



Engineering Standard

SAES-L-132

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Materials Selection for Pipelines, Piping, and Process Equipment

Document Responsibility: Materials Engineering Standards Committee

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1 Scope

- 1.1 This standard covers the minimum materials of construction for the pressure envelope of process static mechanical equipment (pipelines, piping, and process equipment) as governed by the process services and supplements the requirements of piping codes ASME B31, and those of the ASME Boiler and Pressure Vessel Code. The materials are also subject to further requirements and limitations regarding chemical, mechanical, and dimensional properties per specifications referenced in this standard.
- 1.2 Refer to specific static mechanical equipment (pipelines, piping, and process equipment) standards listed in Section 3 for the selection of specific material grades.

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 Procedures

[SAEP-302](#)

Instructions for Obtaining a Waiver of a Mandatory Saudi Aramco Engineering Requirement

[SAEP-602](#)

Process Design Guidelines - Sulfur Recovery

Saudi Aramco Engineering Standards

[SAES-B-017](#)

Fire Water Systems Design

[SAES-D-001](#)

Design Criteria for Pressure Vessels

<u>SAES-D-100</u>	<i>Design Criteria of Atmospheric and Low-Pressure Tanks</i>
<u>SAES-E-004</u>	<i>Design Criteria of Shell and Tube Heat Exchangers</i>
<u>SAES-E-006</u>	<i>Design Criteria of Double Pipe Heat Exchangers</i>
<u>SAES-E-007</u>	<i>Design Criteria of Air-Cooled Heat Exchangers</i>
<u>SAES-E-014</u>	<i>Design Criteria of Plate and Frame Heat Exchangers</i>
<u>SAES-E-015</u>	<i>Design Criteria of Electric Heat Exchangers</i>
<u>SAES-F-001</u>	<i>Design Criteria of Fired Heaters</i>
<u>SAES-H-002</u>	<i>Internal and External Coatings for Steel Pipelines and Piping</i>
<u>SAES-L-105</u>	<i>Piping Line Classes</i>
<u>SAES-L-108</u>	<i>Selection of Valves</i>
<u>SAES-L-109</u>	<i>Selection of Flanges, Stud Bolts, and Gaskets</i>
<u>SAES-L-133</u>	<i>Corrosion Protection Requirements for Pipelines, Piping, and Process Equipment</i>
<u>SAES-L-136</u>	<i>Pipe, Flange and Fitting Material Requirements</i>
<u>SAES-L-410</u>	<i>Design of Pipelines</i>
<u>SAES-L-610</u>	<i>Nonmetallic Piping for In-Plant</i>
<u>SAES-L-620</u>	<i>Design of Reinforced Thermosetting Resins (RTR) Piping in Hydrocarbon and Water Injection Systems</i>
<u>SAES-L-650</u>	<i>Construction of Nonmetallic Piping in Hydrocarbon and Water Injection Systems</i>
<u>SAES-S-010</u>	<i>Sanitary Sewers</i>
<u>SAES-S-040</u>	<i>Saudi Aramco Water Systems</i>
<u>SAES-S-050</u>	<i>Sprinkler and Standpipe Systems in Buildings</i>
<u>SAES-W-010</u>	<i>Welding Requirements for Pressure Vessels</i>
<u>SAES-W-011</u>	<i>Welding Requirements for On-Plot Piping</i>
<u>SAES-W-012</u>	<i>Welding Requirements for Pipelines</i>

Saudi Aramco Materials System Specifications

<u>01-SAMSS-017</u>	<i>Auxiliary Piping for Mechanical Equipment</i>
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<u>01-SAMSS-025</u>	<i>Specification for Heavy Duty Polytetrafluoroethylene (PTFE) and Perfluoroalkoxy (PFA) Lined Carbon Steel Pipe and Fittings</i>
<u>01-SAMSS-034</u>	<i>RTR (Fiberglass) Pressure Pipe and Fittings</i>
<u>01-SAMSS-035</u>	<i>API Line Pipe</i>
<u>01-SAMSS-041</u>	<i>Lining of Tanks and Vessels with Elastomeric Materials</i>
<u>01-SAMSS-042</u>	<i>Reinforced Thermoset Resin (RTR) Pipe and Fittings in Water and Hydrocarbon Services</i>
<u>01-SAMSS-043</u>	<i>Carbon Steel Pipes for On-Plot Piping</i>
<u>01-SAMSS-050</u>	<i>Thermoplastic Tight Fit Grooved or Perforated Liners for New and Existing Pipelines</i>
<u>01-SAMSS-051</u>	<i>High Density Polyethylene (HDPE) Pipe and Fittings</i>
<u>01-SAMSS-333</u>	<i>High Frequency Welded Line Pipe</i>
<u>02-SAMSS-005</u>	<i>Butt Welding Pipe Fittings</i>
<u>02-SAMSS-011</u>	<i>Forged Steel and Alloy Flanges</i>
<u>32-SAMSS-005</u>	<i>Manufacture of Atmospheric Tanks</i>

3.2 Industry Codes and Standards

Note that for all the industry codes and standards listed below, the current or latest editions are relevant, except where otherwise indicated.

