API Ballot id# 6416
SC5 TG TGC

Work Item Number	3088
Title of Work Item	Material Characterization for Upset and Weld-on Connectors in RP 5C5
Ballot Revision Level	0
Type of Ballot (Initial, Comment, Comment resolution (reference API ballot#), 1st Re-ballot, 2nd Re-ballot, etc.)	Initial Letter Ballot
Submitter Name(s)	Mark Turnbaugh / Pierre Martin
API Document Modified	API RP 5C5
Revision Key	Current API document in black, Deletions in red strikethrough ~~remove~~, Ballot Additions in blue underlined add,

Work Item Charge: Review and propose clarifications/improvements to the material characterization/mapping details for the purpose of determining the testing loads in API RP 5C5, including identification of requirements for upset and weld-on connectors.

Ballot Rationale: The work group has resolved comments from the 2024 Comment Ballot and recommends moving forward with the Letter Ballot.

Procedures for Testing Casing and Tubing Connections

API RECOMMENDED PRACTICE 5C5
FOURTH EDITION, JANUARY 2017

ADDENDUM 1, MAY 2021

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Definitions:

Prolongation: An extension of metal added to a forging to permit removal and subsequent testing without destroying the forging. This extension is integrally made during the forging process and removed after final heat treatment. (See API 20B 2nd Edition November 2020)

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5 General Test Requirements

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5.5 Material Characterization

5.5.1 General

The pipe shall be mechanically tested to determine the yield strength for calculation of the pipe body reference envelope for each test specimen. The coupling stock shall be mechanically tested to determine its yield strength. The pup and coupling stock mechanical test data should be considered in the determination of the CEE for each test specimen. For the material characterization of upset or weld-on connectors, see Annex H.

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Annex H
(normative)

Material Characterization of Upset and Weld-on Connectors

H.1 General

This section and sub-sections supplement 5.5, 6.3, 7.3, and Annexes A, B, C, and D.

This annex is intended to provide additional guidance to the main body of this standard for the topic of material strength characterization and load schedule generation for upset end and weld-on connections. The intent of this section is to follow the same principles outlined in the main body of the document.

The upset, transition zone, weld zone, or forging material characterization may be considered for CEE calculations, if applicable.

For weld on connections the pipe and forging shall be mechanically tested to determine the corresponding yield strengths. The mechanical test data should be considered in the determination of the CEE for each test specimen.

For upset connections the pipe and upset area shall be mechanically tested to determine the corresponding yield strengths. The mechanical test data should be considered in the determination of the CEE for each test specimen.

H.2 Material Property Tests

H.2.1 Material Test Coupons

Mechanical property characterization shall be conducted on material that accurately represents the various locations ~~It is the responsibility of the connection manufacturer to perform mechanical property characterization on material that accurately represents the various locations~~ and specific materials comprising the connection test samples, especially those areas identified as being the critical ones regarding connection performance.

Material for mechanical property characterization shall be from the same heat and heat treatment lot and shall be subjected to the same processing parameters used to manufacture the connection test samples. The forging and upset area shall be characterized~~; the weld may also be characterized where there is a concern of failure at the weld.~~. The effect of the weld on material properties shall be accounted for when characterizing the pipe material if the weld impacts the CEE. It shall be stated in the executive summary if the weld effect was part of the material characterization of the pipe.

H.2.2 Material Testing Requirements

The pipe body, forgings, and upset areas shall be tested according to 5.5.2.2 and 5.5.2.3 except as stated in H.2.2.1 and H.2.2.2.

H.2.2.1 Weld-on Test Specimens

Material being tested shall have the same hot working and heat treatment as material being used in the connection test program. Variations in localized cooling rates, experienced by forgings in different locations or orientations within a batch heat treating process, and the subsequent effect on resultant mechanical properties should be considered in the selection of sacrificial and connection test specimen forgings.

The following combinations of heat treatment type and material testing are known to be used:

- Batch heat treatment with sacrificial forging(s)
- Batch heat treatment with prolongations
- Continuous processing heat treatment with sacrificial forging(s)
- Continuous processing heat treatment with prolongations

When prolongations, as defined in API 20B, are utilized to determine mechanical properties, a prolongation shall be used for each pin and box. ~~Care shall should be taken,~~Prolongation should be according to API 20B, to make sure that prolongations are providing representative mechanical properties for the critical areas of the forging.

In the case that a sacrificial forging is used, a map for batch heat treatment or a list for continuous processing showing connection test specimen and sacrificial forging placement/sequence during heat treatment shall be provided.

For batch heat treat processing, it is preferred that a prolongation from each actual connection test specimen forging is used for mechanical property characterization instead of a sacrificial test forging; however, it is understood that this is often not practical due to the limited size of connection test specimen forgings.

For continuous processing, identical processing parameters should be used and identical process indicators should be observed during the heat treating of both sacrificial and connection test specimens. Sacrificial forging(s) for mechanical testing shall be processed in sequence with the connection test forgings.

The surface hardness of the forgings shall be used to determine the sacrificial forging for mechanical property characterization of the lot, as well as the most suitable forgings for connection testing. At least three surface hardness readings shall be made on all forgings within the lot, evenly spaced around the circumference of each forging at a given section. Each measured surface hardness shall be reported for all forgings in the lot. The sacrificial forging shall be the forging which has the median average surface hardness of the heat treatment lot. The connection test specimens' average surface hardness shall be those nearest to the average surface hardness of the sacrificial forging~~The connection test specimens' average surface hardness shall be as close as possiblebe the specimens with the closest to the average surface hardness of the sacrificial forging which shall be selected as the median surface hardness of the heat treatment lot~~. An example of this screening can be found in H.6.2.2. The method used to select the connection test specimens and sacrificial forging shall be fully documented within the test report.

Material test location within the connector profile should follow those qualified in production. Where it is not feasible to test the forging material in the same way as is qualified in production (i.e., forging shape is different), longitudinal material property tests should be conducted on tensile test specimens at 1/2T of the critical heat treatment thickness and T from any second surface where T is the radial thickness of the critical heat treatment thickness as shown in Figure H.1~~Figure H.1~~.

If it is determined the weld needs material characterization, then it should be done by agreement between the manufacturer and the test lab.

For those connections and welds that will undergo post-weld heat treatment (PWHT) during sample manufacturing, a simulated post-weld heat treatment (sPWHT), representative of actual PWHT, should be performed according to API 5C6 simulated post-weld heat treatment procedure on the forging and pipe tensile coupons prior to performing the ambient or elevated tensile tests. Pipe material after sPWHT does not have to meet the minimum pipe specification requirements to be used in testing, but the actual material performance properties obtained after sPWHT shall be used for the final assessment factors, as referenced in H.4.

The typical layout of the test specimen is provided in Figure H.1~~Figure H.1~~. As shown in Figure H.1~~Figure H.1~~, testing orientation (longitudinal vs. transverse), when referenced in this specification, shall refer to the geometric orientation, not the grain flow orientation.

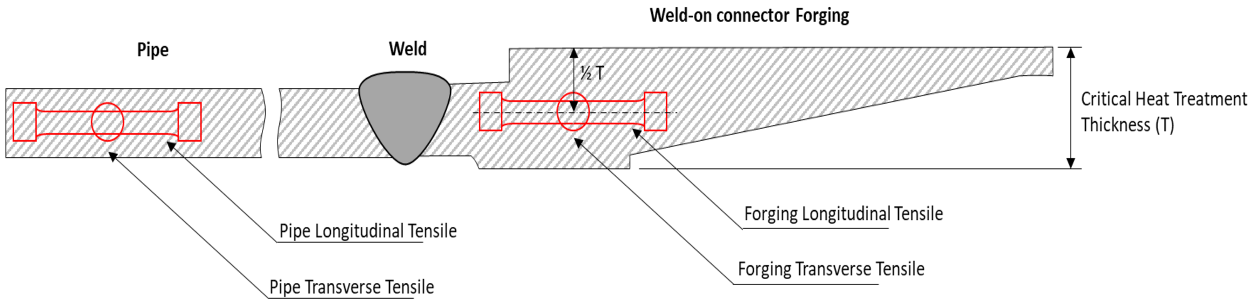


Figure H.1 – Weld-on Connector Specimen Layout

H.2.2.2 Upset Test Specimens

Material being tested shall be from the same heat, same hot working, and heat treatment lot as the material being used in the connection test program. If the upsets are batch heat treated, variations in localized mechanical properties should be considered.

Transition zone characterization may be conducted by agreement. If the upset end impacts that CEE then the transition zone shall be characterized.

When possible, the upset ends and pipe body on each test specimen shall be characterized as shown in Figure H.2. ~~It is preferable to have material characterization of the pipe body ends and upset ends for each tested specimen, according to Figure H.2.~~

~~If it is determined the transition needs material characterization, then it should be done by agreement between the manufacturer and the test lab.~~

In the case upset ends do not allow for material characterization, the following method shall be used:

- A sacrificial sample shall be cut to determine material characteristics at specific locations within the sacrificial joint from each heat, hot working, and heat treatment lot according to Figure H.2~~Figure H.2~~.
- The test sample upset area yield strength shall be characterized with the pipe body yield strength of the connection test specimen, as seen in Figure H.3~~Figure H.3~~.
- The test sample upset area yield strength shall be characterized ~~, multiplied by the ratio,~~ as seen in **Equation H.1** ~~**Error! Reference source not found.**~~. ~~, of the sacrificial upset actual and the sacrificial pipe actual where~~ T~~t~~he sacrificial pipe actual and sacrificial upset actual are the average yield strengths of the four quadrants of the respective sacrificial material coupons, as seen in Figure H.2~~Figure H.2~~.

$$Test_{Upset\ Actual} = Test_{Pipe\ Actual} \times \left(\frac{Sacrificial_{Upset\ actual\ average}}{Sacrificial_{Pipe\ Actual\ average}}\right) \qquad (H.1)$$

Figure H.2~~Figure H.2~~ and Figure H.3~~Figure H.3~~ illustrate the material test coupon locations.

