Construction Issues

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$$$ Problem $$$

- Recently there have been occurrences of through wall cracked welds discovered during the hydrotest phase of pipeline construction.
- These discoveries are extremely troubling as typically cracked welds are found and repaired or removed during the non destructive testing and repair phase of pipeline construction.
- Concerns
  - Are there partially cracked welds that remain?
  - Long term viability of the pipeline? Fatigue? External loading?
  - Ramifications of a failure of a pipeline operating at 72% or 80% SMYS?

"Houston We Have A Problem"

Applicable facts

- No failures in unrepaired mechanized girth welds
- Leaks found in repaired mechanized girth welds
- Leaks found in manual cellulosic girth welds
- Leaks found in repaired manual cellulosic girth welds
- A failed manual road bore tie-in weld was found with a cleaning pig just prior to hydrotest.
- Another failure found during hydrotest was due to overstressing the root bead by movement which caused a crack that was welded over - “hinging”
- All of the failures have been found in X-70 or X-80 pipe 20” or greater in diameter

Additional investigations

- Problems detected
  - Cracked repaired mechanized welds
  - Cracked road bore tie-in welds
  - Repaired welds with non-crack defects

- Smart pigging programs underway

Applicable facts (cont)

- In all cases (except of hinging) metallurgical investigations concluded hydrogen assisted cracking (HAC) was the failure mechanism
- Construction records associated with the leaks and additional investigations were reviewed and most of the time either ultrasonic inspection or radiography were completed the same day as the weld; no Non Destructive Testing (NDT) reports indicate cracks - this helps confirm Delayed HAC. In some cases the NDT was completed on the following day, here again no NDT reports indicate cracks. UT was used on the mechanized projects and radiography was used on the manual welding projects.
- Construction records indicate some cracked welds were found during construction and removed.
- Ambient temperature ranged from below 0 to 60º F

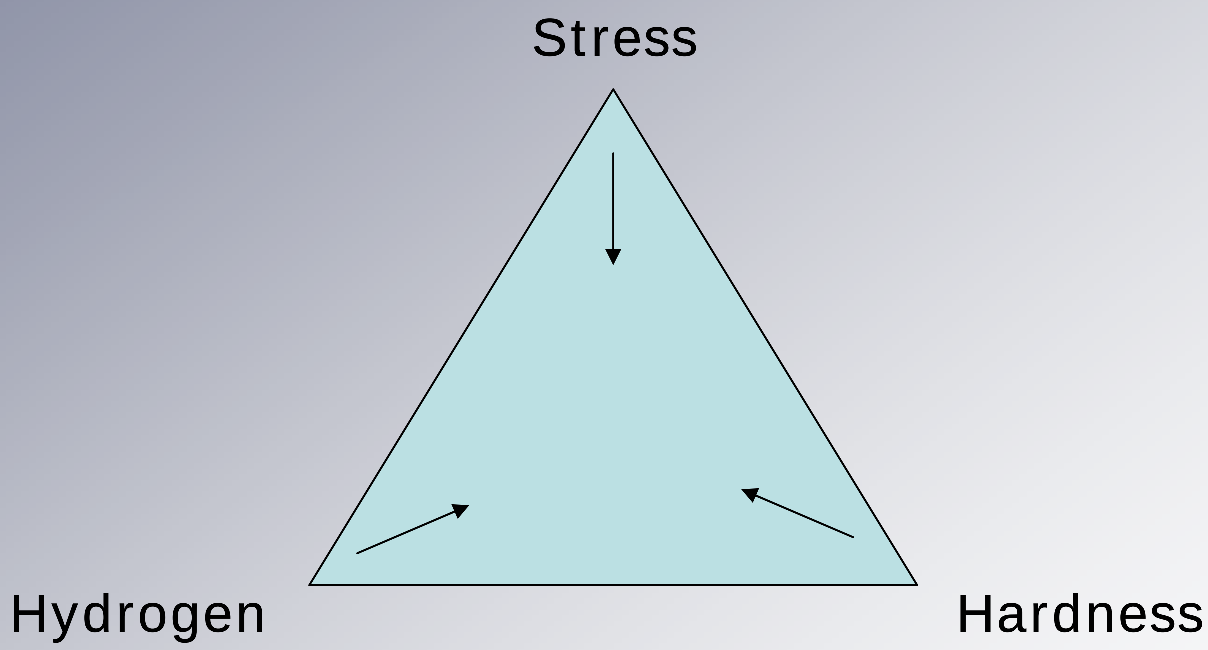
Applicable facts (cont)

