Engineering Standard

SAES-F-007 12 April 2006

System Design Criteria of Flares

Flare Systems Design Standards Committee Members
Nowaishi, Khalid Khalifah, Chairman
Pantula, Prasad Rama Kameshwara, Vice Chairman
Anizi, Salamah Salem
Awwami, Adnan Ni'Mah
Kim, Steve Un
Naffaa, Mahmoud Youniss
Sharhan, Ziyad Sharhan

Saudi Aramco DeskTop Standards

Table of Contents

1 Scope

1.1 This standard covers the minimum mandatory requirements for the system design and installation of flares used to burn combustible gaseous and liquid discharges in onshore and offshore installations and encompasses equipment and devices downstream of outlets of relief/depressurizing valves up to and including flare tips.

1.2 This standard also includes the system design of equipment used to separate liquid from discharges, where applicable.

1.3 This standard does not include design requirements for temporary flares (such as well flares) as well as incinerators or equipment used for the burning of combustibles on ships.

1.4 This entire standard may be attached to and made a part of purchase orders.

1.5 This standard covers the design requirements of new flares and the repair of existing flares.

2 Conflicts and Deviations

2.1 Any conflicts between this standard and other applicable Saudi Aramco Engineering Standards (SAESs), related 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 General Supervisor, Downstream Process Engineering Division 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.

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 Mandatory Saudi Aramco Engineering Requirement*

SAEP-354	*High Integrity Protective Systems Design Requirements*

Saudi Aramco Engineering Standards

SAES-A-102	*Air Pollutant Emission Source Control*
SAES-A-105	*Noise Control*
SAES-A-112	*Meteorological and Seismic Design Data*
SAES-B-006	*Fireproofing for Plants*
SAES-B-054	*Access, Egress, and Materials Handling for Plant Facilities*
SAES-B-055	*Plant Layout*
SAES-B-058	*Emergency Shutdown, Isolation and Depressuring*
SAES-B-063	*Aviation Obstruction Marking and Lighting*
SAES-B-067	*Safety Identification and Safety Colors*
SAES-D-001	*Design Criteria of Pressure Vessels*
SAES-H-001	*Selection Requirements for Industrial Coatings*
SAES-H-101	*Approved Protective Coating Systems*
SAES-L-350	*Construction of Plant Piping*
SAES-N-001	*Basic Criteria, Industrial Insulation*
SAES-N-100	*Refractory Systems*
SAES-N-110	*Installation Requirements - Castable Refractories*

Saudi Aramco Materials System Specifications

32-SAMSS-004	*Manufacture of Pressure Vessels*
32-SAMSS-022	*Flare Tips*

Saudi Aramco Engineering Report

SAER-5317	*Relief System Evaluation*

Saudi Aramco Forms

7305-ENG	*Equipment Noise Data Sheet*
9543-ENG	*Pressure Relief Device-Process Selection Basis for Flare Systems*
9544-ENG	*Flare Loading Summary*

9547-ENG	*Flare System, Flare Tip Data Sheet*
9548-ENG	*Flare System, General Data Sheet*
9549-ENG	*Flare System, Flare Knockout/Seal Drum Data Sheet*
9561-ENG	*Flare System-Process Data Sheet*
9562-ENG	*Flare System-Utility Data Sheet*

Saudi Aramco Standard Drawings

AE-036549	*Minimum Instrumentations for Separator Vessels*
AE-036550	*Branch Connections to Flare Headers*

3.2 Industry Codes and Standards

American Petroleum Institute

API RP 521	*Guide For Pressure-Relieving and Depressuring Systems, Fourth Edition, 1997*
API STD 526	*Flanged Steel Safety-Relief Valves, Fifth Edition, June 2002*
API STD 537	*Flare Details for General Refinery and Petrochemical Service*

International Society for Measurement and Control

ISA S84.01	*Application of Safety Instrumented Systems for the Process Industries*

4 Definitions

Acid Gas: A gas containing H_2S and/or CO_2, with a lower heating value of 18,600 kJ/scm (500 BTU/scf) or less.

Burn Pit: A pit where the flared fluids enter through a horizontal tip. The fluids are flared as they enter the pit. Usually a burn pit is used to flare a stream containing liquids.

Design Engineer: The Engineering Company responsible for specifying on the data sheets the process and mechanical design requirements for flare systems.

Dry Gas Seal: A device used to reduce the amount of purge gas required to maintain a safe level of oxygen upstream of the seal.

Enclosed Ground Flare: An enclosed ground flare's burners are inside a shell that is internally insulated. This shell reduces noise, luminosity, heat radiation and provides wind protection. A high pressure drop nozzle is usually adequate to provide the mixing necessary for smokeless operation. However, multi-jet, multi-tip, and multi-stage are utilized for these flares.

Flare Gas Recovery System (FGRS): A system to recover the daily normal continuous flare gas, and direct it back to the processing facility using a compressor.

Flare Manufacturer: The company responsible for the manufacture of complete flare systems, or components of flare systems, in accordance with 32-SAMSS-022.

Flare System: Includes all piping, valves, pressure vessels and devices downstream of relief/depressuring outlet block valves, to and including flare tip(s).

Flash Back Protection System: A system to prevent a flame front from traveling back to the upstream piping and equipment. Normally flash back is caused when air (oxygen) inadvertently introduced into the flare system.

HIPS: High Integrity Protective System is an instrumented shut down system that meets the minimum requirement of an ISA S84.01, SIL-3 system.

