Engineering Standard

SAES-L-132 5 October 2005

Material Selection for Piping Systems

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1 Scope

1.1 This standard covers the basic materials of construction for various piping systems as governed by the fluid to be transported, and supplements the requirements of piping codes ASME B31. The materials are also subject to the further requirements and limitations regarding chemical, mechanical and dimensional properties per specifications stated in this standard.

1.2 For gasket materials, refer to SAES-L-109. For valves, refer to SAES-L-108.

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 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.

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 Standards

SAES-A-301	*Materials Resistant to Sulfide Stress Corrosion Cracking*
SAES-H-002	*Internal and External Coatings for Steel Pipelines and Piping*
SAES-L-105	*Limitations on Piping Components*
SAES-L-108	*Selection of Valves*

SAES-L-109	*Selection of Flanges, Stud Bolts and Gaskets*
SAES-L-130	*Material for Low Temperature Service*
SAES-L-133	*Corrosion Protection Requirements for Pipelines/Piping*
SAES-L-610	*Nonmetallic Piping*

Saudi Aramco Materials System Specifications

01-SAMSS-016	*Qualification of Pipeline and Pressure Vessel Steels for Resistance to Hydrogen-Induced Cracking*
01-SAMSS-017	*Auxiliary Piping for Mechanical Equipment*
01-SAMSS-035	*API Line Pipe*
01-SAMSS-038	*Small Direct Charge Purchases of Pipe*
01-SAMSS-332	*High Frequency Welded Line Pipe, Class B*
01-SAMSS-333	*High Frequency Welded Line Pipe, Class C*
02-SAMSS-005	*Butt Welding Pipe Fittings*
02-SAMSS-011	*Forged Steel Weld Neck Flanges for Low and Intermediate Temperature Service*

3.2 Industrial Codes and Standards

American Petroleum Institute

API RP14E	*Design and Installation of Offshore Production Platform Piping Systems (2000)*
API RP571	*Damage Mechanisms Affecting Fixed Equipment in the Refining Industry-First Edition (2003)*
API RP941	*Steels for Hydrogen Service at Elevated Temperatures and Pressures in Petroleum Refineries and Petrochemical Plants*
API RP945	*Avoiding Environmental Cracking in Amine Units-Third Edition (2003)*
API SPEC 5L	*Specification for Line Pipe*

American Society of Mechanical Engineers

ASME B31.1	*Power Piping*
ASME B31.3	*Process Piping*

ASME B31.4	*Liquid Transportation Systems for Hydrocarbons, Liquid Petroleum Gas, Anhydrous Ammonia, and Alcohols*
ASME B31.8	*Gas Transmission and Distribution Piping Systems*

American Society for Testing and Materials

ASTM A106	*Standard Specification for Seamless Carbon Steel Pipe for High-Temperature Service*
ASTM A333	*Standard Specification for Seamless and Welded Steel Pipe for Low-Temperature Service*

National Association of Corrosion Engineers

NACE	*Corrosion Data Survey, Metals, 5th edition, 1979*
NACE	*Corrosion Data Survey, Non-Metals, 5th edition, 1978*

Norsok Standard

P-CR-001	*Common Requirements, Process Design*

4 Material Selection

4.1 Pipe and piping components in contact with the service environment shall be made of the basic materials of construction listed in Table 1 for the fluids under the design conditions indicated, or of an equivalent or better material subject to the approval of the assigned Engineering Specialist in the Consulting Services Department. For service conditions which differ from those listed in Table 1, consult the Engineering Specialist.

4.2 Refer to SAES-L-105 for complementary information on pipe classes.

4.3 Bends and welds in carbon steel piping regardless of wall thickness shall be stress relief heat treated for one hour in the range of 595 to 650°C for certain services as indicated in the remarks column of Table 1.

4.4 All material for use in wet, sour services described in SAES-L-133, paragraph 6.2.1 shall be resistant to sulfide stress cracking (SSC) in accordance with SAES-A-301.