- In all of the mechanized weld repair failures cellulosic electrodes were used for the root and hot pass. Fill and cap passes varied from cellulosic, low hydrogen, or Flux Cored Arc Welding (FCAW).
- In all of the failed manual welds cellulosic electrodes were used.
- In all procedures preheat was specified and ranged from “if ambient temperature below 50º F use 150º F preheat” to a blanket statement requiring “250º F minimum preheat”
- Statements about “Time Between Passes” were varied as well as “Time Between All Other Passes”

Hydrogen Assisted Cracking (HAC)

- To have HAC there must be three things present in the weld; a source of hydrogen, a micro-structure susceptible to the effects of hydrogen, and stresses in the weld.
  - Hydrogen is present in the coating of all E XX10 electrodes.
  - There are always stresses present in the weld due to heating and cooling; and the restraint geometry inherent in a pipeline weld. Higher stress levels can be present in repair welds, tie-in welds, transition welds, and welds with poor joint alignment.

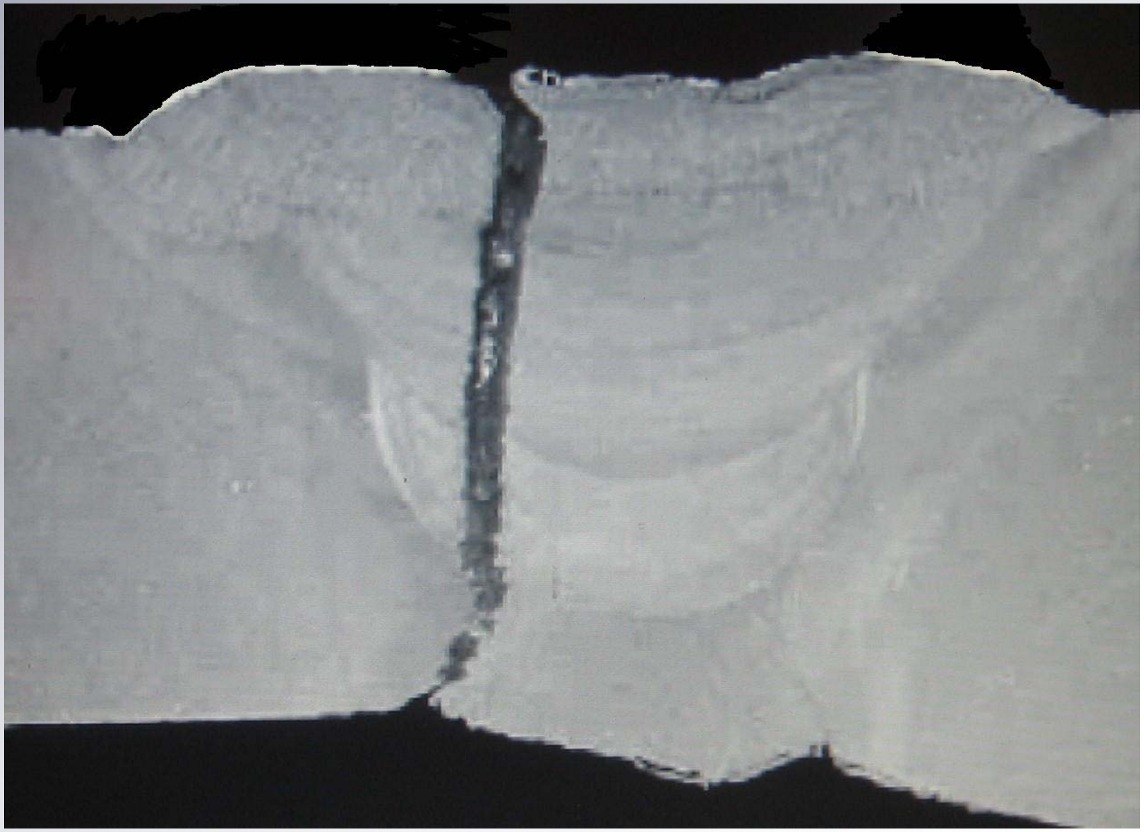
Hydrogen Cracking Relationships



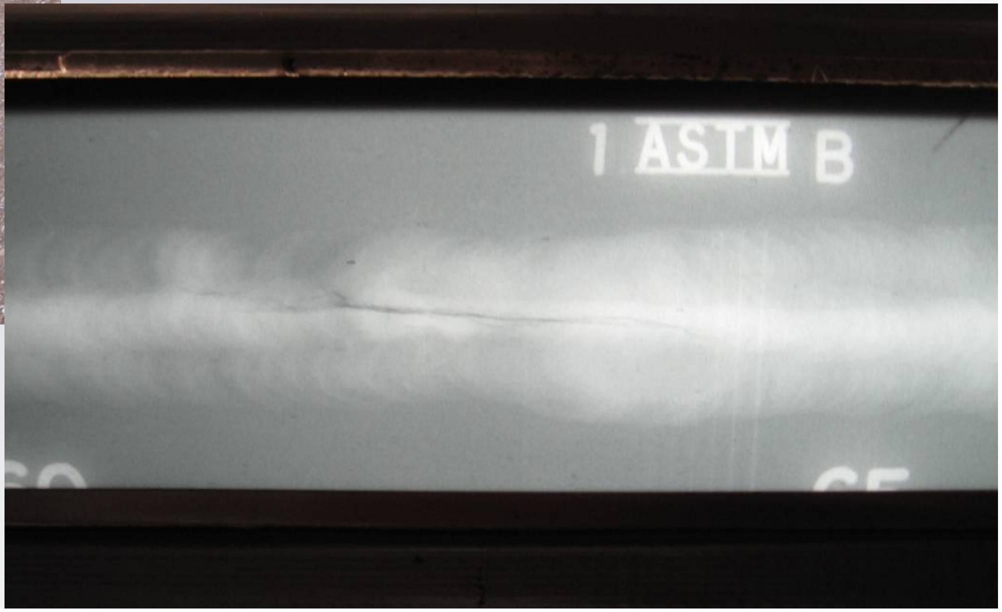
Weld hydrogen the story

- Hydrogen is present in cellulosic electrodes
- Hydrogen is very soluble in molten and hot weld metal
- Hydrogen is less soluble in weld metal at room temperature
- Hydrogen defuses out of the weld metal as the weld metal cools
- Diffusion is time and temperature dependant
- If allowed enough time at temperature the hydrogen will leave the weld
- Trapped hydrogen can cause cracking

