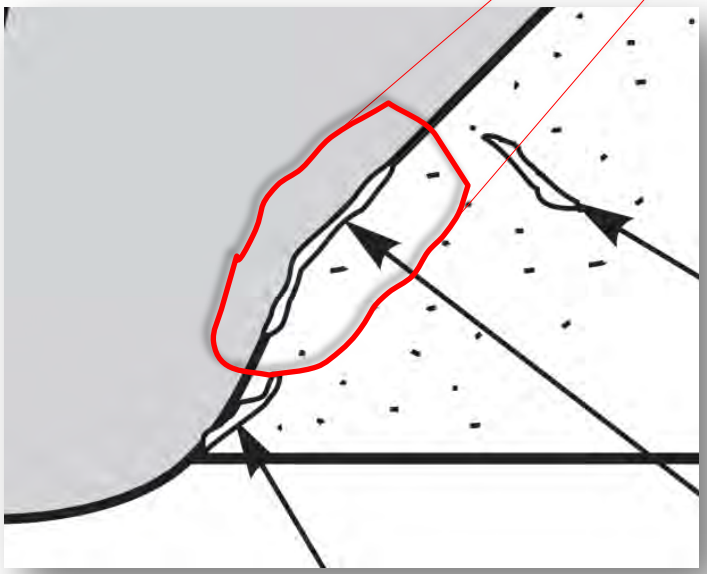

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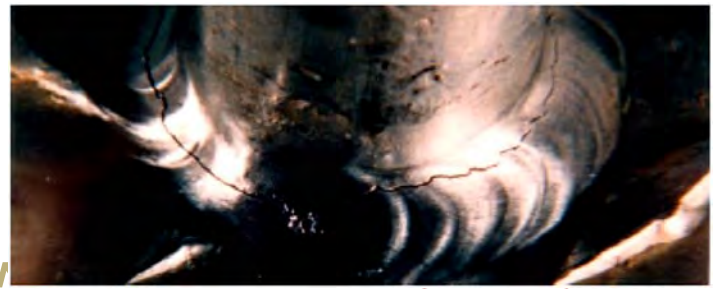
# Causes

- Hydrogen cracking has been one of the biggest problems when welding of armor steels
- Cracks are delayed since hydrogen does not become entrapped above 200$^0$C (392°F)
- Depending on the rate of hydrogen diffusion, the delay of the cracks can change
- Diffusion rates depends on the steel's microstructure and temperature, lower temperatures means slower diffusion

# Causes

Hydrogen Cracking

- Is the process by which various metals, including high-strength armor steels, become brittle and fracture following exposure to hydrogen
- Begins during the welding procedure where there are elevated temperatures
- Usually happens 24-48 hours after the weldments are at ambient temperatures



# Causes:
## Conditions of Hydrogen Embrittlement

### Three Conditions of Hydrogen Cracking

- The presence of hydrogen
  - Delivered by gases released from the electrode coating or flux, and some from the atmosphere
- A susceptible microstructure
  - Determined by the chemistry of the electrode and base metal and the welding parameters
  - Martensitic microstructures are above ≈35 HRC are susceptible
    - All current armor steels are martensitic
- Tensile stress
  - Caused by thermal expansion and contraction of the weld as it is deposited, aligning the base materials, and handling
  - Martensitic structures have inherent residual stresses due to the 4% Volume expansion.

# Electrodes and Flux

- Shielding gas also contains hydrogen from organic elements in the coating and moisture
- Different electrodes causes different hydrogen content in the weld metal
- SMAW electrodes produce the widest range of hydrogen content
- GMAW electrodes produce the smallest range of hydrogen content
- Electrodes must be stored and handled properly

# Weld Metal Hydrogen Designations

| Hydrogen Designation | Maximum Average Content, mL($H_2$)/100g | Examples |
|---|---|---|
| High | >15 | Cellulosic electrodes, flux cored electrodes |
| Medium | 10 | Basic electrodes, flux cored electrodes, solid wire electrodes |
| Low | 5 | Basic electrodes, flux cored electrodes, solid wire electrodes |
| Very Low | 3 to 5 | Baked basic electrodes, solid wire electrodes |
| Ultra Low | ≤3 | Baked basic electrodes, solid wire electrodes |

# Basic vs. Low Hydrogen Electrodes

- Basic Electrodes

  - Most common type of electrode

  - Typical levels of hydrogen found in welds created using this type of electrode is 5ml/100g

- Low Hydrogen Content Electrodes

  - Typical levels of hydrogen found in welds created using this type of electrode is 3ml/100g

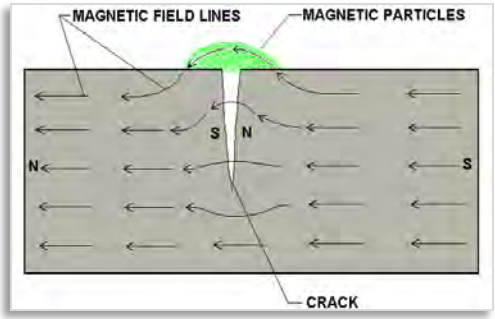
  - Electrodes are packed in hermetically sealed containers. This keeps moisture out for extended periods of time

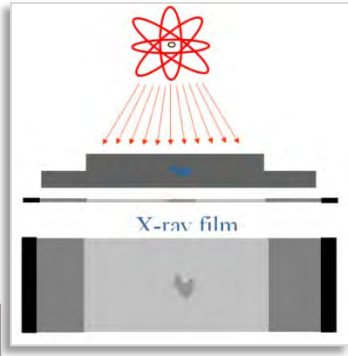
# Ceramic Weld Backings

- Used to reduce costly gouging and grinding
- Ceramics are absorbent to liquids and other materials
- Improper handling may result in moist ceramic backings releasing hydrogen into the weldments

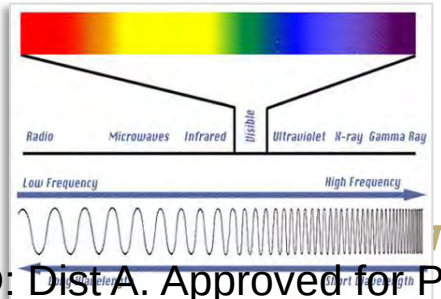
# Inspection

- 48 hour holds
  - AWS D1.1 : ASTM 514, ASTM517
  - Ground Combat Vehicle Weld Code (GCVWC) :ASTM 514, ASTM517
  - MIL-DTL-46100, MIL-DTL-12560J, & MIL-DTL-32332
- Inspection Methods
  - Visual
  - PT
  - MT
  - UT
  - RT
- No cracks are allowed on Armor!!!








# Prevention

- Reduce Source of $H_2$
- Low Hydrogen Processes
  - SMAW
  - FCAW
- Electrode Selection
  - Solid Core Wires or Metal Core
  - Non- Low Hydrogen Rods
- Electrode Storage
  - Rod ovens
  - Room temperatures/dew point control
  - Time spent in atmosphere
- Minimize causes of residual stresses
  - Fixture Gaps
  - Control Heat Input

# Conclusion

- Materials and Types for Cracking
  - Hot Cracking
  - Cold Cracking
- Types of cracks
- Causes
  - Hydrogen
  - Electrode Selection
  - Electrode Storage
- Inspection Methods
  - PT, UT, RT, MT
- Preventions
  - Hydrogen
  - Electrode Selection
  - Electrode Storage

# Question???

## Any Question???

## TARDEC - RDTA-EN / Materials, Environmental and Corrosion Team