HPAAS: High Pressure Air Assist System for smoke suppression of flares. A system to achieve smokeless flare operation utlizing compressed air.

Incinerator: A furnace in which a combustible material is burned and in which the residence time and burning zone temperature are controlled.

Liquid Blowdown Drum: A vessel which retains liquid from a liquid closed drain and/or from safety relief valves in liquid service and discharges evolved vapor to the relief system.

Liquid Seal Drum: A horizontal or vertical vessel in which a liquid (usually water) level is used to maintain a positive pressure in the relief system upstream of the seal drum, under conditions of no flow. Also, used for staging between flares or a flare gas recovery system and a flare.

Main Flare Header: A main line (normally off-plot) which receives vapor or gas discharge from the unit headers or unit knockout drums and terminates at a flare or the base of the flare stack. The main flare knockout drum and/or liquid seal drum is in the main flare header unless they are located at the base of the flare stack.

Main Flare Knockout Drum: A vessel, located in either a main flare header or at the base of a flare stack, which removes liquids that condense in or are carried over into the flare system.

Maximum Continuous Flow: A flow which may be continuous for periods from a few minutes to days or weeks. An example is flaring associated gas. (The maximum continuous flow in a unit relief header, in a multi-unit plant, may not be the flow that contributes to the maximum continuous flow in the main flare header).

Maximum Instantaneous Flow: This flow is due to depressurization and/or an emergency relief. It is the maximum sum of the loads resulting from any single contingency considered for emergency relief and/or emergency shutdown requiring depressurization, and the plant(s) or unit(s) feed gas flow associated with that relief or shutdown situation.

Multitip Multistage Flare: A flare made up of a number of stages, where each stage usually has more than one tip. The tips are of proprietary designs and are designed to burn smokeless and with low radiation due to the high velocity flow from each tip. It is usually staged by means of control valves and rupture devices (as a safety backup to each control valve). It may be elevated or low level.

Normal Continuous Flow: The flow due to combustible purge gas and other small continuous sources and normal venting.

Commentary Note:

> *The value of normal continuous flow shall also include the leakage rate during normal plant operation, and be estimated based on the rate after five or ten years of operation. Rates are typically between 0.05 and 0.5% of the maximum instantaneous flow which must be quantified based on historical data of similar plant.*

P&ID: Piping & Instrument Diagram.

PFD: Process Flow Diagram.

Pipe Type Flare Tip: A flare tip which is constructed from a pipe or thin-walled hollow cylinder (sometimes called a barrel), with addition of pilots and flame retention devices for flame stability. The flare gas passes through the barrel.

Relief System: A system of valves and piping used during an emergency to rapidly reduce pressure in process equipment.

Saudi Aramco Engineer: Supervisor of the Flare & Relief Systems Unit of the Downstream Process Engineering Division, Dhahran.

Shock Chilling Effect: The temperature of a fluid causing shock chilling. Shock chilling is defined as the rapid decrease in temperature of a component caused by a sudden flow of fluid colder than -20°C (-4°F) and at a temperature lower than the initial temperature of the component by 40°C (72°F) regardless of pressure.

SIL-3: Safety Integrity Level 3 (SIL-3) refers to the ISA S84.01 definition of the probability of failure on demand for a Level 3 safety system. The probability of failure on demand for a Level 3 system is specified as 10^{-3} to 10^{-4}.

Unit Knockout Drum: A vessel, located in a unit or close to the boundaries of a unit which retains liquid carryover and/or condensate discharged from a unit relief header and discharges the vapor to a main flare header.

Unit Relief Header: A pressure relief line associated with a particular unit. Unit headers collect the vapors/liquids from the various safety relief and depressuring valve discharge lines for discharge to a unit knockout drum or to a main flare header.

5 Responsibilities

5.1 The Design Engineer is responsible for specifying the process and mechanical design requirements and completing the data sheets in accordance with this standard.

5.2 The Flare Manufacturer is responsible for the manufacture of flare system components, which includes the complete sizing, mechanical design, Code and structural calculations, supply of all materials, fabrication, non-destructive examination, inspection, testing, surface preparation, and preparation for shipment, in accordance with the completed data sheets and 32-SAMSS-022.

6 System Design

6.1 Design Considerations

6.1.1 General

Flare system and flare-tip type selection shall be based on an overall technical, envirnmental and economic evaluation. The Saudi Aramco Engineer together with the proponent, and Facilities Planning Department shall be involved in the initial scope development, determination of smokless capacity and selection of a flare system.

6.1.2 Reliability

To enhance the reliabilty of the larger diameter flare tips, a staged flare system is recommended. A flare gas recovery system (FGRS) is the preferred option for the first stage.

6.1.3 Smokeless Design

During technical evaluation of smokeless flare technologies, the in-house High Pressure Air Assist System (HPAAS) shall be the first choice to be considered.

6.2 Flare System Components

6.2.1 A flare system shall consist of (but is not restricted to) the following basic components:

1) Safety relief and/or depressuring valve discharge piping
2) Main and unit relief headers
3) Main flare knockout drum(s) and pump out facilities (except for burn pits)
4) Flare stack(s) [for elevated flare(s)]
5) Burn pit suitably lined with refractory, surrounded by a protective dike (for burn pits)
6) Flare tip(s)
7) Pilots
8) Ignition system
9) Flashback protection system
10) Monitoring panel
11) Flare gas flowmeters for low and high flaring ranges, and purge gas flow meter(s)

6.2.2 The need for the following components in a flare system shall be evaluated based on individual system requirements:

1) Seal (liquid or dry)
2) Isolation valves (in the relief piping)
3) Unit knockout Drum(s) and pumpout facilities
4) Liquid seal drum(s)
5) Unit isolation valves and spectacle blinds and purge connections.
6) Access platform for maintenance and operations.

