

# Improving API 1104 for the Twenty-second Edition

**API-AGA Joint Committee on Oil and Gas Pipeline Field Welding Practices**  
**Bill Bruce – Secretary**

**January 17-19, 2017 – JW Marriott Austin – Austin, Texas**

## Introduction

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- Twenty-second edition of API 1104 is nominally scheduled for 2018
  - September 2013 (Twenty-first Edition) plus five years
- Incremental improvements to the standard are developed at annual meeting and throughout the year by various subcommittees and task groups
- Important to occasionally step back and think about where we want to go with the standard in the long term
  - e.g., are we addressing emerging trends?
- Opportunities for improvement to address two emerging trends will be highlighted
  1. Reduce level of ambiguity – discussed at January 2016 meeting
  2. Girth weld strength matching
    - Weld metal strength vs. strength of pipe material in axial direction
    - Heat-affected zone (HAZ) softening
- Open discussion pertaining to other opportunities

## 1. Ambiguity in API 1104 – discussed at January 2016 meeting


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- API 1104 contains quite a bit of ambiguity
  - For welding procedure qualification (and welder qualification) in particular
    - e.g., contains no guidance on what to specify on a welding procedure specification (WPS) in relation to what was used to make the test weld
- Two schools of thought on this
  - Allows flexibility for the user
  - Creates confusion during audits
- Regulatory oversight has increased significantly in recent years
  - Operators continue to reported issues as the result of ambiguity and differences in opinion it creates with regard to the intent of some of the requirements
    - Violations of § 192.225 and § 195.214 (Welding Procedures) are often cited in notice of probable violations (NOPVs)
    - “...must be recorded in *detail*...” in above and “...*details* of each qualified procedure shall be recorded...” in 5.2 of API 1104 are often cited
- We should do what we can to reduce ambiguity in the next edition of API 1104

## Interpretations Task Group/Database

- API 1104 committee receives many requests for interpretation
- Intent for some requirements in API 1104 is contained in the interpretations database – <http://mycommittees.api.org/standards/techinterp/transpipe/default.aspx>
  - e.g., database contains a number of interpretations that address what to specify on a WPS with regard to what was used to make the test weld
- Interpretations database was a primary resource in the development of the PRCI guidance document for API 1104
  - But, guidance document is not part of API 1104, is not sanctioned by API, and its existence is unknown to most users of API 1104
  - <https://www.prci.org/Research/DesignMaterialsConstruction/2774/API-1-2/3145/18341.aspx>
- We should use interpretations process and database as basis for improvements



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LEADING PIPELINE RESEARCH

**Guidelines for Interpretation and Application of API 1104 –  
Twenty-first Edition**  
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Prepared for the Design, Materials, and Construction Technical Committee  
of  
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Revision 0	April 17, 2014	April 17, 2014	First draft of final report.
Revision 1	July 18, 2014	July 18, 2014	Comments and suggestions incorporated.

## New ITG “Ground Rules”

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- Requests for interpretation (particularly multiple requests about the same issue) are often a good indicator of an opportunity for improvement
- New ITG ground rules include a requirement to provide feedback to the relevant subcommittees
  4. All responses to the request must be developed with respect to what the standard currently says and not what was “intended”. Note that “intent” may be a driver to forming a response only if the document language is not clear or specific.
  5. What the standard should (or meant to) say can also be discussed, but this must not influence the response. This discussion can be used as a basis for future improvements/revisions to the standard. **A record of these potential improvements/revisions shall be provided to the relevant subcommittee chairs.**
- ITG is now comprised of subcommittee chairs (since 2013)
  - Formerly Modifications, Interpretation, and Policy Subcommittee

## Previous Request for Interpretation and Response

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- Question

- “Paragraph 5.4.2.12 states that "A change in the range for speed of travel constitutes an essential variable." and requires that the procedure be requalified if this range is changed. How is the range of travel speed for each pass established?
  - A) By measuring the travel speed of each pass during procedure qualification and listing the exact speeds employed by the welder for each pass.
  - B) By establishing a reasonable range of travel speeds based on experience and/or experimentation at the filler metal manufacturers recommended amperage and voltage ranges and welding the procedure qualification coupon within that specified range.
  - C) By some other method (Please explain).”

- Answer


- “The Company establishes the range that they feel is appropriate and one way is as you have suggested in B.”

