أدنــوك
ADNOC

ADNOC GROUP PROJECTS & ENGINEERING

FLARE & BLOWDOWN PHILOSOPHY

Philosophy

AGES-PH-08-002

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GROUP PROJECTS & ENGINEERING FUNCTION/ PT&CS DIRECTORATE

CUSTODIAN	Group Projects & Engineering / PT&CS
DISTRIBUTION	Specification applicable to ADNOC & ADNOC Group Companies

The Group Projects & Engineering Function is the owner of this Specification and responsible for its custody, maintenance and periodic update.

In addition, Group Projects & Engineering Function is responsible for communication and distribution of any changes to this specification and its version control.

This document will be reviewed and updated in case of any changes affecting the activities described in this document.

INTER-RELATIONSHIPS AND STAKEHOLDERS

1.1 The following are inter-relationships for implementation of this Specification:

(a) ADNOC Upstream and ADNOC Downstream Directorates; and

(b) ADNOC Onshore, ADNOC Offshore, ADNOC Sour Gas, ADNOG Gas Processing. ADNOC LNG, ADNOC Refining, ADNOC Fertilisers, Borouge, Al Dhafra Petroleum, Al Yasat

1.2 The following are stakeholders for the purpose of this Specification:

(a) ADNOC PT&CS Directorate

1.3 This Specification has been approved by the ADNOC PT&CS is to be implemented by each ADNOC Group company included above subject to and in accordance with their Delegation of Authority and other governance-related processes in order to ensure compliance.

1.4 Each ADNOC Group company must establish/nominate a Technical Authority responsible for compliance with this Specification.

Definitions:

'ADNOC' means Abu Dhabi National Oil Company.

'ADNOC Group' means ADNOC together with each company in which ADNOC, directly or indirectly, controls fifty percent (50%) or more of the share capital.

'Approving Authority' means the decision-making body or employee with the required authority to approve Policies and Procedures or any changes to it.

'Business Line Directorates' or **'BLD'** means a directorate of ADNOC which is responsible for one or more Group Companies reporting to, or operating within the same line of business as, such directorate.

'Business Support Directorates and Functions' or **'Non- BLD'** means all the ADNOC functions and the remaining directorates, which are not ADNOC Business Line Directorates.

'CEO' means chief executive officer.

'Group Company' means any company within the ADNOC Group other than ADNOC.

'Standard' means normative references listed in this specification.

'COMPANY' means 'Abu Dhabi National Oil Company or any of its group companies. It may also include an agent or consultant authorized to act for, and on behalf of the COMPANY'.

'CONTRACTOR' means the party which carries out the project management, design, engineering, procurement, construction, commissioning for ADNOC projects.

'SHALL' Indicates mandatory requirements "**Group Company**" means any company within the ADNOC Group other than ADNOC.

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1 PURPOSE

This philosophy provides minimum requirements and recommendations for the selection and specifications of Flare and Blowdown systems.

This philosophy is applicable to:

i. Design and installation of flare systems in new plants and facilities;
ii. De-bottlenecking of existing plants and facilities.

Objectives of the Flare and Blowdown Philosophy are as follows:

i. Define safe and cost-effective methods for disposal systems;
ii. Explain the different types of flare equipment;
iii. Provide philosophy for the flare system configurations, sizing and design conditions;
iv. Provide philosophy for depressurization and blowdown criteria.

Additionally, it is recommended that all project Flare and Blowdown philosophies shall be based on this philosophy.

2 SCOPE

The Flare and Blowdown philosophy details the requirements for the design of the Flare and Blowdown system. Further to this philosophy, API STD 520 Parts I and II [5& 6] and API STD 521 [1] shall be respected in the design of flare systems.

This philosophy covers following aspects of Flare and Blowdown systems:

i. Flare Disposal Systems (gas, liquid & two phase);
ii. Relief line sizing, sub-header and header sizing;
iii. Depressurization / Blowdown System;
iv. Criteria for flare piping studies such as FIV & AIV.

The philosophy has the following exclusions:

i. Sizing of relief valves;
ii. Equipment design conditions which will be covered in Process Design Criteria [12].

3 DEFINED TERMS / ABBREVIATIONS / REFERENCES

Abbreviations	
ACWL	Air Craft Warning Lighting
AIV	Acoustic Induced Vibration
API	American Petroleum Institute
ASME	American Society of Mechanical Engineers
BDV	Blowdown Valve
BLEVE	Boiling Liquid Expanding Vapor Explosion
BTL	Bottom Tan Line
CAPEX	Capital Expense
COP	Codes of Practice
CWDT	Critical Wax Deposition Temperature
D	Diameter
EDP	Emergency Depressurization
EDPV	Emergency Depressurization Valve
EHT	Electrical Heat Tracing
EPC	Engineering, Procurement and Construction
ESD	Emergency Shutdown
ESDV	Emergency Shutdown Valve
FC	Fail Closed
FEED	Front End Engineering Design
FERA	Fire and Explosion Risk Assessment
FFG	Flame Front Generator
FIV	Flow Induced Vibration
FO	Fail Open

Abbreviations	
GLC	Ground Level Concentrations
HHLL	High High Liquid Level
HLL	High Liquid Level
HP	High Pressure
HSE	Health and Safety and Environment
HSSE	Health, Safety, Security and Environment
IA	Instrument Air
IPF	Instrumented Protection Function
ISBL	Inside Battery Limit
KO	Knock-Out
KPI	Key Performance Indicators
L	Length
LAH	High Liquid Level Alarm
LAHH	High-High Liquid Level alarm
LAHHH	High-High-High Liquid Level alarm
LALL	Level Alarm Low Low
LEL	Lower Explosion Limit
LFL	Lower Flammability Limit
LHV	Lower Heating Value
LLL	Low Liquid Level
LLLL	Low Low Liquid Level
LNG	Liquefied Natural Gas
LO	Locked Open
LP	Low Pressure

Abbreviations	
LPG	Liquefied Petroleum Gas
LSH	Level Switch High
LSL	Level Switch Low
LSLL	Level Switch Low Low
LTCS	Low Temperature carbon Steel
LZHH	High-High Level trip (maximum level)
LZLL	Low-Low Level trip
MABP	Maximum Allowable Back Pressure
MDMT	Minimum Design Metal Temperature
MLL	Maximum Emergency Liquid Level
NLL	Normal Liquid Level
NPSH	Net Positive Suction head
OD	Outside Diameter
OSBL	Outside Battery Limit
P	Pressure
PAHH	Pressure Alarm High high
PCV	Pressure Control Valve
PSV	Pressure safety valve
PZV	Emergency Control Valve
PRD	Pressure Relief Device (For liquid)
Q	Flowrate
RO	Restriction Orifice
SDV	Shutdown Valve
SIF	Safety Integrity Function

Abbreviations	
SIL	Safety Integrity Level
t	Wall thickness
TERV	Thermal Expansion Relief Valve
TWA	Time Weighted Average exposure
UPS	Uninterrupted Power Supply
V	Volume m^3

4 NORMATIVE REFERENCES

International Code(s) and Standards

References
1. API STD 521 Pressure-Relieving and Depressuring Systems, 6th Edition, Jan 2014
2. ASME SEC VIII DIV.1 ASME Boiler and Pressure Vessel Code, 2019
3. API STD 526 Flanged Steam Pressure Relief Valves, 7th Edition, September 2017
4. ASME B31.3 Process Piping 2018
5. API STD 520 Part I Sizing, Selection, and Installation of Pressure-relieving Devices (Sizing and Selection), 9th Edition, July 2014,
6. API 520 STD Part II – Sizing, Selection and Installation of Pressure Relieving Devices- Installation 6th Edition, March 2015
7. API STD 537 Flare Details for Petroleum, Petrochemical and Natural Gas Industries, 3rd Edition, March 2017,
8. API RP 14C Recommended Practice for Analysis, Design, Installation, and Testing of Basic Surface Safety Systems for Offshore Production Platforms, Seventh Edition, March 2007

This is a live document and the impact of future revisions of International Standards to be reflected in this document in subsequent revisions / factored in by FEED Engineer and Contractors in Design.

5 REFERENCE DOCUMENTS

5.1 ADNOC Specifications

Ref.	Document No.-	Title
9	AGES-PH-03-002	Emergency Shutdown and Depressurisation Philosophy
10	AGES-SP-04-004	Emergency Shutdown (SIS) Specification
11	AGES-SP-04-005	Emergency Shutdown Valve Specification-
12	AGES-GL-08-001	Process Design Criteria
13	AGES-PH-08-001	Isolation, Drain and Vent Philosophy
14	HSE-GA-ST07	HSE Design Philosophy Standard
15	HSE-OS-ST21	Management of Hydrogen Sulfide (H_2S) Standard
16	HSE-EN-ST02	Pollution Prevention Control
17	AGES-PH-03-001	Emergency Shutdown & Depresurisation System Philosophy

5.2 Standard Drawings

None at present

5.3 Other References (Other Codes/IOC Standards)

None at present

6 DOCUMENTS PRECEDENCE

The specifications and codes referred to in this specification shall, unless stated otherwise, be the latest approved issue at the time of project award.

