Meeting was called to order and a quorum was established.

Membership was reviewed and instructions provided to indicate desire to be considered for membership by marking next to the membership column. An updated membership roster will be compiled.

The question was proposed if the TG needed to continue based on the completion of the work to address End Dimensioning to look at pipe manufacturing limits and discrepancies between the limits of pipe manufacturing and welding process. Straw poll unanimously supported continuing the TG in light of potential new work items in compliance with the Charter directive.

The floor was open to new business.

SC5 WG4340, the proposed limits on Micro Alloying elements, was proposed and comments were solicited. Presentation attached.

PHSMA directed work was presented, “Girth Welds in Newly Constructed Pipelines” and “Impact of Girth Weld High-Low Misalignment” to highlight the challenges of fit up and the HAZ softening during stress-strain events. It was concluded that limiting Ultimate Tensile Strength of the pipe could help assuage this issue. The TG will consider this issue and make any proposals to SC5 for future work items. Presentations attached.

Hearing no further new business a motion was received to adjourn and seconded, unanimous for.
Background and Charge

- Background: A new work item was initiated at summer 2015 API meeting following completion of HIPERC work from Europe and considering the history of successful application of lower C, micro-alloyed steels processed with modern rolling methods including high temperature processing (HTP) worldwide.

- Charge: Consider 5L changes to C, Nb, V, Ti, N, and Al in Table 5, H.1 & J.1 to better reflect micro-alloy theory and proven experience.

- There is a parallel work item in ISO 3183 Annex M where a similar proposal has been made.
Work Group Members

- Phil Kirkwood (Consultant)
- Tom Lawrence (TMK-IPSCO)
- Martin Francis (AM)
- Colleen Fatla (JMC Steel)
- Claudio Tommasi (Tenaris)
- Mike Childress (SW Gas)
- Russell Dearden (Tata Steel)
- Pankaj Mittal (Welspun)
- Robert MacKenzie (Enbridge)
- Carlo Iasella (USS)
- Aaron Litschewski (Stupp Pipe)
- Matt Merwin (USS)
- Marion Erdelen-Peppler (SMF)
- Martin Connelly (Tata Steel)

- B. Henley (Tex-Tube)
- Tim Burns (Shell)
- Alfons Krom (Gas Unie)
- Laurie Collins (Evraz)
- Michael Grimes (ExxonMobil)
- Alex Afaganis (Evraz)

Related advantages

- Theoretically based microalloy addition limitations related to maximum carbon content.
- Consistent chemical composition restrictions between body and other key annexes of API 5L including H (Sour) and J (offshore).
- Annex H (Sour) - Reductions in carbon and the ability to increase niobium at the expense of manganese will reduce segregation and enhance properties.
- Annex J (offshore) - Improved toughness, reduced segregation and improved weldability.
Microalloy additions – Nb and V

- Nb added for grain refinement during rolling, transformation strengthening and precipitation strengthening. Considerable technical support presented previously.
- Technical background for Nb changes is included in supporting data attached.
- V alloying is also commonly used either with or without Nb for precipitation strengthening.

Microalloy additions - Ti

- Ti is added for castability, reheating grain size control by the formation of TiN precipitates which pin grain boundaries.
- Higher Ti levels are linked to poor low temperature HAZ Cv/CTOD toughness if Ti is too high (much above Ti:N stoichiometric of 3.41:1) as large TiN cuboids can form which can lead to poor HAZ toughness.
- Typical additions may be up to 0.03% Ti but are dependent on N distribution. At lower Ti and N levels typically used with modern steelmakers, this ratio is impractical and has been exceeded and excellent toughness has been maintained.
- Historically higher Ti additions have been made but it is less common today.
Present Table 5

- The focus is on welded pipe grades X52ME/L360ME and higher
- These requirements were the basis of metallurgical developments especially in steel coils for spiral pipes and are the reference for International Tenders.

### Proposed evolution of Table 5

- **Proposal agreed at Jan 7 meeting:**
  1. Apply new notes m and n to welded pipe grades between X52M/L360M and X80M/L555M
  2. **New note m:**
     
     "Unless otherwise agreed, Nb + V + Ti ≤ 0.15%; Nb + C ≤ 0.20%; Ti ≤ 0.03% ."
  3. **New note n:**
     
     Unless otherwise agreed, 0.06 % maximum for aluminium, 0.012% maximum nitrogen, and the aluminium:nitrogen ratio shall be ≥ 2:1.
Proposal for changes to Annexes H & J

Annex H (Sour Service) and Annex J (Offshore Service)
- Significant experience with higher Nb sour and offshore pipelines
- Al is added to deoxidize the steel and for some amount of grain refinement.
- Al levels are controlled to ≤ 0.06% for internal cleanliness.
- Al:N ≥ 2:1 are placed to ensure steel is fully killed.
- N limits are often controlled to ≤0.012% for special applications.

