Engineering Standard

SAES-L-120 30 April 2005

Piping Flexibility Analysis

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 piping sections which transition between underground and above ground.

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

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 Criteria*

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

4 Definitions

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

Plant Piping: Pressure piping system within an identified **plant-area** per SAES-L-100.

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.

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 table.

Pipelines: See definition of cross country pipelines per SAES-L-100.

Fully Restrained Above-ground Piping: A pipeline or a pipe section which has no axial nor lateral movement. This could be achieved by means of structural elements for above ground lines such **Ring Girders**.

Fully Restrained Underground Piping: A pipeline or a pipe section which has no 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.

5 General

5.1 Responsibilities

The design agency is responsible to insure that every piping system has been checked and evaluated for flexibility and compliance with requirements of the applicable code; this could be achieved by either performing a detailed **formal piping flexibility analysis** or a formal review using acceptable industrial methods such as chart, hand calculations, tables, etc.

5.2 Design Records

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

5.3 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 such as pumps, compressors, turbines etc. resulting from excessive thrusts and moments in piping.

6 Piping Flexibility Analysis Requirements

6.1 The following piping systems are exempt from formal flexibility analysis requirement:

6.1.1 Fully restrained underground lines.

6.1.2 Fully restrained aboveground lines as defined in section 4. The design agency is permitted to perform analysis to such piping to assess other design requirements such as pipe supports.

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

6.2 The formal analysis shall include calculations, using generally accepted computer software for piping flexibility analysis such as CAESAR-II.

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

6.3.1 Process and power piping as per the Chart-B-1 of Appendix-B of this standard.

6.3.2 Lines under any of the following categories:

a) Lines in sour gas service 4 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 header in Gas Manifold Unit.

6.3.3 Lines that contain expansion joints.

6.3.4 Lines with internal refractory lining.

6.3.5 Relief systems whether closed or relieving to atmosphere.

6.3.6 Lines subjected to slugging.

6.3.7 Jacketed lines for 6" NPS and larger.

6.3.8 Nonmetallic process lines.

6.3.9 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) Storage tanks lines for 12" NPS and larger.

6.4 Piping systems which will be subject to flexibility analysis shall be checked and evaluated for flexibility and compliance with requirements of the applicable code, manufacturer standards, vendor requirement and Saudi Aramco practices. Specifically this would include verification that pipe stresses and nozzle loads are below allowable.

It would also include the development of loads acting on restrains and verification of their acceptability. These loads would be used to define design load requirements for structures, brackets etc, as well as in the design and selection of pipe support attachments.

7 Load Conditions

7.1 It is the responsibility of the design agency, to identify the load combinations that a line will be subject to. The following load cases shall be analyzed as a minimum:

7.1.1 Sustained load condition: this will include, but not to be limited to: pressure, pipe weight plus content, weight of piping components, etc.

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

7.1.3 Operational case: this will combine both thermal and sustained together. This case may not be covered by some Codes, however it is the responsibility of the design agency to insure that such case is well analyzed based on good engineering practices.

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

7.2 A sufficient number of calculations shall be made to establish the most severe combinations of loading conditions which result in the highest combined piping stresses at various locations, the highest equipment loads, and the highest loads on anchors, connected equipment, guides, and stops.

7.3 Temperature Range

The analysis shall be based on different temperatures as established by the design specification.

Also, the following load cases shall be considered for formal piping flexibility analysis in addition to the design conditions 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.

7.4 Pressure Relief Valves and De-pressuring System

For Pressure Relief Valves and De-pressuring Systems, analysis shall include:

a) The relief discharge reaction.

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

c) Dynamic loads from worst possible flow conditions.

7.5 Wind Loads

The wind force on the piping system subjected to wind loading (NPS 10" and larger lines) shall be included in the formal analysis. Refer to SAES-A-112 for environmental loads that may affect piping design.

7.6 External Lateral Loads

The stress calculation 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.

7.7 Friction Forces

Friction forces from supports and guides shall be considered as external 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	0.45
Teflon to steel	0.20
Teflon to Teflon	0.10
Sand to tape wrap	0.25
Sand to FBE coated	0.20
Sand to plastic coating	0.20
Sand to concrete	0.40

7.8 Earthquake Loads

For design conditions which include occasional loads such as earthquake per SAES-A-112, or external hydrodynamic forces, or occasional short-term

pressure variation above the normal maximum, the pressure rating of components and/or the allowable stress may be increased as permitted by the applicable Code for such conditions without additional restrictions.

8 Limitations on Load Cases

8.1 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.

8.2 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).

Commentary Note:

The rational is that Stress Intensification Factor (SIF) values per ASME B31 Codes are mainly to ensure that steel pipe will withstand stresses due to thermal fatigue for the specified life of the piping system. The calculated stresses using the ASME B31 SIF are not actual stresses; they are called Code Stress.