It shall be the CONTRACTOR'S responsibility to be, or to become, knowledgeable of the requirements of the referenced/related Codes and Standards.

Resolution and/or interpretation precedence shall be obtained from the COMPANY in writing before proceeding with the design.

In case of conflict, the order of document precedence shall be:

- UAE Statutory requirements
- This philosophy document
- Project documents
- International codes and standards

7 SPECIFICATION DEVIATION/CONCESSION CONTROL

None at present.

8 FLARE PHILOSOPHY

The flare and blowdown are key components of the closed emergency release system in any plant or facility. Emergency releases originating from pressure relief valves, vapor blowdowns, process stream diversion and equipment drainage, which cannot be discharged directly to the atmosphere for reasons of safety or pollution control, are routed to the flare tip through closed systems and a KO drum facility where liquids and vapors are separated.

The flare provides a means of safe disposal of the hazardous hydrocarbon, flammable and toxic gas streams from process plants, by burning them under controlled conditions such that adjacent equipment or personnel are not exposed to hazards, and at the same time meeting pollution control, HSSE and local regulations.

The flare system is designed to dispose of the gases and/or liquids relieved under the following scenarios in general:

i. Operational flaring from process systems during start-up, shutdown or operational upsets;
ii. Emergency depressurization;
iii. Loss of any utility or other emergency situation;
iv. Blowdown and depressuring loads;
v. Relief discharges from PSVs

8.1 Disposal Systems

The flare system contains pressure relieving devices (PSV), flare sub-headers and headers, KO Drums, flare seal mechanisms (if applicable), flare stack which includes the flare tips, burners and pilot. Each of these will be addressed in this document.

8.2 Flare Capacity Load Estimation

The flare load can generally be estimated by considering the following as a minimum:

a) Relief load from various overpressure protection scenarios including and not limited to the below:

i. Blocked outlet;
ii. External fire;
iii. Steam failure;
iv. Power failure (partial and total);
v. Reflux failure;
vi. Instrument air failure;
vii. Gas blow-by;
viii. Exchanger tubes rupture;
ix. Abnormal heat input;
x. Thermal expansion;
xi. Control valve malfunction;
xii. Loss of cooling.

b) Process upsets leading to automatic depressurization of any equipment/unit.

c) Emergency equipment/process unit depressurization (fire scenario).

d) Emergency depressurization of complete plant.

e) Any other upset scenarios specific to a particular business unit.

The following shall be considered to define the flare load for sizing the flare system:

1. Flare loads shall not be additive for any two or more ‘’non related’’ scenarios;

2. One governing relief load from the different upset scenarios covered under (a) above, shall only be considered. The decision to add the relief load from the depressurization of a unit or a section of unit (as referred under items (b),(c),(d),(e)) shall be evaluated on a case by case basis, considering the criteria such as fire zoning philosophy, operating and shutdown philosophy etc.

8.2.1 Flare Load Reduction Credits

The use of IPF at the inlet of the plant/facility invariably helps to reduce the flare loads which result in cost optimized design by avoiding the blocked outlet scenario(s). API STD 521 section 4.2.6 and section 5.3.4.3 [1] allow adoption of IPF in such scenarios, subject to SIF classification for the subject IPF loop and validation which **SHALL [PSR]** meet SIL-3 requirements as a minimum. This approach shall be analyzed and adapted, wherever practical, to achieve significant CAPEX saving. This approach shall be considered for both greenfield and brownfield designs.

The other approach to reduce the flare loads is to adapt inherent safe design depending on the cost benefit analysis.

In case of brownfield applications, a dynamic simulation approach can be applied to take credit for ‘’flare header packing for depressurization scenarios’’

8.3 Segregation of Flare Headers

Depending on the type of gas/composition being flared and pressure/temperature levels, the need to segregate the flare systems shall be analyzed. Hydrocarbon flare systems are used to handle and dispose of all vapor and liquid hydrocarbon releases from the facilities. In hydrocarbon industries, the following type of flares are typically utilized based on their segregation:-

Table 8.1 Types of Flare

Type of Flare	PSV Set Pressures (Note 2)	Design Temperature (Note 2)	Composition
LP Flare	Below 7 barg	-29 °C and above (Carbon Steel)	Wet/Dry hydrocarbon gas
HP Warm Flare	7-10 barg and above	-29 °C and above (Carbon Steel) Below -29 °C up to -46 °C (LTCS)	Wet/Dry hydrocarbon gas
HP Cold Flare (Note 5)	50 barg and above	Below -46 °C (SS)	Dry hydrocarbon gas
Tank Flare	Very low pressure systems such as API 650/API 620 tanks	-29 °C and above (Carbon Steel)	Wet/Dry hydrocarbon gas
Acid Gas Flare (Note 4)	Below 7 barg	-29 °C and above (Carbon Steel) (Note 6)	Acid gas rich hydrocarbon
Others (the need for any other segregated flare to be evaluated on a case by case basis by individual business units)			

Notes:

1. The need for segregating the HP Cold Flare and HP Warm Flare, besides relieving/design temperature, is to ensure that there is no hydrate formation in the flare header by virtue of mixing dry/wet hydrocarbons at their relieving temperatures.
2. The above mentioned pressure/temperature levels are indicative and should be evaluated on a case by case basis considering a cost benefit analysis and other studies as applicable.
3. As regards to the extent of flare segregation, it essentially includes flare headers/ sub-headers, KO drum, flare stack and flare tip. However, the KO drums, stack and flare tip can be shared for HP/LP flares subject to meeting their respective backpressure criteria.
4. Selection of disposal means for Hydrogen Sulphide/CO_2 rich streams needs to be evaluated on a case by case basis.
5. In refinery and cryogenic units, the pressure limit for the HP Cold Flare may not be strictly applicable and only temperature criteria may govern.
6. Superior metallurgy may be selected as per material study recommendations depending on acid gas composition.

8.4 Design Pressure

Refer to Process Design Criteria section 7 [12].

8.5 Design Temperature

Refer to Process Design Criteria section. 8 [12]

a. Maximum Design Temperature
   Refer to Process Design Criteria section 8 [12].
b. Minimum Design Temperature
   Refer to Process Design Criteria section 8 [12]

8.6 Maximum Allowable Backpressure of Flare Systems

The maximum total allowable back pressure (MABP) i.e. superimposed (constant/variable) + built-up pressure for each relieving PSV shall not be exceeded in any scenario. API STD 526 [3] details the pressure-temperature limits of all types and sizes of PSVs as per their flange ratings.

i. For conventional PSVs, MABP (built up) is limited to 10% of the PSV gauge set pressure, for non-fire contingencies and to 21 % for fire contingencies as per API STD 520 Pt I. [5]
ii. For balanced bellows PSVs, total MABP is limited to 50 % of the PSV gauge set pressure- as per API 520 Pt I [5] and when the superimposed backpressure is variable such that it can not be accommodated by conventional PSVs.
iii. Pilot operated PSVs may be considered when the total backpressure exceeds 50% of the PSV gauge set pressure. The use of pilot operated valves shall be reviewed carefully considering the following:

    a. Service requirement, pilot operated PSVs may be used provided the process medium is dry and clean;
    b. The difference between the maximum operating pressure and PSV set pressure etc, is typically less than 10%;
    c. When the PSV inlet pressure losses exceed 3% of the PSV set pressure;
    d. In large capacity (8T10) and high set pressure service due to their smaller size and weight.

8.7 Liquid Discharges

In general, liquid relief to the flare collection system should be avoided. If this cannot be prevented, careful consideration will be given to potential problems associated with liquid disposal from pressure relief devices and liquid de-inventorying into the flare systems shall be addressed and designed for, such as flare header pipe rack supports and flare KO drums and pumps. In order to avoid accumulation of liquid in the vapor flare collection headers, all vapor flare headers shall be sloped towards the flare KO drums.