The material test coupons according to Figure H.2~~Figure H.2~~ shall be located at the following positions:

- Within 12 inches of pipe end free ends
- Within 12 inches of upset ends

The coupon samples according to Figure H.3~~Figure H.3~~ shall be located at the following positions:

- Within 12 inches of pipe end free ends

The material characterization of the specified samples shall be tested according to 5.5.2. The specimen AMYS shall be the minimum of the test sample upset area yield strengths. The pipe body reference curves shall be built based on the pipe body material characterization. The upset reference curve shall be considered for the CEE calculation if the upset mechanical properties are weaker than the pipe.

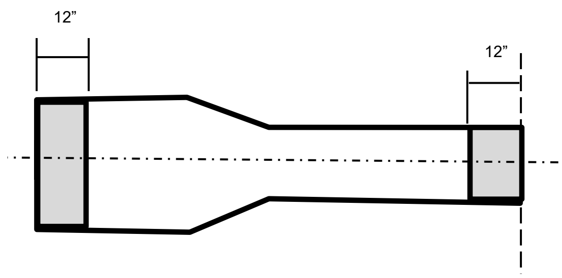


Figure H.2 – Location of material test coupon for pipe body and upset ends.

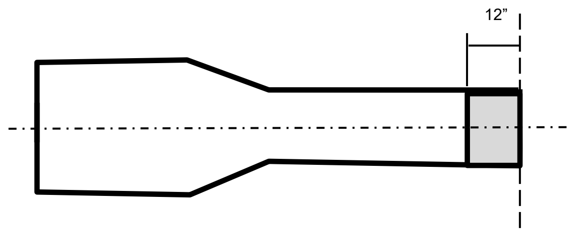


Figure H.3 – Location of material coupon for connection test specimen pipe body samples.

H.2.3 Material Requirements

The material requirements for each set of test specimens shall follow 6.3.3 except as stated in this section.

The actual properties of the pups do not directly affect the performance of a weld-on connection and can limit the applied loads during the test. A-end and B-end pups may be from separate mother joints to lessen the difference in the minimum material yield strength between the two pups. ~~pups which can be used to better match the pipe strength to the connection strength~~.

For a forged connection, the greater average yield strength between the box and pin forging should not exceed the minimum yield strength of the other forging by more than 70 MPa (10ksi).

For connections where the pin and box material have different SMYS, as with a thread-direct pin in a forged box, the difference between the average material yield strengths shall be by agreement between the user and the manufacturer.

H.2.4 Material Dimensional Measurements for ~~weld~~Weld-on ~~connection~~Connections

The dimensional measurements of the pipe sections shall follow 5.5.3.

The dimensional measurements of the connection OD shall follow 5.5.1 for coupling requirements and should be reported at critical cross-section (CCS).

Welds do not need to be dimensionally measured but care should be taken regarding nondestructive examination performed on specimens' welds if there is a safety concern for the test, but non-destructive testing should be performed on the welds if there is a concern for safety in the test.

~~For dimensional measurements of weld-on connection specimens, pipe pups shall follow 5.5.3, connection box shall follow 5.5.1 for coupling requirements and should be reported at critical cross-section (CCS). Connection pin ID should be reported at critical cross-section prior to coating. Welds do not need to be dimensionally measured but care should be taken regarding nondestructive examination performed on~~

~~specimens' welds if there is a safety concern for the test.~~

H.2.5 Material Dimensional Measurements for Upset ~~sample~~Connections

The dimensional measurements of the pipe sections shall follow 5.5.3.

~~For upset end connections, see 5.5.3.~~ The dimensional measurements of the connection OD shall follow 5.5.1 for coupling requirements. ~~For upset ends the internal and external connector diameters need to be documented after machining and before coating with the required dimensions in Table B.6.~~

The upset box connector should have the outside diameter measured at 1 inch from the box nose face and at the CCS location as seen in Figure H.4~~Figure H.4~~.

- ~~The upset pin connector should have the inside diameter measured at 1 inch from the pin nose face and at the CCS location as seen in Figure H.4.~~

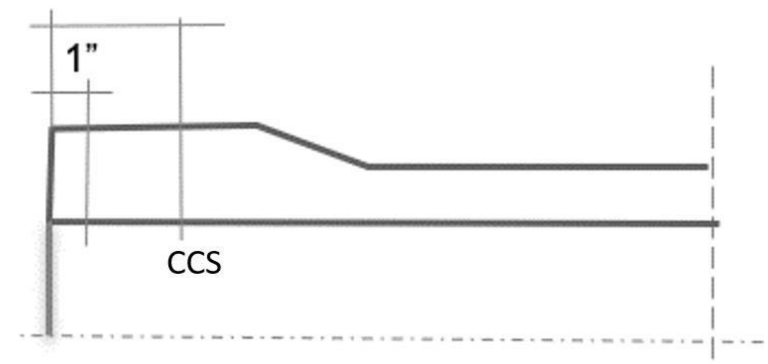


Figure H.4 – Box Upset connector Dimensional Measurement Locations

H.3 Load Schedule Determination

Follow 7.3.1.3.

H.4 Assessment Factor Determination for Weld-on Connections

For weld-on connections, a plot of the pipe body reference envelope with the actual Connection Capacity Envelope and the test load envelope, as seen in Figure H.5~~Figure H.5~~, shall be reported; additionally, four assessment factors ~~should~~ shall be documented for each uniaxial loading using the equations in this section. For connections where the pipe capacity tends to limit some loads of the test, each assessment factor gives a comparison of the actual connection to the actual pipe body load capacity. If any assessment factor equation results in a value larger than 100 %, then the assessment factor shall be 100 %. If a test load is limited by any specific test equipment used, then the assessment factor shall not be calculated for that load.

Tension	:	F_t^a/CCE_t^a	(H.2)
Internal pressure at zero axial load	:	$P_i^a\ /CCE^a\ p_i$	(H.3)
Compression	:	F_c^a/CCE_c^a	(H.4)
External pressure at zero axial load	:	$P_o^a\ /CCE^a\ p_o$	(H.5)

Where the above parameters are defined as follows:

F_t^a Actual pipe body tension capacity at zero pressure at ambient temperature

CCE_t^a Actual connection tension capacity at zero pressure at ambient temperature

F_c^a Actual pipe body compression capacity at zero pressure at ambient temperature

CCE_c^a Actual connection compression capacity at zero pressure at ambient temperature

P_i^a Actual pipe body internal pressure capacity at zero axial load

$CCE^a\ p_i$ Actual connection internal pressure capacity at zero axial load

P_o^a Actual pipe body internal pressure capacity at zero axial load

$CCE^a\ p_o$ Actual connection internal pressure capacity at zero axial load

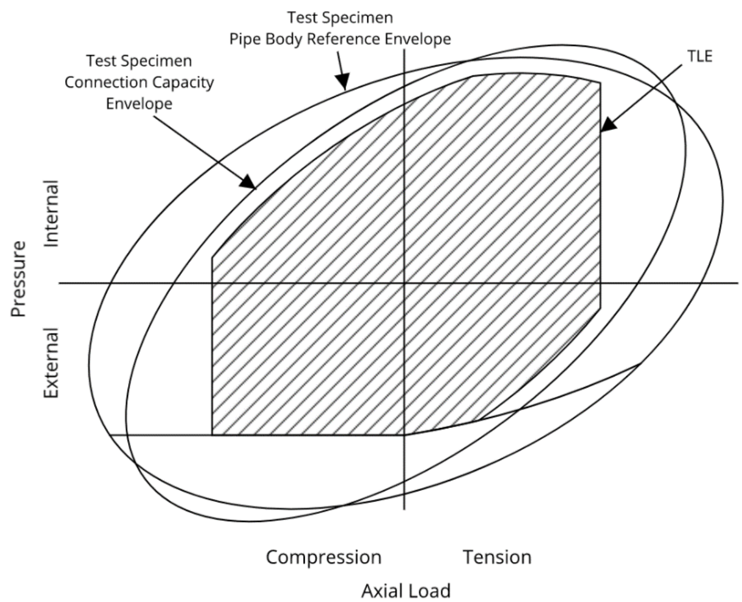


Figure H.5 – Actual Connections Capacity Envelope and Test Load Envelope at Ambient

H.5 Report-Out Requirements

H.5.1 General

This section covers any additions or exclusions to the requirements given in Annex A (Connection Specification Sheet and Test Specimen Datasheet), in Annex B (Data Forms), and Annex C (Connection Full Test Report).

H.5.2 Addendum to Annex A

H.5.2.1 Connection Specification Sheet

H.5.2.1.1 Connection Datasheet

Pipe body minimum performance properties shall use the minimum pipe wall thickness as specified in the pipe specification (e.g. for API 5L SAW pipe has a thickness tolerance of -0.039 in. for wall thicknesses greater than 0.747 in. rather than -12.5 % for seamless).

H.5.2.1.2 Sacrificial Forging Selection Specification

The connection manufacturer shall fully document the process used to select the sacrificial forgings used to characterize the test connection material for the test specimens.

H.5.2.2 Test Specimen Datasheet

The connection manufacturer shall provide the assessment factors calculated using the methodology described in H.4 in a table format. For weld-on connections, substitute Table H.1~~Table H.1~~ for Table A.2.