## What Can We Do to Convey Intent?

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- These interpretation responses represent the intent of the committee
- A certain degree of flexibility is required in API 1104
  - Some pipelines are more high risk than others
    - Generic procedures qualified to go in a welding manual
    - Project specific procedures
  - API 1104 needs to be “scalable”
- What can we do to convey the intent of the committee in the standard?
  - Clarify the requirement in the standard itself?
  - Use a tiered approach?
    - Leave as-is for less-critical applications?
    - Supplemental essential variables and tighter allowable ranges for more-critical applications (e.g., for project specific applications)?
  - Provide guidance note(s) after the requirement?
  - Provide guidance in a commentary section or companion document?

## How Do We Reduce Ambiguity?

- What improvements can we make to reduce ambiguity?
  - e.g., travel speed is an essential variable for procedure qualification, yet ironically, what API 1104 provides as an example procedure qualification record (PQR) does not even have a place to record travel speed
    - Figure 2 – Sample Coupon Test Report 
- The lack of guidance on what to specify on a WPS with regard to what was used to make the test weld, combined with the ability to specify a very wide range (and the thought of increased regulatory oversight) encourages users to specify very wide ranges
  - May be allowed
  - May prevent welding outside the “qualified range”
  - May not be technically sound for some applications

COUPON TEST REPORT							
Date _____	Test No. _____						
Location _____	Weld Position: _____			Roll <input type="checkbox"/>	Fixed <input type="checkbox"/>		
State _____	Mark _____						
Welder _____	Time of day _____						
Welding time _____	Mean temperature _____			Wind break used _____			
Weather conditions _____	Voltage _____			Amperage _____			
Reinforcement size _____	Welding machine type _____			Welding machine size _____			
Pipe type and grade _____	Filler metal _____						
Wall thickness _____	Outside diameter _____						
	1	2	3	4	5	6	7
Coupon stenciled							
Original specimen dimensions							
Original specimen area							
Maximum load							
Tensile strength							
Fracture location							
<input type="checkbox"/> Procedure	<input type="checkbox"/> Qualifying test		<input type="checkbox"/> Qualified				
<input type="checkbox"/> Welder	<input type="checkbox"/> Line test		<input type="checkbox"/> Disqualified				
Maximum tensile _____	Minimum tensile _____		Average tensile _____				
Remarks on tensile strength tests _____							
1. _____							
2. _____							
3. _____							
4. _____							
Remarks on bend tests _____							
1. _____							
2. _____							
3. _____							
4. _____							
Remarks on nick break tests _____							
1. _____							
2. _____							
3. _____							
4. _____							
Test made at _____	Date _____						
Tested by _____	Supervised by _____						
NOTE Use back for additional remarks. This form can be used to report either a procedure qualification test or a welder qualification test.							

Figure 2—Sample Coupon Test Report



## Additional Opportunities for Improvement

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- Travel speed is an essential variable for procedure qualification...
  - ...but amps and volts are not (can be changed to any value without requalification)
  - Main body of API 1104 does not consider the concept of heat input, which takes into account the collective effect of amps, volts, and travel speed of the resulting thermal cycle of the weld
  - It is time to recognize heat input as optional essential variable to travel speed
  
- Preheat temperature
  - 5.3.2.13 only says the preheat temperature at the “start of the weld” shall be specified
    - What is the “start of the weld”?
    - Does that mean the start of the root bead only, each weld bead, the start of each layer of weld metal, or?
  - It is time to introduce “interpass temperature”
  
- We refer to AWS A3.0 in API 1104
  - AWS will allow us to reproduce critical definitions

## Another Example of Ambiguity

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- Changes to an essential variable outside the range qualified requires that the procedure be requalified
  - “A welding procedure shall be reestablished as a new welding procedure specification and shall be completely requalified when any of the essential variables listed in 5.4.2 are changed.”
  
- What does “completely requalified” mean?
  - Presumably it involves making and testing a new test weld, but why?
- If the new range could have been specified initially (based on the original test weld), why require that a new test weld be made?
- Can I write a new WPS based on an old existing test weld?
  
- What significance does the concept of an essential variable have if the company can specify anything they think is appropriate, regardless of what was used to make the test weld?