8.8 Piping General Requirement for Flare Lines

Installation details and criteria pertinent to PSVs should conform to those specified in API STD 520 PT I [5]. Piping arrangement shall be as follows:

i. Minimum line size should be 2'';
ii. The opening through all pipe and fittings (including stop valves) between a pressure vessel and its PSV shall have at least the area of the PSV inlet connection. For outlet isolation valves, to help minimize the built up back pressure, the flow area in the outlet isolation valve should be equal to or greater than the PSV outlet area connection;
iii. In cases where the outlet pipe for the PSVs is required to be increased beyond the PSV outlet flange size due to backpressure considerations, the outlet isolation valve can still be retained equal to the PSV outlet flange size subject to ensuring that this doesn't pose additional backpressure/noise. In such cases, the expander could be provided downstream of the outlet isolation valve;
iv. Locating a PSV below the header elevation in closed systems should be avoided wherever possible. Laterals from individual devices that need to be located below the header should be arranged to rise continuously to the top of the header entry point; however, means should be provided to prevent liquid accumulation on the discharge side of these valves;
v. The inlet and outlet isolation valves, for PSVs, shall be full bore;
vi. Relief valves, blowdown valves and flare PCV outlet tail pipes shall be self-draining towards downstream header;
vii. Wherever atmospheric relief device(s) are permitted, discharge piping, including process vessels with free vents to atmosphere, shall have a weep hole of 13 mm (½ in) diameter and have an elbow at the lowest point to prevent the accumulation of liquid;
viii. Sub-headers shall be connected at the top of the header and they SHALL drain into the headers. The sub-headers shall be connected in such a way that there are no welds in the lower one-third of the circumference of the header. These connections shall be at 45 degree entry angle in order to reduce the pressure drop, reaction forces and improve the flow regime;
ix. The use of angle entry can be considered to lower pressure drop (including velocity head losses) and reduce reaction forces. 45 degree entry shall be specified for large liquid or two phase flow reliefs where the liquid portion of the relief exceeds 170m^3/h or where the superficial liquid velocity in the sub-header is greater than 1.5m/s;
x. Flare sub header(s) shall be sloped with minimum 1:200 towards the main flare header while the main flare header shall be sloped to a downstream flare KO drum with a minimum slope of 1:500;
xi. Offshore disposal piping (including sub-headers and headers) shall be sloped 1:200 due to space constraints and out-of-level tolerances;
xii. The piping between the flare KO drum / seal drum and the flare stack shall be back sloped towards the KO drums with a minimum slope of 1:500
xiii. Isolation valves for flare headers and sub-headers shall not be butterfly or globe valve types. Any exception to this shall be approved by the Company (e.g. butterfly valves in very low pressure systems);
xiv. All gate isolation valves installed in flare piping shall have their stem in the horizontal position to prevent the accumulation of dirt underneath the stem and to prevent the fall-off of the valve's gate due to stem failure and hence blocking the relief path;
xv. Valves in the relief path shall be avoided as much as possible and shall be locked in open position wherever these cannot be avoided. Where several units are connected to one common disposal system, isolating block valves shall be provided in the unit sub-headers. These valves shall be Locked Open (LO) with the provision for blinding upstream of the block valve for unit isolation. Refer to Isolation, Drain and Vent Philosophy [13] for unit battery limit configuration;

xvi. Disposal system piping should be self-draining towards the discharge end. Pocketing of discharge lines should be avoided. If PSVs handle viscous materials or materials that can solidify as they cool to ambient temperature, the discharge line should be heat traced. A small drain pot or drip leg may be necessary at low points in lines that cannot be sloped continuously to the KO drum. The use of liquid drain traps or other devices with operating mechanisms should be avoided.

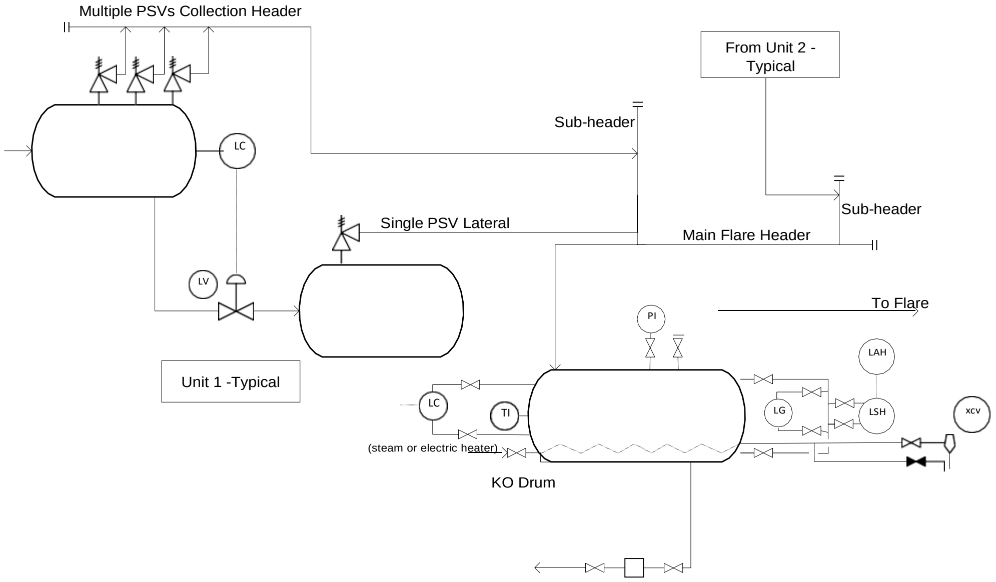
8.9 Flare Hydraulic Sizing Criteria

There could be different types of header in a process facility depending upon the complexity of the plant, which can be categorized as below:

i. Main flare header: usually one common flare header for the entire plant/process complex;
ii. Flare sub-header(s): the common flare header for a particular unit in the process complex which joins the main header;
iii. Collection header(s): this collects flow from a number of PSVs from a particular section within a process unit, which joins either a sub-header and/or main header.

Refer to Figure 8-1 for typical flare headers nomenclature.

Figure 8.1. Typical Flare System Arrangement



The above terminologies may be interchangeable depending on the complexity of the facilities.

The flare headers and PSV piping shall be sized on the following criteria:

i. Main header and sub-headers shall be sized based on required flare load, as calculated and not based on rated flow from individual PSVs;

ii. PSV inlet piping and outlet tail piping, up to and including the collection header or sub-header (as the case maybe), shall be sized based on the combined rated capacity from multiple PSVs connected to a particular item of equipment as per API 521 section 4.9.4.3 [1]. In case the multiple PSVs are connected directly to the sub header instead of a dedicated collection header, then the sub header shall be designed for the combined rated capacity of all PSVs;

iii. For greenfield design, main flare headers and sub-headers shall be sized for 0.5 Mach number to cater for future expansions; the collection header and tail pipes shall be designed for 0.7 Mach number;

iv. For brownfield design, the existing main flare headers and sub-headers shall be considered adequate for Mach numbers up to 0.8 and the collection headers/tail pipes shall be considered to be adequate for Mach number up to 0.9 being a potential CAPEX saving. Further relaxation of Mach number may be considered on a case by case basis subject to checking the adequacy of the piping supports based on AIV/FIV consideration;

v. Maximum calculated backpressures in the flare system shall not exceed the lowest allowable backpressure from the connected PSVs depending upon the PSV type;

vi. $\rho.v^2$ shall be less than 200,000 Pa.s in the main flare headers, sub-headers and collection header/ tail pipes;

vii. For relief valve line sizing API STD 520 Part II [6] and API STD 521 [1] section 5 shall be followed. PSV inlet losses shall be limited to 3% of the set pressure for estimated PSV rated capacity (for all PSV types).

8.10 Noise Levels

For emergency conditions, the following noise limits shall apply for a flare:

i. 115 dB (A) at the base of the stack;

ii. 115 dB (A) at platform/ground level where the stack is provided with a derrick structure;

iii. For normal operation (including start-up and shutdown), the noise level shall be less than 85 dB (A) at the perimeter of the sterile area, for flow rates up to 15% of maximum flaring capacity or at the maximum relief rate that may occur during normal operation (including starting-up and shutting-down) whichever is higher.

8.11 Vibration Fatigue Criteria

8.11.1 Acoustic Induced Vibration (AIV)

AIV may cause failure in piping systems; AIV energy generation occurs immediately downstream of high flowrate and high pressure drop flow restriction devices and is caused by highly turbulent mixing of the choked flow exiting the device. This produces an intense area for pressure fluctuations and shock waves downstream of the device. This generates high frequency acoustic energy that propagates down the pipe as an acoustic wave together with vibration energy within the pipe wall. Failures occur in areas of asymmetric stress concentration such as branch connections and small bore take offs e.g. vents, drains, pressure tappings. With AIV there is no visible pipe movement and due to high frequency vibration, fatigue failures occur in minutes or hours.An AIV study will be performed for any vapor PSVs that produce more than 155 dB sound level. Additionally, an AIV study shall be performed for flare system headers/piping where D/t ratio exceeds 70.

This study is usually conducted during detailed Engineering stage/ Execute stage.

8.11.2 Flow Induced Vibration (FIV)

A FIV study shall be performed for relief system laterals and headers with flows from valves other than PSVs where both the flow exceeds the ρv^2 criteria (see Table 8.2) and the flow occurs for an extended period of time (a total of 3 days over the life of the facility which roughly corresponds to 300 relieving events each with a duration of 15 minutes.)