All material for use in wet, sour services described in SAES-L-133, paragraph 6.2.2 shall be resistant to hydrogen induced cracking (HIC), as described in SAES-L-133 paragraph 7.2.2.

4.4.1 The following components, when purchased in accordance with the Purchase Specifications shown, are considered resistant to sulfide stress cracking:

a) Pipe purchased to 01-SAMSS-035, 01-SAMSS-038, 01-SAMSS-332, or 01-SAMSS-333.

b) Fittings purchased to 02-SAMSS-005.

c) Flanges purchased to 02-SAMSS-011.

4.4.2 Pipe, fittings, or flanges for use in wet, sour services where sulfide stress cracking is a possibility and not purchased to any of the above specifications shall meet the requirements of SAES-A-301.

4.4.3 The following components, when purchased in accordance with the Purchase Specifications shown, are considered resistant to hydrogen induced cracking:

a) Seamless pipe purchased to 01-SAMSS-035, 01-SAMSS-038, API SPEC 5L, ASTM A106 Grade B, or ASTM A333 Grade 6.

b) ERW or straight and spiral submerged-arc welded pipe purchased to 01-SAMSS-016.

c) Fittings purchased to 02-SAMSS-005.

d) Flanges purchased to 02-SAMSS-011.

4.4.4 Piping, fittings, or flanges not meeting the requirements of paragraph 4.4.3 above shall not be used in wet, sour services where hydrogen induced cracking is a possibility.

5 Maximum and Minimum Velocities

5.1 Exceptions to the maximum velocities are proprietary piping (e.g., metering skid, surge relief skid, etc.) or piping requiring flow balance in branch segments (e.g., firewater spray/sprinkler systems). Where velocities are not otherwise limited by Table 1, the maximum and minimum fluid velocity in carbon steel piping shall be limited to the following:

5.1.1 Single-Phase Gas lines

For in-plant piping, except during a relief and flare flow, the maximum velocity in gas lines shall be limited to 18.3 m/s. In-plant noise may be a problem when velocities in gas lines exceed this limit. Higher velocities are acceptable when the piping layout configuration is relatively simple and has a minimum number of fittings and valves subject to review and

approval of the Engineering Specialist in the Consulting Services Department.

For cross-country pipelines, when noise is not a concern, the maximum gas velocity is an economic balance between acceptable pressure drops, the desired gas flow rates and other factors.

Flow velocity in gas lines shall not be less than 4.6 m/s to minimize accumulation of water at the bottom of the pipe. This minimum velocity limit does not apply to dry sweet gas with controlled and monitored dew point limit.

5.1.2 Liquid lines

Flow velocity in single-phase liquid lines for services other than shown in Table 1 shall be limited to 4.6 m/s.

Higher flow velocity may be used in special cases or in intermittent services subject to review and approval by the Engineering Specialist in the Consulting Services Department.

Flow velocity shall not be less than 1 m/s to minimize deposition of solids and accumulation of water at the bottom of the pipe.

5.1.3 Gas/Liquid two-phase lines

Except for liquid relief and blowdown lines, flow velocities in flowlines and other lines transporting gas and liquid in two-phase flow shall not exceed the fluid erosional velocity (reference API RP14E, paragraph 2.5.a) as determined by equation (1):

$$V_e = \frac{c}{\sqrt{\rho_m}} \qquad (1)$$

where:

V_e: Fluid erosional velocity, feet/second

c: Empirical constant = 100 for continuous service and = 125 for non-continuous service

(for solid-free fluids where corrosion is not anticipated or when corrosion is controlled by inhibition or by employing corrosion resistant alloys, values of "c" up to 150 to 200 may be used for continuous service. When "c" values higher than 100 for continuous service are used, periodic surveys to assess pipe wall thickness should be considered).