American Petroleum Institute

<u>API RP 571</u>	<i>Damage Mechanisms Affecting Fixed Equipment in the Refining Industry</i>
<u>API RP 934-A</u>	<i>Materials and Fabrication of 2¼Cr-1Mo, 2¼Cr-1Mo-¼V, 3Cr-1Mo, and 3Cr-1Mo-¼V Steel Heavy Wall Pressure Vessels for High-Temperature, High-pressure Hydrogen</i>
<u>API RP 934-C</u>	<i>Materials and Fabrication of 1¼Cr-½Mo Steel Heavy Wall Pressure Vessels for High-pressure Hydrogen Service Operating at or Below 825°F (441°C)</i>
<u>API RP 934-E</u>	<i>Recommended Practice for Materials and Fabrication of 1¼CR-½Mo Steel Pressure Vessels for Service above 825°F (440°C)</i>

[API RP 941](#) *Steels for Hydrogen Service at Elevated Temperatures and Pressures in Petroleum Refineries and Petrochemical*

[API SPEC 5L](#) *Specification for Line Pipe*

[API 15S](#) *Qualification of Spoolable Reinforced Plastic Line Pipe*

International Organization for Standardization

[ISO 4437](#) *Buried Polyethylene (PE) Pipes for the Supply of Gaseous Fuels*

[ISO 10358](#) *Plastics Pipes and Fittings - Combined Chemical Resistance Classification Table*

[ISO 13703](#) *Petroleum and Natural Gas Industries - Design and Installation of Piping Systems on Offshore Production Platforms*

[ISO 15663](#) *Petroleum and Natural Gas Industries - Life-Cycle Costing*

[ISO 21457](#) *Petroleum, Petrochemical, and Natural Gas Industries - Materials Selection and Corrosion Control for Oil and Gas Production Systems*

[ISO 23936-1](#) *Non-Metallic Materials in Contact with Media Related to Oil and Gas Production - Part 1: Thermoplastics*

Manufacturers Standardization Society of the Valve and Fittings Industry

MSS SP54 *Quality Standard for Steel Castings for Valves, Flanges, Fittings, and Other Piping Components – Radiographic Examination Method*

National Association of Corrosion Engineers

[NACE MR0175/ISO 15156](#) *Petroleum and Natural Gas Industries Materials for Use in H₂S-Containing Environments in Oil and Gas Production*

[NACE MR0103/ISO 17945](#) *Materials Resistant to Sulfide Stress Cracking in Corrosive Petroleum Refining Environments*

NACE *Corrosion Data Survey - Metal Section*

[NACE](#) *Corrosion Data Survey - Nonmetals Section*

National Fire Protection Association

[NFPA 58](#)*Liquefied Petroleum Gas Code*

NORSOK Standards

[NORSOK M-001](#)*Materials Selection*[NORSOK P-002](#)*Process System Design*

4 Materials Selection Philosophy

4.1 Robust materials selection shall be made to ensure operational reliability and integrity throughout the design life of the pipeline, piping system or process equipment (see NORSOK M-001). Reviewing mechanical property requirements and corrosion resistance is the first step in the selection process.

4.2 The main criteria for materials selection shall be:

- Health and safety of personnel and the public, and protection of the environment.
- Optimization of cost versus projected design life.
- Consideration of a fall back or repair position.
- Effect on product and process contamination.

4.2.1 Health, Safety, and Protection of the Environment

The safety of plant personnel, protection of the environment, conservation of resources, and preservation of assets shall be key objectives in selecting materials of construction.

Materials of construction shall be suitable for the intended service, having predictable deterioration rates for the process stream compositions and external environments, at design temperature and pressure, through the design life of the component.

Materials shall be selected to prevent catastrophic failures or major environmental releases. Selected materials shall have low risk of rapid damage mechanisms, such as brittle fracture, stress corrosion cracking (SCC), low cycle fatigue, overload, etc., and have predictable mechanical and corrosion performance.

For pressure containment, only approved materials that are included in recognized codes and specifications, such as API, ASME and ASTM shall be used.

4.2.2 Cost versus Projected Design Life

Materials of construction shall be selected considering the balance between initial capital expenses, operational integrity reliability, and future inspection and maintenance expenses.

Materials of construction shall be selected to provide a minimum design life of 20 years and predictable performance on an acceptable cost basis. The selection should minimize the risk of short design life and unexpected shutdowns; review impacts on maintenance, expense costs and repair time; and review any potential effects on product and process contamination.

In cases where a service life that significantly exceeds design life can be justifiably foreseen, and where materials selection options identified for the design life are cost limited and are only marginally adequate; then the use of a service life based total cost of ownership can be made. If more expensive materials options are proven to be the economically superior option, then these shall be proposed as the primary choice.

Use ISO 15663 for guidance on life-cycle costing.

4.2.3 Repairability or Fall Back Position

Materials of construction shall be capable of being repaired with reasonable effort in an acceptable (minimum) amount of downtime or practical means of altering or bypassing the affected equipment shall be possible until repairs can be made.

Repairability or fallback position should consider replacement lead times and ease of maintenance, inspection, and repair.

4.2.4 Product and Process Contamination

Materials selection shall consider the impact of corrosion rates, surface area, recycle stream rates, solubility, effect of corrosion products on corrosion, and other factors on contamination of the process stream.

4.3 Non-Metallic Materials

Saudi Aramco is actively embarking on the use of non-metallic materials in order to avoid costly corrosion issues, and to ensure long-term operability and profitability of facilities.

Where non-metallic materials are indicated as the “base case” in [Table 2](#) and [Table 3](#), and the design conditions do not violate the limitations of the indicated

non-metallic material, the use of metallic materials shall only be allowed through prior approval of the Chairman of the Materials Engineering Standards Committee.

5 Materials Selection

5.1 Materials Selection based on Design Temperature

5.1.1 Basic materials selection shall be made on the basis of the design temperature of the pipeline, piping system or process equipment. [Table 1](#) provides an overview of suitable metallic materials of construction for different temperature ranges.

5.1.2 Note that the temperature below which impact testing of carbon steel is mandated is different for pipelines, piping and process equipment. For details of these refer to [SAES-L-105](#), [SAES-L-136](#), [SAES-D-001](#), and [SAES-E-004](#) respectively.

5.1.3 The minimum design metal temperature (MDMT) shall be established based on all foreseeable operating conditions and possible upset conditions such as auto-refrigeration and shock chilling.