Table 8.2: ρv^2 Criteria for Let Down and Flare PCVs

Fluid Phase	ρv^2 Criteria
Liquid and multiphase	$\rho v^2 \geq 20{,}000\ kg/ms^2$
Gas	$\rho v^2 \geq 50{,}000\ kg/ms^2$

An example of this is flow from a large pressure control valve which is expected to be in operation for an extended period (weeks).

This study is usually conducted during detailed Engineering stage/ Execute stage.

8.12 Flare KO Drum Design Criteria

A KO drum is provided to separate and collect the liquid, before the vapors pass to the flare package, and to prevent large liquid droplets in the outlet vapor stream, which may cause burning rain (lit flare) or liquid rain (unlit flare) and to provide sufficient hold up time for the emergency liquid relief following an emergency relief scenario. The KO drum shall be design based on the criteria stated below:

i. For economic reasons, a horizontal KO drum should be considered for large vapor flow and large liquid releases;

ii. For vertical KO drums, API STD 521 [1] Annex C method usually leads to larger vessels than the gas load factor method. For horizontal KO drums API STD 521 [1] Annex C method may lead to smaller vessels and it is recommended to use the gas load factor method. A gas load factor of 0.1 m/s shall be used;

iii. If a KO drum is required to be combined with the maintenance closed drain drum, the KO drum must be designed for possible interactions of the fluids relieving to the flare. This scenario may be applicable only for the facilities that have minimum equipment to drain during maintenance or may have layout/space constraints, for example remote degassing stations, wellhead towers. The KO drum should be sized to include the volume expected from normal maintenance activities and maximum emergency relief;

iv. For large process complexes such as refineries and petrochemicals, the requirement for providing flare KO drums within individual unit battery limits or an intermediate KO for more than one unit against one common KO drum for each flare system, should be evaluated on a case by case basis based on the cost benefit analysis;

v. A split-entry or split-exit configuration can be used to reduce the drum diameter (but increase the length) for large flow rates and should be considered if the vessel diameter exceeds 3.66 m (12 ft); Where a horizontal KO drum is provided with two inlets the vessel should have a length L > 5 D;

vi. The momentum criterion for nozzles shall be as follows:

a. Inlet nozzles which are not equipped with any internals shall be sized for a dynamic pressure of 1,500 N/m^2.

b. Nozzles provided with a half open pipe shall not exceed a dynamic pressure of 5,000 N/m^2;

c. Nozzles provided with a Schoepentoeter inlet device shall not exceed a dynamic pressure criteria of 10,000 N/m^2. (Schoepentoeter shall be of a sturdy design to be able to cope with high loads);

d. Gas outlet nozzle shall not exceed 6000 N/m^2.

vii. The distance between the bottom of the feed inlet device bottom and highest liquid level trip shall be a minimum of 150 mm for horizontal vessels and a minimum of 300 mm for vertical vessels;

viii. No deflector plate or demisting gas outlet device is permitted in the KO drum gas outlet. The design shall recognize that the maximum gas release case and the maximum liquid release case are not necessarily coincident. If no valid liquid case exists and the vapor is either condensable or has a condensable component, then the design liquid case should be a minimum of 2 wt% of the maximum gas rate to the flare KO drum;

ix. The height above the LZHH is to provide sufficient time for safe shutdown of the total facility, to provide sufficient hold up for the emergency relief incoming to the KO drum and is based on the closing time of the SIF, delay in operator's response and failure of starting the KO drum pump at LAH;

x. Where tripping of facilities is practical and the risks associated with liquid carryover are high, e.g. offshore facilities, a high level trip as recommended by API RP 14C [8] shall be installed;

xi. The flare KO drum must have sufficient hold-up capacity to prevent any surges of liquid filling the flare KO drum and entering the flare stack, leading to incompletely combusted discharges, flame out, soot, smoke and potential burning rain. To determine the liquid hold-up requirements, all potential emergencies and sources of liquid flow should be considered. The hold-up capacity of the drum is based on containing the largest in-flow of liquid for sufficient time to allow shutdown of the source. This liquid hold-up time is usually 30 minutes (API STD 521 Annex C [1]). It is important to consider liquid that may already be accumulated in the drum. A conservative estimate is to assume that the drum is initially at its high high alarm level;

xii. The liquid levels and residence times shall be as per Table 8.3 below.

Table 8.3 Liquid Level and Residence Time for Horizontal KO Drums

Liquid Level	Action	Holdup
Gas Cap		Adequate to remove specified liquid droplet for peak gas relief/depressurization case
LZHH (MLL - Max Liquid Level)		LAHH to LZHH – 20 minute holdup based on peak liquid relief case and maximum liquid generated during full plant depressuring, (Note 1)
LAHHH	Plant Trip (Notes 2,3)	LAHH to LAHHH – 10 minute holdup based on peak liquid relief case
LAHH	Standby pump start & Critical Alarm	LSH to LAHH – 1 minute based on pump capacity with minimum of 200 mm above LSH
LSH	1st Pump start & Alarm	LSL to LSH – 5 minute based on pump capacity with minimum of 200 mm above LSL
LSL	Pumps stop	LZLL to LSL – 1 minute based on pump capacity with minimum of 200 mm above LZLL
LZLL	Pumps trip	Vessel BTL to LZLL - Adequate to submerge Heater (if any) or 0.15m minimum

Notes:

1. This liquid hold-up time is usually 30 minutes (API STD 521 Annex C [1]). This is a combination of the time required for operator intervention (10 minutes between LAHH and LAHHH) and 20 minutes above LAHHH which is roughly the emergency release time before closing the inlet feed to the plant, which depends on the closing time of the inlet SDVs.
2. The decision to trip the plant on high high liquid level needs to be evaluated by individual business units depending upon their facilities configurations, for example: this action of plant/train shutdown is recommended where there are multiple trains or one common KO is provided for multiple trains/units.
3. This Plant Trip action shall not result in concurrent depressurization.

8.12.1 Flare KO Drum Level Instrumentation

It is important that the level indication in the flare drum is reliable as a rising level can be a warning of a potentially serious upset condition. The level indication must span the entire drum, not just the operating range. The level instruments should be robust with a high reliability and with voting level specified by SIL requirements; it is preferable that two technology types are used. Level instruments should be designed to handle the expected range of liquids and densities that could be discharged to the drum.

In general, high high level in the flare KO drum shall initiate an automatic overall total plant shutdown, however this depends on project philosophy. Where the high liquid level trip causes a total plant shutdown, it is good practice to use a high integrity 2 out of 3 voting system to prevent spurious shutdowns.

8.12.2 Droplet Size Criteria for Flare Drums

Large liquid droplets and liquid loading can cause smoke, release of liquid droplets from the flare or mechanical damage. It is essential that an effective liquid separation KO drum is provided to prevent carryover of liquid droplets to the flare tip which could result in burning rain/liquid rain. It is recommended that the flare KO drum size is based on the maximum of the following:

a. A maximum droplet diameter between 300 and 600 μm. This should be confirmed by the flare tip vendor to prevent carry-over of heavier hydrocarbons. Larger droplet sizes can be used for sonic tips such as high pressure sonic flare tips. However, vendor confirmation is required for the maximum droplet size which will not limit the flare tip's performance;
b. The gas cap area above the maximum emergency liquid level shall be designed with a maximum gas load factor of 0.1 m/s. If a Scheopentoter (or equivalent) inlet device is used, a maximum gas load factor of 0.15 m/s can be considered;
c. The gas/liquid separation efficiency of a KO drum shall be determined by its gas load factor, λ (sometimes referred as K factor which is related to Souders-Brown velocity) and is calculated by the following equation

$$\lambda = \frac{Q}{A_g}\sqrt{\frac{S_g}{S_l - S_g}}$$

where:

λ	=	Gas load factor (m/s)
Q	=	Gas flow rate (m^3/s) at operating conditions
A_g	=	Area available for gas flow (m^2)

For vertical vessels, A_g is the horizontal cross sectional area of the vessel.
For horizontal vessels, A_g is the vertical cross sectional area of the gas cap available above the LAHH level.

S_g	=	Gas density (kg/m^3) at operating conditions
S_l	=	Liquid density (kg/m^3) at operating conditions

For essentially dry gas loads or for ISBL KO drum or intermediate KO drums, a higher gas load factor of 0.25 m/s can be considered.

8.12.3 Flare KO Drum Pumps

Relief liquid collected in the flare KO drum is typically pumped to tankage or back into the process. The flare KO drum pumps should be designed to discharge the emergency liquid hold-up volume within a reasonable time period for restarting the process, and not on the liquid load feeding the KO drum. The time to pump out the liquids is specified on a case by case basis, typically 2 - 8 hours.

