Engineering Standard

SAES-L-120 29 June 2010

Piping Flexibility Analysis

Document Responsibility: Piping Standards Committee

Saudi Aramco DeskTop Standards

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1 Scope

1.1 This standard defines the design requirements governing the flexibility analysis of piping systems and supplements ASME B31.1, ASME B31.3, ASME B31.4, and ASME B31.8 codes as applicable.

1.2 This standard is applicable to both onshore and offshore unrestrained piping systems including the transition piping sections between underground and above ground.

1.3 This standard is not applicable to fully restrained aboveground or underground and offshore sub-sea pipelines.

1.4 This standard is not applicable to both aboveground and underground nonmetallic process piping systems. Piping flexibility analysis for non-metallic piping in all area shall be according to ASME B31.3.

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-112	*Meteorological and Seismic Design Data*
SAES-L-100	*Applicable Codes & Standards for Pressure Piping Systems*

3.2 Industry Codes and Standards

American Society of Mechanical Engineers

ASME B31.1	*Power Piping*
ASME B31.3	*Process Piping*
ASME B31.4	*Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids*
ASME B31.8	*Gas Transmission and Distribution Piping Systems*

4 Definitions

Detailed Piping Flexibility Analysis: Detailed piping flexibility analysis is a detailed calculation using acceptable computer software to calculate the stresses, displacements and restraint forces of a piping system.

Formal Piping Flexibility Analysis: Formal piping flexibility analysis is a manual calculation to check the stresses, displacements and restraint forces of a piping system to verify code compliance.

Formal Review: Formal review as required in section 6 is a check for piping flexibilities of a line with the use of an acceptable industrial method such as chart or tables.

Plant Piping: Pressure piping system within an identified plant-area designed in accordance to ASME B31.1, ASME B31.3, ASME B31.4 or ASME B31.8.

Plant-Area: The designated area engaged in the production, processing, storage and transportation of crude oil, gas, refined products and their derivatives. It could be inside an onshore perimeter fence, or on the decks of offshore structures.

Transportation Piping: Pressure piping system that is designed in accordance to ASME B31.4 or/and ASME B31.8. Per SAES-L-100.

Fully Restrained Above-ground Piping: A pipeline or a pipe section which has neither vertical nor lateral movement. This could be achieved by means of structural elements for above ground lines such as **Ring Girders**.

Fully Restrained Underground Piping: A pipeline or a pipe section which has neither axial nor lateral movement because it is buried in the ground.

Pipe Anchors: Pipe anchor is a piping restraint, which restricts the line from transverse, axial, lateral and rotational movement.

Pipe Guide: A structural element which limits lateral movement of the line.

Line Stop: A structural element attached to the pipe, which limits its axial movement.

Ring Girder/Clamp: A structural element, which limits lateral and vertical movements of the line. Ring girder may allow axial line movement depending on their tightness.

Maximum Temperature: The maximum temperature in a piping system is the highest temperature expected in service, such as the fluid temperatures, ambient temperatures, solar radiation, heating or cooling medium temperatures.

Minimum Temperature: The minimum temperature in a piping system is the lowest expected temperature during service life.

Differential Temperature: Differential Temperature is the temperature range between the maximum and minimum temperatures.

5 General

5.1 Responsibilities

The design agency is responsible to ensure that every piping system has been checked and evaluated for flexibility and compliance with requirements of the applicable code. The design and analysis for the piping system shall be conducted by a qualified stress engineer.

5.2 Qualifications of the Stress Engineer

The stress engineer shall be qualified and experienced in the design and analysis of piping systems. The qualifications of the stress engineer shall be verified by CSD and approved by PMT or proponent and shall meet the following criteria as minimum:

- Completion of an engineering degree or equivalent from accredited organization.
- Minimum of 5 years experience in the design and analysis of pressure piping systems.

Deviation from the above requirements may be acceptable subject to the review

and approval by the Chairman of Piping Standards Committee in Consulting Services Department.

5.3 The flexibility analysis reports shall be recorded as part of the design package and submitted for review as outlined in Appendix A.