5.2 Materials Selection Based on Process Environment

5.2.1 Materials selection shall be based on an evaluation of all potential degradation mechanisms. API RP 571 can be used to identify some of the degradation mechanisms. All internal and external media shall be considered for the entire design life. Consider the following major degradation types when selecting materials of construction:

- a) Environmental cracking
- b) Thinning (general or localized)
- c) Mechanical Damage
- d) Thermal damage
- e) Swelling of non-metallics
- f) UV degradation of non-metallics

5.2.2 For corrosive services, additional corrosion control measures as detailed in [SAES-L-133](#) shall be considered.

5.2.3 Pipelines, piping systems, and process equipment in contact with the service environments listed in [Table 2](#) shall be made of the basic materials of construction for the fluids under the design conditions indicated.

- 5.2.4 An equivalent or better material can be used subject to the approval of the Materials Engineering Standards Committee Chairman. For service conditions which differ from those listed in [Table 2](#), consult the Materials Engineering Standards Committee chairman.
- 5.2.5 When assessing materials for pipelines, piping systems, and process equipment in contact with the service environments listed in [Table 2](#), the impacts of stagnation and intermittent flow (process induced or due to equipment cycling), shall be considered. If the basic materials of construction for the fluids in question cannot adequately meet the intermittent conditions, higher grade materials shall be used.
- 5.2.6 When integrity operating windows (IOW's) are developed for processes in new projects, concerns over suitability of materials are identified if operating condition excursions were to occur. Materials selection shall be re-assessed taking the modified variable(s) into consideration.
- 5.2.7 Piping materials for water services, utilities, firefighting systems in buildings, and non-process sewage systems shall be as indicated in [Table 3](#).
- 5.2.8 Unified numbering system (UNS) numbers of alloys referred to in [Table 2](#) are provided in [Table 5](#). An explanation of the abbreviations used for non-metallic materials are provided in [Table 6](#).

5.3 Special Considerations

5.3.1 Wet Sour Service

- 5.3.1.1 All material for use in wet sour services described in [SAES-L-133](#), Section 6.2.1 shall be resistant to sulfide stress cracking (SSC) in accordance with [NACE MR0175/ISO 15156](#).

Commentary Notes:

NACE MR0103 shall only be used to define sour service in refinery process environments. Technical requirements to avoid sulfide stress cracking (SSC) shall follow those detailed in the applicable Saudi Aramco Materials System Specifications (SAMSS) with reference to NACE MR0175/ISO 15156.

In the case of uncertainty in requirements between NACE MR 0175/ISO 15156 and NACE MR0103, CSD/MED shall be the final arbiter.

- 5.3.1.2 All materials for use in wet sour services described in [SAES-L-133](#), Section 6.2.2 shall also be resistant to

hydrogen induced cracking (HIC) as described in [SAES-L-133](#), Section 7.2.2.

5.3.1.3 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](#), or [01-SAMSS-333](#).
- b) Fittings purchased to [02-SAMSS-005](#).
- c) Flanges purchased to [02-SAMSS-011](#).

5.3.1.4 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 [NACE MR0175/ISO 15156](#).

5.3.1.5 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-043](#), [API SPEC 5L](#), [ASTM A106](#) Grade B, or [ASTM A333](#) Grade 6.
- b) Straight submerged-arc welded pipe purchased to [01-SAMSS-035](#) or [01-SAMSS-043](#) as sour service pipe (with annex H and annex K requirements of [API SPEC 5L](#)).
- c) High frequency welded pipe purchased to [01-SAMSS-333](#) as sour service pipe (with annex H and annex K requirements of [API SPEC 5L](#)).
- d) Fittings purchased to [02-SAMSS-005](#).
- e) Flanges purchased to [02-SAMSS-011](#).

5.3.1.6 Piping, fittings, or flanges not meeting the requirements of Section 5.3.1.5 shall not be used in wet, sour services where hydrogen induced cracking is a possibility.

5.3.2 Stainless Steels

5.3.2.1 The minimum acceptable solid austenitic stainless steel for piping or equipment is type 316 or 316L (UNS S31600 or UNS S31603).

5.3.2.2 Solid austenitic stainless steel type 304 or 304L is not permitted

for piping or equipment due to external chloride stress corrosion cracking concerns. Type 304 or 304L may be used as cladding material where appropriate.

5.3.2.3 As per [SAES-L-133](#) paragraph 7.2.5, solid austenitic stainless steel operating at temperatures above 50°C shall be protected against external chloride stress corrosion cracking, regardless of whether the equipment or piping system is insulated or not.

5.3.2.4 Austenitic stainless steel shall not be used in chloride environments containing more than 50 ppm chloride at temperatures above 50°C. For applications above this threshold temperature, contact the Materials Engineering Standards Committee Chairman.

5.3.2.5 Duplex stainless steel shall not be used in sour service applications.

5.3.2.6 Ferritic or martensitic stainless steels containing 12% chromium shall not be used for pressure boundary materials except for pump casings and/or valve stems.

5.3.2.7 The use of solid alloys instead of cladding, including austenitic stainless steels, shall be on a case-by-case basis, with prior approval of the Materials Engineering Standards Committee Chairman.

5.3.3 High Temperature Hydrogen Service

5.3.3.1 Piping

- a) All valves shall have API Trim Number 5.
- b) All valve bodies shall be RT inspected to meet Level 2 RT requirements specified in MSS SP54.
- c) Carbon steel above 200°C (400°F) and all 1.25Cr-0.5Mo and 2.25Cr-1.0Mo piping shall be post weld heat treated.
- d) Temper resistant 2.25Cr-1.0Mo filler metal shall not be used for piping construction.

5.3.3.2 Vessels

- a) Reactors in hydrotreating processes such as hydrocracker, gas oil hydrotreater, diesel hydrotreater, and naphtha hydrotreater shall be constructed in 2.25Cr-1.0Mo steel. Vessel fabrication shall follow API RP 934-A. The use of 2.25Cr-1.0Mo-0.25V, 3.0Cr-1.0Mo, and 3.0Cr-1.0Mo-0.25V

requires prior approval of the Pressure Vessels Standards Committee Chairman and the Materials Engineering Standards Committee Chairman.