Table H.1 – Weld-on Connection Test Specimen Datasheet

Identifying Section	Dated Revision
A.2.1 Test Specimen Pipe Body Reference Envelope Document No. (attach copy)	Revision No./Date
A.2.2 Test Specimen Connection Evaluation Envelope Document No. (attach copy)	Revision No./Date
A.2.3 Test Specimen Test Load Envelope Document No. (attach copy)~~A.2.3 Test Specimen Pipe Body Reference Envelope Document No. (attach copy)~~	Revision No./Date
A.2.4 Test Specimen Load Schedule Document No. (attach copy)~~A.2.4 Test Specimen Test Load Envelope Document No. (attach copy)~~	Revision No./Date
A.2.5 Test Specimen Limit Load Document No. (attach copy)~~A.2.5 Test Specimen Load Schedule Document No. (attach copy)~~	Revision No./Date
A.2.6 Assessment Factors Document No. (attach copy)	Revision No./Date

H.5.3 Addendum to Annex B

H.5.3.1 General

Data forms provided in this annex are an alternative optional template to those provided in Annex B with the intention of aiding in the reporting of the additional requirements found in this annex. As in Annex B, any substitution to these forms shall reflect data pertinent to the intent of the data form in accordance with C.1 and this annex as referenced.

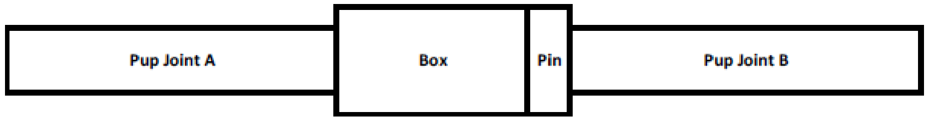
H.5.3.2 Form B.3 Weld-on Connection Substitution

Figure H.6~~Figure H.6~~ is a substitution for Figure B.3 to include the pertinent data on the second forging for most weld-on connections.

H.5.3.3 Form B.3 Upset Connection Substitution

Figure H.7~~Figure H.7~~ is a substitution for Figure B.3 to include the pertinent data for upset connections.

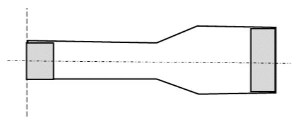
Size		**Grade (Pipe/Forging)**		**Project No.**		**Date**	
Weight		**Connection**		**Location**		**Technician**	
Specified Wall		**Specimen No.**		**UT Meter**		**Witness**	



1			**Pup Joint A**							**Box Forging**							**Pin Forging**							**Pup Joint B**						
2		Mother Tube No.																												
3		Coupon No.																												
4			**Spec. No.**	**Temp.**	**API AMYS**	**0.2% Off-set Yld.**	**0.5% Off-set Yld.**	**UTS**	**Young's Modulus**	**Spec. No.**	**Temp.**	**AMYS**	**0.2% Off-set Yld.**	**0.5% Off-set Yld.**	**UTS**	**Young's Modulus**	**Spec. No.**	**API AMYS**	**Temp.**	**0.2% Off-set Yld.**	**0.5% Off-set Yld.**	**UTS**	**Young's Modulus**	**Spec. No.**	**API AMYS**	**Temp.**	**0.2% Off-set Yld.**	**0.5% Off-set Yld.**	**UTS**	**Young's Modulus**
		Test Results																												
5	**Quadrant 1**	**Strip 1**																												
6		**Strip 2**																												
7		**Round 1**																												
8		**Round 2**																												
9	**Quadrant 2**	**Strip 1**																												
10		**Strip 2**																												
11		**Round 1**																												
12		**Round 2**																												
13	**Quadrant 3**	**Strip 1**																												
14		**Strip 2**																												
15		**Round 1**																												
16		**Round 2**																												
17	**Quadrant 4**	**Strip 1**																												
18		**Strip 2**																												
19		**Round 1**																												
20		**Round 2**																												

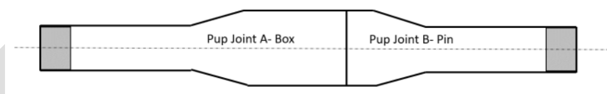
Figure H.6 – Substitute Material Property Datasheet for a Forged Connection

Size		Grade	
Weight		Connection	
Specified Wall		Specimen No.	



		Pipe sacrificial						Upset sacrificial				
Mother Tube No.												
Coupon No.												
		Spec. No.	Temp.	API AMYS	0.2% Off-set Yld.	UTS	Young's Modulus	Temp.	API AMYS	0.2% Off-set Yld.	UTS	Young's Modulus
Test Results												
Quadrant 1	Strip 1											
	Strip 2											
	Round 1											
	Round 2											
Quadrant 2	Strip 1											
	Strip 2											
	Round 1											
	Round 2											
Quadrant 3	Strip 1											
	Strip 2											
	Round 1											
	Round 2											
Quadrant 4	Strip 1											
	Strip 2											
	Round 1											
	Round 2											

Grade		Project #		Date	
Connection		Location		Technician	
Specimen No.		UT Meter		Witness	



		Pup Joint A						Pup Joint B					
Mother Tube No.													
Coupon No.													
		Spec. No.	Temp.	API AMYS	0.2% Off-set Yld.	UTS	Young's Modulus	Spec. No.	Temp.	API SMYS	0.2% Off-set Yld.	UTS	Young's Modulus
Test Results													
Quadrant 1	Strip 1												
	Strip 2												
	Round 1												
	Round 2												
Quadrant 2	Strip 1												
	Strip 2												
	Round 1												
	Round 2												
Quadrant 3	Strip 1												
	Strip 2												
	Round 1												
	Round 2												
Quadrant 4	Strip 1												
	Strip 2												
	Round 1												
	Round 2												

Figure H.7 – Substitute Material Property Datasheet for an Upset Connection

H.5.4 Addendum to Annex C

H.5.4.1 Executive Summary

The following information shall be included in the executive summary in addition to the required information from Annex C for weld-on connections: a table with the calculated assessment factors in accordance with H.3.

H.5.4.2 Connection Specifications

The following information shall be included in the executive summary in addition to the required information from Annex C: assessment factors table document number (Table H.1~~Table H.1~~, H.5.2.2).

H.5.4.3 Material Specification and Mechanical Properties

The following shall be included for the material specification and mechanical properties.

a. Forging stock specification and mechanical properties.

b. Surface hardness measurements of forging lots (weld-on connections only).

c. Specify the sacrificial and test specimen forgings along with the average and mean hardness results.

d. Sacrificial forging selection specification.

H.5.4.4 Material Geometry for the Pipe and coupling Stock (OD and Wall Thickness Measurements)

The OD measurement of the test specimen box connector shall be reported in the place of the test specimen coupling (see Figure B.5).

H.6 Practical Example

H.6.1 General

This section details the inputs for developing the test specimen pipe body reference curves, connection capacity envelope, CEE, and TLE for a generic, hypothetical weld-on connection and upset connection as examples to the user of this standard.

H.6.2 Weld On Example

H.6.2.1 General

For the weld-on example, a 22 in. x 1.250 in. X80 DSAW UOE pipe welded to a 90ksi SMYS connection will be used for a test at ambient temperature. Standard API collapse equations in API 5C3 (for *External Pressure Resistance*) are used in this example, however other standards governing the pipe performance ~~can~~may ~~-~~be used such as RP1111. The sacrificial forging method is used for material characterization. In the case of using prolongations, the material characterization would more closely follow the example shown in Annex D with tensile tests specific to each forging.

As welds are performed, assessed, and qualified according to other different international standards (ASME, AWS, etc.), if agreed between manufacturer and testing facility, an assessment of girth welds should take place to ensure test safety and to prevent the weld from compromising the test.

H.6.2.2 Forged Connection Sacrificial Forging Selection

This section gives an example of how to select the proper sacrificial forging to characterize the material strength of the test specimens.

A lot of nine box forgings are heat treated in a batch process. After heat treatment, three hardness measurements are made on the OD of each forging 120˚ apart. The results are shown in Table H.2~~Table~~

~~H.2~~.

Table H.2 – Average OD Hardness

Forging ID	Hardness 1	Hardness 2	Hardness 3	Average	Median	Delta
1	269	277	269	271.7	262.0	9.7
2	262	255	269	262.0		0.0
3	269	262	255	262.0		0.0
4	255	262	262	259.7		-2.3
5	277	269	269	271.7		9.7
6	290	277	277	281.3		19.3
7	255	262	262	259.7		-2.3
8	255	255	255	255.0		-7.0
9	269	269	255	264.3		2.3

The average OD hardness value is determined for each forging as well as the median hardness of the averages. Finally, the difference between each average hardness and the median value is calculated.

Forging 3 is selected as the sacrificial forging for mechanical property testing since its average hardness is the closest in value to the median value. Forging 2 is the most suitable for connection testing, followed by Forgings 4, 7 and 9. The same process is used to select the sacrificial forging for the pin forgings.

H.6.2.3 Test Specimen Pipe Body Reference Curves

The pipe body reference curves at ambient temperature are calculated in accordance with D.2 using the input parameters shown in Table H.3~~Table H.3~~. The resulting pipe reference curves are shown in Figure H.8~~Figure H.8~~.

