Engineering Standard

SAES-L-131 31 August 2005

Fracture Control of Line Pipe

Table of Contents

Previous Issue: 28 January 2004 Next Planned Update: 1 September 2009
Revised paragraphs are indicated in the right margin

Primary contact: Abdullah M. Al-Rumaih on 873-4398

1 Scope

This standard covers line pipe supplementary fracture toughness requirements to control crack propagation at temperatures above 0°C in carbon steel pipe used for off-plot transportation piping, such as cross-country pipelines, flowlines, trunklines, and testlines, as defined in SAES-L-l00. The requirements apply to line pipe with wall thicknesses of 6.35 mm to 38.1 mm (0.25 to 1.5 inch), 6-inch or larger NPS, in accordance with API SPEC 5L 01-SAMSS-035, 01-SAMSS-332, and 01-SAMSS-333.

2 Conflicts and Deviations

2.1 Any conflicts between this standard and other applicable Saudi Aramco Engineering Standards (SAESs), Materials System Specifications (SAMSSs), Standard Drawings (SASDs), or industry standards, codes, and forms shall be resolved in writing by the Company or Buyer Representative through the Manager, Consulting Services Department (CSD) of Saudi Aramco, Dhahran.

2.2 Direct all requests to deviate from this standard in writing to the Company or Buyer Representative, who shall follow internal company procedure SAEP-302 and forward such requests to the Manager, Consulting Services Department of Saudi Aramco, Dhahran.

3 References

The selection of material and equipment, and the design, construction, maintenance, and repair of equipment and facilities covered by this standard shall comply with the latest edition of the references listed below, unless otherwise noted or modified by specific provisions of this standard.

3.1 Saudi Aramco References

Saudi Aramco Engineering Procedure

SAEP-302	*Instructions for Obtaining a Waiver of a Mandatory Saudi Aramco Engineering Requirement*

Saudi Aramco Engineering Standard

SAES-L-100	*Applicable Codes and Standards for Pressure Piping Systems*

Saudi Aramco Materials System Specifications

01-SAMSS-022	*Fracture Control Testing Procedures for Line Pipe*

01-SAMSS-035	*API Line Pipe*
01-SAMSS-332	*High Frequency Welded Line Pipe, Class B*
01-SAMSS-333	*High Frequency Welded Line Pipe, Class C*

3.2 Industry Codes and Standards

American Petroleum Institute

API SPEC 5L-SR5	*Specification for Line Pipe-Fracture Toughness Testing (Charpy V-Notch) for Outside Diameter 4.5 Inches or Larger*

4 Classification of Line Pipe

Line pipe, within the scope of this standard, is herein classified according to the fracture toughness acceptance criteria required for different types of fluid service.

4.1 **Class I Line Pipe**: This class is for liquid lines with maximum vapor pressure up to 690 kPa (100 psia).

4.2 **Class IV Line Pipe**: This class is for gas, two-phase flow, and liquid lines such as NGL, whose vapor pressure may exceed 690 kPa (100 psia). This category also incorporates the former Class II and Class III.

Commentary Note:

Class III was originally for buried gas pipelines and Class II has been used for liquids such as NGL, whose vapor pressure may exceed 100 psia. The former classes II, III, and IV are now all in Class IV.

5 Testing Requirements

5.1 Class I pipe shall be tested per 01-SAMSS-022 (parent metal Charpy V-notch test) and shall meet the requirements of API SPEC 5L-SR5A (shear area).

5.2 Class IV pipe shall be tested per 01-SAMSS-022 (parent metal, heat-affected zone, and weld metal Charpy V-notch tests). The API SPEC 5L-SR5B absorbed energy values (based on transverse specimens), from tests at 0°C, shall meet or exceed the values determined below. In no case may the required energy value be less than 20 ft-lb (27 J). The energy values calculated below are considered to be the average energy of three specimens.

5.2.1 For lean natural gas (> 90% Methane) or liquids (with vapor pressure/MAOP < 0.35):

$$Cv = (0.0147)\ \sigma_H^2\ (Dt/2)^{0.284}$$

Cv : Required Charpy V-notch absorbed energy (average of three full size transverse specimens) per API SPEC 5L-SR5B.3 and 01-SAMSS-022, in ft-lb

σ_H : Maximum allowable hoop stress, ksi
(This is normally the Design Factor x SMYS)

D : Outside diameter, inches

t : Nominal pipe wall thickness, inches

Toughness values listed in the attached Tables 1 through 4 are based on the above formula, at various design factors and strength levels (valid up to strength level X65).

Commentary Note:

The above equation is based on lean natural gas (> 90% methane, acoustic velocity 1300 fps) and no backfill over the pipe. The equation is conservative for the case of a buried pipeline.

5.2.2 For liquids (with vapor pressure/MAOP > 0.35), the formula in Table 5 may be used. However, it is generally advisable to modify the design to increase the design pressure (MAOP) in order to reduce the ratio.