## New Example of Ambiguity

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- Multiple welder qualification to 6.3
  - 6.3.1 says “For the second test, the welder shall lay out, cut, fit, and weld a branch-on-pipe connection...”
  - PHMSA has reportedly argued recently that the use of a saddle cutting beveling machine is not be allowed
  - This was the subject of a request for interpretation in 2001
  
- Question
  - “...does layout mean:
    - 1. The welder shall layout the branch connection from scratch (using wraparounds, steel squares, or any tools necessary)?
    - 2. The welder can layout the branch connection utilizing a precut template?”
  
- Answer
  - “The decision as to the method of layout is left to the company.”

## 2. Girth Weld Strength Matching

- Many changes in the pipeline industry have occurred over the past few decades
  - Higher-strength line pipe steels
  - High-productivity mechanized gas-metal arc welding equipment (dual torch, tandem arc, etc.)
  - Inspection using automated ultrasonic testing (AUT)
- Many of the construction practices that were used prior to these changes are still used today
  - Conventional “stove-pipe” welding methods (i.e., using cellulosic-coated electrodes)
  - Inspection using radiographic testing (RT)
- Even for “modern” pipelines, tie-in and repair welds are often made using conventional methods



## Recent Pipeline Construction Quality Issues

- Pipeline girth weld failures continue to occur in North America
  - Some in newly-constructed pipeline during pre-service hydrostatic proof testing
- Advisory Bulletin was issued by the US DOT Pipeline and Hazardous Materials Safety Administration (PHMSA) that highlights these and other issues (ADB-10-03)
- Contributing factors include:
  - High-low misalignment
  - Unequal-wall-thickness transitions
  - High longitudinal stress/strain associated with lifting and lowering-in practices
  - Inadequate tie-in and repair welding procedures
  - Improper inspection and delay times
  - Insufficient adherence to qualified welding procedures
- Recently-completed project at DNV GL for Pipeline Research Council International (PRCI) addressed these issues



## Girth Weld Strength Matching

- The rate of pipeline incidents (leaks and ruptures) attributed to defective girth welds has traditionally been low
  - Axial stresses (i.e., those perpendicular to girth welds) from pressure loading are significantly lower in a completed pipeline than those in the circumferential (hoop stress) direction
- Axial stresses in completed girth welds
  - Occur during lifting and lowering-in
  - Occur when the pipeline does not fit the ditch
- Some strain capacity can be exhausted by exceeding elastic limit during lifting and lowering-in
  - Particularly at undermatching strength girth welds
- Undermatching strength girth welds can be due to:
  - Pipe strength in axial direction is greater than weld metal strength
  - Softening in the heat-affected zone



## Two Recent PHMSA Advisory Bulletins

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- ADB-09-01 – Potential Low and Variable Yield and Tensile Strength and Chemical Composition Properties in High Strength Line Pipe
  - Following the discovery of suspected understrength line pipe
- ADB-10-03 – Girth Weld Quality Issues Due to Improper Transitioning, Misalignment, and Welding Practices of Large Diameter Line Pipe
  - Following girth weld failures during new construction activities
  
- Since ADB-09-01 (low and variable yield strength), trend for as-received line pipe strength levels has been toward the higher end of the acceptable range
  - Manufacturers aiming higher to account for variability in tensile testing practices by third-party labs (flattening procedure, Bauschinger effect, extensometer placement, etc.)
  - Anything a third-party lab does that is not ideal will tend to reduce the apparent strength

## Recent Industry Observations – 1 of 4

- Maximum allowable yield strength in API 5L for PSL 2 pipe
  - Typically >20 ksi above SMYS (e.g., ~87 ksi for X65, ~92 ksi psi for X70)
- Tensile properties in the axial (cross girth weld) direction
  - No requirements in API 5L (for pipe larger than 8-5/8 in. diameter)
    - Strength in axial direction is sometimes higher than strength in transverse direction
- Recent results for X65:



Specimen ID (N/A)	Tensile Orientation (N/A)	Original Width (in)	Original Thickness (in)	Orig GL (in)	UTS (psi)	0.5% Yield Stress (EUL) (psi)	Elongation (%)	ROA (%)	Failure Location (N/A)
15357-6-T1	Axial	1.500 38.1 (mm)	0.250 6.4 (mm)	2.008 51.0 (mm)	97100 670 (MPa)	94100 649 (MPa)	25.8	70.3	Base Material
15357-6-T2	Axial	1.500 38.1 (mm)	0.250 6.4 (mm)	2.008 51.0 (mm)	97300 671 (MPa)	91800 633 (MPa)	23.2	73.0	Base Material
15357-6-T3	Circumferential	1.502 38.2 (mm)	0.250 6.4 (mm)	2.009 51.0 (mm)	93800 647 (MPa)	69500 479 (MPa)	24.6	71.0	Base Material
15357-6-T4	Circumferential	1.502 38.2 (mm)	0.250 6.4 (mm)	2.009 51.0 (mm)	93700 646 (MPa)	82900 572 (MPa)	24.9	68.7	Base Material

**Comments:** Extensometer was placed on the OD surface for samples T1 & T3, ID surface for samples T2 & T4.

- 92 to 94 KSI yield strength in the axial direction for X65!!!
  - E8010 is unlikely to overmatch (and E9010 should not even be considered)



## Recent Industry Observations – 2 of 4

- All of the recent failures involved manual welds
- AWS E8010 yield strength requirements
  - 67 ksi minimum
- Typical yield strength results
  - 67-90 ksi (Lincoln 70+), 69-79 ksi (Lincoln 8P+ and Arc 80)
- Many recent weld failures have been the result of girth welds with significantly undermatched strength in the presence of significant axial loading
  - Evidence of necking in and adjacent to the weld 
  - Evidence of plastic strains in and adjacent to girth welds the form of cracks in epoxy field joint coating 
- There is no requirement in API 1104 for the measured tensile strength across the weld to be greater than the actual tensile strength of the pipe material
  - Cross weld tensile specimens are allowed break in the weld as long as they do so above the specified-minimum tensile strength of the pipe material



## Recent Industry Observations – 3 of 4

- Many of the recent weld failures involved cases where the profile of the pipe string did not match the profile of the ditch



- Some welds have had quality issues but other are mostly the result of undermatching strength

## Recent Industry Observations – 4 of 4

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- Failures like these are often attributed to the weld
  - Weld may be perfectly acceptable from a code compliance perspective
  - Real culprits are high axial loads and line pipe material that is too strong
    - Accumulation of strain at undermatching strength girth welds
- Action items?:
  1. Pay more attention to producing girth welds with matching or overmatching strength?
    - Change API 1104 requirements?
    - Cannot get much higher strength with cellulosic-coated electrodes
      - Consider combination process instead
        - Cellulosic root and hot passes/low-hydrogen vertical down or FCAW for fill and cap
  2. Impose maximum-allowable axial strength requirements for line pipe?
    - API 5L or company purchase specifications
  3. Standardize flattened strap tensile testing practices?
    - New DNV GL JIP being launched in association with NIST to address this
  4. Pay more attention to quality control during field bending operations?
    - Make sure profile of the pipe string matches the profile of the ditch

## How Do We Address Undermatching Strength Girth Welds?

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- Need for a tiered approach in Section 5?
  - Tier 1 – keep things the way they are for qualification of generic procedures that will be used for non-project-specific applications (i.e., procedures that will go into the company welding manual)
  - Tier 2 – for project-specific applications, require procedure qualification on project pipe and require weld strength overmatching (i.e., cross-weld tensile specimens must break in the base material remote from the weld)
- Focus so far has been on weld metal strength vs. axial strength of base material
  - HAZ softening has also been identified as a concern with modern line pipe materials
    - See Yong-Yi's presentation in API 1104/5L Joint Work Group meeting next
- Cap height
  - Section 7 says "At no point shall the crown surface fall below the outside surface of the pipe, nor should it be raised above the parent metal by more than 1/16 in. (1.6 mm)."
  - Figure 1 suggests 1/32 to 1/16 in. – does this need to be reassessed?
  - Why limit cap height to 1/16 in.?

## Summary – Ambiguity and Girth Weld Strength Matching

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- Make sure we're addressing emerging trends
- Reduce ambiguity by learning (and making improvements as the result of) inquiry process
- Beware of undermatching strength girth welds
  - Pipe with very high strength in axial direction
  - Softening in the heat-affected zone
- Tiered approach to procedure qualification in Section 5?
- Revise cap height requirements?
- Make sure the profile of the pipe string matches the profile of the ditch

## Open Discussion – Other Opportunities for Improvement

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- Reduce level of ambiguity
- Girth weld strength matching
- Other opportunities

- May be a good idea to devise a long term strategy for the standard
  - General Interest Realignment Subcommittee assignment?