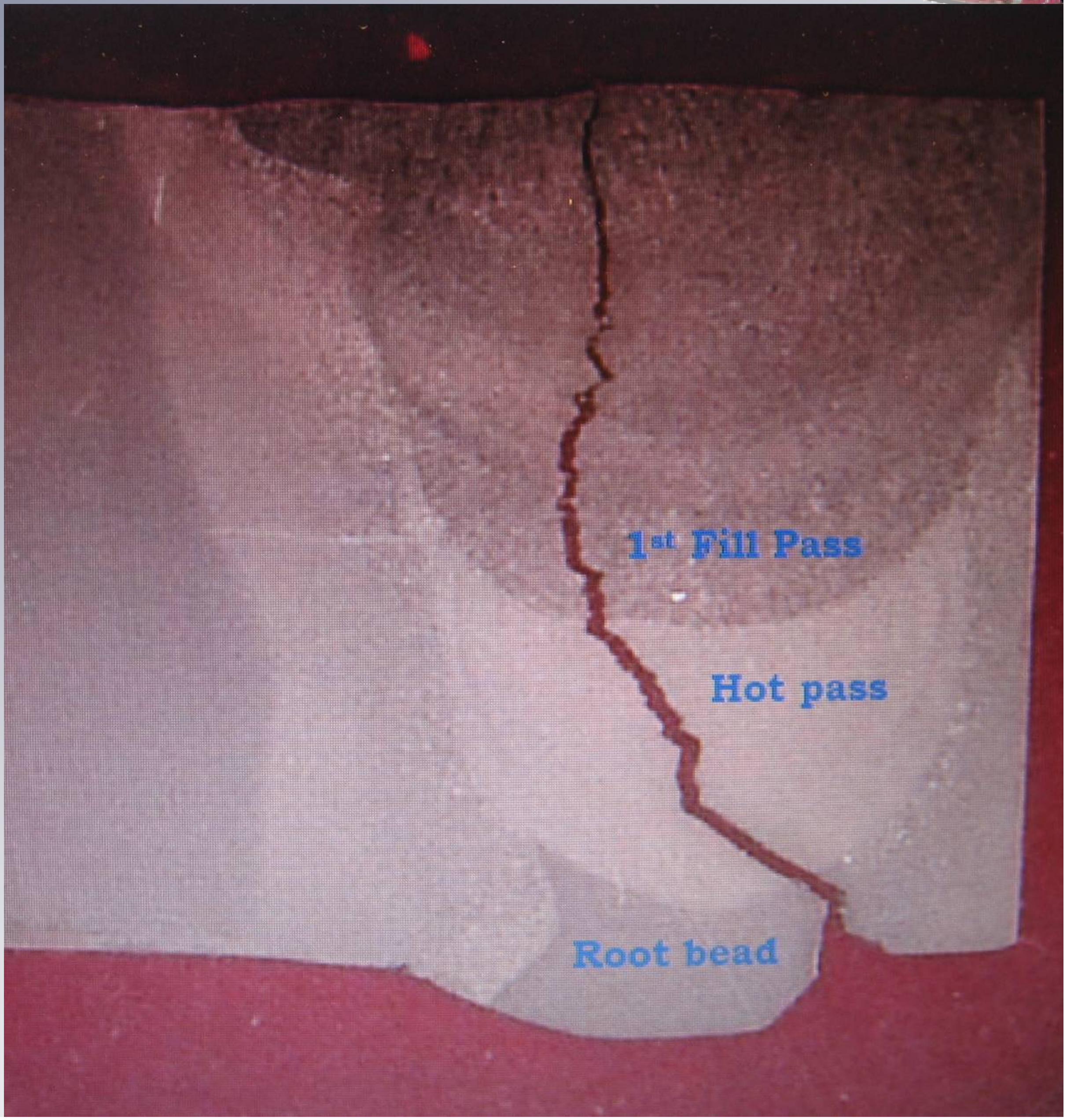
Cross section of a HAC Pipeline Weld



Repair Weld Cracking Issues



Cross section of a HAC Pipeline Repair Weld



Microstructure hardness

- Historically values greater than 350 HV should be evaluated for the risk of hydrogen assisted cracking
- Investigations have revealed weld hardness values of the failed welds within the range of 200 to 260 HV.

Solutions – Engineering Controls

- Development of welding procedures that manage the risk of HAC
- NDT practices that address risk
- Careful construction management

Main Line Welding

- Manual
  - Cellulosic (E-XX10)
  - Low hydrogen (E-XX18 or E-xx45)
  - Semiautomatic (GMAW or FCAW)
  - Combinations
  - Weld defect repair
- Mechanized
  - Low hydrogen process
  - Weld defect repair

Solutions

- In a high strength pipeline weld use low hydrogen welding process (GMAW – FCAW - E XX18 – E XX45)
- If using cellulosic electrodes - Allow time at temperature to allow hydrogen to diffuse from the weld (higher preheat temperatures, preheat maintenance, minimum interpass temperature, avoid weld interruption)
- Minimize installation stresses
- Optimize weld metal electrode selection

Solutions (cont)

- Welders must follow welding procedures
- Verify welder performance with welding inspection
- Employ competent welding inspectors
- Preheat verification
- Avoid accelerated weld cooling
- Delay NDT to allow for the possibility of delayed hydrogen assisted cracking to be detected
- Optimize radiographic procedures for crack detection
- Verify NDT technician's knowledge, skills, abilities
- Audit the NDT technicians work

Welding recommendations

- Develop low hydrogen welding procedures
- Welding procedures that utilize cellulosic electrodes should specify adequate preheat and a minimum interpass temperature.
- In lieu of specifying a minimum interpass temperature careful attention should be undertaken regarding time between completion of the root bead, the start of the second bead and the maximum time between the completion of the second bead and the start of other beads.