5.2.3 For "rich" gases containing significant amount of hydrocarbons or gases that do not meet the definition of lean gas, contact the Materials Engineering Unit of CSD for gas decompression and fracture velocity calculation to define the required fracture arrest toughness. The following information is needed:

- Gas composition
- Gas temperature and pressure
- Diameter and wall thickness of pipe
- Design factor
- Pipe strength grade (SMYS)
- Maximum allowable operating pressure (MAOP)

Commentary Note:

For rich gas service, gases other than methane and liquids with high vapor pressure like NGL, CSD can perform calculations using the computer programs GASDECOM and DUCTOUGH with the method outlined in NG-18 Report No. 208 "Final Report on Fracture Control

Technology for Natural Gas Pipelines" from the Pipeline Research Committee International.

5.3 A correction factor shall be used for Charpy V-notch energies greater than 70 ft-lb (95 J) as follows:

When Cv ≥ 70 ft-lb (95 J), $Cv = Cv + (0.00269)\ Cv^{2.04} - 21.18$

5.4 Specimen Orientation: All specimens shall be oriented transverse to the rolling direction. The orientation specified in API SPEC 5L SR5 shall apply except that for spiral welded (helical seam) pipe, the specimen shall be transverse to the rolling direction of the skelp (perpendicular to the helical seam).

6 Material Selection & Testing Subcommittee

Graham Lobley	**Coordinator**
Abdullah Al-Rumaih	Member
Fahad Al-Bash	Member
Olavo Dias	Member
Muhsen Al-Sannaa	Member
Mauyed Mehdi	Member
Nasser Balhareth	Member
Khalid Al-Nabulsi	Member
Robin Tems	Member
Abdelhak Kermad	Member
Brian Burgess	Member
Hojin Choi	Member
Wajdi Al-Mugbel	Member
Gregory Stark	Member

Revision Summary

31 August 2005 Major revision.

Table 1 – Required Charpy Values (ft-lbs) for Line Pipe in Lean Natural Gas (> 90% Methane) or Liquid (Vapor Pressure/MAOP < 0.35) Service

Design Factor = 0.72

Dt (inches^2)	36 ksi	42 ksi	52 ksi	60 ksi	65 ksi
2	20	20	21	27	32
3	20	20	23	31	36
4	20	20	25	33	39
5	20	20	27	36	42
6	20	20	28	37	44
7	20	20	29	39	46
8	20	20	31	41	48
9	20	21	32	42	49
10	20	21	33	43	51
11	20	22	33	45	52
12	20	22	34	46	54
13	20	23	35	47	55
14	20	23	36	48	56
15	20	24	37	49	57
16	20	24	37	50	58
17	20	25	38	50	59
18	20	25	38	51	60
19	20	25	39	52	61
20	20	26	40	53	62
21	20	26	40	53	63
22	20	27	41	54	64
23	20	27	41	55	64
24	20	27	42	56	65
25	20	28	42	56	66
26	20	28	43	57	67
27	21	28	43	57	67
28	21	28	44	58	68
29	21	29	44	59	69
30	21	29	44	59	69
32	22	30	45	60	71
34	22	30	46	61	72
36	22	31	47	62	73
38	23	31	48	63	74
40	23	31	48	64	75
42	23	32	49	65	76
44	24	32	50	66	77
46	24	33	50	67	78
48	24	33	51	68	79

Note: This table was generated for API SPEC 5L pipe from the formula in Para. 5.2.1

D : Outside diameter, inches

t : Nominal pipe wall thickness, inches.

Table 2 – Required Charpy Values (ft-lbs) for Line Pipe in lean Natural Gas (> 90% Methane) or Liquid (Vapor Pressure/MAOP < 0.35) Service

Design Factor = 0.6

Dt (inches^2)	36 ksi	42 ksi	52 ksi	60 ksi	65 ksi
2	20	20	20	20	22
3	20	20	20	21	25
4	20	20	20	23	27
5	20	20	20	25	29
6	20	20	20	26	31
7	20	20	20	27	32
8	20	20	21	28	33
9	20	20	22	29	34
10	20	20	23	30	35
11	20	20	23	31	36
12	20	20	24	32	37
13	20	20	24	32	38
14	20	20	25	33	39
15	20	20	25	34	40
16	20	20	26	34	40
17	20	20	26	35	41
18	20	20	27	36	42
19	20	20	27	36	42
20	20	20	28	37	43
21	20	20	28	37	44
22	20	20	28	38	44
23	20	20	29	38	45
24	20	20	29	39	45
25	20	20	29	39	46
26	20	20	30	39	46
27	20	20	30	40	47
28	20	20	30	40	47
29	20	20	31	41	48
30	20	20	31	41	48
32	20	21	31	42	49
34	20	21	32	43	50
36	20	21	33	43	51
38	20	22	33	44	52
40	20	22	34	45	52
42	20	22	34	45	53
44	20	22	34	46	54
46	20	23	35	46	54
48	20	23	35	47	55

Note: This table was generated for API SPEC 5L pipe from the formula in Para. 5.2.1

D : Outside diameter, inches

t : Nominal pipe wall thickness, inches.

