

FLARE AND BLOWDOWN SYSTEM**JGS 210-120-1-41E**

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1. SCOPE

- (1) This standard practice provides the recommendations and the guidelines for the basic design of piping and equipment in flare and blowdown systems provided in petroleum, petrochemical and similar plants.
- (2) This standard practice should be applied with any regulations governing flare and blowdown facilities in the country where the facilities are to be installed. The requirements of the national and local regulations should take precedence over any other requirements.
- (3) Specific instructions given in the Project Specifications take precedence over the requirements in this standard practice.

2. WORK PROCEDURE**2.1 Input to the Design****2.1.1 Source of Process Conditions**

The data to be used for the flare and blowdown system design should be clarified on the following points:

(1) Source of data

The data will be obtained from, but not limited to, the following documents:

- Process Flow Diagram (PFD)
- Basic Engineering Design Data (BEDD)
- Piping & Instrument Diagram (P&ID)
- Equipment data sheets
- Piping material specification
- Flare load summary
- Rupture disk summary

(2) Related documents to be used as a part of the input data.**(3) Related documents to be checked or revised based on the calculation results.****2.1.2 Required Data for the Design**

The following is a summary of data to be used for the design :

(1) General data

- Item No. and service of protected equipment
- Tag number of pressure relief devices
- Service for identification
- Code and standard to be applied, if specified
- Set pressure or specified bursting pressure

(2) Relieving load data

- Cause of failure
- Fluid name for identification
- Required relieving capacity
- Relieving temperature, inlet/outlet
- Physical properties at relieving conditions
 - Liquid service : Specific gravity, Viscosity
 - Vapor service : Molecular weight, Viscosity, Specific heat ratio (k), Compressibility factor (Z)
 - Two-phase : all data for liquid and vapor both at inlet and outlet
- Back pressure, maximum allowable and constant for controlling case, if available.
- Accumulation for controlling case

(3) Construction data

- Destination of discharge

2.2 Output from the Design

The data sheet and specifications of basic design will include, but not limited to, the following ;

(1) Hydraulic calculation sheet including the following :

- General data
- Relieving load data
- Construction data
- Unit identification, if any
- Rated relieving capacity
- Design load of each lines and headers
- Calculated back pressure
- Velocity and/or Mach number
- Line size and equivalent length
- Title block or notes

(2) Skeleton of vessel for the following equipment

- Knock-out drum
- Seal drum
- Quench drum, if provided
- Liquid blowdown drum, if provided

(3) Pump data sheet

(4) Flare stack data sheet

- Item number and service
- Maximum flare load
- Normal flare load defined as seal gas rate
- Vapor temperature
- Fluid name and compositions
- Physical properties at relieving conditions
 - Vapor service : Molecular weight, Viscosity, Specific heat ratio (k)
- Allowable pressure drop

(5) Vent stack data sheet, if provided

- Item number and service
- Maximum relieving load
- Normal load defined as seal gas rate
- Vapor temperature
- Fluid name and compositions
- Physical properties at relieving conditions
 - Vapor service : Molecular weight, Viscosity, Specific heat ratio (k)
- Allowable pressure drop
- Height required from dispersion study, if hazardous component is contained in the vent gas.

(6) Piping and instrument diagram for the flare system

(7) Instrument data sheets

(8) Utility requirement

- Water for seal and quench
- Steam for smokeless burning and heating
- Fuel gas for dry seal, pilots and igniter
- Compressed air for igniter
- Electric power

2.3 Work Steps

The flare system design will be conducted as follows ;

- (1) Relieving load calculation for each pressure relieving device in accordance with JGS 210-120-1-40E "Pressure Relieving Design".
- (2) Prepare pressure relieving device data sheet in accordance with JGS 210-120-1-61E "Pressure Relief Devices", but back pressures on the data sheet are still allowable values.
- (3) Confirm location of equipment of the flare system. Evaluate equivalent length and slope of headers and elevation of the flare system equipment.
- (4) Evaluate design load of flare system as mentioned in 4.1 of these criteria.
- (5) Sizing of headers in accordance with JGS 210-120-1-37E "Hydraulic Design", taking back pressure limitation into account.
- (6) Confirm that the calculated back pressures are well below the allowable back pressure in any case and revise the pressure relieving device data sheet if required.
- (7) Prepare data sheets and specifications as given in 2.2 above.

2.4 Computer Programs

#FLINE can be used to calculate backpressure in flare header.

3. SELECTION PROCEDURE

3.1 Selection of Disposal Systems

While the various systems for the disposal of relieving vapor or liquid are mentioned below, the disposal system should be selected according to the expected frequency, duration of operation, required capacity and fluid properties.