6.3 Flare Gas Loads

6.3.1 A flare system shall be designed to handle normal continuous flows, maximum continuous flows, and maximum instantaneous flows. The base case for flare design is the conventional system, and shall not take into account instrumented safety shutdown systems. However, if major savings can be demonstrated by implementing instrumented safety shutdown systems (based on a life-cycle cost analysis), then the use of HIPS to be investigated and evaluated based on SAEP-354, High Integrity Protective Systems Design Requirements.

6.3.2 Potential tip damage due to operation at normal continuous flows shall be considered in evaluating the different flare systems and flare tips.

6.4 Design Temperature

6.4.1 The operating temperature shall be the temperature of gas/liquid being handled, taking into account the temperature change across valves.

6.4.2 A minimum margin of 30°C (54°F) shall be added to the maximum operating temperature to determine the design temperature.

6.4.3 The design temperature of piping, vessels, and attachments required for flare systems shall include consideration for shock chilling effects. Consider the gas expansion and/or liquid vaporization for light hydrocarbon or other materials which may lead to lower temperature conditions in a flare system, requiring a choice of material other than that which would be selected on the basis of maximum flare design temperature.

6.4.4 In all cases the materials of construction shall be suitable for the full range of design metal temperatures.

6.5 Design Pressure

6.5.1 The design pressure of a flare system shall be based on the maximum back pressure developed during flaring.

6.5.2 Under no circumstance shall the design pressure be less than 50 psig (345 kPag).

6.5.3 The Saudi Aramco Engineer shall specify:

1) The limiting process design pressure at the inlet of process unit knockout drums for special high pressure flare systems.
2) Any exceptions for low pressure systems.

6.6 Horizontal Spacing and Height

6.6.1 The spacing of flares from other equipment and facilities shall meet the minimum requirements to satisfy the following constraints:

1) Basic spacing
2) Thermal radiation
3) Air quality
4) Noise

6.6.2 For optimum location of a flare, normal wind direction must be considered. Flares shall be located in the prevailing crosswind direction of the facilities in order to prevent the flare from igniting any gases released from the plant.

6.6.3 The thermal radiation, air pollution and noise constraints shall be met by a combination of horizontal spacing and height.

6.6.4 The minimum horizontal spacing requirements for flares shall be in accordance with SAES-B-055.

6.7 Radiation

6.7.1 The location of flare systems shall include the effects of flare heat radiation on personnel. The maximum onshore permissible flare radiation levels for personnel exposure shall be as given in Table 1.

6.7.2 For offshore facilities, the maximum radiation limits for personnel shall be as follows (excluding solar radiation):

1) For maximum instantaneous flaring, 2000 BTU/hr-ft² (6.3 KW/m²)
2) For maximum continuous flaring, 1000 BTU/hr-ft² (3.2 KW/m²)
3) In a position where continuous manning may be required, 1000 BTU/hr-ft² (3.2 kW/m²)

Table 1 - Maximum Onshore Flare Radiation Intensities for Personnel Exposure, Excluding Solar Radiation

Flare Radiation		Conditions
kW/m²	BTU/hr-ft².	(Refer to Notes 1, 2 and 3)
1.6	500	Areas where personnel can be continuously exposed.
3.2	1000	Areas where personnel access shall be restricted (for onshore facilities).
4.7	1500	Areas where exposures up to several minutes may be required, with appropriate clothing.
6.3	2000	Areas where exposures of up to one minute may be required, with appropriate clothing.
9.4	3000	Areas where personnel have access, e.g., at grade below the

		flare, or on a service platform on a nearby tower. Exposure must be limited to a few seconds.

Notes:

1) Personnel can be continuously exposed in an area in which the total radiation when flaring would be 500 BTU/hr-ft² (1.6 kW/m²) from the flare, plus solar radiation.

2) On vessels, towers or other elevated structures where rapid escape is not possible, ladders must be provided on the side away from the flare, so that structures may provide some shielding when the flare radiation intensity is greater than 2000 BTU/hr-ft² (6.3 kW/m²).

3) Facilities adjacent to flares shall be evaluated for the acceptable radiation exposure.

Commentary Note:

The radiation levels of Table 1 are based on API RP 521, July 1993 Errata which recommends the above values for "Maximum Design Flare Radiation levels Including Solar Radiation". However, based on Loss Prevention Department recommendations, the acceptable flare radiation levels shall be based on the exclusion of solar radiation.

6.7.3 The maximum radiation intensity, excluding solar radiation, for equipment/structures shall be 3500 BTU/hr-ft² (11.0 kW/m²), except for flare headers for which 5000 BTU/hr-ft² (15.7 kW/m²) is acceptable.

6.7.4 Lower radiation limits may be required for equipment/structures sensitive to high temperatures.

6.7.5 For radiation calculations, a wind speed of 22 mph (32 ft/s) shall be used. When considering temperature sensitive equipment/structures a range of wind speeds must be used to estimate the maximum temperature.