- b) Reactors in catalytic reforming processes, such as Platformer and Continuous Catalytic Regeneration (CCR), shall be constructed in 1.25Cr-0.5Mo steel.
- c) 2.25Cr-1.0Mo materials shall not be used to fabricate vessels in cyclic services such as coke drums. Coke drums shall be constructed in 1.25Cr-0.5Mo steels.
- d) 1Cr-½Mo and 1¼ Cr-½Mo steels with thickness exceeding 100 mm (4 in) can be used for components (shell, head, integrally reinforced nozzles, flanges, etc.) of vessels within the scope of API RP 934-C and API RP 934-E, provided that the fracture toughness requirements of the aforementioned recommended practices can be met.

5.3.4 Post weld heat treatment requirements shall follow those specified in [SAES-W-010](#) for pressure vessels, [SAES-W-011](#) for on-plot piping, and [SAES-W-012](#) for pipelines.

6 Maximum and Minimum Velocities

Exceptions to the maximum velocities stated in this standard 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 2](#), the maximum and minimum fluid velocity in carbon steel piping shall be in accordance with [SAES-L-133](#), Section 6.4.

The basis for some of the indicated velocity limitations are ISO 13703, ISO 21457, ISO 23936-1 and NORSOK P-002.

Commentary Note:

Gas velocities through process piping in sulfur recovery units is allowed up to 100 ft/s (30.5 m/s) in accordance with [SAEP-602](#).

Revision Summary

25 November 2015	Major revision to align this standard with international standards and Saudi Aramco best practices.
24 August 2016	Major revision to align standard with SAES-D-001 and to correct non-metallic materials in Table 2 and Table 3. This is the governing document of the materials selection requirements for piping, process equipment and pipelines. The document is now updated to pave the way for mandating all proven non-metallic applications within Saudi Aramco facilities.
25 December 2016	Change the primary contact to Muaili, Saad M

Table 1 - Metallic Materials Selection based on Design Temperature ⁽¹⁾

Design Temperature				
$T_{MDMT} \leq -101^{\circ}\text{C}$	$-101^{\circ}\text{C} < T_{MDMT} \leq -45^{\circ}\text{C}$	$-45^{\circ}\text{C} < T_{MDMT} \leq T_{impact}$	$T_d \leq 400^{\circ}\text{C}$	$T_d > 400^{\circ}\text{C}$
$T_{MDMT} \leq -150^{\circ}\text{F}$	$-150^{\circ}\text{F} < T_{MDMT} \leq -49^{\circ}\text{F}$	$-49^{\circ}\text{F} < T_{MDMT} \leq T_{impact}$	$T_d \leq 800^{\circ}\text{F}$	$T_d > 800^{\circ}\text{F}$
<ul style="list-style-type: none"> • Austenitic stainless steel ⁽²⁾ • Aluminum 	<ul style="list-style-type: none"> • Austenitic stainless steel • 3.5% Ni steel • 9% Ni steel 	<ul style="list-style-type: none"> • Low temperature carbon steel • Impact tested carbon steel 	<ul style="list-style-type: none"> • Carbon steel ⁽³⁾ 	<ul style="list-style-type: none"> • Low alloy steel ⁽⁴⁾ • High temperature alloys ⁽⁵⁾
<p>T_{MDMT}: Minimum design metal temperature</p> <p>T_d: Design temperature</p> <p>T_{impact}: Temperature below which impact testing of carbon steel is mandated by SAES-D-001, SAES-E-004, SAES-L-105 and SAES-L-136 respectively.</p> <p>(1) Note that as a second step the process environment needs to be considered. Modify the basic materials selection from this table according to the corrosivity of the process environment.</p> <p>(2) Impact testing of austenitic stainless steel welds is required below -101°C for piping and below -196°C for pressure vessels.</p> <p>(3) Only in services where gaseous hydrogen (H_2) is not present. Refer to API RP 941 for materials selection in the presence of hydrogen. Carbon steel shall not be used above 400°C (800°F) which is considered the onset temperature for graphitization (see API RP 571).</p> <p>(4) Selected based on required mechanical or creep strength.</p> <p>(5) For fired heater tube metal temperatures higher than 371°C (700°F), austenitic stainless steel type 347 shall be used. For reboiler/fired heater inlet and outlet piping, the minimum metallurgy shall be 9Cr-1Mo steel.</p>				

Table 2 - Materials Selection based on Process Environment

Environment	Basic Material	Conc. %	Temp. (°C)	Max. Piping Velocity (m/s)	Remarks
<i>Oil & Gas Wellfield Environments ⁽¹⁾</i>					
Liquid, flowlines, = (<30mg/l solids)	Subsea flexible pipe	-	0 - 120	5.0	Offshore only Base case (par. 4.3)
	RTP ⁽²⁾	-	0 - 80	5.0	Onshore only Base case (par. 4.3) API 15S
	RTR (epoxy resin)	-	0 - 93	5.0	Onshore only Base case (par. 4.3) 01-SAMSS-042 , Table 2.4.1-2 ⁽³⁾
	Carbon steel ⁽⁴⁾	-	0 - 275	6.0	
	Corrosion resistant alloys (CRAs) ⁽⁴⁾	-	0 - 400	> 7.0	
Two-phase, flowlines, (<30 mg/l solids)	Subsea flexible pipe	-	0 - 120	5.0	Offshore only Base case (par. 4.3)
	RTP ⁽²⁾	-	0 - 80	5.0	Onshore base case (par. 4.3) API 15S
	RTR (epoxy resin)	-	0 - 93	5.0	Onshore only Base case (par. 4.3) 01-SAMSS-042 , Table 2.4.1-2 ⁽³⁾
	Carbon steel ⁽⁴⁾	-	0 - 275	25.0	Non-corrosive service
	Carbon steel ⁽⁴⁾	-	0 - 275	10.0	Corrosive service
	Corrosion resistant alloys (CRAs) ⁽⁴⁾	-	0 - 400	25.0	Corrosive service
Liquid, other piping/ pipelines, (<30 mg/l solids)	Carbon steel ⁽⁴⁾	-	0 - 275	6.0	
	Corrosion resistant alloys (CRAs) ⁽⁴⁾	-	0 - 400	> 7.0	
	RTP ⁽²⁾	-	0 - 80	5.0	Require CSD design approval (API 15S)
	RTR (epoxy resin)	-	0 - 93	5.0	Require CSD design approval 01-SAMSS-042 , Table 2.4.1-2 ⁽³⁾

