Consumers Energy

- Jackson, MI
- Founded in 1886 (Jackson Electric Light Works)
- 6.8 million customers
- 1.7 million Natural Gas customers
- Approx. 8,000 employees
Delivering Gas service to 45 of 68 lower peninsula counties.
Consumers Energy’s Natural Gas System

- 1.7 Million Customers
- Nearly 27,000 Miles of Distribution Main
- 2,467 Miles of Transmission Pipeline
- 7 Compressor Stations
- 15 Storage Fields

WORKING TO DELIVER THE ENERGY YOU NEED, WHenever YOU NEED IT.
Federal & State Regulation

**Federal Regulation:**
- Department Of Transportation (DOT)
- Pipeline and Hazardous Materials Safety Administration (PHMSA)
- Code of Federal Regulations

**State Regulation:**
- Michigan Department Of Transportation (MDOT)
- Michigan Public Service Commission (MPSC)
- Michigan Gas Safety Standard
Subpart E—Welding of Steel in Pipelines

§192.221 Scope.

(a) This subpart prescribes minimum requirements for welding steel materials in pipelines.
(b) This subpart does not apply to welding that occurs during the manufacture of steel pipe or steel pipeline components.

§192.225 Welding procedures.

§192.227 Qualification of welders.
§192.225  Welding procedures.

(a) Welding must be performed by a qualified welder in accordance with welding procedures qualified under section 5 of API 1104 (ibr, see §192.7) or section IX of the ASME Boiler and Pressure Vessel Code “Welding and Brazing Qualifications” (ibr, see §192.7) to produce welds meeting the requirements of this subpart. The quality of the test welds used to qualify welding procedures shall be determined by destructive testing in accordance with the applicable welding standard(s).

(b) Each welding procedure must be recorded in detail, including the results of the qualifying tests. This record must be retained and followed whenever the procedure is used.

- API 1104  - Welding of Pipelines and Related Facilities
- ASME BPVC Sec. IX – Qualification Standard For Welding And Brazing Procedures, Welders, Brazers, And Welding And Brazing Operators
Welding Procedures

Michigan Added Rules

R 460.20304 Welding procedures.

In addition to the requirements contained in 49 C.F.R. §192.225, which is adopted by reference in R 460.20606, an operator shall ensure that a welding procedure meets all of the following requirements:

(a) Is qualified under either section IX of the ASME boiler and pressure vessel code, which is adopted by reference in R 460.20604, or section 5 of API standard 1104, which is adopted by reference in R 460.20603, whichever is appropriate to the function of the weld.

(b) Is qualified under appendix B of API standard 1104, which is adopted by reference in R 460.20603, for pipelines operating at greater than 60 psig.

(c) A copy of the welding procedure being followed is on the jobsite when welding is performed.
Welding Procedures

**Construction** (API 1104 main body)
- No product in system

**In-Service** (API 1104 appendix B)
- Product in system (flow/pressure)
PHMSA Issues Advisory Bulletins to Owners/Operators

http://phmsa.dot.gov/pipeline/regs/advisory-bulletin
Welding Construction Issues

• Line pipe weld misalignment,
• Improper bevel and wall thickness transitions,
• Out of roundness due to cut induction bends, and
• Other improper welding practices.
Improper Welding Practices:
- Bevel and Wall Thickness transitions
- Early clamp release
- Arc burns
- Incorrect preheat and inter-pass temp control
- Improper electrode storage
- Use of “hinging” to aid in pipe line-up
- Poor inspector oversight
- Inadequate documentation – welder/procedure

Always follow Welding Procedure and Job Specs
Welding Construction Issues

Welding Misalignment:
- Equal WT – 1/8 inch equally distributed
- Unequal WT – 3/32 inch
- Unequal WT – Transition Bevels
Welding Construction Issues

Unequal Wall Thickness Transitions

Fig. 1-5 Acceptable Design for Unequal Wall Thickness

Thin Wall Line Pipe Thick Wall Cut Induction Bend

Internal Offset
R 460.20307 Welding preheating.

Rule 307. In addition to the requirements contained in 49 C.F.R. §192.235, which is adopted by reference in R 460.20606, if preheating is required, then an operator shall monitor the preheat temperature to ensure that the required preheat temperature is reached before beginning, and is maintained during, the welding operation.
Preheat and Inter-pass Temp Control

Preheat: Temperature of the entire weld zone immediately before the arc is initiated for any/all weld passes.