Repair welding recommendations

- Develop dedicated repair welding procedures
- Minimize the use of cellulosic electrodes or manage risk
- Develop specific through wall repair procedures
- Develop specific partial wall repair procedures
- Consider repair welder’s skills
- Possibly higher preheat temperatures and a minimum interpass temperatures
- Cold weather considerations
- Avoid accelerated weld cooling

Repair welding recommendations (cont)

- Preheat application and measurement
- Preheat maintenance (minimum interpass temperature)
- Consider the quenching effects of adjacent pipe material – deep short defects
- Avoid weld interruption during repairs
- Avoid delays between passes
- Welder must follow welding procedure
- Verify performance with welding inspection
- Employ competent welding inspectors
- Optimize NDT
- 12 to 72 hour delay (API 1104 App. B states not less than 24 hr. delay before specimen bending)

Welding Procedure Development

- API 1104 main body - Appendix A - ASME IX - Appendix B
- These standards are a “List of Rules”
- Recently Identified Problems
  - Did not state all required variables
  - Did not qualify sufficient procedures for project
  - Failed test coupons
  - Special issues API 1104 Appendix A (next slide)

API 1104 Appendix A

- To use Appendix A must have:
- Stress analysis
- AUT error determination
- Written welding procedure with weld testing results
- Identified Problems
  - No stress analysis
  - No AUT error determination See API Section 11.4.4 & A 5.1
  - Insufficient Charpy tests or CTOD tests that “bust out” (20th edition)
  - Testing lab issue - CTOD test locations are different in the 20th edition
  - Failed bend, nick, or tensile test results
  - Using the example calculation in Appendix A is not acceptable

Must Follow Welding Procedures 192.225 – 195.214

- Manual Welding Identified Problems
  - Using wrong procedure
  - Speed of travel outside specification
  - Electrical characteristics outside specifications
  - Inadequate preheat
  - Inadequate minimum interpass temperature
  - Exceeding maximum time between root bead and hot pass

Porosity

- Welders were not experienced with the gas-shielded FCAW process
- Welders had history of repairs due to porosity defects
- Welders thought more gas would prevent porosity
- High gas flow rates cause turbulent flow from nozzle contaminating the shielding gas
- Welders must follow the welding procedure

Preheat

- Heating the weld joint before welding
- Temperature of the weld joint immediately before the arc is struck. (Arc start temperature)
- Procedures can state Infrared Thermometer, Contact Pyrometer, or Temperature Indicating Crayon
- Range of preheat values found in the welding procedure
- Various heat application methods – propane torch, liquid propane torch, oxyacetylene rosebud, induction

Temperature Indicating Crayons

The crayon holder

specifies the melt

temperature

Use of Temperature Indicating Crayon

- Temperature indicating crayons (Tempilstik) are specially formulated to change color and melt at a specific temperature.
- On a cold pipe surface upon heating, the mark changes color and melts at the specific temperature
- Used on a hot surface, the crayon only indicates the temperature is greater than the specified temperature on the crayon if the crayon melts
- Applying the crayon on an area adjacent to a weld joint and then heating with a propane torch directed on the mark will give a false temperature indication. In this case, the flame heats the crayon mark faster than the pipe. The pipe will not be up to the required temperature.
- On a hot surface, the crayon should be used after heating and two different temperature crayons may be necessary to determine the preheat is within the welding procedure.

- Contact pyrometers and infrared thermometers can be also used to verify preheat.
- Caution infrared thermometers are not accurate on sand blasted surfaces and values can change based on the emissivity of the weld area

Electrical Characteristics

- Values should be within the ranges specified on the welding procedure

Interpass Temperature

- The temperature at a location near the start position of the welding arc(s) recorded immediately before initiating consecutive pass or passes. (from API 1104 Appendix A)
- Minimum Interpass Temperature – lowest temperature allowed to start welding – most times it is the preheat temperature
- Maximum Interpass Temperature – highest temperature allowed to start welding.