5.4 Flexibility analysis for piping system shall be in accordance with the applicable code allowable and shall be performed using the highest differential temperature imposed by design, operation, startup, shutdown, transient, steam out, and design contingency conditions. All credible thermal load combinations shall be considered.

5.4.1 Piping system shall have sufficient flexibility to prevent any of the followings:

- Failure of piping or support from overstress or fatigue.
- Leakage at joints.
- Detrimental stress or distortion in piping or connected mechanical equipment resulting from excessive thrusts and moments in piping.

5.4.2 The computed pipe movement shall be within the prescribed limit. Also, it shall be properly accounted for in the flexibility analysis.

5.4.3 The piping system behavior shall be studied such that it will not have any physical effect on adjacent system or equipments.

6 Piping Flexibility Analysis Requirements

6.1 The detail of the required piping flexibility analysis shall be in accordance to Appendix B and paragraph 6.3.

6.2 The following piping systems are exempt from both detailed and formal flexibility analysis requirements:

6.2.1 Fully restrained underground lines.

6.2.2 Fully restrained aboveground lines as defined in section 4. Using stress analysis considering straight pipe will not calculate the forces on the pipe supports.

6.2.3 Duplicate piping systems do not require individual formal piping flexibility analysis. One calculation is sufficient.

6.3 Detailed piping flexibility analysis shall be performed, as a minimum, for each of the following piping systems:

6.3.1 Lines under any of the following categories:

a) Lines in sour gas service 10 inches NPS or larger.

b) Lines in sour crude service 12 inches NPS or larger.

c) Aboveground flow-lines, test-lines and trunk-lines between two axial restrains such as camel crossings or anchors, etc.

d) Gas manifold headers in Gas Manifold Unit including future planned connections as defined in the DBSP.

6.3.2 Lines that contain expansion joints.

6.3.3 Lines supported by other lines if preapproved by the Chairman of the Piping Standards Committee.

Commentary Note:

Pipe sizes 2" and smaller supported by not less than 4 times its diameter pipe do not require approval if the stresses on both pipe are within the codes allowable.

6.3.4 Lines with internal refractory lining. The increased stiffness of piping systems caused by refractory lining shall be included in the piping flexibility.

6.3.5 Relief systems relieving to atmosphere. The discharge piping shall be restrained to contain the thrust loads.

6.3.6 Jacketed lines for 6" NPS and larger.

6.3.7 Lines connected to any of the following:

a) Fired heaters and steam generators.

b) Rotating equipment suction and discharge nozzles with NPS 2" and larger.

c) Air-cooled heat exchanger lines for 4" NPS and larger.

d) Reactors for all lines.

e) Pressure vessels and tanks lines for 8" NPS and larger.

7 Design Conditions

7.1 Temperature Range

The analysis shall be based on temperatures range as established by the design code. Range of thermal expansion shall be considered between minimum and

maximum temperature.

7.2 The following shall be considered for detailed piping flexibility analysis as a minimum:

a) Steam out condition for lines connected to vessel, which cannot be disconnected during steam out, etc.

b) The effect of solar radiation of 160°F should be considered on empty condition.

8 Load Conditions

It is the responsibility of the design agency, to identify the load combinations that a line will be subjected to during its service life. The following load cases shall be analyzed as a minimum:

8.1 Sustained load: this case will include, but not limited to: pressure, pipe weight plus content, weight of piping components, weight of the insulation, etc.

8.2 Thermal load: this case will cover the temperature range and any imposed thermal displacement.

8.3 Operational case: this case will cover the operational displacement of the piping system and loads exerted on any attached equipment.

8.4 Hydrotest Load: this case will cover the weight of test medium (water).

8.5 Occasional Load: this case will cover sustained load with loads due to an upset short duration condition, such as wind, earthquake, etc. Wind and earthquake loads shall not be simultaneously considered in the stress analysis.

8.5.1 Wind Loads

The exerted wind loads on the piping systems for 10" NPS and larger lines at 10 meters and higher shall be considered in the stress analysis. Refer to SAES-A-112 for environmental loads that may affect piping design.