- Slows cooling rate in the weld metal and base metal producing a more ductile microstructure.
- Slower cooling rate provides opportunity for hydrogen to diffuse.
- Reduces shrinkage stresses in the weld and adjacent base metal.

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- Slows cooling rate in the weld metal and base metal producing a more ductile microstructure.
- Slower cooling rate provides opportunity for hydrogen to diffuse.
- Reduces shrinkage stresses in the weld and adjacent base metal.
Construction Preheat Conditions

Material Issues
- High strength materials
- Heavy wall thicknesses (≥ .500)
- Highly restrained joints

Type of Electrode
- Cellulosic
- Others containing more than optimum levels:
  - H8
  - H16

Weather Conditions
- Cold Temps
- Blowing Wind
- Rain, Snow, Moisture

Always follow Welding Procedure Specification (WPS)
*Responsibility of both the Inspector and Welder
In-Service Welding

API 1104 20th Edition Appendix B

In-Service Welding:
Pipelines and piping systems which contain petroleum, petroleum products, or fuel gases that may be pressurized and/or flowing. Weld is deposited while system is in service.

Two main concerns:
• Avoid burning through where the welding arc causes the pipe wall to be breached. - Welder Safety.
• Avoid hydrogen cracking potential. Welds made in-service cool at an accelerated rate. - System Integrity.

Currently Appendix B is not federally mandated in 49 CFR 192. Michigan rules apply to systems operating at greater than 60 psi.
In-Service Welding

Hydrogen Cracking:
HIC – Hydrogen Induced Cracking
HAC – Hydrogen Assisted Cracking
• Cold cracking
• Delayed cracking
• Under-bead cracking
How does hydrogen cracking occur?

Three things must be satisfied simultaneously:

- Hydrogen in the weld
  - Electrode
  - Environmental
- Susceptible microstructure
  - Fast cooling rate
  - Material type
- Stress acting on the weld
  - Applied stress
  - Inherent stress
Practical welding processes for short cycle field applications:

**SMAW**
- EXX10: 40-60mL/100gm
- EXX18, EXX15, EXX16
  - H4 <4mL/100gm
  - H8 <8mL/100gm
  - H16 <16mL/100gm

**GMAW**
- ER70S-6:
  - <4mL/100gm
- ER80S-D2:

**FCAW**
- E70T-X
- E71T-X
- E81T-X
  - 5-20mL/100gm

Recommended hydrogen content of electrode: <4ml/100gm
API 1104 20th Edition
Appendix B In-Service Welding Essential Variable differences

- Carbon Equivalent (CE) and material grade are NOT essential variables
- Wall Thickness is NOT an essential variable
- Thermal Cooling Capacity IS an essential variable
  - operating conditions, cooling rates
- Weld Deposition Sequence IS an essential variable
In-Service Welding

Procedure Qualification Essential Variables:
• Pipeline Operating Conditions
  • (weld cooling rates)
• Weld Deposition Sequence

Use of water qualifies for most severe conditions

API 1104 figure B-2
Qualifying both Sleeve and Branch. Required Testing:
- Tensile
- Nick Break
- Root or Side Bend
- Face or Side Bend

Additional Tests:
- Macro Testing (600 grit)
- Hardness Testing (350 Hv)
Weld Sequence Example:
1. Weld Complete
2. Alternate each pass from one side to another
3. Complete one end before moving to other. Only tack weld the side welded first (if necessary)
4. Weld complete
5. Weld complete
Bead Placement Sequence Example: Tempering Sequence
Conclusions:

- If possible, cellulosic electrodes should be purchased in small, hermetically-sealed packages.
- Electrodes should be stored in cool, dry locations, and should not be exposed to direct sunlight.
- Preheat and interpass temperature recommendations should be strictly adhered to, and if possible, a post-weld hydrogen bake-out should be utilized.
- For steels of grade X70 and above, the conservative approach is to use low-hydrogen electrodes, GMAW, or FCAW.
- If cellulosic electrodes must be used for these higher-strength steels, the lowest grade which will produce adequate strength for the intended application should be chosen.
- Placing dried electrodes in humidity cabinets or dipping them in water is not recommended.
- Electrodes which have been exposed to overly dry or overly humid conditions should be discarded.
# Cellulosic Electrodes