Table H.3 – Parameters used to Calculate Pipe Reference Curves at Ambient Temperature

Specified OD	Specified Wall	SYMS	D_{avg}	~~T_{min}~~ t_{min}	~~T_{avg}~~ t_{avg}	AMYS
22 in.	1.25 in.	80,500 psi	22.046 in.	1.213 in.	1.246 in.	85,000 psi

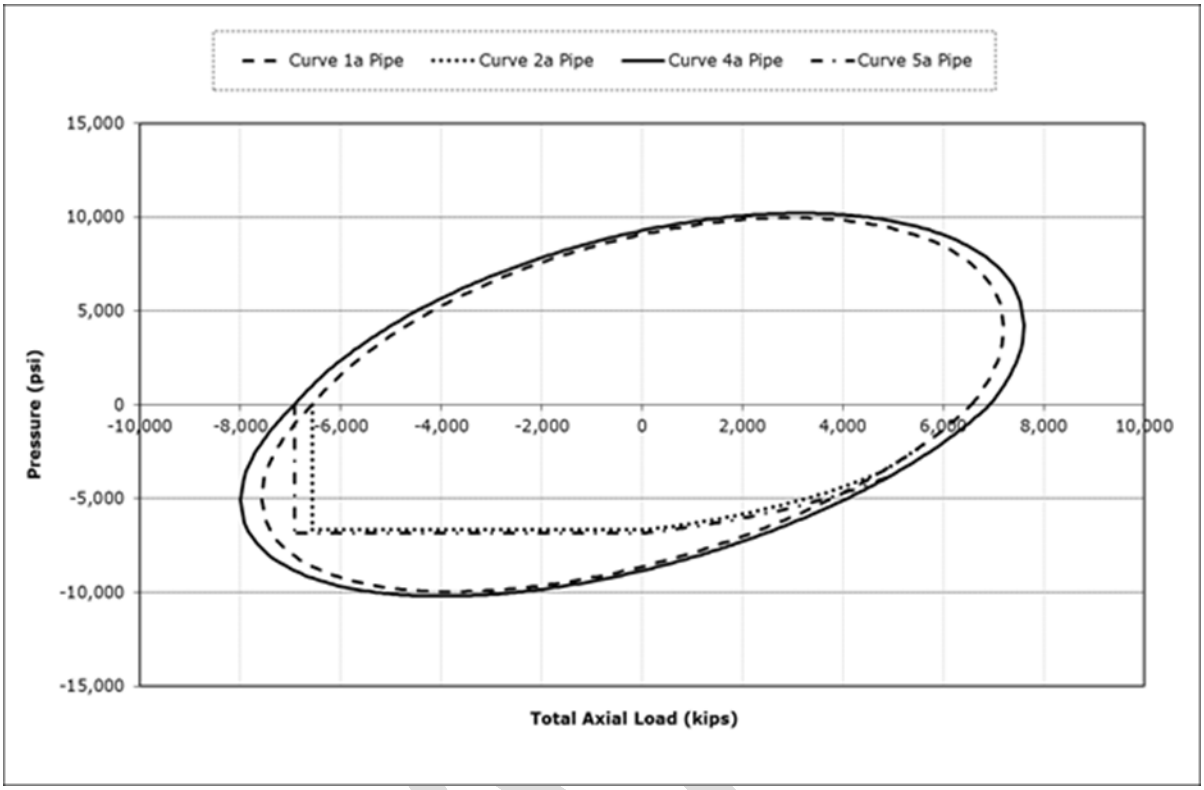


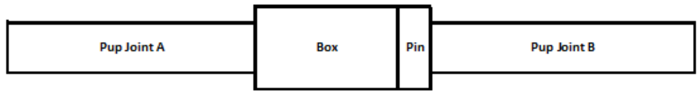
Figure H.8 – Test Specimen Pipe Body Actual and Nominal VME and API Collapse Curves at Ambient Temperature

H.6.2.4 Test Specimen Connector Connection Capacity Envelope

The connection capacity envelopes at ambient temperature, as seen in Figure H.10~~Figure H.10~~, are generated based on the input parameters shown in Table H.4~~Table H.4~~. AMYS is obtained as the minimum of the actual pin and box yield strengths from sacrificial forgings according to the selection process explained in H.2.2.1 and H.6.2.2. Figure H.9~~Figure H.9~~ shows the material test results for test specimen 1 with the governing parameters made bold for both the forgings and the pipe. The superposition of the pipe body reference curves and connection capacity envelopes is shown in Figure H.11~~Figure H.11~~.

Table H.4 – Parameters used to Calculate Connection Capacity Envelopes at Ambient Temperature

Specified OD	Specified Wall	SYMS	AMYS
22 in.	1.25 in	90,000 psi	100,000 psi



1			Pup Joint A							Box Forging							Pin Forging							Pup Joint B						
2		Mother Tube No.	Pipe Numer P1A012-3							Heat # ABC01234567							Heat # ABC01234568							Pipe Number P1A012-4						
3		Coupon No.	MT2							Forging ID #3							Forging ID # 7							MT4						
4			Spec. No.	Temp.	API SMYS	0.2% Off-set Yld.	0.5% Off-set Yld.	UTS	Young's Modulus	Spec. No.	Temp.	API SMYS	0.2% Off-set Yld.	0.5% Off-set Yld.	UTS	Young's Modulus	Spec. No.	API SMYS	Temp.	0.2% Off-set Yld.	0.5% Off-set Yld.	UTS	Young's Modulus	Spec. No.	API SMYS	Temp.	0.2% Off-set Yld.	0.5% Off-set Yld.	UTS	Young's Modulus
		Test Results																												
5	Quadrant 1	Strip 1																												
6		Strip 2																												
7		Round 1	5L	68°F	80.5	85.5	**85.0**	94.0	30.2	N/A	68°F	90.0	**100.0**	101.0	115.0	29.8	N/A	68°F	90.0	108.9	108.3	118.3	30.4	5L	68°F	80.5	86.0	86.2	93.9	30.1
8		Round 2																												
9	Quadrant 2	Strip 1																												
10		Strip 2																												
11		Round 1	5L	68°F	80.5	85.3	85.1	95.0	29.5	N/A	68°F	90.0	101.0	102.0	116.0	29.7	N/A	68°F	90.0	107.8	107.2	117.1	30.1	5L	68°F	80.5	85.0	85.2	91.4	30.4
12		Round 2																												
13	Quadrant 3	Strip 1																												
14		Strip 2																												
15		Round 1	5L	68°F	80.5	85.5	85.3	95.1	30.1	N/A	68°F	90.0	100.5	101.5	114.0	29.9	N/A	68°F	90.0	108.2	107.6	117.8	30.1	5L	68°F	80.5	85.3	85.6	91.6	31.0
16		Round 2																												
17	Quadrant 4	Strip 1																												
18		Strip 2																												
19		Round 1	5L	68°F	80.5	85.7	85.4	96.0	30.4	N/A	68°F	90.0	102.0	102.9	118.0	29.8	N/A	68°F	90.0	109.0	108.3	118.1	30.0	5L	68°F	80.5	86.1	86.3	93.3	30.8
20		Round 2																												

Figure H.9 – Example Material Test results for Specimen 1

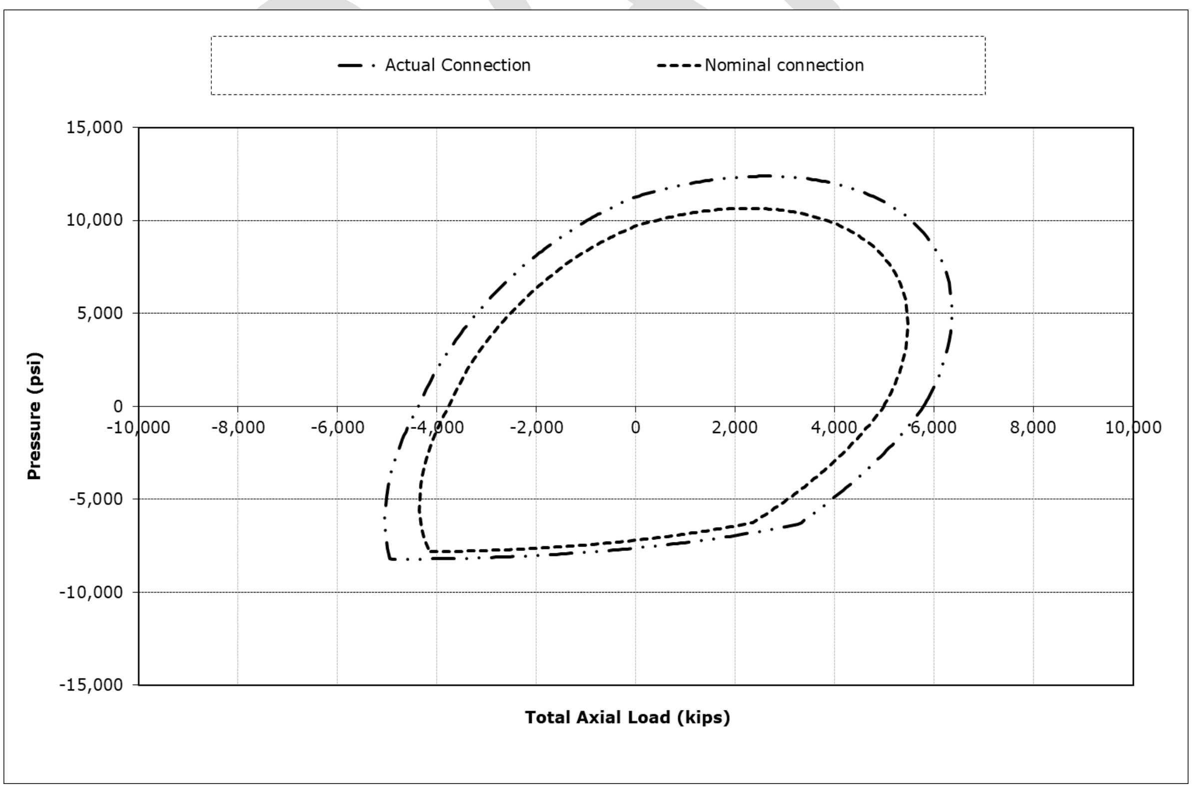


Figure H.10 – Test Specimen Connection Actual and Nominal Capacity Envelopes at Ambient