The pumps are typically electric driven 2 x 100% (1 duty; 1 standby) with emergency power supply. The first pump will start at LAH and the second pump will start if the level continues to increase to LAHH. Both pumps will stop on low liquid level. Flare KO drum pumps will be inhibited from starting if the heater has failed and the contents in the KO Drum are:

i. Below minimum design temperature of receiving facility;
ii. Below freezing point;
iii. Below hydrate formation point;
iv. Below CWDT (Critical Wax Deposition Temperature).

Flare pumps in dirty service (asphaltenes, wax, sand etc.) shall be provided with continuous minimum recirculation flow in order to promote circulation and avoid dirt accumulation and stagnation in the flare KO drum.

Pumped systems shall be designed so that liquid back-flow from the disposal system to the flare KO drum cannot occur, either through gravity or from pressurized disposal systems.

Centrifugal pumps are preferred to reciprocating pumps based on process parameters (discharge pressure, NPSH etc.).

8.12.4 Flare KO Drum Heater

Heaters are required in flare KO drums to prevent water freezing or wax and hydrate solids forming. The heater shall be sized to heat low temperature releases due to depressurization and winterization. If the liquid is volatile (e.g. liquid propane) heating shall be provided to vaporize the liquid.

The heater will be submerged in the liquid below LLLL. The KO drum pump starts at HLL/HHLL and stops at LLL. Since the inventory below LLL will always be kept warm, the heater only needs to be sized for additional duty to heat the liquid above LLL. Therefore, only the liquid inventory between LLL and HLL should be considered for heater sizing. An extended period of time can be assumed for heating the cold liquids (e.g. 2 - 8 hours).

The minimum temperature to be considered for liquid inventory prior to heating should be either minimum ambient temperature or minimum temperature at relief/blowdown discharge.

The heating may be provided by an electric heater or steam coil.

8.12.5 Liquid Seal Drum

The purpose of a liquid seal (if used) in a flare system includes the following:

i. to prevent any flashback originating from the flare tip from propagating back through the flare system;
ii. to maintain a positive system pressure to ensure no air leakage into the flare system and permit use of a flare gas recovery system;
iii. to prevent ingress of air into the flare system during sudden temperature changes or condensation of flare gas, such as can occur following a major release of flare gas or following a steaming operation.

Liquid seals are located between the main knock-out drum and the flare stack and are quite often incorporated into the base of the stack. They are sized for the maximum vapor-release case.

Water seals can be used if the minimum temperature of the stream is above 0 ^{o}C. For cold service, glycol or other materials should be used depending on the anticipated temperatures of the vapors. The use of water seal drums shall be evaluated on a case by case basis considering the following:

i. Composition of the gas specially with respect to H_2S content;
ii. Difficulty in maintaining the seal under high ambient conditions;
iii. Potential of hydrates due to low temperature gas such as in the cold flares;
iv. Potential carryover of water and corrosion in the downstream flare header;
v. Potential polymer fines accumulation (specific to petrochemical applications).

Since the operation of water seal vessels is cumbersome, an alternative could be to install a bursting disk or a pin-actuated device in parallel with a full size emergency control valve (PZV). The parallel operation ensures 100 % availability of the flare and relief system and, by giving the pressure switch of the PZV a lower setting than the bursting pressure, prevents premature rupture of the bursting disk or opening of a pin-actuated device.

Water seal drums shall be avoided in Acid Gas flare services.

Alternatively Water seals shall be protected against freezing by installing an internal coil (steam heater) and/or electrical heat tracing (EHT), and continuous water makeup and purge. A low temperature alarm and EHT alarms shall be provided. Safeguards such as pin-actuated relief device shall be considered and evaluated to provide a safe and open path to flare.

8.13 Types of Flare

There are three main types of flare disposal systems; vertical elevated flares, burn pits and ground flares:

8.13.1 Vertical Elevated Flares.

The elevated flare is by far the most commonly used type of flare in industry. The flared vapor is discharged from the flare KO drum to the elevated flare.

General characteristics:

i. Can be made smokeless except at high capacity loads;
ii. Noisy, due to steam used for smoke reduction;
iii. High luminosity, but can be reduced with steam;
iv. Best for dispersion compared to other flares

Disadvantages:

i. High cost;
ii. Visual and noise pollution;
iii. Large space required;
iv. Flare emissions and flame visibility creating environmental limitations;
v. Requirement for wind shields and ACWL (air craft warning lighting).

8.13.2 Horizontal Flares/ Burn pits

The flared liquids and two-phase flows are piped to a horizontal flare burner that discharges into an open pit excavation.

Pollution characteristics:

i. Poor smokeless quality;
ii. Some luminosity;
iii. Poor for air pollution.

Disadvantages:

i. Pollution is not acceptable in most cases;
ii. Large space required;
iii. Short life;
iv. High maintenance.

8.13.3 Enclosed-Flame Flares / Ground Flares

General Characteristics

i. Wide turndown;
ii. Reduced noise,
iii. Reduced flame visibility;
iv. Minimal radiation.

Disadvantages

i. Requires complex safety instrumentation emissions monitoring systems due to the risk of vapor cloud accumulation;
ii. Requires numerous small high pressure flare tips to achieve smokeless flaring.

8.14 Types of Flare Tips

Flare tips are generally categorized into:

i. Unassisted flare tips (open flare pipe (subsonic tips) or high pressure flare tips (sonic tip)).
ii. Assisted Flare tips (steam assisted, water assisted, air assisted etc)- sonic tips.
-

Sonic and Sub-sonic flare tips are explained below:

8.14.1 Subsonic Tips-

Subsonic burners have following features:

i. Burner velocity is typically low resulting in pressure drops less than 0.7 bar, usually between 0.2-0.5 bar;
ii. Used for successful burning of low heating value gases;
iii. Preferred options for back pressures of less than 1 barg.

8.14.2 Sonic Tips

Also known as high pressure flare tips, sonic tips have the following features:

i. Favoured when radiation and dispersion requirements need to be met with a smaller flare stack height and sterile radius;
ii. Typically uses improved gas/air ratio with improved burning, low radiation levels resulting in reduced stack size;
iii. Typically generate high noise, so local noise regulations should be checked.

8.15 Smokeless flaring

Many hydrocarbon flames are luminous due to incandescent carbon particles formed in the flames. Under certain conditions, these particles are released from luminous flames as smoke.

Various techniques are available for producing smokeless operation, most of which are based on the premise that smoke is the result of a fuel-rich condition and is eliminated by promoting uniform air distribution throughout the flame.

To promote even air distribution throughout the flames (and thus prevent smoke formation), energy is required to create turbulence and mixing of the combustion air within the flare gas as it is being ignited. The energy can be present in the gases, in the form of pressure, or it can be exerted on the system through another medium, such as injecting high/medium pressure steam, compressed air or low pressure blower air into the gases as they exit the flare tip. To create conditions favourable for smokeless combustion, flare designs range in complexity from a simple open pipe with an ignition source to integrated, staged flare systems with complex control systems.

Opacity is defined by the Ringelmann numbering scale

Ringelmann 0 is clear;

Ringelmann 1 = 20 % opacity;

Ringelmann 2 = 40% opacity;

Ringelmann 3 = 60% opacity;

Ringelmann 4 = 80% opacity;

Ringelmann 5 = 100% opacity.

The following shall be considered for smokeless operation and design:

a. Flares need not be designed as smokeless for the maximum emergency peak load. Smokeless operation (Ringelman -1) may be considered for continuous load of 15% of the peak design load;
b. Flares can be designed for smokeless operation using steam/air as assisting medium. Other means such as high pressure water, high pressure gas injection may be considered on a case by case basis wherever steam/air is not available or practically feasible;
c. Use of unassisted smokeless flaring (for example, high pressure flaring) should be explored with flare tip vendors (proprietary designs) as an alternative to assisted smokeless flares.

8.16 Fuel Gas Injection for improving LHV

Fuel gas can be injected into the flare system to increase the lower heating value (LHV) of the gas. This scenario occurs when the possibility of flameout exists. According to API STD 521 [1] section 5.7.3.4 for preliminary calculations, fuel gas injection is required for flare gases with a heating value of:

i. Less than 7.5 MJ/m^3 (220 Btu/Scf) for unassisted flares; or

ii. Less than 11.2 MJ/m^3 (300 Btu/Scf) for assisted flares

Gas assisted flare tips are required for high CO_2/inert and H_2S rich gases to support the combustion of flare gas. Low gas exit velocity tips are required for the successful combustion of low heating value gases in order to avoid over-aeration of the combustion mixture, which can result in potentially incomplete combustion and flame instability.