ρ_m: Density of the gas & liquid mixture at operating pressure and temperature, lbs/ft³

$$\rho_m = \frac{12409S_lP + 2.7RS_gP}{198.7P + RTZ}$$

where:

S_l: Liquid specific gravity at standard conditions (water = 1; use average gravity for hydrocarbon-water mixtures)

P: Operating pressure, psia

R: Gas/liquid ratio cu-ft/barrel at standard conditions

S_g: Gas specific gravity at standard conditions (air = 1)

T: Operating temperature, ºR

Z: Gas compressibility factor, dimensionless

Once the erosional velocity is known, the minimum cross-sectional area, A, required to avoid fluid erosion is determined from equation (2):

$$A = \frac{9.35 + \frac{ZRT}{21.25P}}{V_e} \qquad (2)$$

where:

A: Minimum pipe cross-sectional flow area required, square inch per 1000 barrels liquid per day.

The minimum velocity in two-phase lines should be about 10 ft/s (3.05 m/s) to minimize slugging of separation equipment. This is particularly important in long lines with elevation changes.

5.1.4 Steam Lines

For insulated steam lines, the velocity range for continuous service shall be as follows:

Saturated Steam: 30 – 40 m/s (100 – 130 ft/sec)

Superheated Steam: 40 – 60 m/s (130 – 200 ft/sec)

For vent steam, the maximum velocity is limited to 60 m/s (200 ft/sec).

5.2 The maximum allowable fluid velocity in 90-10 CuNi piping varies according to the size of the line as shown in Table 2.

5.3 For sizing of firewater systems, the maximum velocity of the water, based on the nominal capacity of the outlets (hydrants and monitors), shall not exceed two times the maximum velocity listed in Table 1 for the material of the pipe.

5.4 The velocity requirements of paragraphs 5.1.1 and 5.1.2 may be superseded to allow the installation of pipeline sizes that allow through scraping with single diameter ILI tools. This is subject to the approval of the Chairman of the Materials and Corrosion Control Standards Committee.

Commentary Note:

An example of such a relaxation in the velocity requirement would be where a new line is being constructed to tie-in to the upstream end of an existing pipeline and where a smaller diameter pipe would be utilized for the new line to meet the maximum/minimum velocity requirement of this standard. To allow single diameter scraping tools to be used for both the new and existing sections of the pipeline, the new section may use the same pipe diameter as the existing line, even though the velocity minimum may not be achieved.

5.5 DGA Velocities

Based on company experience, maximum velocity limit for CS piping in rich DGA is 1.5 m/s and 3.05 m/s for lean DGA.

6 Material Selection and Testing Subcommittee

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Revision Summary

5 October 2005	Minor revisions. Updated Table 1 (added new environments, materials, and relaxed some velocities), revised steam definitions and velocities, added DGA velocities section, and added a table for alloy material definitions. Revised the "Next Planed Update."