Environment	Basic Material	Conc. %	Temp. (°C)	Max. Piping Velocity (m/s)	Remarks
Two-phase, other piping/pipelines, (<30 mg/l solids)	Carbon steel ⁽⁴⁾	-	0 - 275	25.0	Non-corrosive service
	Carbon steel ⁽⁴⁾	-	0 - 275	10.0	Corrosive service
	Corrosion resistant alloys (CRAs) ⁽⁴⁾	-	0 - 400	25.0	Corrosive service
	RTP ⁽²⁾	-	0 - 80	5.0	Require CSD design approval (API 15S)
	RTR (epoxy resin)	-	0 - 93	5.0	Require CSD design approval 01-SAMSS-042 , Table 2.4.1-2 ⁽³⁾
Liquid, piping/pipelines (excl. flowlines), (>30 mg/l solids)	Carbon steel ⁽⁴⁾	-	0 - 275	5.0	
	Corrosion resistant alloys (CRAs) ⁽⁴⁾	-	0 - 400	7.0	
Two-phase, piping/pipelines (excl. flowlines), (>30 mg/l solids)	Carbon steel ⁽⁴⁾	-	0 - 275	10.0	Non-corrosive service
	Carbon steel ⁽⁴⁾	-		5.0	Corrosive service
	Corrosion resistant alloys (CRAs) ⁽⁴⁾	-	0 - 400	10.0	Corrosive service
Gas, single-phase, piping/pipelines (incl. flowlines)	Carbon steel ⁽⁴⁾	-	0 - 275	60.0	Non-corrosive service
	Carbon steel ⁽⁴⁾	-	0 - 275	15.0	Corrosive service
	RTP ⁽²⁾	-	0 - 80	5.0	Unconv. resources (UR) - flowlines only API 15S
<i>Transportation Pipelines ⁽⁵⁾</i>					
Liquid	Carbon steel ⁽⁴⁾	-	0 - 275	6.0	
	Corrosion resistant alloys (CRAs) ⁽⁴⁾	-	0 - 400	> 7.0	
	RTP ⁽²⁾	-	0 - 80	5.0	Require CSD design approval (API 15S)
	RTR (epoxy resin)	-	0 - 93	5.0	Require CSD design approval 01-SAMSS-042 , Table 2.4.1-2 ⁽³⁾

Environment	Basic Material	Conc. %	Temp. (°C)	Max. Piping Velocity (m/s)	Remarks
Gas, single-phase	Carbon steel ⁽⁴⁾	-	0 - 275	60.0	Non-corrosive service
	Carbon steel ⁽⁴⁾	-	0 - 275	15.0	Corrosive service
<i>Refinery & Other Downstream Processing Facilities</i>					
Hydrocarbon, liquid/gas, sour	Carbon steel ⁽⁴⁾	-	0 - 275	-	
	1.25Cr-0.5Mo ⁽⁶⁾	-	0 - 275	-	
	2.25Cr-1.0Mo ⁽⁶⁾	-	0 - 275	-	
	9.0Cr-1.0Mo ⁽⁷⁾	-	> 275	-	H ₂ -free
	316/316L	-	> 260	-	H ₂ present
Hydrocarbon, liquid/gas, sweet	Carbon steel	-	0 - 400	-	
Hydrocarbon, crude unit overhead line	Carbon steel	-	0 - 130	22.8	
	Alloy C-276 clad carbon steel	-	0 - 130	45.7	
Hydrogen	Carbon steel	0 - 100	0 - 200	18.3	
	Carbon steel or low alloy steel	0 - 100	> 200	18.3	See API RP 941
Amine, lean	Carbon steel	-	0 - 190	3.0	See SAES-L-133 , paragraph 6.4.5
	316L	-	0 - 190	4.0	
Amine, rich	Carbon steel	-	0 - 190	1.5	See SAES-L-133 paragraph 6.4.5
	316L	-	0 - 190	4.0	
LPG / NGL	Carbon steel	-	> 0	4.0	
	HDPE	-	0 - 60	5.0	LPG piping < 4" only (NFPA 58/ISO 4437)
Sulfur, molten	Carbon steel	-	MP - 195	2.25	Keep dry, moisture causes corrosion.
	316L	-	MP - 295	4.0	MP denotes melting point.

Environment	Basic Material	Conc. %	Temp. (°C)	Max. Piping Velocity (m/s)	Remarks
<i>Chemicals & Other Fluids</i>					
Acid, hydrochloric	PTFE/PFA lined carbon steel	0 - 37	0 - 100	2.4	See 01-SAMSS-025
	HDPE lined carbon steel	0 - 36	0 - 60	2.4	For storage tanks and piping <6" only.
	Carbon steel with elastomeric lining	0 - 100	-	-	For storage tanks only See 32-SAMSS-005 and 01-SAMSS-041
	RTR (vinyl ester)	0 - 37	0 - 60	2.4	See 01-SAMSS-034 (GRV)
	Alloy 400	0 - 5	ambient	1.5	
	Alloy B2	0 - 37	0 - 82	1.5	
	Alloy C-276	32 - 37	0 - 50	1.5	
Acid, hydrofluoric	Carbon steel ⁽⁸⁾	97 - 100	0 - 65	1.0	PWHT to avoid SCC
	Alloy 400	97 - 99	66 - 150	2.0	PWHT ⁽⁹⁾ to avoid SCC
	PTFE/PFA lined carbon steel	0 - 37	0 - 65	2.4	See 01-SAMSS-025
Acid, nitric	PVDF lined carbon steel	0 - 50	0 - 50	2.4	Piping only
	PTFE/PFA lined carbon steel	0 - 70	0 - 100	2.4	See 01-SAMSS-025
	Carbon steel with elastomeric lining	0 - 100	-	-	For storage tanks only See 32-SAMSS-005 and 01-SAMSS-041
	316L	0 - 70	0 - 80	4.0	
	316L	71 - 95	0 - 50	4.0	
Acid, phosphoric	PTFE/PFA lined carbon steel	0 - 50	0 - 100	2.4	See 01-SAMSS-025
	Carbon steel with elastomeric lining	0 - 100	-	-	For storage tanks only See 32-SAMSS-005 and 01-SAMSS-041
	316L	0 - 85	0 - 70	4.0	