Proposal:
1. Harmonize Tables H.1 and J.1 with Table 5 proposed Nb, V and Ti changes from previous slide and eliminate maximum Nb and Ti maxima from table.
2. Maintain Al, Al:N and N controls for offshore and sour service steels

Path Forward

Next Steps:
- Review agreement from January 7;
- Consider applying to <X52M;
- Consider similar controls on SMLS and Normalized pipe.

Questions?
Girth Welds in Newly Constructed Pipelines

Yong-Yi Wang

Center for Reliable Energy Systems
5858 Innovation Dr.
Dublin, OH 43016
USA
614-376-0765
ywang@cres-americas.com

January 19, 2016

Lower grades, such as X70, now have carbon less than 0.05%.

Evolution of Chemical Composition

- Reduction in carbon, decrease in HAZ hardness
HAZ Softening – X100

- X100, ~2000
- Mechanized GMAW. High level of HAZ softening
HAZ Softening – X70

- X70, ~2000
- Mechanized GMAW. Moderate level of HAZ softening
Hardness and Strength Distribution near a New Girth Weld

Pipe 1
YS = 86,000 psi

E8010 hot pass, fill and cap YS ~ 78,000 psi

Pipe 2
YS = 91,500 psi

X70, early 2010’s
GW: Manual SMAW

E6010 root bead
YS ~ 66,000 psi
Permitted Strength Range – API 5L PSL 2 Pipes

- Range of yield strength = 20-30 ksi
- Range of UTS = 28-50 ksi
Examples of Actual vs. Specified Minimum Strength

- X70, ~1990
Potential girth weld failure due to strain concentration along the HAZ while the nominal strain in the pipe is low.
Girth Weld Failure

- Failure in the HAZ at ~0.44-0.50% overall strain in the pipe
- Girth weld was in compliance with API 1104.
Girth Weld Failure

- Girth weld failure in the HAZ from a line constructed in ~2010.
Requirements of 1104 and Possible Consequence

- Key “performance” requirements in API 1104
  - Indications from NDT are smaller than the set limits (acceptance criteria)
  - Maximum stress in the cross-weld tensile test is equal or greater than the specified minimum tensile strength of the pipe.

- Implications
  - Girth weld strength undermatching against the actual strength of pipe and HAZ softening are permitted as long as the maximum stress in the cross-weld tensile test is not less than the specified UTS of the pipe.

- Possible consequence
  - Girth welds could fail at low overall strain (less than 0.3-0.5%) due to high strain concentration in the weld area.
When we had steels with high carbon and high hardenability
- No HAZ softening
- There were cases of weld strength undermatching the actual strength of the pipe; but wide smooth weld cap prevented strain concentration

Key drivers to GW failures: vintage vs. modern welds
- Vintage
  - Large flaws remaining after construction (including hydrogen cracks)
- Modern
  - Weld strength undermatch
  - HAZ softening
  - Less-forgiving weld profiles
  - Hydrogen cracks
Moderate levels of strain can exist even in areas not associated with ground movement
- Pipe being forced into ditch
- Crossings

Most pipelines should have some level of tolerance to longitudinal stresses/strains.

Longitudinal stresses/strains are typically not actively managed in areas of “stable ground” or no past history of failures, even there are longitudinal stress/strain limits in the design phase.

The requirements in API 5L/1104 does not guarantee strain capacity beyond ~0.3%.
- Strain-based design starts at 0.5%. The implications are that current API 5L/1105 is good to 0.5%. This is not the case.
The girth weld incidents cited here are not exclusively a “welding issue.”

The problem can only be solved through proper

- Pipe specifications, and
- Welding procedure design and execution.

Selecting the right welding procedure/process can help.

- Through the understanding the impact of welding on materials surrounding the welds.
- Welding parameters that have impact
  - Mechanized vs. manual welds
  - Heat input level vs. construction speed/efficiency
  - Weld profile, including weld overbuild
Q&A
Impact of Girth Weld High-Low Misalignment

Yong-Yi Wang and Kunal Kotian

Center for Reliable Energy Systems
5858 Innovation Dr.
Dublin, OH 43016
USA
614-376-0765
ywang@cres-americas.com

January 19, 2016
Background and Incentives

- Some newly constructed pipelines in the US experienced
  - Hydrostatic failures
  - In-service leaks soon after lines were put in service
- PHMSA issued ADB-10-03 (March 18, 2010)
  - Girth weld quality issues were identified.
  - Some of the contributing factors:
    - Improper transitioning
    - High-low misalignment
    - Improper welding practice and/or not following qualified welding procedure
    - Hydrogen-assisted cracking
    - High stresses acting on girth welds from improper pipe support and backfill in hilly terrains
- A joint task group was formed between API 5L and 1104 committees.
  - Expected outcome:
    - set “allowable misalignment”, and/or
    - Pipe dimensional tolerance
Background and Incentives

- Current language in API 1104
  
  “For pipe ends of the same nominal thickness, the offset should not exceed 1/8 inch (3 mm). When there is greater misalignment, it shall be uniformly distributed around the circumference”

- Is the language adequate?
  