## Table 6. Results of Bend Testing for Restrained Welds Made Using Short Arc Lengths with Electrodes in the As-Received, Dried, and Rehydrated Conditions

<table>
<thead>
<tr>
<th>Product</th>
<th>Type</th>
<th>Condition</th>
<th>Bend Radius</th>
<th>No. of Defects</th>
<th>Total Length (mm)</th>
<th>Largest Defect Length (mm)</th>
<th>Comments</th>
<th>Corrected Defect Number</th>
<th>Corrected Defect Length (mm)</th>
<th>Test Lab Evaluation of Bends*</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESAB SW 10P</td>
<td>E6010</td>
<td>As-received</td>
<td>1.25</td>
<td>5</td>
<td>5.5</td>
<td>3</td>
<td>3 mm of root defects</td>
<td>4</td>
<td>2.5</td>
<td>PH &lt;1/8 in., pass</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dried</td>
<td>2.5</td>
<td>7</td>
<td>5</td>
<td>2</td>
<td>2 mm of root defects</td>
<td>6</td>
<td>3</td>
<td>Crack &gt; 1/8 in., fail</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rehydrated</td>
<td>2.5</td>
<td>8</td>
<td>7</td>
<td>2</td>
<td>5 mm of root defects</td>
<td>5</td>
<td>4</td>
<td>PH &lt;1/8 in., pass</td>
</tr>
<tr>
<td>Hobart PM Pro-60</td>
<td>E6010</td>
<td>As-received</td>
<td>2.5</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>PH &lt;1/8 in., pass</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dried</td>
<td>2.5</td>
<td>11</td>
<td>9</td>
<td>3</td>
<td>6 mm of root defects</td>
<td>6</td>
<td>3</td>
<td>Crack &gt; 1/8 in., fail</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rehydrated</td>
<td>2.5</td>
<td>5</td>
<td>7</td>
<td>5</td>
<td>5 mm of root defects</td>
<td>4</td>
<td>2</td>
<td>Crack &gt; 1/8 in., fail</td>
</tr>
<tr>
<td>Lincoln SA 70+</td>
<td>E8010-</td>
<td>As-received</td>
<td>1.5</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>PH or crack &lt;1/8 in., pass</td>
</tr>
<tr>
<td></td>
<td>G</td>
<td>Dried</td>
<td>2.5</td>
<td>1</td>
<td>1.5</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>PH &lt;1/8 in., pass</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rehydrated</td>
<td>1.5</td>
<td>0</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>1</td>
<td>0.5</td>
<td>PH &lt;1/8 in., pass</td>
</tr>
<tr>
<td>Lincoln SA 90</td>
<td>E9010-</td>
<td>As-received</td>
<td>1.5</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>PH or crack &lt;1/8 in., pass</td>
</tr>
<tr>
<td></td>
<td>G</td>
<td>Dried</td>
<td>1.5</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>PH &gt;1/8 in., fail</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rehydrated</td>
<td>1.5</td>
<td>5</td>
<td>9</td>
<td>7</td>
<td>7 mm of root defects</td>
<td>4</td>
<td>2</td>
<td>PH &gt;1/8 in., fail</td>
</tr>
</tbody>
</table>

*PH = pinholes
Conclusions:

- Use Low-Hydrogen electrodes
  - Less than 4mL/100 (H4)
  - Use GMAW
- Purchase in low quantity packages
- Purchase hermetically sealed pkg.
- Discard unused portion at end of day
- Evaluate hardness levels to hydrogen content of filler metal
Table 7. Results for Full-Scale Weldability Trials at DNV (continued)