Table 1 – Piping Materials Selection

Environment	Conc. %	Temp. (°C)	Air Present	Velocity (m/s) #	Basic Material	Remarks
Acid, hydrochloric	1-37	0 - 49	N/A	0 - 2.4	PVC	Not applicable (N/A) means air may be present and not adversely affect corrosion rates. No ferric ions or other oxidants
	1 - 37	0 - 82	No	0 - 1.5	Hastelloy B2	
Acid, hydrofluoric	1 - 70	0 - 50	No	0 - 2	Monel 400	
	71 - 100	0 - 40	No	0 - 1	Carbon steel	Post-weld heat treatment may be required
Acid, nitric	1 - 70	0 - 80	N/A	0 - 4	Type 304L S/S	
	71 - 95	0 - 50	N/A	0 - 4	Type 304L S/S	
Acid, phosphoric	1 - 85	0 - 49	N/A	0 - 2.4	PVC	
	1 - 85	0 - 70	N/A	0 - 4	Type 316L S/S	
Acid, sulfuric	0 - 103	0 - 50	N/A	0 - 4	Alloy 20	
	101 - 102	0 - 50	N/A	0 - 1	Carbon Steel	Carbon steel and type 316L S/S lines shall not be flushed with water
	90 - 103	0 - 50	N/A	0 - 1	Type 316L S/S	
	0 - 100	0 - 250	N/A	0 - 5	High silicon iron	
	0 - 60	0 - 65	N/A	0 - 2.4	CPVC	
	0 - 100	0 - 200	N/A	0 - 2.4	Fluoropolymer-Lined steel	e.g. for carbon steel spools downstream of sulfuric injection points
Acid, sulfamic	0 - 20	0 - 93	N/A	Para. 5	Alloy 20	Weld with Inconel 625 filler
	0 - 100	0 - 200	N/A	0 - 2.4	Fluoropolymer-lined steel	
ADIP (Amino-Diisopropanol)	10 - 30	0 - 150	N/A	0 - 0.9	Carbon steel	No copper or aluminum alloys. See paragraph 4.3
Air, Plant	N/A	0 - 400	N/A	N/A	Carbon steel	
Air, Instrument	-	0 - 400	N/A	N/A	Galvanized steel	Carbon steel for Header
Ammonia anhydrous	100	0 - 50	No	Para. 5	Carbon steel	No copper alloys. See SAES-L-130
Carbon dioxide, Dry	100	0 - 400	N/A	Para. 5	Carbon steel	
Carbon dioxide, Wet	100	0 - 93	N/A	Para. 5	Type 304L S/S	
Chemicals, injection, corrosion, and scale inhibitor, boiler treatment	100	0 - 93	N/A	Para. 5	Type 316L S/S	

Maximum (also see paragraph 5)

Table 1 – Piping Materials Selection (Cont'd)

Environment	Conc. %	Temp. (°C)	Air Present	Velocity (m/s) #	Basic Material	Remarks
Chlorine, Dry	100	0 - 70	No	Para. 5	Carbon steel	
Chlorine, Wet	<100	0 - 70	N/A	Para. 5	Hastelloy C-276	More than 2000 ppm water
Chlorine/water	1 - 10	1 - 49	N/A	0 - 2.4	PVC	
	1 - 10	1 - 71	N/A	0 - 2.4	CPVC	
Crude oil or products	-	-	-	-	-	See Hydrocarbons
DGA (Diglycolamine), Rich	-	0 - 138	No	0 - 1.5	Carbon steel	See paragraph 5.5
DGA, Lean	-	0 - 138	No	0 - 3.05	Carbon steel	See paragraph 5.5
DGA, Rich	-	139 - 190	No	0 - 1.5	Carbon steel	Paras. 4.3 and 5.5
DGA, Lean	-	139 - 190	No	0 - 3.05	Carbon steel	Paras. 4.3 and 5.5
DGA, Rich or Lean	-	0 - 190	No	0 - 4	Type 304L S/S	
DGA, Rich or Lean	-	0 - 190	No	0 - 4	Type 316L S/S	
Freons	100	0 - 70	N/A	0 - 3	Carbon steel	See SAES-L-130
Hydraulic oil	100	-	N/A	0 - 4	Type 304 or 304L S/S 316L S/S	Type 316L S/S or Monel 400 offshore. See 01-SAMSS-017.
Hydrocarbons Sweet & Sour	100	0 - 280	No	Para. 5	Carbon steel	
	100	280 - 340	No	Para. 5	1 ¼ Cr ½ Mo 5 Cr ½ Mo	Select based on McConomy curves
	100	-	N/A	Para. 5	Type 316L S/S	
Hydrocarbons, Naphtha (Crude Unit overhead line)	100 100	130 130	N/A N/A	22.8 max 45.7 max	Carbon steel Hastelloy C-276 clad carbon steel	See SAER-5941 See SAER-5941
Hydrocarbon gas plus hydrogen	-	-	No	Para. 5	Per Nelson Chart	See API RP941
Hydrogen	100	-	No	Para. 5	Per Nelson Chart	See API RP941
Hydrogen sulfide, Dry	100	0 - 260	No	Para. 5	Carbon steel	See paragraph 4.4
Hydrogen sulfide, Wet	100	0 - 260	No	Para. 5	Carbon steel Type 316L S/S	Use 316L for high velocity and erosion resistance
Hypochlorite (sodium or calcium)	5	0 - 49	N/A	0 - 2.4	CPVC	
	5	0 - 49	N/A	0 - 5	RTRP (FRP)	See SAES-L-610. Clear solutions, without suspended solids
	5	0 - 49	N/A	0 - 4	Hastelloy C-276	
LPG, NGL	100	Above 0	No	0 - 4	Carbon steel	See SAES-L-130