Temperature

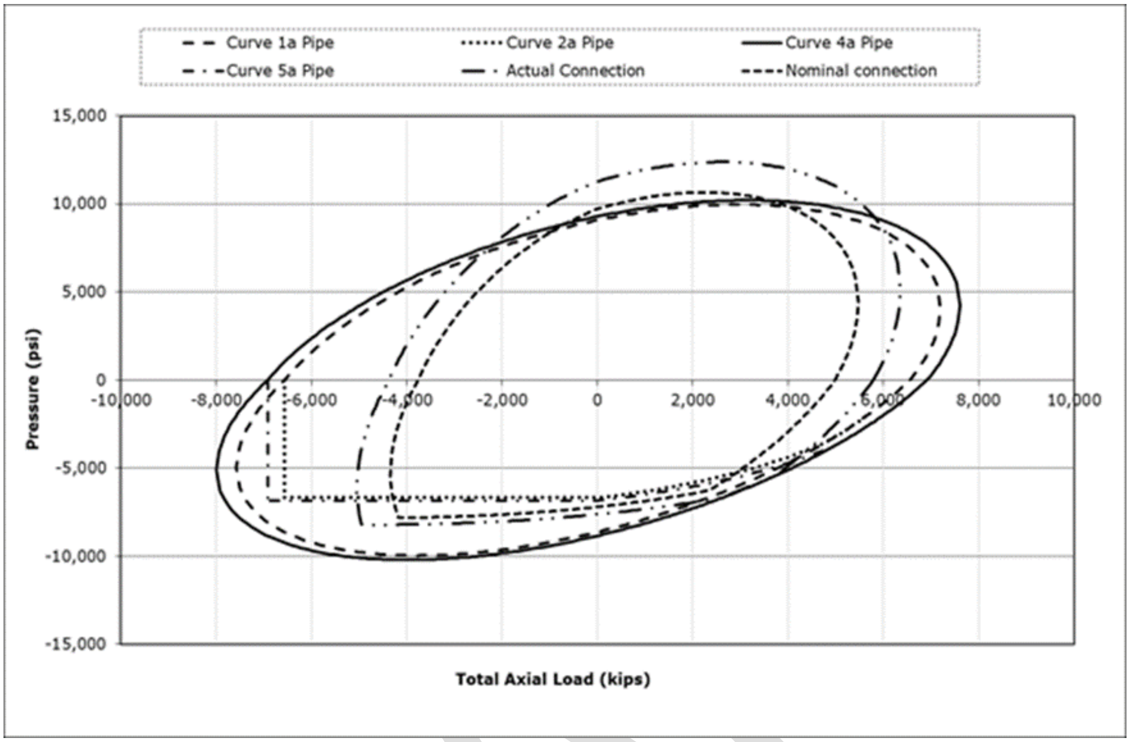


Figure H.11 – Test Specimen Pipe Body Reference Curves and Connection Actual and Nominal Capacity Envelopes at Ambient Temperature

H.6.2.5 CEE and TLE at Ambient

The resulting CEE[a] and TLE[a] curves at ambient temperature with the actual pipe body reference curve and actual connection capacity envelope are shown in Figure H.12~~Figure H.12~~. The CEE[a] and TLE[a] load points along with the limiting factor as required in 7.3.1.3 are given in Table H.5~~Table H.5~~.

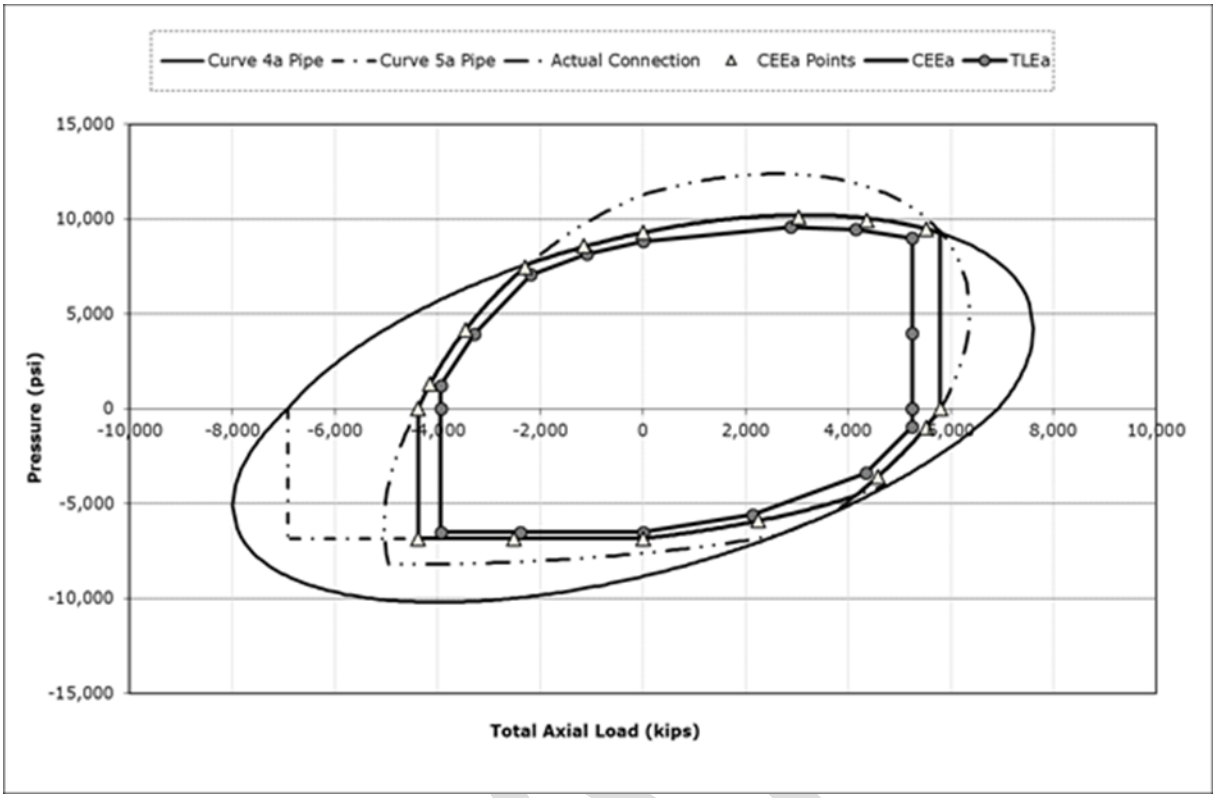


Figure H.12 – Test Specimen CEE[a] and TLE[a] Curves at Ambient Temperature

Table H.5 – 95 % CEE[a] Points and TLE[a] Load Points at Ambient Temperature

Load Point	Connection Evaluation Envelope (CCE)		Test Load Envelope (TLE)		Limiting factor	
	Axial Load (kips) Fa	Pressure Load (psi) pi or po	Axial Load (kips) Fa	Pressure Load (psi) pi or po	Axial	Pressure
10a95	5794	0	5247	0	Connection-material	N/A
11a95	N/A	N/A	5247	1988	Connection-material	Pipe body
12a95	N/A	N/A	5247	3975	Connection-material	Pipe body
13a95	5523	9452	5247	8980	Connection-material	Pipe body
14a95	4364	9936	4146	9440	Connection-material	Pipe body
15a95	3024	10069	2873	9566	Pipe body	Pipe body
16a95	0	9282	0	8818	N/A	Pipe body
17a95	-1152	8576	-1094	8147	Connection-material	Pipe body
18a95	-2303	7441	-2188	7069	Connection-material	Pipe body
19a95	-3455	4158	-3282	3950	Connection-material	Connection-material
20a95	-4145	1288	-3938	1224	Connection-material	Connection-material
21a95	-4376	0	-3938	0	Connection-material	Pipe body
22a95	-4376	-6845	-3938	-6503	Connection-material	Pipe body
23a95	-2513	-6845	-2388	-6503	Connection-material	Pipe body
24a95	0	-6845	0	-6503	N/A	Pipe body
25a95	2250	-5894	2138	-5599	Connection-material	Pipe body
26a95	4569	-3579	4340	-3400	Connection-material	Connection-material
27a95	5523	-1000	5247	-950	Connection-material	Connection-material

Because the weld-on connection is made from a different material than pipe body, the connection efficiency is not consistent across pipe wall thicknesses. Connection minimum performance is defined by the manufacturer and shall take into account the minimum specified yield strength of the forging(s), the specified pipe OD, and the specified pipe wall. The minimum pipe performance is based on SMYS, specified OD, specified wall, and minimum wall as defined by the applicable specification (e.g. API 5L). Table H.6~~Table H.6~~ provides an example report-out format like the connection datasheet as required in A.1.5.