3.1.1 Blowdown System for Vapor Relief Stream

Systems for the disposal of voluntary or involuntary vapor discharges are :

- To atmosphere
 - To lower pressure process vessel or system
 - To closed pressure relief system and flare
- (1) Vapor discharge to atmosphere
 - (a) Vapor relief streams can be vented directly to atmosphere if all of the following conditions are satisfied :

Table-1 Requirements for atmospheric venting

- Such disposal is not in conflict with the present regulations concerning pollution and noise.
- The vapor is effectively non-toxic and non-corrosive.
- Vapor which is lighter than air or vapor of any molecular weight that is non-flammable and non-hazardous or vapor of any molecular weight relieved at where there is no ignition source.
- There is no risk of condensation of flammable or corrosive materials.
- There is no chance of simultaneous release of liquid, except for water.

For example, a vent for natural gas can finally be relieved to atmosphere because of non-toxic, non-corrosive, lighter molecular weight than air, non-condensable, non-corrosive and usually liquid-free. Also, venting gas from LPG tank located at off-site area can be relieved to atmosphere because there is usually no ignition source around tank.

- (2) Vapor discharge to lower pressure process vessel or system
Individual pressure relief valves may discharge to a lower pressure process system or vessel capable of handling the discharge. Although this type is rarely used, it is effective for discharges that contain materials which must be recovered.

(3) Vapor discharge to closed pressure relief system and flare

The following vapor discharge should be collected in a closed pressure relief system which terminates in a flare, namely a flare system.

- (a) Vapor from depressuring valves
- (b) Vapor which contains 1% H₂S or more by volume
- (c) In all cases where the atmospheric discharge of vapor or discharge to a lower pressure system is not permissible or practicable.

In all cases, the installation of a closed pressure relief system should result in a minimum of air pollution and the release of combustion products.

3.1.2 Blowdown System for Liquid Relief Stream

Systems for the disposal of voluntary or involuntary liquid discharges are :

- To on-site liquid blowdown drum
- To lower pressure process vessel or system
- To oily water sewers only if the material will not cause hazardous conditions
- To pump suction if pump will not overheat or can withstand the expected temperature rise
- To burn-pit
- To vaporizer

Thermal expansion relief valves may discharge small quantities of volatile liquid or vapor into the atmosphere, provided the valve outlet is in a safe location.

(1) Liquid discharge to on-site liquid blowdown drum

The liquid should be discharged to an on-site liquid blowdown drum which is capable of retaining the liquid discharged at the required liquid relief rate for a period of 20 minutes. This drum should have a vapor discharge line to the closed pressure relief system.

(2) Liquid discharge to lower pressure process vessel or system

The liquid should be discharged to a lower pressure process vessel or system which is capable of handling the required liquid relief rate plus any flashed vapor.

(3) Liquid discharge to oily water sewer

Liquid discharge to an oily water sewer should be non-volatile and non-toxic. The required liquid relief rate should be within the oil removal capability of the oily water treating system.

(4) Liquid discharge to pump suction

Required liquid relief should discharge to an upstream liquid reservoir from which the pump takes suction.

The liquid relief may discharge directly to the pump suction line if sufficient cooling is provided to prevent a temperature rise of the liquid recycled through the pump when the pressure relief valve opens or when a constant displacement pump is used.

(5) Liquid discharge to burn-pit

Liquid relief or voluntary liquid blowdown which need not be returned to the process or discharged to an oily water sewer, should be discharged to a burn-pit, if environmentally accepted.

(6) Liquid discharge to vaporizer

The liquid should be discharged to a vaporizer which is capable of vaporizing a liquid relief of no more than 5,000 kg/h.

3.2 Separation of Flare Headers

Although one common flare header system should generally be provided for each plant, additional special purpose headers will be feasible in some cases.

- (1) The additional special purpose headers should, therefore, be investigated according to temperature of relieving vapor, and corrosive properties from the economical viewpoint.
- (2) Separation of header based on pressure level will be unusual.

3.2.1 Corrosion

- (1) For corrosive service a separate header with the special anti-corrosive material should be provided.
- (2) Acid gas flare header should be provided for the following services :
 - All acid gases from the sulfur plant.
 - All fluid, (except for steam) containing 50 vol% or more of H₂S.

Carbon steel with 2.5 mm of corrosion allowance may be applicable for the acid gas flare, but consult the material research engineer.

3.2.2 Temperature

- (1) Where low-temperature fluid should be handled such as in an ethylene plant or other cryogenic plant, a separate header will be feasible for the following reasons :
 - Economical because the low temperature header will be small even if high grade material is adopted.
 - To avoid freezing of water contained in hot fluid when cold fluid is relieved.
- (2) Take the following into account when establishing the separate cold flare header.
 - Auto-refrigeration due to flashing two-phase flow or entrained mist
 - Auto-refrigeration due to the Joule-Thomson effect of vapor
 - Relaxation of material by providing heater on the cold flare.
- (3) Materials applicable for low temperature service are as follows :

Table-2 Materials for low temperature service

Material	JIS B8270	ASME B31.3
Carbon steel	-10°C or higher	-29°C or higher
Al-killed C.S	-10°C to -45°C	-29°C to -46°C
3½ Ni	-45°C to -100°C	-46°C to -101°C
TP304	-100°C or lower	-101°C or lower

- (4) Example for combination of the flare header system is as follows :