Environment	Basic Material	Conc. %	Temp. (°C)	Max. Piping Velocity (m/s)	Remarks
Acid, sulfuric	PTFE/PFA lined carbon steel	0 - 100	0 - 100	2.4	
	Carbon steel with elastomeric lining	0 - 100	-	-	For storage tanks only See 32-SAMSS-005 and 01-SAMSS-041
	Carbon steel	101 - 102	0 - 50	1.0	Air-free Shall not be flushed with water to avoid severe corrosion damage.
	High silicon iron	0 - 100	0 - 250	5.0	
	316L	90 - 103	0 - 50	1.0	
	Alloy 20	0 - 103	0 - 50	4.0	
Acid, sulfamic	PTFE/PFA lined carbon steel	0 - 100	0 - 100	2.4	See 01-SAMSS-025
	Carbon steel with elastomeric lining	0 - 100	-	-	For storage tanks only See 32-SAMSS-005 and 01-SAMSS-041
	Alloy 20	0 - 20	0 - 93	4.6	Welded with Alloy 625 filler wire
ADIP ⁽¹⁰⁾ (Amino-diisopropanol)	Carbon steel	10 - 30	0 - 150	0.9	
Air, Plant	Carbon steel	-	0 - 400	-	
	Galvanized steel	-	0 - 200	-	
	HDPE	-	0 - 60	10.0	
Air, Instrument	Carbon steel	-	0 - 400	18.3	
	Galvanized steel	-	0 - 200	18.3	
	316L	-	0 - 400	18.3	Instrument tubing only
Ammonia, anhydrous ⁽¹¹⁾	Carbon steel	0 - 100	0 - 50	4.6	
Carbon dioxide, Dry	Carbon steel	0 - 100	0 - 400	18.3	
Carbon dioxide, Wet	316L	0 - 100	0 - 93	10.0	
	HDPE lined carbon steel	0 - 100	0 - 60	10.0	

Environment	Basic Material	Conc. %	Temp. (°C)	Max. Piping Velocity (m/s)	Remarks
Chemicals, injection, corrosion, and scale inhibitor, boiler treatment	316L	0 - 100	0 - 93	4.6	Also applies to permanent chemical storage tanks
Chlorine, Dry	Carbon steel	0 - 100	0 - 70	18.3	
Chlorine, Wet	Alloy C-276	0 - 100	0 - 70	10.0	>2000 ppm water
Chlorine-water mixtures ⁽¹²⁾	PVC	0 - 0.3	0 - 60	5.0	Saturated
	CPVC	0 - 0.3	0 - 80	5.0	Saturated
	PE	0 - 0.3	0 - 60	5.0	Saturated
	RTR (vinyl ester)	0 - 0.3	0 - 60	5.0	See 01-SAMSS-034 (GRV)
	PTFE/PFA lined carbon steel	0 - 0.3	0 - 100	5.0	See 01-SAMSS-025
Freon	Carbon steel	0 - 100	0 - 70	3.0	See SAES-L-136 / 01-SAMSS-043
Hydraulic oil	RTR (vinyl ester)	-	0 - 100	5.0	Base case (par. 4.3) See 01-SAMSS-034 (GRV)
	PTFE/PFA lined carbon steel	-	0 - 230	5.0	See 01-SAMSS-025
	Carbon steel with elastomeric lining	-	-	-	For storage tanks only See 32-SAMSS-005 and 01-SAMSS-041
	316/316L	-	-	4.0	See 01-SAMSS-017
	Alloy 400	-	-	4.0	Offshore only
	Type 6Mo	-	-	10.0	Offshore only Weld with Alloy 825
	25Cr Duplex	-	-	10.0	Offshore only F _{PREN} ≥ 42
Hypochlorite (sodium or calcium)	CPVC	0 - 12.5	0 - 80	2.4	See ISO 10358
	PTFE/PFA lined carbon steel	0 - 20	0 - 230	2.4	See 01-SAMSS-025

Environment	Basic Material	Conc. %	Temp. (°C)	Max. Piping Velocity (m/s)	Remarks
Lube oil / Seal oil	316/316L	-	-	6.0	See 01-SAMSS-017
	Type 6Mo	-	-	10.0	Offshore only Weld with Alloy 825
	25Cr Duplex	-	-	10.0	Offshore only F _{PREN} ≥ 42
Sodium hydroxide (Caustic soda)	PTFE/PFA lined carbon steel	0 - 80	0 - 22	2.4	See 01-SAMSS-025
	Carbon steel	0 - 100	0 - 45	1.5	
	Carbon steel	0 - 100	46 - 80	1.5	PWHT mandatory
	Alloy 400	0 - 100	50 - 150	4.0	
	Alloy 600	0 - 100	50 - 150	4.0	

Notes:

- (1) Well-head piping, flowlines, test lines, and trunklines
- (2) Aromatic hydrocarbon shall be limited based on manufacturer qualification.
- (3) Only for liquid hydrocarbons consisting of naphthenic and cyclo-aliphatics. Do not use in aliphatic or aromatic liquid hydrocarbons.
- (4) Sour service requirements to be taken into consideration. See NACE MR0175/ISO 15156.
- (5) Pipelines used to transport hydrocarbon fluids between processing plants or storage facilities to export terminals and end users.
- (6) 1.25Cr-0.5Mo and 2.25Cr-1.0Mo steels shall not be used to control corrosion in hydrogen free sulfidation environments.
- (7) 5.0Cr-0.5Mo steel shall be avoided in all refinery applications as this material provides limited corrosion resistance in hydrogen free sulfidation environments. The construction cost difference between 5.0Cr-0.5Mo and 9.0Cr-1.0Mo is not significant, but mixing 5.0Cr-0.5Mo materials with 9.0Cr-1.0Mo materials has caused significant problems in sulfidation environments. 9.0Cr-1.0Mo shall not be used to build pressure vessels. Instead carbon steel clad with ferritic stainless steel type 405 or martensitic stainless steel type 410S vessels shall be used.
- (8) Base metal; %C > 0.18 wt.% & %Cu + %Ni < 0.15 wt.%. Weld metal; %Cu + %Ni + %Cr < 0.15 wt.%
- (9) Typical PWHT for Alloy 400 in hydrofluoric acid service is 530 – 650°C for 1 hour.
- (10) No copper or aluminum alloys allowed in this service.
- (11) No copper alloys allowed in this service.
- (12) For chlorine concentrations exceeding 10%, contact the Materials Engineering Standards Committee Chairman.

Table 3 - Piping Materials for Water Systems, Utilities and Sewage

Environment	Basic Material	Temp. (°C)	Max. Piping Velocity (m/s)	Remarks
<i>Steam</i>				
Boiler feed water	Carbon steel	1 - 200	2.25	
Steam	Carbon steel	100 - 400	-	See SAES-L-133 , par. 6.4.1.4
	1.25Cr-0.5Mo	400 - 480	-	
	2.25Cr-1.0Mo	480 - 560	-	
Steam condensate	Carbon steel	-	2.25	
	316L	-	4.0	CO ₂ contaminated
<i>Water Services</i>				
Chilled water	RTR (polyester resin)	1 - 60	5.0	Base case (par. 4.3) 01-SAMSS-034
	PVC	1 - 60	5.0	Base case (par. 4.3)
	PP	1 - 80	5.0	Base case (par. 4.3) ISO 10358
	HDPE	1 - 60	5.0	Base case (par. 4.3) 01-SAMSS-051
	Carbon steel with elastomeric lining	-	-	For storage tanks only 01-SAMSS-041 & 32-SAMSS-005
	Carbon steel	> 0	2.25	
	Galvanized steel	> 0	2.25	
Cooling water, Inhibited	RTR (vinyl ester)	1 - 60	5.0	Base case (par. 4.3) 01-SAMSS-034
	HDPE	1 - 60	5.0	Base case (par. 4.3) 01-SAMSS-051
	Carbon steel	1 - 99	5.0	Inhibited against corrosion of steel
	Galvanized steel	1 - 99	5.0	

Environment	Basic Material	Temp. (°C)	Max. Piping Velocity (m/s)	Remarks
Demineralized or distilled water	RTR (polyester resin)	1 - 60	5.0	Base case (par. 4.3) 01-SAMSS-034
	PVC	1 - 60	5.0	Base case (par. 4.3)
	CPVC	1 - 80	5.0	Base case (par. 4.3)
	HDPE	1 - 60	5.0	Base case (par. 4.3) 01-SAMSS-051
	316/316L	1 - 200	4.0	
Drinking water (sweet)	PVC	1 - 60	5.0	Base case (par. 4.3)
	CPVC	1 - 80	5.0	Base case (par. 4.3)
	HDPE	1 - 60	5.0	Base case (par. 4.3) SAES-S-040 and 01-SAMSS-051
	RTR (epoxy resin)	1 - 93	5.0	Base case (par. 4.3) SAES-L-610
	Carbon steel, cement lined	1 - 120	3.0	SAES-H-002
	316/316L	1 - 120	3.0	For small diameter connections only
	90-10 Cu-Ni	1 - 120	2.4	For small diameter connections only
	Copper	1 - 99	2.4	
Fire control (seawater), above ground piping	Carbon steel, cement lined or FBE coated	Ambient	3.0	SAES-H-002
	90-10 Cu-Ni ⁽¹⁾	Ambient	Table 4	Alloy C70600
	Type 6Mo	Ambient	10.0	Welded with Alloy 625 filler wire
	25Cr Duplex	Ambient	10.0	F _{PREN} ≥ 42
Fire control (utility), above ground piping	90-10 Cu-Ni ⁽¹⁾	Ambient	See Table 4	Alloy C70600
	Copper	Ambient	1.2	
	Carbon steel	Ambient	2.25	Only for dedicated, non-corrosive systems (SAES-B-017)

Environment	Basic Material	Temp. (°C)	Max. Piping Velocity (m/s)	Remarks
	Galvanized steel	Ambient	2.25	Only for dedicated, non-corrosive systems (SAES-B-017)
	Carbon steel, cement lined or FBE coated	Ambient	3.0	See SAES-H-002
	Type 6Mo	Ambient	10.0	Welded with Alloy 625 filler wire
	25Cr Duplex	Ambient	10.0	F _{PREN} ≥ 42
	UL Listed CPVC	Ambient	2.4	For Fire Sprinkler system in Light Hazardous Occupancies (SAES-S-050)
Fire control, dedicated (seawater/utility), underground piping	RTR (epoxy resin)	1 - 93	5.0	SAES-B-017 and SAES-L-610
	HDPE	1 - 60	5.0	SAES-B-017 and 01-SAMSS-051
Fire control, non-dedicated / utility distribution, underground piping	RTR (epoxy resin)	1 - 93	5.0	See SAES-S-040
	HDPE	1 - 60	5.0	See SAES-S-040
	PVC	1 - 60	5.0	See SAES-S-040
Utility water (raw)	RTR (epoxy resin)	1 - 93	5.0	Base case (par. 4.3) SAES-L-610
	PVC	1 - 60	5.0	Base case (par. 4.3)
	CPVC	1 - 80	5.0	Base case (par. 4.3)
	HDPE	1 - 60	5.0	Base case (par. 4.3) See SAES-S-040 & 01-SAMSS-051
	Carbon steel with elastomeric lining	-	-	For storage tanks only See 32-SAMSS-005 and 01-SAMSS-041
	Carbon steel, cement lined or FBE coated	1 - 120	3.0	See SAES-H-002
	Copper	1 - 99	1.2	
Treated sewage effluent (TSE)	RTR (epoxy resin)	1 - 70	5.0	Base case (par. 4.3) SAES-L-610
	PVC	1 - 60	5.0	Base case (par. 4.3)