Table H.6 – Example Connection Minimums Report-out with Efficiencies

Rating	Uni-axial Tension	Uni-axial Compression	Uni-axial Internal Pressure	Uni-axial External Pressure
CEE point	10a90	21a90	6a80, 16a90, 16a95	24a90, 24a95
Minimum Pipe	6560 kips	-6560 kips	8794 psi	-6692 psi
Minimum Connection	5248 kips	-3963 kips	10,211 psi	-7198 psi
Efficiency	80 %	60 %	112 %	107 %

The actual connection performance is impacted by actual connector dimensions and material strengths while actual pipe performance is impacted by actual pipe dimensions and material strengths. The actual connection and pipe ratings with efficiencies are given in terms of uniaxial loading in Table H.7. Since no direct relation exists between the connection capacities and the pipe capacities, the actual capacities are used to provide an assessment factor for each uniaxial load of the connection capacity envelope using the equations in H.4.

Table H.7 – Example Connection Actuals Report-out with Efficiencies

Rating	Uni-axial Tension	Uni-axial Compression	Uni-axial Internal Pressure	Uni-axial External Pressure
CEE point	10a90	21a90	6a80, 16a90, 16a95	24a90, 24a95
Actual pipe	6921 kips	-6921 kips	9282 psi	-6503 psi
Actual connector	5794 kips	-4376 kips	11,271 psi	-7620 psi
Actual efficiency	84 %	63 %	121 %	111 %
Assessment Factor	100 %	10 0%	82.4 %	85.3 %

H.6.3 Upset Connection

H.6.3.1 Upset Connection

The material characterization is performed with a sacrificial sample taken from the same lot as described in H.2.2.2. The governing parameters, as seen in **Equation** ~~#,~~ **H.1**, are given for the sacrificial box in Table H.8~~Table H.8~~. The same process may be performed for the pin side if the pin and box sides are not upset to the same geometry or via the same hot working. For this example, the box and pin are both characterized through the same single sacrificial upset.

Table H.8 – Governing Sacrificial Upset Material Results for Box and Pin

Sacrificial Upset Actual Average	Sacrificial Pipe Actual Average	Test Pipe Minimum Actual	Sacrificial Ratio	Test Upset Actual
126,~~9~~892 psi	125,603 psi	125,570 psi	101.027 %	126,860 psi

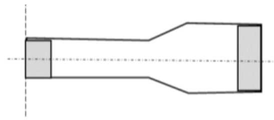
H.6.3.2 Test Specimen Pipe Body Reference Curves

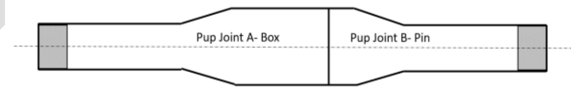
The pipe body reference curves at ambient temperature are calculated based on the input parameters shown in Table H.9~~Table H.9~~. The resulting reference curves are shown in Figure H.14~~Figure H.14~~. The minimum of the pin and box test pipe actual yield strengths are shown as bold in Figure H.13~~Figure H.13~~.

Table H.9 – Parameters for Pipe Reference Curves at Ambient Temperature

Specified OD	Specified Wall	SYMS	D_{avg}	T_{min}	T_{avg}	AMYS
7 5/8 in.	0.5 in.	125,000 psi	7.654 in.	0.507 in.	0.523 in.	125,570 psi

Size	7 5/8	**Grade**	Q125	**Project #**	P123456	**Date**	26-October-2022
Weight	39.00#	**Connection**	Custom connection	**Location**	100 Connection Lane, Connector Ville,MO	**Technician**	J.Doe
Specified Wall	0,500	**Specimen No.**	1	**UT Meter**	59620	**Witness**	S.Wisp

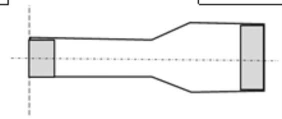


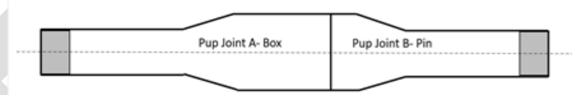


		Pipe sacrificial						**Upset sacrificial**				
Mother Tube No.		Pipe P0123456										
Coupon No.		MT1						UP #2				
		Spec. No.	**Temp.**	**API AMYS**	**0.2% Off-set Yld.**	**UTS**	**Young's Modulus**	**Temp.**	**API AMYS**	**0.2% Off-set Yld.**	**UTS**	**Young's Modulus**
Test Results												
Quadrant 1	**Strip 1**											
	Strip 2											
	Round 1	ASTM 370	68°F	125 603	126 312	142 500	30,5	68°F	126 932	126 950	141 610	30,1
	Round 2											
Quadrant 2	**Strip 1**											
	Strip 2											
	Round 1	ASTM 370	68°F	125 103	125 905	143 220	30,2	68°F	126 432	127 550	142 120	29,9
	Round 2											
Quadrant 3	**Strip 1**											
	Strip 2											
	Round 1	ASTM 370	68°F	126 203	126 420	141 940	30,3	68°F	127 532	127 605	142 600	30,2
	Round 2											
Quadrant 4	**Strip 1**											
	Strip 2											
	Round 1	ASTM 370	68°F	125 503	125 645	140 980	30,1	68°F	126 672	126 960	142 850	30,3
	Round 2											

		Pup Joint A						**Pup Joint B**					
Mother Tube No.		Pipe 543210						Pipe 654321					
Coupon No.		MT2						MT4					
		Spec. No.	**Temp.**	**API AMYS**	**0.2% Off-set Yld.**	**UTS**	**Young's Modulus**	**Spec. No.**	**Temp.**	**API AMYS**	**0.2% Off-set Yld.**	**UTS**	**Young's Modulus**
Test Results													
Quadrant 1	**Strip 1**												
	Strip 2												
	Round 1	ASTM 370	68°F	**125 570**	125 750	140 720	29,9	ASTM 370	68°F	125 720	125 860	140 100	30,1
	Round 2												
Quadrant 2	**Strip 1**												
	Strip 2												
	Round 1	ASTM 370	68°F	126 180	126 330	140 920	30,1	ASTM 370	68°F	125 501	125 750	140 300	29,9
	Round 2												
Quadrant 3	**Strip 1**												
	Strip 2												
	Round 1	ASTM 370	68°F	125 760	125 690	140 410	30,2	ASTM 370	68°F	126 103	126 210	141 320	30,1
	Round 2												
Quadrant 4	**Strip 1**												
	Strip 2												
	Round 1	ASTM 370	68°F	125 980	125 410	141 230	30,1	ASTM 370	68°F	125 603	125 700	141 110	30,2
	Round 2												

Size	7 5/8	**Grade**	Q125	**Project #**	P123456	**Date**	26-October-2022
Weight	39.00#	**Connection**	Custom connection	**Location**	100 Connection Lane, Connector Ville,MO	**Technician**	J.Doe
Specified Wall	0,500	**Specimen No.**	1	**UT Meter**	59620	**Witness**	S.Wisp

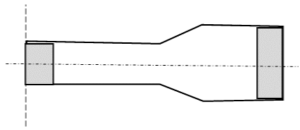


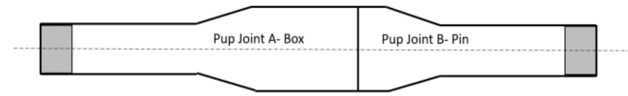


		Pipe sacrificial						**Upset sacrificial**				
Mother Tube No.		Pipe P0123456										
Coupon No.		MT1						UP #2				
		Spec. No.	**Temp.**	**API AMYS**	**0.2% Off-set Yld.**	**UTS**	**Young's Modulus**	**Temp.**	**API AMYS**	**0.2% Off-set Yld.**	**UTS**	**Young's Modulus**
Test Results												
Quadrant 1	**Strip 1**											
	Strip 2											
	Round 1	ASTM370	68°F	125 603	126 312	142 500	30,5	68°F	126932	126950	141 610	30,1
	Round 2											
Quadrant 2	**Strip 1**											
	Strip 2											
	Round 1	ASTM370	68°F	125 103	125 905	143 220	30,2	68°F	126432	127 550	142 120	29,9
	Round 2											
Quadrant 3	**Strip 1**											
	Strip 2											
	Round 1	ASTM370	68°F	126 203	126 420	141 940	30,3	68°F	127 532	127 605	142 600	30,2
	Round 2											
Quadrant 4	**Strip 1**											
	Strip 2											
	Round 1	ASTM370	68°F	125 503	125 645	140 980	30,1	68°F	126832	126960	142 850	30,3
	Round 2											

		Pup Joint A						**Pup Joint B**					
Mother Tube No.		Pipe 543210						Pipe 654321					
Coupon No.		MT2						MT4					
		Spec. No.	**Temp.**	**API AMYS**	**0.2% Off-set Yld.**	**UTS**	**Young's Modulus**	**Spec. No.**	**Temp.**	**API AMYS**	**0.2% Off-set Yld.**	**UTS**	**Young's Modulus**
Test Results													
Quadrant 1	**Strip 1**												
	Strip 2												
	Round 1	ASTM370	68°F	**125 570**	125 750	140 720	29,9	ASTM 370	68°F	125 720	125 860	140 100	30,1
	Round 2												
Quadrant 2	**Strip 1**												
	Strip 2												
	Round 1	ASTM370	68°F	126 170	126330	140 920	30,1	ASTM 370	68°F	125 501	125 750	140 300	29,9
	Round 2												
Quadrant 3	**Strip 1**												
	Strip 2												
	Round 1	ASTM370	68°F	125 370	125 690	140 410	30,2	ASTM 370	68°F	126 103	126 210	141 320	30,1
	Round 2												
Quadrant 4	**Strip 1**												
	Strip 2												
	Round 1	ASTM370	68°F	125 170	125 410	141 230	30,1	ASTM 370	68°F	125 603	125 700	141 110	30,2
	Round 2												