High Weld Defect Rate

- Concerns
- Having defects not an issue. Excessive defects can be.
- Defect repair, NDT and tracking can be an issue.
- Industry experience usually shows

  - 2 – 10% defect rate on mechanized welding

  - 2 – 5% on manual welding

  - less than 2% can be an issue - examine NDT – are operators procedures adequate? – are radiographic or ultrasonic procedures adequate? – are NDT technician following procedures? - are the NDT technicians proficient?

Causes of High Defect Rate

- Equipment issues
- Pipe sizing issues
- Inexperienced welders
- Start up issues
- Stacked defects
- Allowing contractors to set up equipment while welding main line pipe
- X-ray or AUT falling behind eliminates timely feed back. Feed back is a valuable tool to improve weld quality.
- Root-Hot pass welding way out front of fill and cap

Inspection

- Large variation in inspector competency
- What are the inspectors responsibilities?
  - Welding inspector must be knowledgeable and competent
  - Verify welding procedure is followed
  - Observe
  - Document
  - Report
  - Correct
  - Work stoppage
  - Not fall asleep in the pickup truck

During the follow-up inspection process repaired welds with non-crack defects were discovered

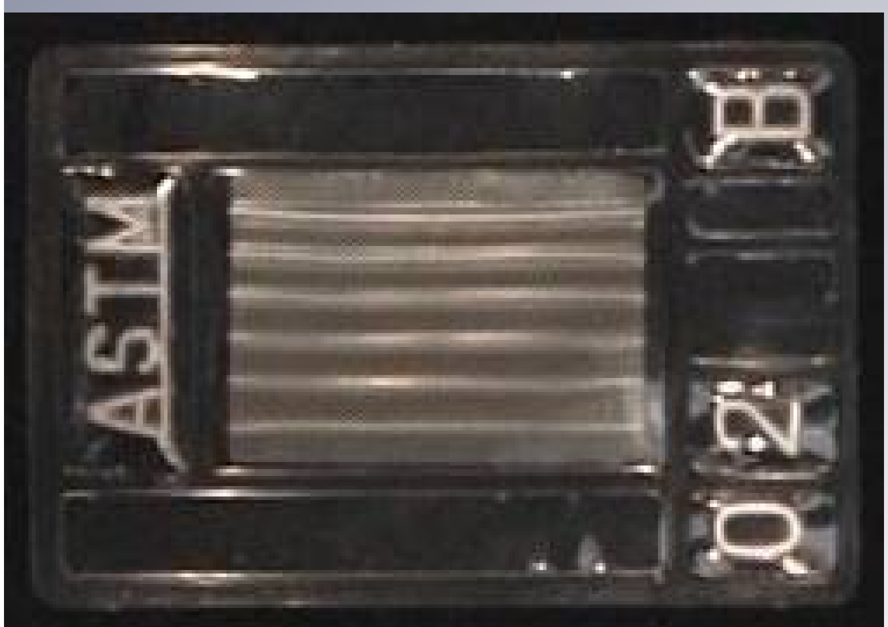
- Defects remained after a failed repair attempt and were not detected by manual ultrasonic testing (MUT).
- Lessons learned
  - Accurately relay defect location and depth to repair welder
  - The repair welder should confirm the metal removal depth to ensure defect removal
  - Encourage welder to look for defect during arc gouging and/or grinding process (this helps confirm removal)
  - Verify MUT technician’s knowledge, skills and abilities
  - Verify actual job performance through recording and auditing