8.3 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 above ground 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.

8.4 Expansion Joints

Swivel joints, expansion joints, flexible pipe (metallic or non-metallic), 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.

8.5 Differential Settlement

For new design or when adding new equipments in 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.

8.6 No credit shall be given to reduce stresses nor loads on nozzle connection by using cold spring because it is not permitted.

Revision Summary

30 April 2005	Revised the "Next Planned Update". Minor revisions to re-organize the standard, adding paragraph 7.8, creating a new section 8 out of the old sub-section 7.8. Creating new appendix to the old Chart-6.1 as an appendix for better organization.

Appendix A – Stress Analysis Reports Submittal

Case A: Computer software used in the analysis is available in Saudi Aramco: formal Piping Stress analysis reports should include the following:

1. An electronic copy of the input files for all cases evaluated.
2. Isometric drawing should include the following:
   a) Node numbering.
   b) Dimensions (which should be consistent with modeling unit system).
   c) Material specifications.
   d) Details of the restraints.
3. Summary report highlighting the following:
   a) Maximum stresses for all cases including the combined stress.
   b) Maximum displacements.
   c) Equipment loads.
   d) Spring hanger reports.
   e) Maximum restraint forces and moments.
4. The manufacturer data sheets for the following, as applicable:
   a) Expansion Joints.
   b) Spring hangers.
   c) Process equipment nozzle allowable stresses.
   d) Rotating equipment nozzle allowable load as per the manufacturer data sheet.

Case B: Computer software used in the analysis is 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.

Appendix B – Formal Piping Flexibility Analysis Requirement Chart

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

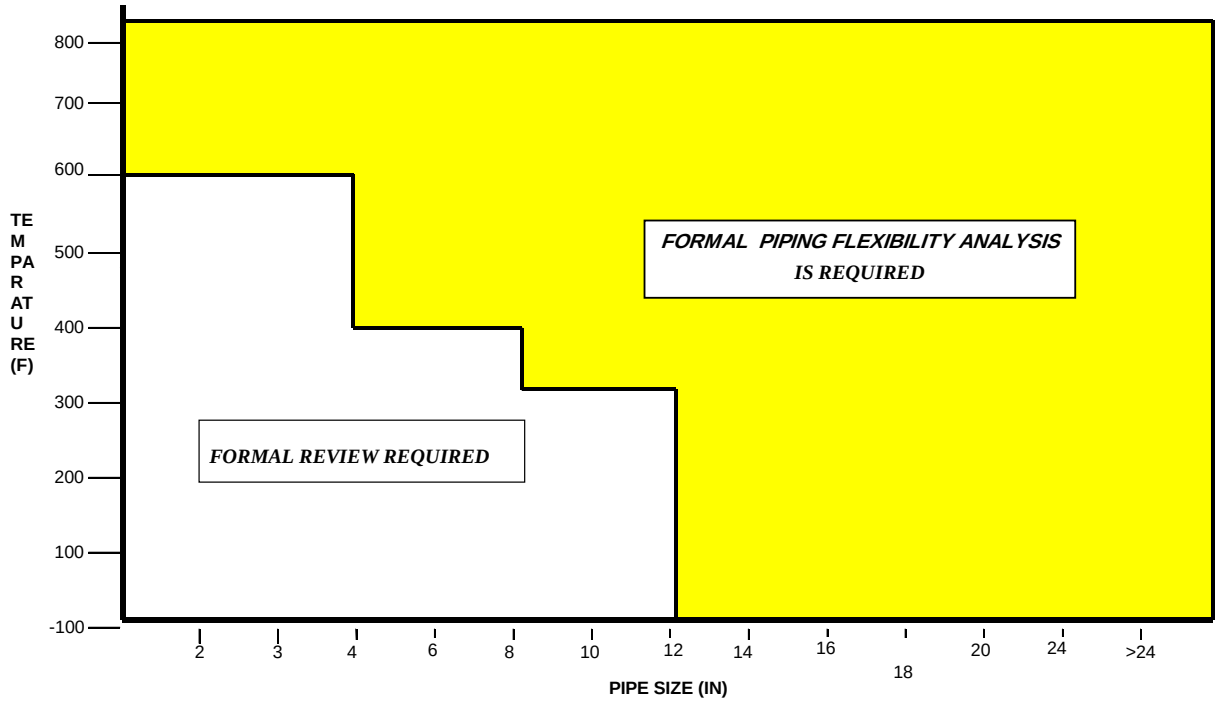

Chart-B-1: Formal Piping Flexibility Analysis Requirement Chart for Power & Process Piping