Maximum (also see paragraph 5)

Table 1 – Piping Materials Selection (Cont'd)

Environment	Conc. %	Temp. (°C)	Air Present	Velocity (m/s) #	Basic Material	Remarks
Lube oil and Seal oil	100	-	N/A	0 - 6	Type 304/304L	See 01-SAMSS-017
	100	-	N/A	0 - 6	Type 316/316L	See 01-SAMSS-017
Sodium hydroxide (Caustic soda)	7	0 - 75	N/A	0 - 1.5	Carbon steel	
	7	76 - 100	N/A	0 - 1.5	Carbon steel	Paragraph 4.3
	20	0 - 50	N/A	0 - 1.5	Carbon steel	
	50	15 - 49	N/A	0 - 1.5	Carbon steel	
	50	50 - 80	N/A	0 - 1.5	Carbon steel	Paragraph 4.3
	50	50 - 150	N/A	0 - 4	Alloy 600	
	50	50 - 150	N/A	0 – 4	Monel 400	
Steam	100	100 - 400	No	Para. 5	Carbon steel	
	100	400 - 480	No	Para. 5	1-¼ Cr ½ Mo Alloy steel	
	100	480 - 560	No	Para. 5	2-¼ Cr 1 Mo Alloy steel	
Steam condensate	-	-	No	0 - 2.25	Carbon steel	
	-	-	N/A	0 - 4	Type 304L S/S	CO_2 contaminated
Sulfur, molten	100	MP - 150	N/A	0 - 2.25	Carbon steel	Keep dry, moisture causes corrosion. MP denotes melting point
	100	MP - 295	N/A	0 - 4	Type 316L S/S	
Water, boiler feed	-	1 - 200	No	0 - 2.25	Carbon steel	
Water, cooling (inhibited)	-	1 - 99	N/A	0 - 2.25	Carbon steel	Inhibited against corrosion of steel
	-	1 - 99	N/A	0 - 2.25	Galvanized steel	
Water, chilled	-	Above 0	No	0 - 2.25	Steel	
	-	Above 0	No	0 - 2.25	Galvanized steel	
	-	1 - 49	N/A	0 - 2.4	PVC	
Water, demineralized or distilled	-	1 - 49	N/A	0 - 2.4	PVC	
	-	1 - 71	N/A	0 - 2.4	CPVC	
	-	1 - 200	N/A	0 - 4	Type 304 S/S	
Water, drinking (sweet)	-	0 - 120	N/A	0 - 3	Cement lined steel	See SAES-H-002, ACPS-103 for limitations
	-	1 - 49	N/A	0 - 2.3	PVC	
	-	50 - 70	N/A	0 - 2.3	CPVC	
	-	1 - 80	N/A	0 - 5	RTRP (FRP/GRP)	See SAES-L-610. Clear solutions, without suspended solids. RTRP is to be based on Epoxy Resin if temperature exceeds 70ºC with max limit up to 80ºC
	-	1 - 99	N/A	0 - 2.4	Copper	

Maximum (also see paragraph 5)

Table 1 – Piping Materials Selection (Cont'd)