8.5.2 Earthquake Loads

Earthquake loads shall be calculated per UBC Section 2336 and per SAES-A-112.

9 Special Requirements

9.1 External Load Limits on Equipment Nozzles

The maximum allowable loads exerted by piping on equipment nozzles shall be in accordance with equipment manufacturer recommendations or the applicable industrial code allowables.

9.2 Piping system subjected to water or steam hammer shall be analyzed accordingly. Forces due to water or steam hammer shall be determined to provide suitable support systems.

9.3 Pressure Relief Valves and De-pressuring System

For pressure relief valves and de-pressuring systems, analysis shall include:

a) The relief discharge reaction for open relief.

b) Piping flexibility for thermal expansion during hot relief or contraction during cold relief.

c) Dynamic loads from worst possible flow conditions.

9.4 External Localized Loads

The stress analysis shall take into account the circumferential bending stress in the pipe wall due to any loads from supports, anchors, and/or soil pressure or other external forces, except when transmitted through a full encirclement sleeve welded circumferentially to the pipe.

9.5 Friction Forces

Friction forces from supports and guides shall be considered as external localized loads acting in the direction opposite to the expected displacements.

In the absence of experimental or reliable Vendor's data, the friction factors in Table 1 shall be used for the flexibility calculation.

Table 1 – Friction Factors

Materials	Friction Factors
Steel to steel	0.40
Steel to steel round bar	0.30
Steel to concrete	0.60
Teflon to steel	0.20
Teflon to Teflon	0.10

Materials	Friction Factors
Sand to tape wrap	0.40
Sand to FBE coated	0.40
Sand to plastic coating	0.40
Sand to concrete	0.40

10 Limitations on Load Cases

10.1 Restrained Pipelines

A tie-in temperature range shall be established for the design and construction of all buried and above-ground fully restrained pipelines. The design shall be based on the maximum expected temperature rise during operation as well as the maximum anticipated decrease in temperature after tie-in.

10.2 Lined Piping

In case of cement-lined piping, the equivalent moment of inertia of the lined pipe shall be used and the maximum allowable bending stresses (not hoop stresses) in the steel shall be limited to 100 MPa (15 ksi).

10.3 Branch Connections

Branch connections to buried piping with end anchors (drag anchors) shall be designed with sufficient flexibility to withstand 50 mm axial movement of the mainline without overstressing the connection, unless such movement can be prevented.

For branch connection to an aboveground piping, consideration shall be given to movements of the header at the branch connection and the stress at the branch connection caused by the branch line due to thermal expansion.

10.4 Expansion Joints

Swivel joints, expansion joints, flexible pipe (metallic or nonmetallic), hoses or similar devices shall not be used to reduce the stiffness of the piping system or to reduce load on equipment nozzles in hydro-carbon, flammable, toxic and hazardous services.

They may be used for category D fluid service as defined in ASME B31.3. Expansion joints on lube oil systems in vendor standard designed lube oil skids may be acceptable subject to review and approval by the Chairman of Piping Standards Committee in Consulting Services Department.

10.5 Differential Settlement

For new design or when adding new equipments to existing plants, differential settlement between two foundations shall be considered in the pipe stress calculations.

When large, long-term settlement is expected for equipment, vessels, tanks, etc., the flexibility of the connecting piping and support scheme shall be carefully considered to minimize stresses and loads in the system.

As a guideline, settlement need not be included in the computer analysis when long-term settlement is less than ½". However, visual judgment shall be performed for the adequacy of the system for these small settlements.