Table-3 Example for combination of flare headers

Service	Temperature (°C)	Material	Fluid handled
Hot flare - wet	-29°C or higher	Carbon steel	- Fluid containing water - Butane and heavier hydrocarbon
Hot flare - dry	-29°C to -46°C	Al-killed C.S	- Flashing two-phase flow - Fluid containing entrained mist
Cold flare	-29°C or higher	Carbon steel	- No water contained
	-29°C to -46°C	Al-killed C.S	- Cold fluid
	-46°C to -101°C	3½ Ni	- Propane and lighter hydrocarbon
	-101°C or lower	TP304	
Cold relief	-29°C or higher	Carbon steel	- Vent or vent stack for hydrogen gas

4. DESIGN**4.1 Base Load of Flare System****(1) Basis of flare load**

The rated capacity should be applied to sizing of the inlet and outlet of pressure relief device. The rated capacity (W_{rated}) shall be decided as follows ;

$$W_{\text{rated}} = W_{\text{required}} \times \frac{A_{\text{selected}}}{A_{\text{required}}} \quad (1)$$

Where :

- W_{rated} = rated capacity of pressure relief device
- W_{required} = required capacity of pressure relief device
- A_{selected} = selected orifice area
- A_{required} = required orifice area expected from W_{required}

Common header systems and manifolds in multiple-device installations are generally sized based on the worst-case cumulative required capacities for all devices that may reasonably be expected to discharge simultaneously in a single overpressure event.

The back pressure of individual pressure relief device should be determined based on the maximum relieving load in any contingency.

- (2) The cumulative required capacity for common header system may be reduced taking account of the time delay , load variation and volume effect of system , etc. to optimize the flare system design.

The following short-cut method is available to reduce the cumulative required capacity :

$$(a) 0.75 \times \sum W_i + 0.5 \times \sum W_j \quad (2)$$

$$(b) 100\% \text{ of maximum rated capacity from individual relieving device}$$

Where :

- W_i = required capacities of pressure relief device
from vessels heated by direct fired heater
- W_j = other than the above W_i

However , as the above is short-cut method , the client approval is required for application.

- (3) The dynamic simulation is helpful to reduce the cumulative required capacity considering the time delay , load variation and volume effect of system , etc.

If available, the dynamic simulator should be applied to analyze the timing, duration and peak loads of pressure relieving phenomena and will have a significant effect on the combined load. The simulation should be based on a reasonable calculation basis.

- (4) When the maximum flare load is governed by depressuring, accumulation and time delay of vapor in the flare lines should be considered to reduce a peak load. Dynamic simulation is required for this purpose.

4.2 Piping System

4.2.1 General

- (1) Sizing of flare header should be referred to JGS 210-120-1-37E "Hydraulic Design" in detail.
- (2) Piping arrangement around the pressure relief devices are detailed in JGS 210-120-1-61E "Pressure Relief Devices" section 4.5.

4.2.2 Sizing

- (1) For intermittent services, such as for pressure relief valve discharge piping, 80% of sonic velocity may be acceptable. Care should be taken over the back pressure limitations which is described in JGS 210-120-1-61E "Pressure Relief Devices" section 4.1.4.
- (2) The sonic velocity can be calculated as follows.

$$V_{\text{sonic}} = \sqrt{\frac{g_c kRT}{M}} \quad (3)$$

Where :

V_{sonic}	= sonic velocity	(m/s)
g_c	= gravity conversion factor = 9.81	(kg · m/Kg · s ²)
k	= specific heat ratio = C_p/C_v	(-)
R	= gas constant = 847.9	(Kg/m ²)(m ³)/(kg-mole)(°K)
T	= temperature	(°K)
M	= molecular weight	

Sample Calculation 1. : Natural gas ($M = 18.0$, $k = 1.27$) at 60 °C is flowing through a flare header at a velocity of 80 m/s. Calculate the percent of sonic velocity.

Solution : $V_{\text{sonic}} = [(9.81)(1.27)(847.9)(60+273) / (18.0)]^{0.5} = 442 \text{ m/s.}$

Hence, % of sonic = $(80) / (442) \times 100 = 18.1 \%$.

- (3) Size and length of outlet piping of pressure relief device
 - (a) The connection between the safety relief device and the vessel should be as short as possible.
 - (b) In every case, the nominal outlet pipe should be as large as or larger than the nominal size of the pressure relief device outlet flange; in the case of long outlet piping, the pipe size should sometimes be much larger.¹
 - (c) When pipes from single relieving source but divided into two or more pressure relief devices are combined to one header, the outlet piping internal cross-sectional area should be at least equal to the combined outlet areas of the pressure relief devices connected to it. This criterion is not applied for the common header if two or more relieving sources are connected.
- (4) The pressure loss of individual outlet piping up to manifold should be calculated using the maximum rated capacity of the pressure relief device, which is consistent with the value used to size the inlet piping.
- (5) Noise and vibration

Allowable velocity in the flare header to prevent noise and vibration should be referred to Appendix-1.

¹ API RP 520 Part II 3.3