Environment	Basic Material	Temp. (°C)	Max. Piping Velocity (m/s)	Remarks
	CPVC	1 - 80	5.0	Base case (par. 4.3)
	HDPE	1 - 60	5.0	Base case (par. 4.3) SAES-S-040 and 01-SAMSS-051
	Carbon steel, cement lined or FBE coated	1 - 120	3.0	SAES-H-002
Seawater/saline water	RTR (polyester resin)	1 - 60	5.0	Base case (par. 4.3) SAES-L-610
	HDPE	1 - 60	5.0	Base case (par. 4.3) SAES-S-040 and 01-SAMSS-051
	PTFE/PFA lined carbon steel	1 - 230	5.0	01-SAMSS-025
	Carbon steel with elastomeric lining	-	-	For storage tanks only 32-SAMSS-005 & 01-SAMSS-041
	Carbon steel, cement lined	1 - 120	3.0	See SAES-H-002
	Carbon steel, FBE coated	0 - 50	6.0	Note that sand can cause erosion of the coating.
	90-10 Cu-Ni ⁽¹⁾	1 - 50	See Table 4	Alloy C70600
	Type 6Mo	1 - 50	10.0	Welded with Alloy 625 filler wire
	25Cr Duplex	1 - 50	10.0	F _{PREN} ≥ 42
Seawater injection	RTP	1 - 90	5.0	Base case (par. 4.3) API 15S
	RTR (epoxy-aromatic or cyclo-aliphatic)	1 - 93	5.0	Base case (par. 4.3) 01-SAMSS-042 , SAES-L-620 and SAES-L-650
	HDPE lined carbon steel	1 - 60	5.0	01-SAMSS-050
	Carbon steel, FBE coated	1 - 50	6.0	Filtered, deoxygenated and dechlorinated
Aquifer, desalination brine, produced water, disposal salt, water brine ⁽²⁾	RTR (epoxy resin)	1 - 93	5.0	Base case (par. 4.3)
	HDPE	1 - 60	5.0	Base case (par. 4.3) SAES-S-040 and 01-SAMSS-051
	PTFE/PFA lined carbon steel	1 - 120	5.0	01-SAMSS-025
	Carbon steel, cement lined	1 - 120	3.0	SAES-H-002

Environment	Basic Material	Temp. (°C)	Max. Piping Velocity (m/s)	Remarks
	Carbon steel, FBE coated	1 - 80	6.0	Only with corrosion inhibition. Sand can cause erosion of the coating.
	Carbon steel with elastomeric lining	-	-	For storage tanks only 32-SAMSS-005 & 01-SAMSS-041
	Type 6Mo	1 - 80	10.0	Welded with Alloy 625 filler wire
	25Cr Duplex	1 - 80	10.0	F _{PREN} ≥ 42
<i>Sanitary Sewer Systems</i>				
Gravity; hydrocarbon handling areas, underground	RTR (polyester resin)	1 - 60	5.0	SAES-S-010
	HDPE	1 - 60	5.0	Repair and rehabilitation only SAES-S-010
Gravity; Non-hydrocarbon handling areas, above ground	RTR (polyester resin)	1 - 60	5.0	SAES-S-010
	PVC	1 - 60	5.0	
	HDPE	1 - 60	5.0	Repair and rehabilitation only SAES-S-010
Force mains; hydrocarbon handling areas	RTR (polyester resin)	1 - 60	5.0	SAES-S-010
	HDPE	1 - 60	5.0	Repair and rehabilitation only SAES-S-010
Force mains; Non-hydrocarbon handling areas	RTR (polyester resin)	1 - 60	5.0	SAES-S-010
	PVC	1 - 60	5.0	
	HDPE	1 - 60	5.0	Repair and rehabilitation only SAES-S-010
Vent	RTR (polyester resin)	1 - 60	5.0	Base case (par. 4.3) SAES-S-010
	Galvanized steel	1 - 100	-	
Notes:				
(1) Continuous microbiological control is required in seawater service if stagnant or intermittent flow conditions are anticipated.				
(2) When internal coating is used for piping in water injection service, the weld root bead profiles shall be controlled, girth weld area coating shall be strictly monitored and controlled, corrosion control of flange faces shall be specifically addressed during design, and scraping facilities shall be provided in accordance with SAES-L-410 , Section 18.6.				

Table 4 - 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 5 - Alloy Material Definitions: Common Names and UNS Numbers ⁽¹⁾

Material	UNS Number
Alloy B2	N10665
Alloy 600	N06600
Alloy 400	N04400
Alloy 20	N08020
Alloy C-276	N10276
Alloy 625	N06625
Type 6Mo [Super Austenitic Stainless Steel]	S31254
25Cr Duplex ($F_{PREN} \geq 40$) [Super Duplex Stainless Steel]	S32750 S32760
90-10 Cu-Ni	C70600

Note: ⁽¹⁾ UNS means Unified numbering system for metals and alloys.

Table 6 - Non-Metallic Material Names

Abbreviation	Material
RTR	Fiber-reinforced plastic
PA	Polyamide
HDPE	High density polyethylene
PP	Polypropylene
PVC	Polyvinyl chloride
CPVC	Chlorinated polyvinyl chloride
PTFE	Polytetrafluoroethylene
PFA	Perfluoroalkoxy alkane