6.7.6 The preferred method of radiation calculation for pipe type flares is in accordance with Brzustowski and Sommer's method as outlined in Appendix C of API RP 521. Any other method may be specified by the Design Engineer. However, these methods shall be approved by the Saudi Aramco Engineer. The Flare Manufacturer shall determine and guarantee the radiation levels for all flares to meet Saudi Aramco Requirements. The fraction of heat radiated "F factor" shall be determined based on the flare gas composition. In all cases the value of fraction of energy radiated shall not be less than 0.15.

6.7.7 For the maintenance of a flare tip while other flares are operating, locate flare stacks such that the radiation at flare tip maintenance platforms from any adjacent flares will not exceed 1000 BTU/hr-ft² (3.8 kW/m²) for maximum continuous flaring and 1500 BTU/hr-ft² (5.7 kW/m²) for maximum instantaneous flaring, excluding solar radiation.

6.7.8 When more than one elevated flare and/or ground flare are located in a common flare area, the maximum permissible radiation levels specified above are applicable to combined radiation from all flare systems in the area. However, if standby flares are provided, only one of two mutually replaceable units shall be taken into account for determination of the combined radiation levels.

6.7.9 The sizing and location of flares in a common flare area shall ensure the possibility of maintenance of standby units when other units are operating. The radiation level at a maintenance point shall not exceed 1500 BTU/hr-ft² (5.7 kW/m²).

6.7.10 For burn pit flares, the last 100 m (328 ft) of flare headers and auxiliary piping shall be buried underground or protected by radiation shields.

6.7.11 For burn pit flares, ignition panels should be protected with a radiation shield.

6.8 Air Quality

Ambient air quality constraints, as specified in SAES-A-102, shall apply, during flaring, to the air dispersion of pollutants and the resulting ambient air quality levels outside of the recognized or official boundary of the facility.

6.9 Noise Level

Allowable noise levels shall be determined by the Design Engineer in accordance with SAES-A-105. Allowable noise levels shall be specified on Saudi Aramco Form 7305-ENG.

6.10 Smokeless Flaring For Reduced Visible Emissions

6.10.1 Flares shall be designed with a smokeless capability sufficient to meet the opacity constraints of SAES-A-102.

6.10.2 Provide air-assisted or steam-assisted flares if the smokeless requirements cannot be satisfied with non-assisted flares.

6.10.3 Flares which are installed with one or more air blowers shall be capable of burning flare gas without blowers in operation. The use of two speed motors shall be considered. The tripping of blowers shall not cause flame out.

6.10.4 If a steam-assisted flare is selected, the Design Engineer shall determine the steam requirements for the flare, and consider these in the overall plant steam requirements.

6.10.5 If sufficient steam is not available, the smokeless capability may have to be reduced, subject to the approval of the Saudi Aramco Environmental Protection Department. Also, consider the use of air assisted or multitip flares to eliminate steam requirements.

6.10.6 If specified, provide an enclosed ground flare to handle normal plant operational flaring to eliminate smoke, radiation, and to reduce noise.

6.11 Acid Gas Flaring

6.11.1 For pipe-type flare tips 36 inch (914 mm) and smaller, the minimum acceptable lower heating value shall be 500 BTU/scf (18,600 kJ/scm). If the heating value of the gas is below this value, additional combustible gas shall be added so that the overall heating value meets the minimum required above. Assist combustible gas shall be added into the acid gas flare header far enough upstream to ensure good mixing.

6.11.2 For pipe-type flare tips 36 inch (914 mm) and smaller, the tip exit velocity (for acid gas plus assist combustible gas) shall be limited to a maximum of 145 ft/s (45 m/s).

6.11.3 For pipe-type flare tips larger than 36 inch (914 mm) that do not use assist fluid for smokeless operation, lower heating values or higher velocities may be used if desired for economic reasons, with the recognition that there is not the same assurance of stable burning as for the conditions in 6.11.1 and 6.11.2. The flare tip manufacturer's recommended (based on assisted gas and acid gas compositions) minimum heat content versus maximum tip velocity relationship should be used to determine the limiting values. In all cases the lower limit of minimum heat content used for design shall be a lower heating value of 350 BTU/scf (13,000 kJ/scm). All flares in this category shall be reviewed by the proponent and the Saudi Aramco Engineer.

6.11.4 The use of proprietary flare tips that are especially designed for burning low heat content gases shall be reviewed with the Saudi Aramco Engineer.

6.11.5 The designer shall consider the possibility of solids deposition in an acid gas flare system, and design the system to handle such solids as may form.

6.12 Offshore Flaring

Manned platform complexes shall be provided with a flare that is located on a separate structure remote from other platforms and joined to other platforms by a bridge mounted relief header with a personnel access way.

6.13 Burn Pit Flares

Exception:

> *Except for remote areas or exclusively industrial locations, where there are essentially no spacing limitations, avoid burn pit flares. Provide burn pit flares when specifically requested by the Saudi Aramco Engineer, and approved by the Saudi Aramco Environmental Protection Department Manager.*

6.14 Relief System Piping

6.14.1 Relief system piping shall be designed taking into consideration all factors noted in API RP 521, paragraph 5.4.1.3.

6.14.2 Relief lines shall be sized to ensure that back pressures developed during flaring do not affect the flowing capacity of safety relief valves, depressuring valves or pressure control valves that discharge into a flare system. Consideration must be given to separate high and low pressure flare systems instead of combined large high and low pressures in order to minimize header sizes. Downstream Process Engineering Division approval is required for flare headers and flare tips larger than 48 in (1219 mm) diameter.