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## New JIP on Tensile Testing of Flattened Strap Specimens – 1 of 3

- Flattened transverse test specimens are typically used to measure the tensile properties, including yield strength, of large diameter line pipe

- Maximum allowable operating pressure (MAOP) is based on specified minimum yield strength (SMYS), which must be verified by tensile testing

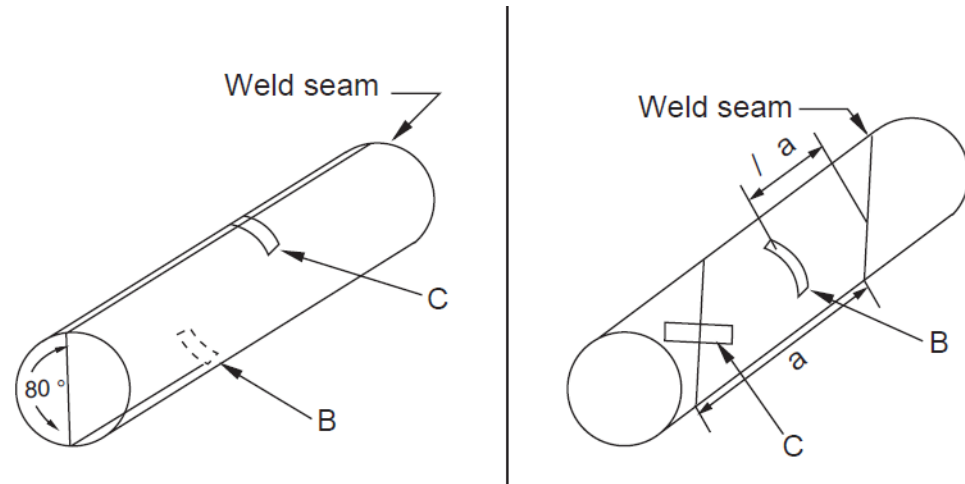
- The absence of standardized sample flattening procedures and wide ranges of acceptable testing parameters in industry standards (e.g., API 5L, ASTM A370) have been known to produce significant variability in measured yield strength

- Values measured by third-party labs may be significantly lower than values measured in pipe mill – numerous potential implications, including MAOP

- Previous JIP resulted in the development of an improved flattening procedure

- Intended to minimize the effect of the Bauschinger Effect

- Became obvious that this is only one source of the significant variability





## New JIP on Tensile Testing of Flattened Strap Specimens – 2 of 3

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- Implications of low yield strength measurement
  - Continued operation at design MAOP
    - Low measurements during testing at third-party labs following expansion during hydrotest
  - Failures of undermatching strength girth welds in newly constructed pipelines
    - See recent industry observations
  - Inaccurate assessments for existing pipelines
    - Remaining strength, fatigue resistance, fracture initiation, defect tolerance, dent behavior, etc.
- Pipe mill tend to be very adept at tensile testing
  - Demonstrated the quality of their product
- Almost everything a third-party lab can do that is not ideal will lower the apparent yield strength

## New JIP on Tensile Testing of Flattened Strap Specimens – 3 of 3

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- New JIP will address this topic from a more fundamental perspective and will include the effects of tensile testing parameters and equipment on measured yield strength
  - Development calibration sample to test tensile testing machine compliance (or stiffness)
  - Effect of testing parameters, such as extensometer type and placement, type of grips and specimen alignment, strain rate or cross-head speed, degree of sample flatness, extensometer gauge length, test specimen shape, etc.
- JIP partners
  - DNV GL – Melissa Gould, et.al.
  - National Institute of Standards and Technology (NIST), Material Measurement Laboratory (MML) – Dash Weeks and Dave McColskey
  - Past Chair of ASTM Committee E28 on Mechanical Testing (formerly with Tinius Olsen [retired]) – Earl Ruth
- Proposal issued November 2, 2016
  - Cost to participate is \$20,000 per participant
  - Support for this significant industry-wide topic is appreciated – please contact [melissa.gould@dnvgl.com](mailto:melissa.gould@dnvgl.com)