Radiography

Image Quality Indicators

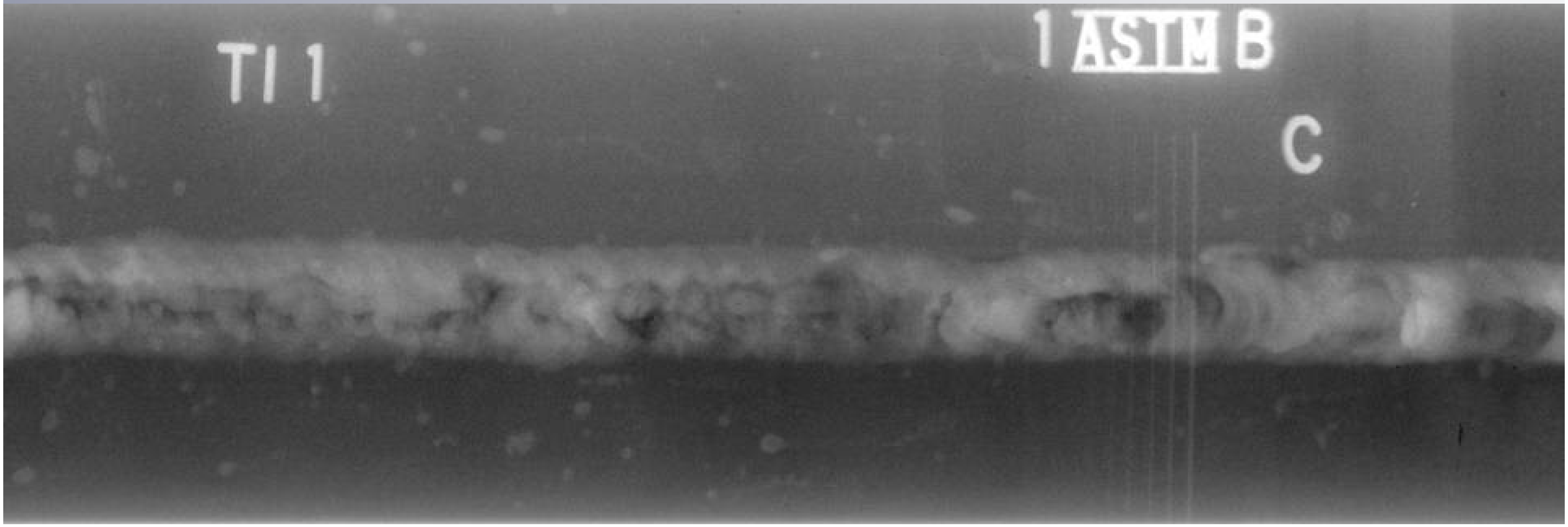
Image Quality Indicators (Penetrameters)

- PHMSA recognizes the 20th edition of API 1104. The 20th edition **only** allows the use of Wire Type Image Quality Indicators.



ASTM Type B Packet

The complete outline of the essential wire must be visible. Essential wire should not be obscured.



Radiographic Requirement

- Both Parts 192 and 195 require a certain percentage (based on location or class location) of welds be nondestructively tested and that a sample of a welders daily work product must be nondestructively tested.
- If the radiographs' image quality indicators are not acceptable, then there may be insufficient numbers of radiographs to meet the percentage and/or daily requirements of the applicable code or operators construction procedures.
- Use of API 1104 Appendix A requires essentially 100% NDT - AUT

Radiographic Problems Identified

- Poor radiograph technique - so bad minimum % could not be achieved
- Poor radiograph developing practices
- Fogged Film and/or artifacts
- Radiographs too dark or light – Density (H&D) out of operator’s specification or API specification
- Improper or poor radiographic interpretation
- Missing one or more segments of the weld radiograph
- Segments of radiographs do not overlap
- Missing radiographs when compared to weld maps
- No repair radiograph

Radiographic Problems Identified

- Radiographed wrong defect area (multiple repairs)– should be able to match up unrepaired areas of repair radiograph to original radiograph
- Numbering irregularities (Changed numbers with magic marker)
- Radiographing same weld twice or multiple times and changed weld identification numbers
- IQI issues – essential wire not visible
- Poor radiographic technique used on transition welds – especially if there is a large difference in thickness

Oak Ridge Radiograph Photos

- Notice chemical stains and brown hue API 11.1.1 a – free from fog and other processing irregularities that could mask defects

- Notice radiograph is too dark

  API specifies except for small localized areas caused by weld irregularities H&D densities > 1.8 and < 4.0 with overall ranges > 1.5 and < 4.2