6.14.3 Relief system piping shall be evaluated for acoustically induced vibration as per SAER-5317 as well as potential vibration from all sources, including dead-leg effects, slug flows, shock loading and shock waves, wave refraction and rarefaction, turbulence generated in the flare systems and relief valve "chattering".

Commentary Note:

> *SAER-5317 contains empirical formulas resulting from field tests of acoustic vibrations resulting from pressure drops across control valves. These formulas may be used as reference for the evaluation of acoustical vibration due to high sound levels in flare systems.*

6.14.4 All piping (including headers between flare knockout drums and flares) shall be self-draining into unit and/or flare knockout drums. A minimum slope of ¼ inch in 10 feet (21 millimeters per 10 meters) is required for all relief and flare piping.

6.14.5 Liquid pockets must be avoided. However, if pockets are unavoidable, provide either a drum with automatic disposal to the main flare line or pump-away capacity. Disposal of the liquid to a lower elevation sump via liquid disposal control valves (or liquid seal systems) is an acceptable alternative to pumpout facilities.

6.14.6 Laterals for pressure relief valves, depressuring valves and pressure control valves shall enter the flare header from above and at an oblique angle to the header. Reference Saudi Aramco Standard Drawing AE-036550.

6.14.7 Headers shall be at least the same size as the laterals, and preferably shall be at least one pipe size larger.

6.14.8 If a flare system serves more than one unit, a block valve and spectacle blind at the unit plot limits are required to allow the unit to be taken out of service for turnarounds without having to take down all units connected to the flare system. Provide a 2 inch (50 mm) gate valve with a blind flange for vent connection on the unit side of this isolation valve for purging the unit flare header prior to the unit startup.

6.14.9 When isolation valves are required in the relief piping, they shall be provided with locking or sealing devices and painted orange.

6.14.10 Header piping must be adequately supported. If liquid can be introduced at the same time that vapor is flowing into the system, the potential for slug flow must be considered. If slug flow can occur, piping bends must be supported for slug flow, or local knock-out drums shall be added.

6.14.11 Header piping must be designed to allow for thermal growth during releases. The maximum heat radiation for long flaring durations shall be used to determine the hot spot temperatures of the exposed parts of the flare header to be considered for designing the thermal expansion loops in the flare header at the hot spot places.

If slug flow can not be eliminated, both the requirement of 6.14.10 and this paragraph shall be satisfied.

Commentary Note:

> *Designs that allow for thermal growth often are in conflict with providing the rigid support required to resist slugs flow.*

6.14.12 Block valves used for flare systems shall be installed such that valve stems are oriented 45° below horizontal and shall not pose an obstruction to normal personnel access in the walkway.

6.15 Knockout Drums

6.15.1 Knockout drums may be designed to incorporate the function of a liquid seal drum. However, combination drums, in which the knockout and seal functions are in the same compartment, shall only be used in those systems where carryover is not expected because of the process or because of upstream liquid knockout drums.

6.15.2 A liquid/water seal drum shall be designed to minimize the accumulation of hydrocarbon liquid.

6.15.3 Knockout drums may be designed to incorporate the function of a liquid blowdown drum.

6.15.4 The design of a gravity separation (knockout) drum shall be based on the method of API RP 521, paragraph 5.4.2.1.

6.15.5 The maximum design liquid level for horizontal unit knockout drums and for those horizontal main flare knockout drums not in series with unit knockout drums shall be 50% of the drum diameter. Main flare knockout drums in series with unit knockout drums may have design levels up to 80% of the drum diameter.

6.15.6 Knockout drums shall have sufficient capacity to ensure residence time in excess of particle drop-out time based on the drop-out velocity required to remove particles larger than 400 microns.

6.15.7 The hold-up capacity of liquid in knockout drums, due to emergency releases, shall be sized for a minimum release of 20 minutes duration with no pump-out. Consideration shall be made for vapor condensation in flare lines during cold weather. This liquid capacity is in addition to that which may be required for liquid closed drain header requirement, if the vessel is also a liquid blowdown drum.

6.15.8 Knockout drums shall not include demister pads or other devices prone to fouling. Vessels of proprietary design that include non-fouling internals to minimize vessel sizes for liquid separation may be used.

6.15.9 Consider providing each unit knockout drum with an internal liquid seal if discharging direct to a flare stack without an off-plot knockout drum.

6.15.10 The need for a unit knockout drum and pumpout facilities located above ground on each process unit, or group of units when two or more units are grouped together and are to be shutdown together, shall be evaluated.

6.15.11 Provide a main flare knockout drum (on the common flare line) close to the flare stack for any of the following cases:

1) Flare line serves more than one operating unit.

2) Distance from process unit to flare stack exceeds 200 m (656 ft).

3) Condensation rate in flare lines is sufficient to make liquid drainback from stack to on plot knockout drum impractical.

6.15.12 Flare knockout drums and pumpout facilities shall be located above ground.

6.15.13 Select the location of main flare knockout drums to ensure personnel working on equipment will not be subjected to a heat intensity (excluding solar radiation) higher than 1500 BTU/hr-ft^2 (4.7 kW/m^2) under design flaring conditions.

6.15.14 If the distance from the main flare knockout drum to the base of the flare exceeds 100 m (328 ft), it shall be approved by the Saudi Aramco Engineer.

6.15.15 Each drum shall be equipped with two automatically operated pumps, one on primary stand-by, one on secondary stand-by. Disposal of the liquid to a lower elevation sump via liquid disposal control valves (or liquid seal systems) is an acceptable alternative.