8.17 Flare Purging and Purge Reduction Seals

Purge gas is required to maintain a positive pressure within the flare systems and to reduce the flammability range of the gases inside the flare header, to prevent ingress of air into the stack, which may lead to flashback. Air ingress may occur as follows:

i. Diffusion of air down the stack;
ii. Wind action across the tip, at low flow rates, resulting in a differential pressure at the top of the stack;
iii. Relief gas with a density lower than air. (This may create a problem when two or more stacks are operating in parallel. The relief gas could leave through one stack, while the heavier air may enter through the other stack and mix with the relief gas, creating an explosive mixture);
iv. Condensation and/or shrinkage of the contents of the relief system resulting in an under pressure within the relief system. This may be caused by an increase in heat removal as a result of a hot release or a rain shower on the header. The shrinkage could be considerable after a major hot, heavy gas relief;
v. During a plant (relief system) shutdown, during which some connections are open and the purge system is inoperative or inadequate for a prolonged period;
vi. Air ingress to the stack through a corrosion hole or through a cracked flange. Internal fire in the stack may jeopardize its structural integrity.

Flare systems shall be designed to prevent flashback and oxygen ingress using liquid seals and/or purge gas to ensure a positive operating pressure inside the flare system during normal operation and hence achieving the vapor recovery function.

Wherever a water seal drum is not provided, adequate purge gas flow shall be maintained to avoid potential flashback due to oxygen ingress. Alternatively, use of a quick opening valve with a relief bypass (or break pin buckling valve) may be considered based on specific risk assessment.

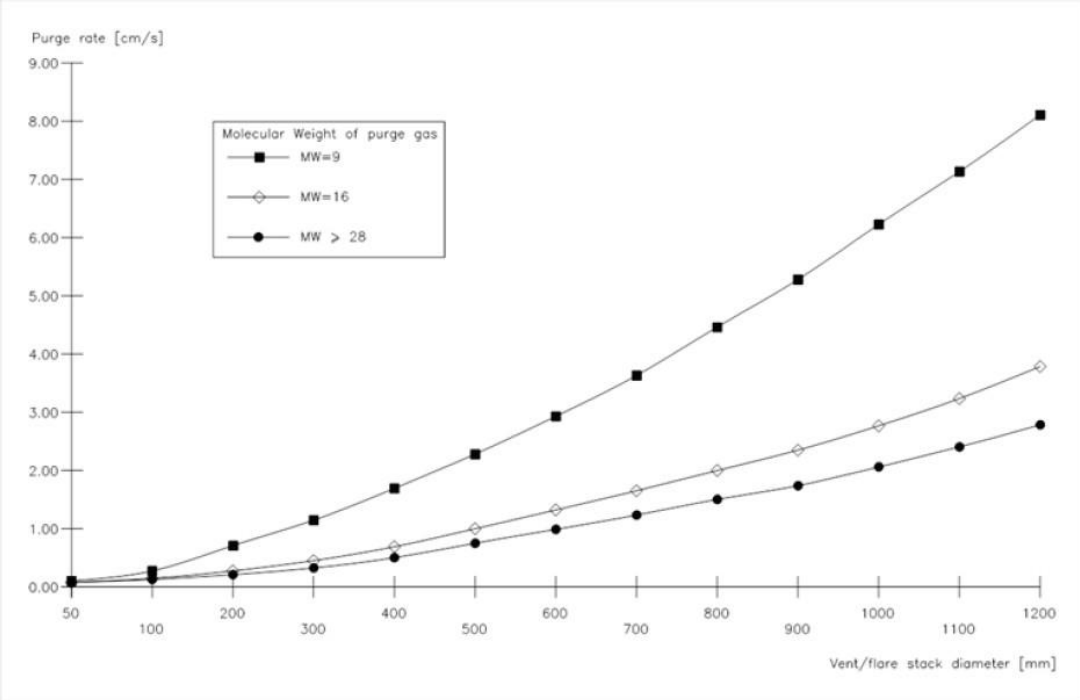
Sub-headers and headers shall be preferably purged with nitrogen with fuel gas as a back-up.

Factors that influence purging design are as follows:

i. The type of a purge gas available; hydrogen rich gas has a higher tendency to back burning;
ii. The economic value of the purge gas;
iii. The direct impact on the environment;
iv. The composition of the gas to be flared;
v. The presence of a flare gas recovery system;
vi. The flaring philosophy; for a non-flaring facility (i.e. with flare gas recovery or large secondary stack) the use of an inert gas as purge gas may be attractive.

The purge rate is fixed by the flare tip vendor requirements, however, for initial estimate the Figure 8.2 shall be used as a general engineering guideline:

Figure 8.2 Purge Rates Required for Pipe Flares



Higher purge rates than the above normal rates may be required during certain scenarios such as during initial start-up or during start-up following a shutdown and after a hot release.

Following a shutdown, the flare headers shall be purged with inert gas to remove all the air prior to igniting the flare pilots. The required nitrogen purging for this scenario exceeds the above purging requirements estimated during normal operation.

There are two common types of seals which can be located at/or below the flare tip; buoyancy and velocity seals, API STD 521 [1] section 5.7.6. These seals primarily tend to help in minimizing oxygen ingress as well as purging rates. However, the design should consider no credit for the presence of these seals in reducing purge requirements.

Buoyancy Seal

The buoyancy seal uses the difference in the relative molecular masses of the purge gas and air to form a gravity seal that, at the proper purge gas flow, prevents the air from entering the stack with the use of two 180 degree bends structure. Buoyancy seals reduce the purge gas velocity required through the tip to 0.003

m/s and limits the oxygen levels to less than 0.1%. However, buoyancy seals are easily blocked and are very easily damaged by shock loads, such as those occurring at the start of emergency depressuring. Therefore, the use of labyrinth/Bouyancy seals shall be evaluated carefully on a case by case basis.

Velocity Seal

In the velocity seal, the air enters through the flare tip and hugs the inner wall of the flare tip with the help of cone shape obstruction baffles. The velocity seal reduces the purge gas velocity through the tip to between 0.006 m/s and 0.012 m/s (higher than buoyancy seals) and limits oxygen to 4 - 8% (higher than buoyancy seals). Velocity seals do not offer protection against air ingress with interrupted purge flow, but they do not suffer from damage caused by depressurizing and blockage. Velocity seals are therefore preferred over buoyancy seals.

Flashback occurs when the local velocity of a mixture of air and gas becomes less than the flame velocity, causing the flame to travel back through the mixture at a velocity lower than sonic velocity. To provide flashback protection, purge fuel gas is to be used in conjunction with a suitable velocity seal positioned below the flare tip.

8.18 Flare Ignition Packages

Dual Diverse systems shall be provided for ignition systems to ensure the flare is lit when required. The primary ignition system shall be the high energy ignition system while the secondary system shall be a flame front generator installed to be the manual back up. Any other type of ignition system can be evaluated on a case by case basis subject to COMPANY approval. For low risk activities which are attended and manned and where the flare is not normally lit, FFG can be used as the sole ignition system.

Each pilot shall be provided with its own independent fuel gas supply line, pilot ignition line (by FFG) and its own set of flame detection measures. Power for the pilot's ignition system shall be supplied from the emergency power system (UPS).

8.19 Flame Detection Systems

Flame detection is essential to verify and confirm that the pilot is ignited and initiate automatic re-ignition of the pilot through the pilot ignition system. Pilots shall have a dual diverse flame detection system. The primary flame detection system shall involve dual thermocouples for every pilot. The secondary flame detection system shall be provided as an alternate to the primary system. This involves various possible technologies such as: UV camera/ Infrared/ Acoustic / ionization technologies.

For low risk activities which are attended and manned and where the flare is not normally lit, dual thermocouples can be used as the sole flame detection system.

8.20 Flare Stack Diameter

The flare stack diameter is determined by the velocity criteria although the pressure drop should also be checked.

The flare stack diameter is usually calculated by the flare tip vendor. The vendor determines the flare stack diameter based on the flow rates provided. The Mach number during peak, short term, and infrequent peak flow should not exceed 0.5.

8.21 Flare Stack Height

Flare Stack height is based on radiation and dispersion criteria in line with COMPANY COPs. In order to determine the height of a flare stack, it is necessary to consider the effects of thermal radiation on personnel and equipment (Table 8.5). It is possible to calculate approximate radiation levels using the methods in API STD 521 [1] section 5.7.2.3 or by using propriety software packages. Accurate flare radiation isopleths are normally calculated by the flare tip vendor as they are dependent on the particular tip design. Other factors that should be considered when sizing the flare stack height are :

i. Maximum acceptable concentration of any toxic substances i.e. H_2S at occupied location;
ii. The hot plume temperatures levels;
iii. Wind effects and atmospheric stability level;
iv. Plot area availability with respect to sterile radius;
v. Access for maintenance;
vi. Associated weight, constructability and maintainability;
vii. Noise;
viii. Flame out condition of the flare tip i.e. cold venting.