  - Limiting misalignment makes sense, but misalignment is not the only factor affecting performance.
  
  - Uniform distribution?
    
    - Makes sense if when such action can reduce the maximum level of misalignment
    
    - Misalignment is often caused by local geometry variations (tenting). How could one distribute such misalignment uniformly around the circumference?
    
    - Even one can uniformly distribute the misalignment, there should be some limit.
  
  - How is the specification checked in the field?
Impact of Misalignment

- Possible negative impact of high-low misalignment
  - Difficulty in making high-quality root pass
  - Local stress concentration at the geometric discontinuities
    - May contribute to the formation of hydrogen cracks
    - Reduced fatigue life
  - Gross stress concentration due to reduced load-bearing cross-sectional area
  - Increased difficulty in NDT
Phase I Welds

- Two girth welds with intentionally made high levels of misalignment
  - **Weld 1**: 36” OD, 0.372” WT, Grade X70
    - Mechanized GMAW on an UOE pipe, girth welding consumable: ER70S-6
    - High-low misalignment between 0.0 and 2.1 mm (misalignment / WT = 0.00-0.22)
  - **Weld 2**: 24” OD, 0.500” WT, Grade X70
    - Manual SMAW on an ERW pipe, girth welding consumable: E8045-P2 H4R
    - High-low misalignment between 0.0 and 5.0 mm (misalignment / WT = 0.00-0.39)

Cross-weld region polished + etched:

Cross-weld region not polished or etched:
Observations from Phase I Tests

- **Weld 1 (mechanized GMAW)**
  - The pipe “UTS” variation of approximately 5% was observed.
  - There is a dependence pipe UTS on o’clock position.
  - Weld strength mismatch ratio = ~1.05 (5% overmatching).
  - All “failures” of the cross-weld samples occurred in the base metal.

- **Weld 2 (manual SMAW)**
  - Weld strength mismatch ratio = 0.95 (5% undermatching)
  - There is a load capacity reduction of 9.5% for misalignment up to 39% of wall thickness.
  - The iso-load capacity relation of CRES models captures the highest load capacity reduction.
Phase 2 Welds

- Four girth welds with intentionally made high levels of misalignment
  - 36” (914 mm) OD 0.531” (13.5 mm) WT X70 spiral pipe

- Tie-in WPS
  - Root: E6010
  - Fills and cap: E8010 HP vertical up flux core using M300 bug
10 kg Vickers hardness traverse
Specimens from GW #55 & 58 tested
Weld #55 results
- Pipe sides have similar hardness
- WM/BM = 0.89
- HAZ/BM ≈ 1
Weld #58 results
- Pipe sides have dissimilar hardness
  - 12% difference in hardness
- WM/BM = 0.82 and 0.93 (two values for 2 pipe sides)
- HAZ/BM ≈ 1
Phase 2 – Cross-weld Tensile Specimens

- CWTs extracted from weld regions with flaws
- Material characterization tests conducted
- CWT tests of specimens with natural as well as artificial flaws (flaw depth ≈ 3 mm or 0.12”)

All dimensions in inches
Phase 2 – Cross-weld Tensile Results

Impact of Girth Weld High-Low Misalignment

<table>
<thead>
<tr>
<th>Type of CWT</th>
<th># of CWTs Tested</th>
<th># of CWTs that Failed in the Weld Region</th>
<th># of CWTs that Failed in the Base Metal</th>
</tr>
</thead>
<tbody>
<tr>
<td>CWTs with No Flaws</td>
<td>12</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>CWTs with Natural Flaws</td>
<td>8</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>CWTs with Artificial Flaws</td>
<td>14</td>
<td>14</td>
<td>0</td>
</tr>
</tbody>
</table>
Observations

- The reduction of cross-weld stress capacity is modest even at high levels of misalignment, when there is
  - a smooth transitioned and sufficiently filled weld profile,
  - no excessive weld strength undermatching, and
  - No large flaws

- High levels of misalignment, by themselves, are not necessarily an integrity concern, provided that
  - (1) under static loading,
  - (2) weld having sufficient toughness, and
  - (3) no large flaws.
Observations

- The misalignment management should therefore focus on:
  - Having well-transitioned weld profiles with sufficient width (not addressed by standard yet)
  - Minimizing the likelihood of having large flaws and/or repair them when necessary (addressed by standard)
  - Not having overly-undermatched weld metal (not addressed by standard yet)
Thank You!

- Q&A