10.6 Cold spring is not permitted to be used in the analysis.

Revision Summary

29 June 2010 Major revision.

Appendix A – Stress Analysis Reports Submittal

Case A: Detailed analysis using Computer software available in Saudi Aramco:
Detailed Piping Stress analysis reports shall include the following:

1. An electronic copy of the input files including all load cases. A clear description of the files contents shall be included
2. Operating/design parameters
3. Stress isometric drawings including the following:
   a) Node numbering
   b) Dimensions (which should be consistent with modeling unit system)
   c) Material specifications
   d) Details of the restraints
4. Summary report highlighting the following:
   a) Maximum stresses for all cases including the combined stress
   b) Maximum displacements
   c) Equipment nozzle qualifications
   d) Spring hanger reports
   e) Maximum restrain forces and moments
5. The manufacturer documents for the following, as applicable:
   a) Expansion Joints
   b) Spring hangers
   c) Process equipment nozzle allowable loads and moments
   d) Rotating equipment nozzle allowable loads and moments

Case B: Detailed analysis using Computer software not available in Saudi Aramco:

1. All the requirements presented for Case A.
2. Complete print out of the input and the output files including the following:
   a) Input data.
   b) Stress reports during operating, sustained and thermal explanation conditions.

c) Restraint report during operating, sustained and thermal explanation conditions.

d) Displacement report during operating, sustained and thermal explanation conditions.

Case C: Formal Manual Analysis

Formal Manual Piping Stress analysis reports shall include the following:

1. Operating/design parameters
2. Piping isometric drawings shall include the following:
   a) Dimensions
   b) Material specifications
   c) Location and Details of the restraints.
3. Hand Calculations
4. Referenced charts or tables if used.

Appendix B –Piping Flexibility Analysis Requirement Chart

B-1 This chart shall be used to identify the required piping flexibility analysis for power and process piping.

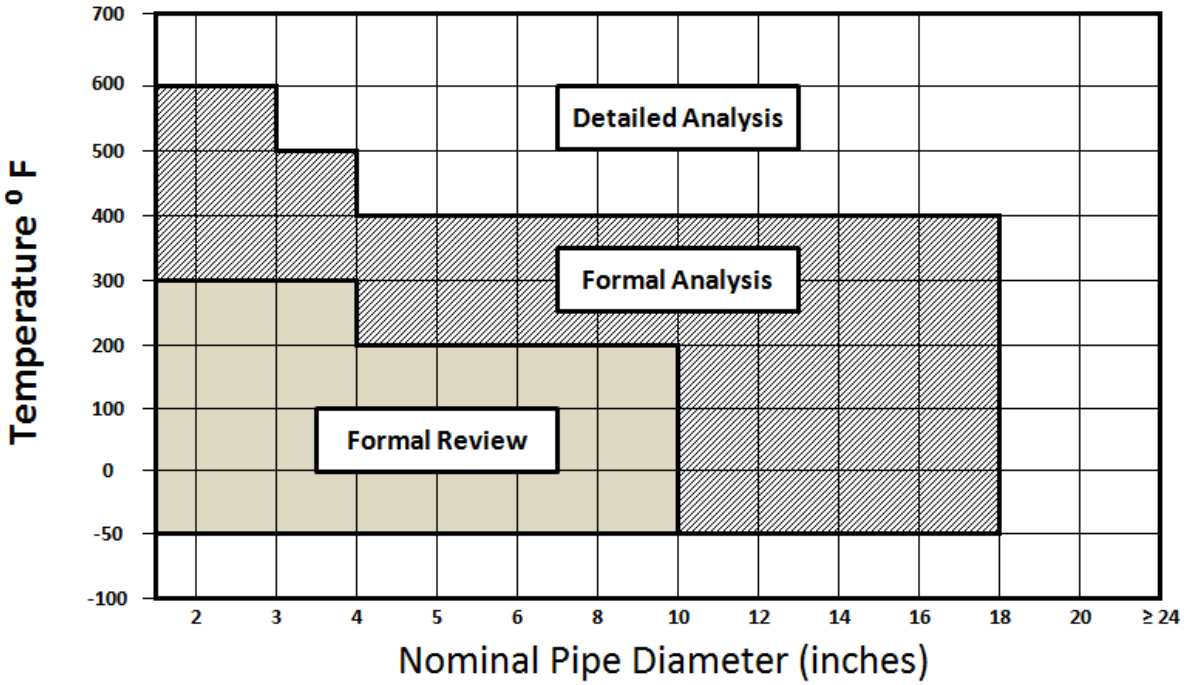

Chart-B-1: Piping Flexibility Analysis Requirements Chart for Power & Process Piping