Height of the flare stack will be confirmed by the flare vendor and Health and Safety Executive (HSE) using specialized software.

Various factors including molecular weight, wind speed, gas composition which in return affects the fraction of heat radiated, flowrate, type of flare tip, liquid content, etc. affect the radiation, not all heat released in a flame will be transferred by radiation, refer to API STD 521 [1] section 5.7.2.3.3.

The effect of adjacent nearby flare stacks needs to be considered when evaluating the radiation and dispersion limit of the flare stack.

Table 8.5 Recommended Design Thermal Radiation for Personnel [14,15,16]

Permissible Design Level kW/m^2	Description / Applicability Criteria-Notes 2,4)
6.31 (Note 3)	Maximum radiant heat intensity at the boundary of the sterile radius with maximum relief rate and/or in areas where emergency actions lasting up to 30 s can be required by personnel without shielding but with appropriate clothing (Note 1).
4.73	Maximum radiant heat intensity in areas where emergency actions lasting 2 min to 3 min can be required by personnel without shielding but with appropriate clothing (Note 1). All the flare associated equipment panels etc shall be located outside the 4.7 kW/m^2 to ensure personnel attending the maintenance work at the flare systems shall not be exposed to the radiation levels more than 4.7 kW/m^2. This criterion shall be considered while placing the flares at one location.
3.15 (Note 3)	The property limit, or perimeter area where the fence is required to be constructed the heat radiation level at maximum emergency relief rate shall be 3.15kW/m^2 including the effect of solar radiation.
1.58	Continuous flaring. Maximum radiant heat intensity at any location where personnel with appropriate clothing can be continuously exposed (Note 1).

Notes:

1. Appropriate clothing consists of hard hat, long-sleeved shirts with cuffs buttoned, work gloves, long-legged pants and work shoes. Appropriate clothing minimizes direct skin exposure to thermal radiation.
2. All above radiation contours shall consider a personnel height of 2 m.
3. In case there is more than one flare at a site, the sterile area of 6.3kW/m^2 of individual flare shall not overlap if both or all the flares are in operation simultaneously. The sterile radii can overlap if anyone of them is in operation at any given point of time and others are spare flares and shall never be put into operation simultaneously. The heat radiation contours of 3.15kW/m^2 (for the property limit) can overlap.
4. These limits shall be considered as inclusive of solar radiation (0.946 kW/m^2).

Dispersion of the maximum emergency relief rate of flammable streams shall be at a safe distance from work areas and elevations (e.g. platforms, tank roofs, etc.) that are likely to be manned. Thus, the Lower Flammability Limit (LFL) contour shall be located within the sterile area and shall not pose any risk of possible ignition/explosion to personnel present outside the sterile area.

The flammability limits should follow the below criteria:

i) i. Flammable: 0.5 LFL

Lower Flammability Limit (LFL) contour shall be located within the sterile area and shall not pose any risk of possible ignition/explosion to personnel present outside the sterile area.

ii) Helidecks: 0.1 LFL

The ground level concentration of H_2S & SO_2 at 2 meter height from grade level shall be less than 10 ppm & 2 ppm respectively. All other toxic gases shall be assessed for the corresponding TWA 8 hour concentration limit.

Avoid ground flaring for gas containing more than 1000ppm H_2S due to emission of SO_2 at ground level, which is toxic to people. Flaring of these gases shall be with an elevated flare system, with height meeting the requirements specified in HSE-OS-ST21 Management of Hydrogen Sulfide (H_2S) Standard [15].

The design of the flare stack shall consider unignited conditions (flame-out) for the dispersion evaluation of H_2S as well as flammability.

8.22 No Normal Flaring & Flare Gas Recovery System

The flare system shall be designed for minimal flaring during normal operation. Considering the individual business unit's KPIs on flaring, the flare gas recovery systems should be installed to capture all the continuous loads from the process/utility units.

A flare gas recovery system should be provided to recover gas from upstream of the KO drums in the flare system. Wherever separate KO drums are provided for ISBL or OSBL, a common flare recovery system should be provided upstream the OSBL KO drum. Recovered gas is recycled back to the process unit or routed for export.

Vapor recovery system may include a vapor recovery compressor or ejector or a combination of both to be evaluated on a case by case basis within a specific business unit.

Flare gas recovery systems shall be proven and contain all reasonable safety measures to ensure the safety of the flare or vent is not compromised (e.g. fast acting fail open valves, bursting disk etc.).

Use of common flare gas recovery systems for a number of flares should be discouraged. If used, a careful safety analysis of the system should be carried out.

8.23 Spare Flare

In facilities where 100% availability is required, a spare flare system may be evaluated on a case by case basis depending on the requirements of the various ADNOC business units.

The extent of sparing the flare system may be evaluated with respect to:

a. Either installing a spare flare KO drum, stack and flare tip. Spare KO drum can be common and shared among various flare systems but designed to the more stringent requirements such as metallurgy and gas/liquid separation.
b. Or limiting the sparing to having a spare flare stack with its own flare tip.
c. Flare headers shall not be spared.

Since it is inevitable that isolation valves shall be installed between the main and spare flare, safety key mechanical interlocking systems **SHALL [PSR]** be considered during design to achieve the following:

a. Ensure the plant is never isolated from the flare stacks;
b. Ensure a safe changeover between the online primary flare and the spare flare;
c. Preventing simultaneous inadvertent line up/ isolation of the main flare and spare flare.

Sufficient purging shall be provided upstream of both flare stacks to sweep any oxygen ingress prior to switching from the online primary flare to the spare flare. Accordingly, the risk of potential flash back is mitigated.

8.24 Flow Measurement Requirements

For facilities with multiple process / operating areas upstream of a common flare system, each area shall have a flow-sensing device (flow detection, not flow quantification) on the flare lateral so that the relieving process /operating area can be quickly identified.

Flare systems shall have devices for flow measurement for flare control and regulatory reporting or environmental purposes, which might require measurements at multiple locations

Consideration should be given to installing flow-measuring devices in each of the main flare headers.

All facilities, having flares, shall install a flare flow monitoring device (e.g. Ultrasonic or Thermal Flow Meter) to account for high and low flow ranges on the vapor line downstream of the liquid knock-out drum. Unit/area wise flowmeters should be encouraged for early and easier identification of leakage sources.

In selecting the flow-measuring device, it shall be verified that the installed device cannot block the flare header and that no low points are created within the device or associated piping.

8.25 Pressure measurement:

Consider providing pressure measurement with high alarm downstream of the flare KO drum to alert against concerns such as long term blockage.

9 DEPRESSURIZATION SYSTEMS

9.1 Introduction & Objectives

The main purposes of Emergency Depressurization are:

i. To minimize the fuel inventory which could supply a fire and reduce the potential for escalation;
ii. To minimize the release of flammable or toxic product in case of non-ignited loss of containment;
iii. To prevent catastrophic equipment failure during an exothermic runaway reaction;
iv. To prevent plugging problems in pipelines;
v. To reduce the risk of vessel or piping rupture due to thermal stress during a fire;
vi. To move the process involving hydrocarbon to a safe state and hence reduce the risk of escalation of fire and BLEVE.

9.2 Applicable Criteria

The criteria used to decide whether an emergency depressurization is required when one of the following applies:

i. Operating at a pressure of 17.2 bar g or higher;
ii. Permanently Manned offshore facilities.
iii. A mixture operating above its boiling point at atmospheric pressure and contains more than 20 m^3 (liquid vessel volume-excluding piping volume) of butane or lighter materials;
iv. P>7 barg and PV_{gas} > 100 bar.m^3 (P- PAHH ; V_{gas}- Maximum gas volume inside vessel or piping or both (based on LALL).

Any deviations from the above criteria, due to any specific requirements (such as from process licensor(s)), **SHALL[PSR]** require COMPANY approval.

9.3 Depressurization Cases

For typical depressurization connection, please refer to Figure 9.26 in section 9.8.10 of AGES-PH-08-001 [13].

Table 9-1 below provides specific guidance on simulating various depressurization cases.