Operators' procedures can be more limiting

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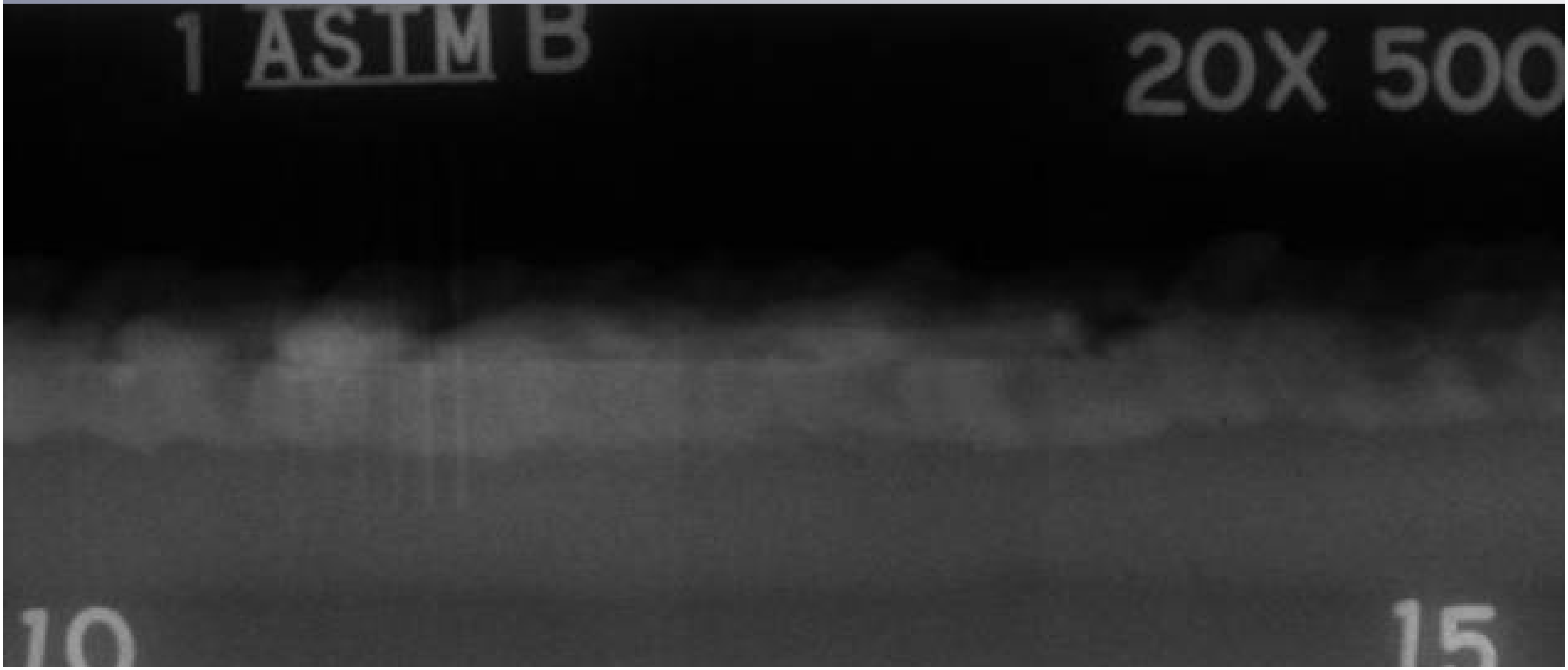
Transition Weld – Density - IQI



- §192.231 Protection from weather.
- The welding operation must be protected from weather conditions that would impair the quality of the completed weld.
- Wind blowing shielding gases, rain quenching welds, cold pipe impacts preheat and minimum interpass temperature.

§192.235 Preparation for welding.

Before beginning any welding, the welding surfaces must be clean and free of any material that may be detrimental to the weld, and the pipe or component must be aligned to provide the most favorable condition for depositing the root bead. This alignment must be preserved while the root bead is being deposited.

- Movement during root bead welding can overstress deposited weld metal and cause cracking.
- Hydrotest failure attributed to "hinging"

Is the pipe moving as the root bead is welded?

Arc burns and welder competency

- Arc burns are not acceptable on high pressure gas pipelines and liquid pipelines.
- The following slides show that arc burns can happen during internal back welding.