<table>
<thead>
<tr>
<th>Weld No./Description</th>
<th>Mechanical Testing Results</th>
<th>Metallographic Examination Results</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Specimen No.</td>
<td>Fracture Test</td>
</tr>
<tr>
<td>D27 - GTN - Water - Cellulosic - High heat input</td>
<td>F1</td>
<td>Cracks(^1,2)</td>
</tr>
<tr>
<td></td>
<td>F3</td>
<td>Cracks(^1,2)</td>
</tr>
<tr>
<td></td>
<td>F5</td>
<td>Cracks(^1,2)</td>
</tr>
<tr>
<td>D30 - EB5 - Water - &lt;4mil/100gm - Low heat input</td>
<td>F1</td>
<td>OK</td>
</tr>
<tr>
<td></td>
<td>F3</td>
<td>OK</td>
</tr>
<tr>
<td></td>
<td>F5</td>
<td>OK</td>
</tr>
<tr>
<td>D31 - EB5 - Water - &lt;4mil/100gm - Low heat input</td>
<td>F1</td>
<td>OK</td>
</tr>
<tr>
<td></td>
<td>F3</td>
<td>OK</td>
</tr>
<tr>
<td></td>
<td>F5</td>
<td>OK</td>
</tr>
</tbody>
</table>
How do we apply these requirements and recommendations to Distribution Systems?

**Distribution Pipeline**
- Typically 1¼ NPS to 12 NPS
- .140 WT to .250 WT
- API 5L-Gr. B to X60

**Preheat Concerns**
- Rubber Stoppers
- Ball Valves (200°F max)
- O-Rings, Gaskets
- Leaking Gas
- Thermal Cooling Capacity

**Burn-Through Concerns**
- Thin walls
- Internal Corrosion
- External Corrosion
- Poor weld seams (old pipe)
In-Service Welding

SMAW Electrodes - What’s available?

- Lincoln Sahara Ready Packs
- ESAB VacPaks
- Bohler Vac-Pack
<table>
<thead>
<tr>
<th>Electrode Type</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
</table>
| E8045, E7048  | • Low Hydrogen  
• Downhill Travel | • 1/8 inch – 11/64 inch  
• 150-300 amps |
| E7018-H4R     | • Low Hydrogen  
• Small Diameters | • DCEP - Uphill  
• 10 lbs. packages |
| E7016-H4      | • Low Hydrogen  
• Small Diameters  
• DCEN – (55 to 100amps) | • 10 lbs. packages |
# In-Service Welding

<table>
<thead>
<tr>
<th>Risks</th>
<th>Challenges</th>
<th>Tactics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen Cracking</td>
<td>• Electrode/Process type</td>
<td>• Use low hydrogen</td>
</tr>
<tr>
<td></td>
<td>• Electrode storage</td>
<td>• &lt;4 mL/100gm</td>
</tr>
<tr>
<td></td>
<td>• Preheat &gt;212°F</td>
<td>• Preheat to remove moisture</td>
</tr>
<tr>
<td></td>
<td>• Surface moisture</td>
<td>• Manage electrode storage</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Susceptible Microstructure</td>
<td>• Preheat is hard to maintain</td>
<td>• Use small diameter electrodes</td>
</tr>
<tr>
<td></td>
<td>• Control hardness limits</td>
<td>• Use stringer passes only</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Tempering pass sequence</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tensile Stresses</td>
<td>• Minimize stress</td>
<td>• Tempering pass sequence</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Use of stringer passes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• API recommended sequences</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Burn Through</td>
<td>• Available electrodes</td>
<td>• Use small diameter electrodes</td>
</tr>
<tr>
<td></td>
<td>• Thin distribution pipe wt’s</td>
<td>• Use DCEN for SMAW welds</td>
</tr>
<tr>
<td></td>
<td>• Wall loss to corrosion</td>
<td>• contacting pipe wall</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Use UT thickness gauges for assessing remaining pipe wall.</td>
</tr>
</tbody>
</table>
Pipeline Distribution – Welding Practices

Summery

**Construction:**
- Follow welding procedures, job specification and quality management manual.
- Bevel and Wall Thickness transitions
- Pipe Alignment
- Correct preheat and inter-pass temp control
- Proper electrode storage

**In-Service Welding:**
- Follow welding procedures, job specification and quality management manual.
- Burn Through
- Hydrogen Cracking
- Weld sequence
- Correct preheat and inter-pass temp control
- Proper electrode storage
References:

- 49 CFR Part 192 - Transportation Of Natural And Other Gas By Pipeline: Minimum Federal Safety Standards
- Development of Heat-Affected Zone Hardness Limits for In-Service Welding
- US Department of Transportation – Construction Issues
- Technical Toolboxes In-Service Welding Practices and procedures – PRCI
- American Society of Mechanical Engineers – ASME B31.8 Gas Transmission and Distribution Piping Systems
Thank You

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