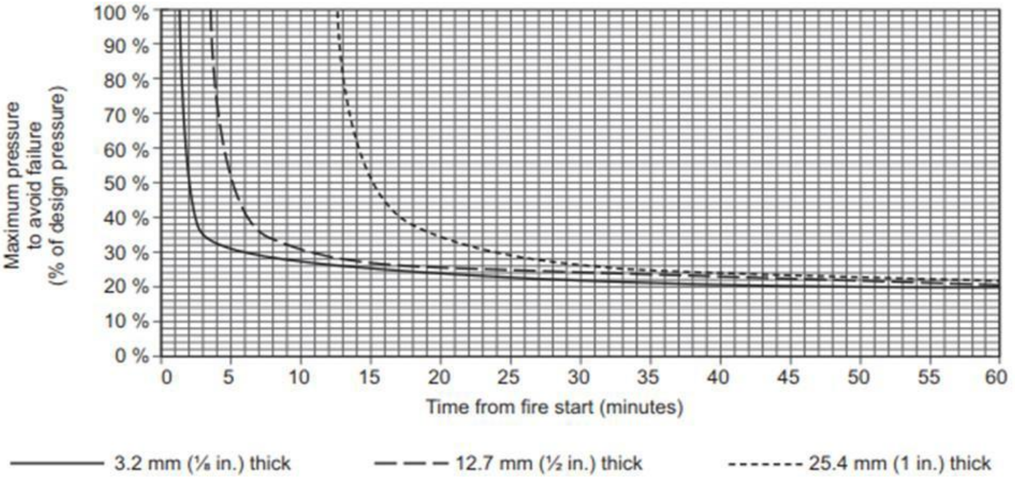
Table 9-1: Summary of Depressurization Cases

Blowdown Scenario	**Emergency fire depressurization**	**Adiabatic (Non-cryogenic & Cryogenic)-Note 4**	**Isochoric Case (constant volume process) - Non cryogenic system**
Initial/Start Pressure	PSV set pressure (Note 1) (For compressors use Settle-Out pressure)	PAHH (For compressors use Settle-Out pressure)	PAHH (For compressors use Settle-Out pressure) and normal operating temperature, isochorically cool the system to minimum ambient temperature. The corresponding pressure arrived shall be the starting point for depressurization.
Initial Temperature	Case 1: Maximum operating temperature Case 2: Minimum operating temperature	Case 1: Maximum operating temperature for estimating the total depressuring time to reach atmospheric pressure. Case 2: Minimum operating temperature to estimate minimum depressuring temperature in case of cryogenic condition.	Minimum ambient temperature
Final Pressure	50% of the design pressure for pool fire scenario (Note 2)	Atmospheric pressure	Atmospheric pressure
Depressurization time	15 minutes for vessels with thickness 1" and higher (Notes 3, 4).	Until atmospheric pressure is reached using RO size from fire case.	Until atmospheric pressure is reached using RO size from fire case.
Initial liquid level	Both HHLL and LLLL shall be studied to determine the governing out of each case.	Non cryogenic case - NLL for maximum operating temperature case Cryogenic case: - Both HHLL and LLLL for minimum operating temperature case to determine governing case	HHLL (for systems having boiling off liquids upon pressure reduction) and LLLL (additional check case) shall be studied to determine the governing case.

Blowdown Scenario	Emergency fire depressurization	Adiabatic (Non-cryogenic & Cryogenic)-Note 4	Isochoric Case (constant volume process) - Non cryogenic system
Ambient condition	Maximum ambient temperature	Minimum and maximum ambient temperature	Minimum ambient temperature
Output	1. RO size 2. Fire Depressurization load	1. MDMT for vessel design (Cryogenic system). 2. Adiabatic Depressurization load for staggering of non-fire zone. 3. Rationalize the depressurization time and flare load during maintenance activities (i.e. flowline manual depressurization to RDS/cluster flare as in the case of Onshore upstream gathering facilities).	1. MDMT for vessel design (Non cryogenic system)
Notes/Remarks	1. For systems which are depressurized automatically (where applicable) initial pressure of PAHH can be considered for sizing the flare system and the PSV set point for sizing the blowdown lines. 2. The API 521 Empirical based fire heat equation (6/7) is exclusively for open pool fires and shall not be used for confined pool or jet fire. Analytical Method explained in API 521 section A.3 shall be used for such cases.	This load should not be typically a governing flare load scenario. This should provide the MDMT temperature to be designed for cryogenic systems. This load can also be used for the non-fire zone when staggering philosophy is adopted.	

Blowdown Scenario	Emergency fire depressurization	Adiabatic (Non-cryogenic & Cryogenic)-Note 4	Isochoric Case (constant volume process) - Non cryogenic system
	3. For vessels with thickness less than 1", detailed fire analysis to be carried out based on stress based analysis to arrive at the time in which the vessel needs to be depressurized with a faster depressurization rate. Refer to API 521 analytical method in section A.3.5.4.6. Refer to Figure 9.1 below As a rule of thumb, Depressurization time shall be decreased by 3 minutes for each 5 mm decrease in wall thickness.. In addition to this approach, the designer shall evaluate reducing the pressure to 6.9 barg (100 psig) in 15 minutes. The governing load out of these two approaches shall be used. 4. Compressor depressurization time may be limited by compressor vendor's maximum depressurization rate to avoid explosive de-compression.		

Figure 9.1. Minimum Depressuring Rates to Avoid Failure of a Gas-filled Vessel



9.4 MDMT

Cryogenic system (systems operating below minimum ambient temperature)

The MDMT of the system in cryogenic services is calculated from the adiabatic case with minimum operating temperature.

MDMT = Inner wall temperature -3°C

Non-Cryogenic system (systems operating above minimum ambient temperature)

The MDMT of the system in non-cryogenic services is calculated from the isochoric case explained above.

MDMT = Inner wall temperature -3°C

MDMT temperature should be specified with the corresponding exposure pressure in the process equipment data sheet and line list. MDMT can be specified at its coincident pressure during depressurization as a means of CAPEX optimization. However, it should be further emphasized that re-pressurization **SHALL [PSR]** be delayed until system has warmed up to a safe value greater than the MDMT due to the above. The same **SHALL [PSR]** be reflected as part of the safe operating procedures/philosophy. If there is no impact on cost/ material as established by Static Equipment Engineer, MDMT **could** be specified with full design pressure to allow inherent safe design and to avoid reliance on safe Operating procedures as detailed above.

9.5 Blowdown Initiation

On detection of a fire or toxic and/or flammable gas release or other specific parameters depending upon the processes involved within different business units, Operator manual initiation or ESD automatic initiation will activate shutdown of the affected fire zone and depressurization. Zones may be depressurized one zone at a time, except where it may be necessary to depressurize more than one zone to prevent detrimental effects in other zones, to be determined on a case by case basis- Refer to AGES-PH-03-001 [17].

The decision between manual initiation against automatic depressurization shall be decided in conjunction with HSE Engineers and other stakeholders (Process Licensors).

9.6 Sequential Blowdown

Sequential blow down of different fire zones may be considered to optimise the flare load and produce an economical flare system design.

This is also referred to as staggered blowdown. If sequenced depressurization is adopted, the system design **SHALL [PSR**] ensure that a failure cannot result in uncontrolled simultaneous depressurization of the whole facility. Design measures for preventing inadvertent opening of multiple BDVs among various fire zones shall be accommodated by design i.e. UPS back up power supply and secured instrument air system.

Staggering calculations **SHALL [PSR**] be done for different combinations of fire zones and documented in a Depressurization Study Report.

In a staggering configuration, depressurization load from adiabatic case may be considered in conjunction with the adjacent fire zone (which is not on fire) depressurization depending on the detailed HSE analysis and fire zone mapping studies.

9.7 Pipeline Depressurization

Pipeline systems for gas and light hydrocarbon service(s) shall be equipped with manual depressurization provisions for one of the following reasons:

i. To mitigate emergencies such as leaks;
ii. Operability / maintenance reasons.

Depressurization connections shall be provided at at least one end of the pipeline. Depressurization study shall be conducted at concept/FEED stage to establish the following:

i. Depressurization load and time;
ii. Facilities required for flaring/venting, sizing of depressurisation valve/RO;
iii. Temperature profile during depressurization;
iv. Operating procedure to be followed during depressurization;
v. Input for material selection and MDMT.

9.8 General Considerations

Under certain conditions, hydrates or ice can form in a hydrocarbon system containing free water. If a severe hydrate or ice formation problem either upstream or downstream of the depressurization valve is possible, mitigations shall be implemented (e.g. provision for methanol injection, other chemical injection, or other methods used to inhibit hydrate formation).

Special consideration should be given to depressurizing systems containing rotating equipment (compressors) and for equipment with internals, e.g. Column, Molecular Sieve units, Vessels with Demister pads etc. Vendors shall be consulted to determine the acceptability of the depressurization rate to ensure the seals and/or elastomers and the internals are not damaged in an emergency depressurization situation.

The facility can be sectionalised to reduce the impact of a fire on the flare system capacity as long as total depressurization cannot occur from a common cause failure (e.g. instrument air failure, loss of electrical power or failure of ESD logic solver instrumentation).

Determination of the fire zones shall be based on fire mapping studies (FERA) considering radiation limits and explosion overpressure. There shall be no overlap between the fire zones. An approximate estimation of the fire zone is with an area between 230-460 m^2 as per API 521 section 4.6.7.2 [1].