Environment	Conc. %	Temp. (°C)	Air Present	Velocity (m/s) #	Basic Material	Remarks
Water, fire control (sea)	-	Ambient	N/A	0 - 3	Steel, cement or FBE lined	See paragraph 5.3 and SAES-H-002, APCS-103/102
	-	Ambient	N/A	0 - 5	RTRP (FRP/GRP)	See SAES-L-610. Clear solutions, without suspended solids
	-	Ambient	N/A	Table 2	90-10 Cu-Ni	Alloy C70600
	-	Ambient	N/A	0 - 10	254 SMO S/S	Weld with Inconel 625 filler wire
Water, fire control (utility)	-	Ambient	N/A	0 - 3	Steel, cement or FBE lined	See paragraph 5.3 and SAES-H-002, APCS-103/102
	-	Ambient	N/A	0 - 5	RTRP (FRP/GRP)	See SAES-L-610. Clear solutions, without suspended solids
	-	Ambient	N/A	0 - 1.2	Copper	
	-	Ambient	N/A	Table 2	90-10 Cu-Ni	Alloy C70600
		Ambient	No	0 - 2.25	Steel	Only for dedicated alarm systems with no flow
		Ambient	No	0 - 2.25	Galvanized steel	
		Ambient	N/A	0 - 10	254 SMO S/S	Weld with Inconel 625 filler wire
Water, utility (raw)	-	1 - 49	N/A	0 - 2.4	PVC	
	-	50 - 70	N/A	0 - 2.4	CPVC	
	-	1 - 70	N/A	0 - 5	RTRP (FRP/GRP)	Clear solutions, without suspended solids
	-	0 - 120	N/A	0 - 3	Cement-lined steel	See SAES-H-002, APCS-103 for limitations
	-	1 - 99	N/A	0 - 1.2	Copper	
Water, sea/saline	-	0 - 120	N/A	0 - 3	Cement-lined steel	See SAES-H-002, APCS-103 for limitations
	-	0 - 50	N/A	0 - 5	RTRP (FRP/GRP)	See SAES-L-610. Clear solutions, without suspended solids
	-	0 – 50	N/A	Table 2	90-10 Cu-Ni	Alloy C70600
	-	0 - 50	N/A	0 - 10	254 SMO S/S	Weld with Inconel 625 filler wire
	-	0 - 50	No	0 - 3.6	Steel	Chlorinated, deaerated, and inhibited against corrosion of steel
	-	0 - 50	N/A	0 - 6	Steel internally coated with APCS-100 or APCS-102	Sand can cause erosion

Table 1 – Piping Materials Selection (Cont'd)

Environment	Conc. %	Temp. (°C)	Air Present	Velocity (m/s) #	Basic Material	Remarks
Water, sea water injection	-	0 - 50	No	0 - 6	Steel internally coated with APCS-100 or APCS-102	Filtered, deoxygenated and dechlorinated
Water, aerated aquifer, desalination brine, produced water, disposal salt, water brine	-	0 - 120	N/A	0 - 3	Cement-lined steel	See SAES-H-002 APCS-103 for limitations
	-	0 - 80	N/A	0 - 6	Steel internally coated with APCS-100 or APCS-102	Sand can cause erosion
	-	1 - 80	N/A	0 - 10	254 SMO S/S	Weld with Inconel 625 filler wire

Maximum (also see paragraph 5)

Table 2 – Maximum Fluid Velocity for 90-10 Cu-Ni Piping

Nominal Pipe Size (inch)	Velocity (m/s)
1	1.4
2	2.2
3	2.8
4 & larger	3.4

Table 3 – Alloy Material Definitions: Common names and UNS numbers

Material	UNS Number
Hastelloy B2	N10665
Alloy 600	N06600
Monel 400	N04400
Alloy 20 (20Cb-3)	N08020
Hastelloy C-276	N10276
254SMO	S31254