Table 3 – Required Charpy Values (ft-lbs) for Line Pipe in lean Natural Gas (> 90% Methane) or Liquid (Vapor Pressure/MAOP < 0.35) Service

Design Factor = 0.5

Dt (inches^2)	36 ksi	42 ksi	52 ksi	60 ksi	65 ksi
2	20	20	20	20	20
3	20	20	20	20	20
4	20	20	20	20	20
5	20	20	20	20	20
6	20	20	20	20	21
7	20	20	20	20	22
8	20	20	20	20	23
9	20	20	20	20	24
10	20	20	20	21	25
11	20	20	20	21	25
12	20	20	20	22	26
13	20	20	20	23	26
14	20	20	20	23	27
15	20	20	20	23	28
16	20	20	20	24	28
17	20	20	20	24	29
18	20	20	20	25	29
19	20	20	20	25	29
20	20	20	20	25	30
21	20	20	20	26	30
22	20	20	20	26	31
23	20	20	20	26	31
24	20	20	20	27	31
25	20	20	20	27	32
26	20	20	21	27	32
27	20	20	21	28	33
28	20	20	21	28	33
29	20	20	21	28	33
30	20	20	21	29	34
32	20	20	22	29	34
34	20	20	22	30	35
36	20	20	23	30	35
38	20	20	23	31	36
40	20	20	23	31	36
42	20	20	24	31	37
44	20	20	24	32	37
46	20	20	24	32	38
48	20	20	25	33	38

Note: This table was generated for API SPEC 5L pipe from the formula in Para. 5.2.1

D : Outside diameter, inches

t : Nominal pipe wall thickness, inches.

Table 4 – Required Charpy Values (ft-lbs) for Line Pipe in lean Natural Gas (> 90% Methane) or Liquid (Vapor Pressure/MAOP < 0.35) Service

Design Factor = 0.4

Dt (inches^2)	36 ksi	42 ksi	52 ksi	60 ksi	65 ksi
2	20	20	20	20	20
3	20	20	20	20	20
4	20	20	20	20	20
5	20	20	20	20	20
6	20	20	20	20	20
7	20	20	20	20	20
8	20	20	20	20	20
9	20	20	20	20	20
10	20	20	20	20	20
11	20	20	20	20	20
12	20	20	20	20	20
13	20	20	20	20	20
14	20	20	20	20	20
15	20	20	20	20	20
16	20	20	20	20	20
17	20	20	20	20	20
18	20	20	20	20	20
19	20	20	20	20	20
20	20	20	20	20	20
21	20	20	20	20	20
22	20	20	20	20	20
23	20	20	20	20	20
24	20	20	20	20	20
25	20	20	20	20	20
26	20	20	20	20	21
27	20	20	20	20	21
28	20	20	20	20	21
29	20	20	20	20	21
30	20	20	20	20	21
32	20	20	20	20	22
34	20	20	20	20	22
36	20	20	20	20	23
38	20	20	20	20	23
40	20	20	20	20	23
42	20	20	20	20	24
44	20	20	20	20	24
46	20	20	20	21	24
48	20	20	20	21	25

Note: This table was generated for API SPEC 5L pipe from the formula in Para. 5.2.1

D : Outside diameter, inches

t : Nominal pipe wall thickness, inches.

Table 5 – Required Charpy Values for Liquids if Vapor Pressure/MAOP > 0.35

$$Cv = 0.00263 \ln \sec \left(\frac{5.23 \ Pv}{(1.39 + n) \ MAOP}\right) \sigma^2 \left(\frac{Dt}{2}\right)^{1/2}$$

Cv	:	Required Charpy V-notch absorbed energy (average of three full size transverse specimens) per API SPEC 5L-SR5B.3 and 01-SAMSS-022, in ft-lb
Pv	:	Vapor pressure of pipeline liquid, psi
n	:	Constant with value as listed in the table below
MAOP	:	Maximum allowable operating pressure (design pressure), psi
σ	:	Flow stress = σ_Y + 10 ksi = σ_{SMYS} + K + 10, in ksi (K from the table below)
σ_Y	:	Estimated actual yield strength = σ_{SMYS} + K, in ksi (K from the table below)
σ_{SMYS}	:	Specified minimum yield strength, ksi
D	:	Outside diameter, inches
t	:	Nominal pipe wall thickness, inches

Computed and Assumed Constants

API Grade	K (ksi)	n
Gr. B	15	0.40
X42	13	0.33
X52	9	0.27
X60	6	0.23
X65	5	0.21
X70	5	0.20

Note: The equation in this form is valid for design factor of 0.72.