6.15.16 The minimum required capacity of each pump/line shall be based on pumping out or draining the total drum contents from the maximum accumulated liquid level to low liquid level in two hours.

6.15.17 If both pumps are motor driven, each motor shall be supplied from a separate (physically separated) double-ended (secondary selective) switchgear lineups and the normal feed for each motor shall be from a different source of incoming power (i.e. different transmission lines). Where separate sources of incoming power are not available, one motor shall be fed from a generator that is either on-line continuously or capable of being automatically started and put on line within one minute. A diesel engine to drive the pump is an acceptable alternative to the generator and electric motor driven pump.

6.15.18 The minimum instrumentation requirements on each drum are local pressure gauge, level gauge, level switches to start/stop pumps, and high and low level alarms with remote indications. See Saudi Aramco Standard Drawing AE-036549.

6.15.19 The high-high and low-low level alarms should be entirely independent from the start/stop switches and their vessel connections. There shall be remote indication of the operating status of each pump. Remote indications of the high and low level alarms and status of each pump shall be in a constantly attended location.

6.16 Flare Tips

6.16.1 Flare tips shall maintain a stable flame over the entire operating range and shall minimize flare tip and auxiliaries damage at low flows.

6.16.2 The velocity of vapors at the flare tip shall be (both for the maximum instantaneous and normal continuous flaring) within the bounds that allow for stable flame performance and proper combustion of the material being flared.

6.16.3 The effect of normal continuous daily flaring, maximum continuous flaring, maximum instantaneous flaring and instantaneous flow changes within these flaring rates, with a sustained wind velocity from zero to maximum design wind speed shall be investigated.

6.16.4 Flare tips shall be designed to minimize flame impingement on the outside or the inside of the tip and on any part of the support structure regardless of gas flow rate, wind speed or wind direction.

6.16.5 For maintenance purposes, means shall be provided for access to and lowering of the flare tip of elevated flares. Access shall also be provided to the flare tip of ground flares and the manways of elevated flares.

6.16.6 Pipe-type flares shall employ a retention device to minimize flame lift-off and blow-out. Proprietary tip designs, which achieve the same objectives, may be used.

6.16.7 Multi-tip, multi-stage flares shall be designed to minimize air ingression. The need for inert purging of multi-tip multi-stage flares shall be evaluated.

6.16.8 Single tip flare tips shall be flanged to allow removal for repairs. Headers to individual stages of multi-tip, multi-stage flares shall be flanged where necessary to allow inspection and cleaning.

6.16.9 The mechanical design, fabrication, materials and inspection of flare tips and ancillaries connected to the flare tip, including pilots, barrels, steam piping, steam jets, and nozzles where applicable, shall be in accordance with 32-SAMSS-022.

6.16.10 Refractory shall be in accordance with SAES-N-100 "Refractory Systems". When outside refractory is specified, inside refractory must also be specified.

6.17 Flare Stacks

6.17.1 Flare stacks shall be designed to drain to main flare knockout drums or liquid seal.

6.17.2 Aviation obstruction lighting/marking shall be provided if required by SAES-B-063.

6.17.3 A hanger system shall be used that will allow the top-most set of lights to be lowered away from the tip when the flare is in operation.

6.17.4 A minimum 30 in (762 mm) diameter manway at the base of the stack shall be provided for inspection and maintenance. In cases where the diameter of the stack is too small to accommodate a 30 inch (762 mm) minimum inside diameter manway, the largest size manway down to 18 in (457 mm) or inspection openings for smaller sizes shall be specified. The minimum sizes shall be in accordance with the design Codes. All manways shall comply with the requirements of SAES-D-001.

6.18 Pilots

6.18.1 Continuous pilots shall be required and shall be designed to ignite the flare gas over the entire operating range of flares and wind speeds.

6.18.2 Pilot lines downstream of fuel gas filter to flare tip shall be manufactured from 316 stainless steel.

6.18.3 Pilots and upper sections of pilot gas lines shall be constructed of materials selected in accordance with paragraph 6.16.9.

6.18.4 Pilot gas systems shall be designed to supply clean, dry and solids-free gas. Gas flows shall be assured under any single contingency, including plant startup.

6.18.5 In facilities where production trap gas must be used, aspirators shall be located at or near grade for maintenance accessibility.

6.18.6 A thermocouple system shall be provided to monitor pilot flames. A flame-out alarm and separate indication for each pilot shall be included. The indication shall be in a constantly attended area.

6.18.7 Thermocouples shall be located in a thermowell inside pilot heads to protect against flame impingement. Pilot flame-out shall be indicated if a thermocouple fails. Consider a grade mounted infrared detector for monitoring pilots on elevated flares as a backup for thermocouples.

6.18.8 Each pilot shall be provided with a thermocouple. Each thermocouple shall be dual-element type. One element of each thermocouple shall be used, with the other terminated at the grade junction box and available as a spare.

6.18.9 The minimum number of pilots shall be in accordance with the Table 2. The flare tip manufacturer should specify additional pilots if he deems necessary.

6.19 Ignition Systems

6.19.1 A remote operated flame front generator ignition system shall be used. Ignition controls shall be located outside of the 1500 BTU/hr-ft² (4.7 kW/m²) radiation zone. For a flame front ignition system, the distance between the flare and the flame front generator shall be minimized. Other types of ignition systems may be acceptable subject to prior approval of the Saudi Aramco Engineer, and the Proponent.