Size	7 5/8	**Grade**	Q125	**Project #**	P123456	**Date**	26-October-2022
Weight	39.00#	**Connection**	Custom connection	**Location**	100 Connection Lane, Connector Ville,MO	**Technician**	J.Doe
Specified Wall	0.500	**Specimen No.**	1	**UT Meter**	59620	**Witness**	S.Wisp





		Pipe sacrificial						Upset sacrificial				
Mother Tube No.		Pipe P0123456										
Coupon No.		MT1						UP #2				
		Spec. No.	**Temp.**	**API AMYS**	**0.2% Off-set Yld.**	**UTS**	**Young's Modulus**	**Temp.**	**API AMYS**	**0.2% Off-set Yld.**	**UTS**	**Young's Modulus**
Test Results												
Quadrant 1	**Strip 1**											
	Strip 2											
	Round 1	ASTM 370	68°F	125,603	126,312	142,500	30.5	68°F	126,932	126,950	141,610	30.1
	Round 2											
Quadrant 2	**Strip 1**											
	Strip 2											
	Round 1	ASTM 370	68°F	125,103	125,905	143,220	30.2	68°F	126,432	127,550	142,120	29.9
	Round 2											
Quadrant 3	**Strip 1**											
	Strip 2											
	Round 1	ASTM 370	68°F	126,203	126,420	141,940	30.3	68°F	127,532	127,605	142,600	30.2
	Round 2											
Quadrant 4	**Strip 1**											
	Strip 2											
	Round 1	ASTM 370	68°F	125,503	125,645	140,980	30.1	68°F	126,832	126,960	142,850	30.3
	Round 2											

		Pup Joint A						Pup Joint B					
Mother Tube No.		Pipe 543210						Pipe 654321					
Coupon No.		MT2						MT4					
		Spec. No.	**Temp.**	**API AMYS**	**0.2% Off-set Yld.**	**UTS**	**Young's Modulus**	**Spec. No.**	**Temp.**	**API AMYS**	**0.2% Off-set Yld.**	**UTS**	**Young's Modulus**
Test Results													
Quadrant 1	**Strip 1**												
	Strip 2												
	Round 1	ASTM 370	68°F	125,570	125,750	140,720	29.9	ASTM 370	68°F	125,720	125,860	140,100	30.1
	Round 2												
Quadrant 2	**Strip 1**												
	Strip 2												
	Round 1	ASTM 370	68°F	126,170	126,330	140,920	30.1	ASTM 370	68°F	125,501	125,750	140,300	29.9
	Round 2												
Quadrant 3	**Strip 1**												
	Strip 2												
	Round 1	ASTM 370	68°F	125,370	125,690	140,410	30.2	ASTM 370	68°F	126,103	126,210	141,320	30.1
	Round 2												
Quadrant 4	**Strip 1**												
	Strip 2												
	Round 1	ASTM 370	68°F	125,170	125,410	141,230	30.1	ASTM 370	68°F	125,603	125,700	141,110	30.2
	Round 2												

Figure H.13 – Example Material Test Results for Specimen 1 and Sacrificial Coupons

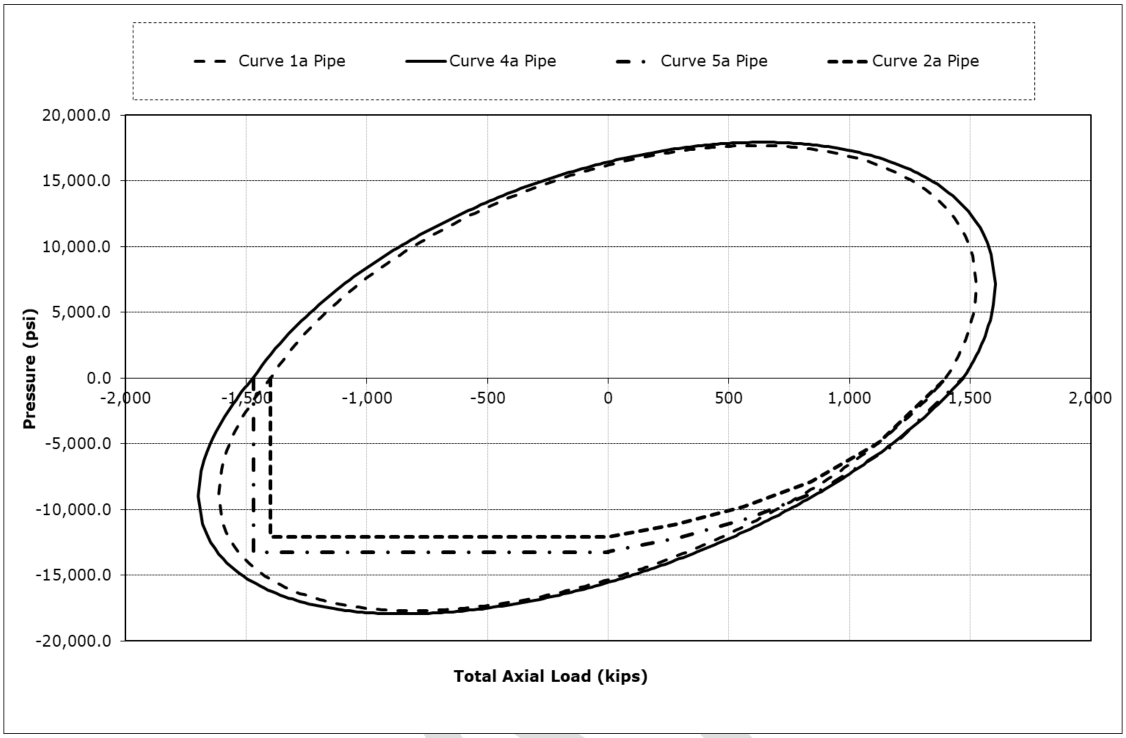


Figure H.14 – Test Specimen Pipe Body Actual and Nominal VME and API Collapse Curves at Ambient Temperature

H.6.3.3 Test Specimen Connector Body Reference Curves

The upset connection capacity envelopes at ambient temperature are generated based on the input parameters shown in Table H.10~~Table H.10~~. The resulting connection capacity envelopes are shown in Figure H.15~~Figure H.15~~. The superposition of the pipe body reference curves and connection capacity envelopes is shown in Figure H.16~~Figure H.16~~. The connection external pressure capacity exceeds the pipe, so it is not shown for ease of viewing.

Table H.10 – Parameters for Connector Capacity Envelope at Ambient Temperature

Specified OD	Specified ID	Actual OD	Actual ID	SYMS	AMYS
8.14 in.	6.55 in.	8.144 in.	6.55 in.	125,000 psi	126,860 psi

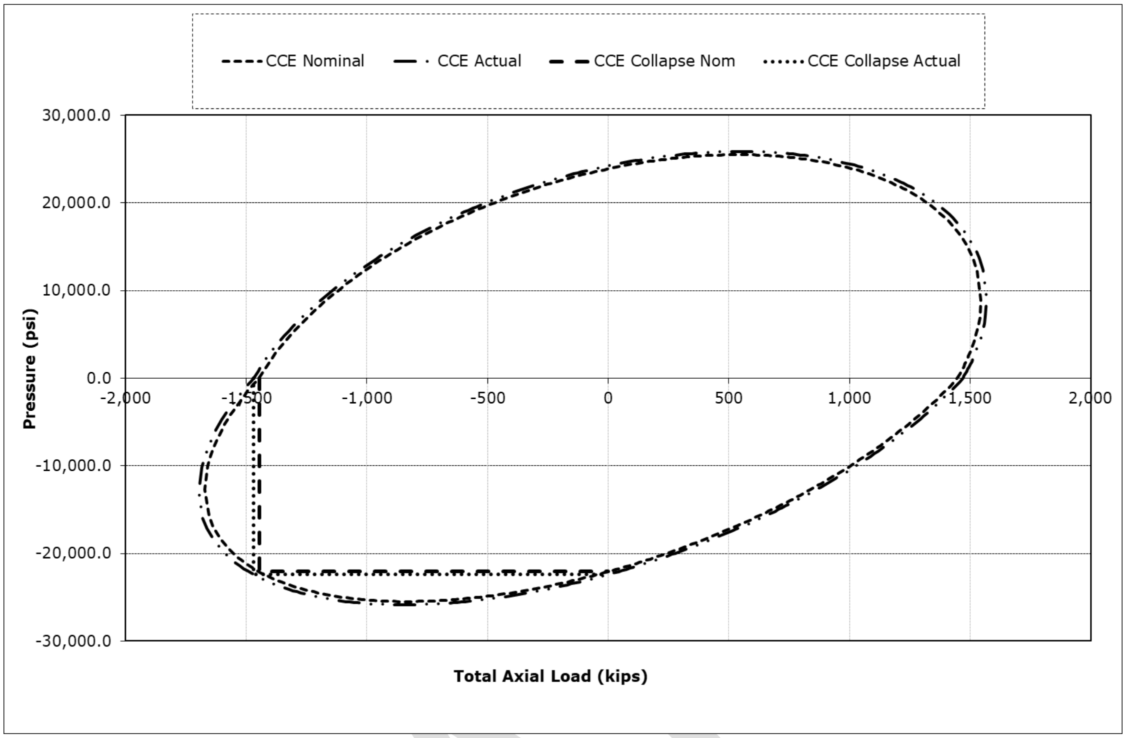


Figure H.15 – Test Specimen Actual and Nominal Connection Capacity Envelopes at Ambient Temperature