6.19.2 Ignition lines from the flame front generator panel to the flare tip shall be manufactured from type 316 stainless steel. The tip mounted section of the ignition system shall be constructed of materials selected in accordance with paragraph 6.16.9.

6.19.3 One type 316 stainless steel fuel gas supply line is required for each pilot burner. A filter shall be installed between carbon steel fuel gas supply lines to the stainless steel fuel gas supply lines to pilots.

6.19.4 Pilot lines and ignitor lines shall be piped separately between the proximity of flame front generators and flare tips.

Table 2 – Minimum Recommended Number of Pilots

	Tip Diameter	Number of Pilots
Pipe-type Acid-gas Flares	Up to 8 inches (203 mm) 10 inches (254 mm) to 40 inches (1016 mm) 42 inches (1067 mm) and above	2 3 4
Other Pipe-type Flares	Up to 8 inches (203 mm) 10 inches (254 mm) to 18 inches (457 mm) 20 inches (508 mm) to 46 inches (1168 mm) 48 inches (1219 mm) and above	1 2 3 4

6.19.5 Piping shall be flanged at the flame front generator and the bottom of tip assemblies to facilitate the removal of flare tips.

6.19.6 All controls required shall be provided to ensure that each pilot can be ignited individually.

6.19.7 Ignitor gas shall be dry and clean (with respect to liquids and solids) and shall be either fuel gas or bottled gas.

6.19.8 Flame front ignition piping shall be designed to minimize low points. Low points, if required, are to be at ignition panels and/or at the flare. Drains and boots shall be provided and located at all necessary low points.

6.20 Flashback Protection Systems

6.20.1 A flashback protection system, by means of a gas purge, is required to prevent the accumulation of explosive mixtures of gas and air in a flare system whenever the waste gas flow rate to a flare tip is less than the required purge rate.

6.20.2 A liquid seal drum may be used in addition to purge gas as flashback protection for flare headers and for in-plant piping.

6.20.3 Flare systems shall be swept with inert gas prior to plant start-up and operation.

6.20.4 The flare system should be provided with a purge gas system. These purges should enter the headers at their far upstream ends and be controlled by a flow regulator with flow indicator.

6.20.5 If a vacuum could occur, purge gas on pressure control shall be provided upstream of the liquid seal drum to maintain positive pressure. Purge gas shall be provided downstream of the seal drum to provide the purge rates specified at the flare tip.

6.20.6 A flame arrestor shall not be used as flashback protection.

6.20.7 Clean (with respect to solids and liquids) and oxygen-free combustible gas, or low oxygen content inert gas, shall be used for purge gas.

6.20.8 Gas flow shall be assured during any single contingency. The maximum allowed oxygen limit in inert gas must be determined separately for each installation.

6.20.9 The flow of flare purge gas shall be independent of all other users and shall not be subject to failure due to a single contingency.

6.21 Purge Gas Rates

6.21.1 When dry gas seals are used, the minimum purge gas rate to prevent air ingression below the seal shall be that recommended by the seal vendor. The Saudi Aramco Engineer may specify a higher rate.

6.21.2 For vertical pipe flares without a dry gas seal, the purge system shall be able to provide at least ½ ft/s (0.15 m/sec) velocity at the tip.

6.21.3 For horizontal pipe flares, the purge system shall be able to provide at least 1 ft/s (0.30 m/sec) velocity at the tip, when using a combustible purge gas, even if the tip has a dry gas seal.

6.21.4 The minimum purge gas rate for multi-tip, multi-stage flares or other proprietary flares shall be specified by the Flare Manufacturer and approved by the Saudi Aramco Engineer.

6.21.5 Purge rates higher than those specified in this standard may be required after flaring a hot gas or condensable vapor.

6.22 Liquid Seal Drums

6.22.1 Liquid seal drums shall be located as close as possible to flares (limited by the thermal radiation constraints). For elevated flares, the drum may be an integral part of the flare stack base.

6.22.2 The critical vapor velocity used in the design of a gravity separation liquid seal drum shall be no greater than 11.5 ft/s (3.5 m/sec). A Flare Manufacturer's proprietary design, with internals, may be used.

6.22.3 The ends of inlet pipes into drums shall be designed, or drum internals provided, to minimize flame pulsation.

6.22.4 The filling rates of seal liquid shall be sufficient to re-establish the seal within 5 minutes if a seal is broken. An alarm, located in the control room, shall indicate if the seal is broken.

6.22.5 Seal liquid shall be protected from freezing down to the minimum flare gas or ambient temperature, or a glycol solution may be used.

6.22.6 Liquid seals may be incorporated into a knockout drum in special circumstances or both functions may be contained in separate compartments in a single vessel.

6.22.7 For liquid seals handling H_2S-bearing gas, the liquid shall be disposed via a closed system and in an environmentally acceptable manner.

7 Mechanical and Structural Design

7.1 Piping

7.1.1 The mechanical design of piping, valves, and fittings required for flare systems shall be specified by the Design Engineer in accordance with Saudi Aramco's L-series Engineering Standards.

7.1.2 The material selection, fabrication and Inspection of piping, valves, and fittings required for flare systems shall be specified by the Design Engineer in accordance with Saudi Aramco's 01 and 02 series Materials System Specifications.

7.1.3 The construction of piping shall be specified by the Design Engineer in accordance with SAES-L-350.

7.1.4 The mating flange of pressure safety relief valves (PZV's) shall comply with the requirements of API STD 526.

7.2 Vessels

7.2.1 The mechanical design of knockout drums shall be specified by the Design Engineer in accordance with SAES-D-001.

7.2.2 The material selection, inspection and fabrication of vessels shall be specified by the Design Engineer in accordance with 32-SAMSS-004.

7.3 Refractory and External Insulation

7.3.1 The design of refractory and external insulation shall be specified by the Design Engineer in accordance with SAES-N-100, and SAES-N-001.

7.3.2 The installation of castable refractory shall be specified by the Design Engineer in accordance with SAES-N-110.

7.4 Painting

7.4.1 The selection of the type of paints and coatings shall be in accordance with SAES-H-001.

7.4.2 The Approved Protective Coating Systems (APCS) shall be selected from SAES-H-101 and specified on the data sheets together with the applicable Class 09 Saudi Aramco Materials System Specification for the surface preparation and painting systems.

7.5 Structural

7.5.1 The Design Engineer shall determine the basic wind speed corresponding to the Saudi Aramco site in accordance with SAES-A-112. The basic wind speed shall be specified on the data sheets.

7.5.2 The Design Engineer shall determine the earthquake zone, soil coefficient and effective peak acceleration ratio (Av) corresponding to the Saudi Aramco site in accordance with SAES-A-112. The earthquake zone and site soil coefficient shall be specified on the data sheets.

7.6 Fireproofing

Fireproofing of equipment shall be in accordance with SAES-B-006.

7.7 Emergency and Isolation Valves

Emergency, isolation, shutdown, and depressurizing valves shall be determined in accordance with SAES-B-058.

8 Design Information

8.1 General

8.1.1 The Design Engineers shall complete all required design data as specified on Saudi Aramco Forms 7305-ENG, 9543-ENG, 9544-ENG, 9547-ENG, 9548-ENG, 9549-ENG, 9561-ENG, and 9562-ENG for both new and modified flare system.

8.1.2 When a new flare system is integrated into an existing flare system, the information required for the existing facilities shall be developed by the Design Engineer from the PFDs, P&IDs and values relief loadings.

8.2 Required Documents

The following documents are required in addition to flare system PFDs and P&IDs.

8.2.1 Relief/Flare System Analysis Report

This report serves as a design basis for new or modified facilities. The report outlines all failure modes, effects and sizes of pressure relief, depressurizing valves and flare systems to prevent any failure. The report shall include the following:

1) Equipment which may be overpressured due to abnormal operating conditions and determine the location of depressuring valves.

2) Relief loads resulting from various contingencies and the disposition of relief discharges.

3) The maximum (controlling) relief load for each PZV, the PZV type and size.

4) Plant ESD(s) if required.

The scope of the report shall include each unit which is discharging into the flare system. Additionally the report shall specify total loads into each flare system from various units connected to the flare. Following are the minimum required data for this report.

8.2.2 Summary Sheets (Forms 9543-ENG and 9544-ENG)

A relief valve and depressuring valve load summary sheet, by unit for valves tied into a flare system, and shall include the following data:

1) Vessel numbers

2) Relief and depressuring valve numbers

3) Relief or depressuring set pressure

4) Relieving pressure and temperature

5) All relief and depressuring loads and causes of loads, including safety relief valve loads that do not govern the sizes of pressure relief valves

6) Molecular weights of relief loads

7) Compressibility factor

8) Identification of loads which could relieve simultaneously to a closed safety relief/flare system for a single cause, such as total and partial power failure

9) Outlet valve, stream temperature.

10) Maximum emergency relief loads used to design unit headers, main header(s), and flare(s)

11) Maximum backpressure on each pressure relief valve

12) Disposition

8.2.3 Flare Schematic Diagrams

The Design Engineer shall prepare a schematic diagram for the flare system from pressure relief and vapor depressuring valves to flare tip(s). This schematic diagram shall cover all vessels, pumps, and equipment in a flare system, and include the following information:

1) Flare line sizes and line slope
2) Equivalent lengths of line sections
3) Vessel equipment numbers and their relative locations
4) Safety relief/depressuring valve numbers
5) Identity of those valves which could simultaneously contribute to the maximum continuous, and maximum instantaneous flaring used to design main header(s), knockout drum(s) and flare(s)
6) Maximum and allowable back pressures at each valve.

8.2.4 Calculation Sheets

Calculation sheets shall include the pressure relief and depressurizing calculations used to establish loads, and flare system component sizing calculations. In addition, calculation sheets shall include fluid composition data used in the calculations, and a set of simulation inputs and outputs.

8.2.5 Radiation Map

A radiation map shall be prepared and show the radiation intensity contours at 500 BTU/hr-ft^2 (1.6 kW/m^2), 1000 BTU/hr-ft^2 (3.2 kW/m^2), 1500 BTU/hr-ft^2 (4.7 kW/m^2), and 3000 BTU/hr-ft^2 (9.4 KW/m^2). The radiation intensities shall be calculated at grade (or offshore platform levels) and at higher operating platform levels in the vicinity of the flare.

9 Maintenance and Repairs

The maintenance and repair of Flare systems, including replacement in-kind, shall be in accordance with the original design modified by Technical Alerts, inspection history, and industry practices. For assistance in the incorporation of these modifications, consult the Saudi Aramco Engineer.

	Revision Summary
29 October 2003	Major revision.
12 April 2006	Minor revision.