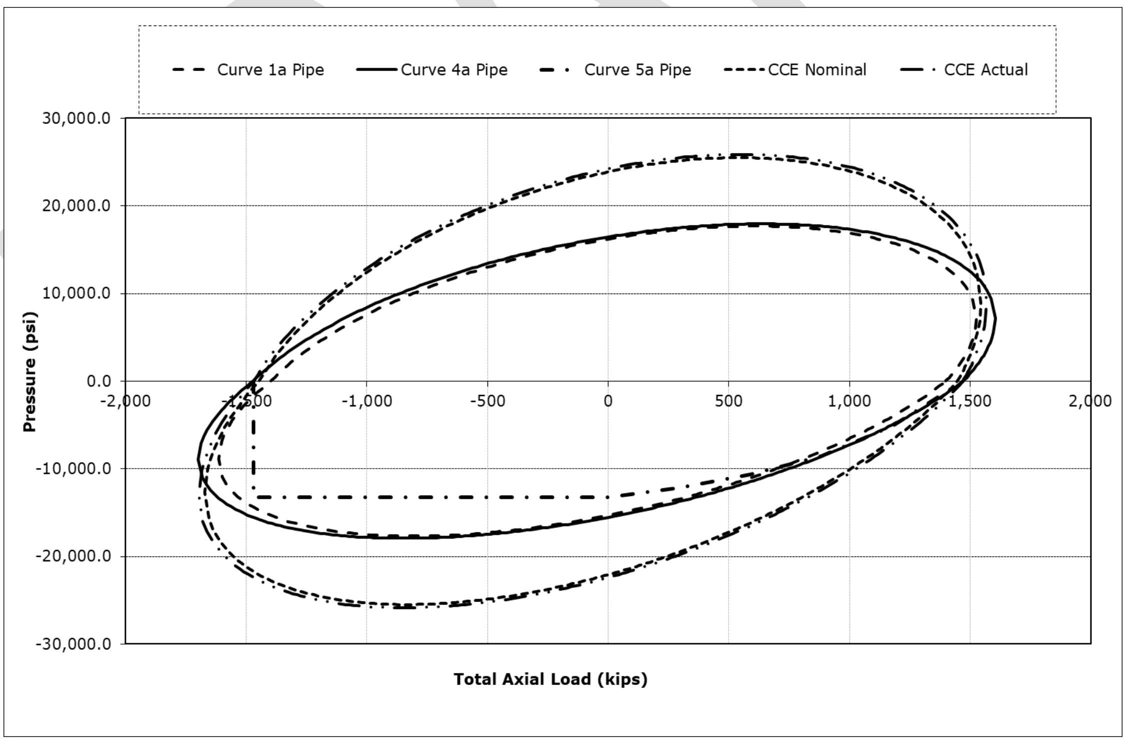


Figure H.16 – Test Specimen Pipe Body Reference Curves with Connection Capacity Envelopes at Ambient Temperature

H.6.3.4 CEE and TLE at Ambient

The resulting CEE[a] and TLE[a] curves at ambient temperature with the actual pipe body reference curve and actual connection capacity envelope are shown in Figure H.17~~Figure H.17~~. The CEE[a] and TLE[a] load points along with the limiting factor as required in 7.3.1.3 are given in

Table *H.11*

~~Table H.~~*11*. The TLE load points were based on Curve 5a with a derating factor of 95 %.

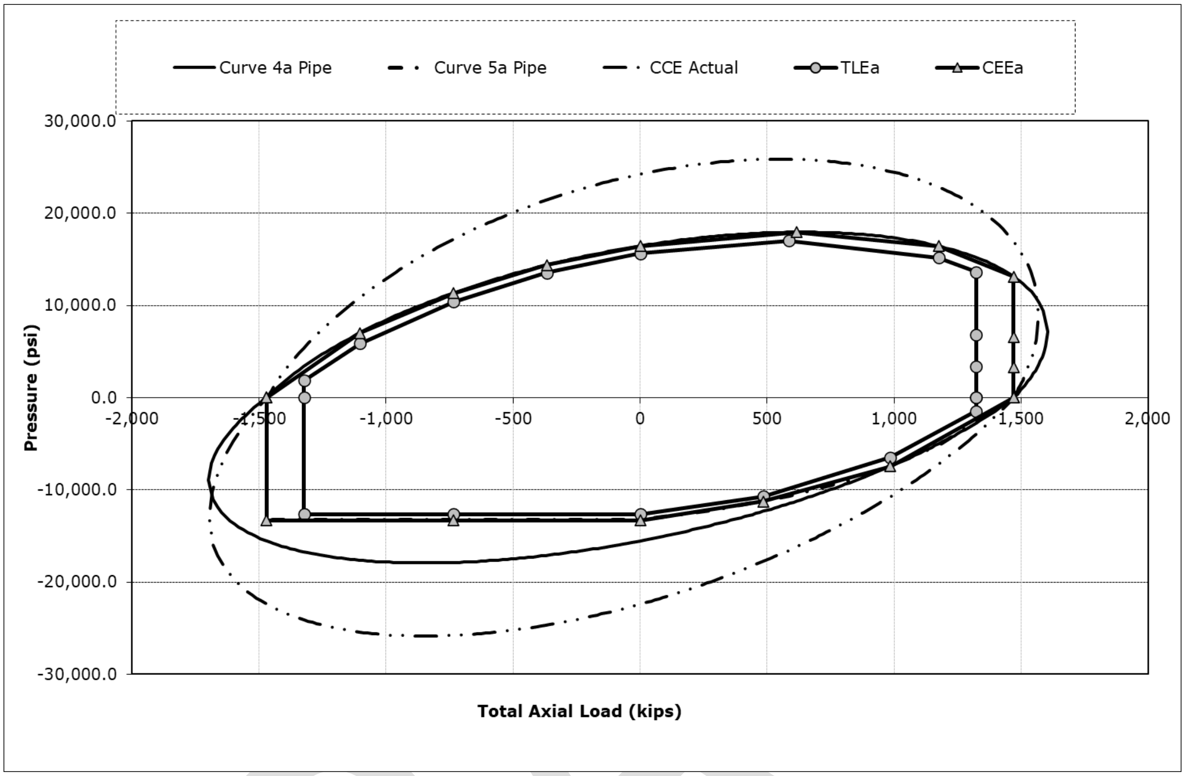


Figure H.17 – Test Specimen CEE[a] and TLE[a] Curves at Ambient Temperature

Table H.11 – 95% CEE[a] Points and TLE[a] Load Points at Ambient Temperature

Load Point	Connection Capacity Envelope (CCE)		Test Load Envelope (TLE)		Limiting factor	
	Axial Load (kips) Fa	Pressure Load (psi) pi or po	Axial Load (kips) Fa	Pressure Load (psi) pi or po	Axial	Pressure
10a95	1,323	0	1,323	0	Connection	N/A
11a95	1,323	4,559	1,323	3,409	Connection	Pipe
12a95	1,323	9,119	1,323	6,818	Connection	Pipe
13a95	1,323	18,237	1,323	13,636	Connection	Pipe
14a95	1,176	20,928	1,176	15,172	Connection	Pipe
15a95	809	24,001	584	17,037	Pipe	Pipe
16a95	0	23,019	0	15,628	N/A	Pipe
17a95	-368	20,189	-368	13,527	Connection	Pipe
18a95	-735	15,788	-735	10,409	Connection	Pipe
19a95	-1,103	9,135	-1,103	5,862	Connection	Pipe
20a95	-1,323	2,978	-1,323	1,836	Connection	Pipe
21a95	-1,323	0	-1,323	0	Connection	N/A
22a95	-1,323	-22,246	-1,323	-12,654	Connection	Pipe
23a95	-735	-22,400	-735	-12,654	Connection	Pipe
24a95	0	-21,280	0	-12,654	N/A	Pipe
25a95	485	-16,598	485	-10,713	Connection	Pipe
26a95	985	-9,346	985	-6,481	Connection	Pipe
27a95	1,323	-2,086	1,323	-1,447	Connection	Pipe

Loading Point	Connection Capacity Envelope (CCE)		Test Load Envelope (TLE)		Limiting factor	
	Axial Load (kips) Fa	Pressure Load (psi) pi or po	Axial Load (kips) Fa	Pressure Load (psi) pi or po	Axial	Pressure
10a95	1,323	0	1,323	0	Connection-material	N/A
11a95	1,323	4,559	1,323	3,409	Connection-material	Pipe-body
12a95	1,323	9,119	1,323	6,818	Connection-material	Pipe-body
13a95	1,323	18,237	1,323	13,636	Connection-material	Pipe-body
14a95	1,176	20,928	1,176	15,172	Connection-material	Pipe-body
15a95	809	24,001	584	17,037	Pipe-body	Pipe-body
16a95	0	23,019	0	15,628	N/A	Pipe-body
17a95	-368	20,189	-368	13,527	Connection-material	Pipe-body
18a95	-735	15,788	-735	10,409	Connection-material	Pipe-body
19a95	-1,103	9,135	-1,103	5,862	Connection-material	Pipe-body
20a95	-1,323	2,978	-1,323	1,836	Connection-material	Pipe-body
21a95	-1,323	0	-1,323	0	Connection-material	N/A
22a95	-1,323	-22,246	-1,323	-12,654	Connection-material	Pipe-body
23a95	-735	-22,400	-735	-12,654	Connection-material	Pipe-body
24a95	0	-21,280	0	-12,654	N/A	Pipe-body
25a95	485	-16,598	485	-10,713	Connection-material	Pipe-body
26a95	985	-9,346	985	-6,481	Connection-material	Pipe-body
27a95	1,323	-2,086	1,323	-1,447	Connection-material	Pipe-body

Bibliography

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API Recommended Practice 5C6, *Pipe with Welded Connectors*