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PROCESS DESIGN OF FLARE AND BLOWDOWN SYSTEMS

(PROJECT STANDARDS AND SPECIFICATIONS)

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SCOPE

This Project Standards and Specifications covers process design and evaluation and selection of relief systems for Oil, Gas and Petrochemical (OGP) process plants.

It includes network and related ancillary installations which are to handle and direct fluids discharged due to overpressure and/or operational requirements to a safe disposal system.

This Standard is primarily concerned with selection of disposal system, sizing of relief headers, sizing of flare systems and burning pits.

REFERENCES

Throughout this Standard the following dated and undated standards/codes are referred to. These referenced documents shall, to the extent specified herein, form a part of this standard. For dated references, the edition cited applies. The applicability of changes in dated references that occur after the cited date shall be mutually agreed upon by the Company and the Vendor. For undated references, the latest edition of the referenced documents (including any supplements and amendments) applies.

1. API (American Petroleum Institute)

API RP 520	"Sizing, Selection and Installation of Pressure-Relieving Devices in Refineries" Part I -Sizing and Selection Part II – Installation
API RP 521	"Guide for Pressure-Relieving and Depressuring Systems"
API Publication 931	"API Manual on Disposal of Refinery Wastes, Volume on Atmospheric Emissions".

2. ASME(American Society of Mechanical Engineers)

ASME B 31.3	"Process Piping"

DEFINITIONS AND TERMINOLOGY

For extensive description reference can be made to API RP 521.

Atmospheric Discharge - Is the release of vapors and gases from pressure-relieving and depressuring devices to the atmosphere.

Autorefrigeration - Is the reduction in temperature as a result of pressure drop and subsequent flashing of light hydrocarbon liquids.

Back Pressure - Is the pressure that exists at the outlet of a pressure relief device as a result of pressure in the discharge system.

Balanced Safety/Relief Valve - Is a safety/relief valve that incorporates means for minimizing the effect of back pressure on the performance characteristics-opening pressure, closing pressure, lift, and relieving capacity.

Built-up Back Pressure - Is the pressure in the discharge header, which develops as result of flow after the safety-relief valve opens.

Closed Disposal System - Is a disposal system that is capable of containing pressures different from atmospheric pressure without leakage.

Conventional Safety/Relief Valve - Is a closed-bonnet pressure relief valve whose bonnet is vented to the discharge side of the valve. The valves performance characteristics-opening pressure, closing pressure, lift, and relieving capacity are directly affected by changes of the back pressure on the valve.

Critical Flow Pressure Ratio - Is the result of the following equation:

$$\frac{P_{CF}}{P_0} = \left[\frac{2}{k+1}\right]^{k/(k-1)} \qquad \text{Eq. (1)}$$

Flare - Is a means of safe disposal of waste gases by combustion. With an elevated flare, the combustion is carried out at the top of a pipe or stack where the burner and igniter are located. A ground flare is similarly equipped, except combustion is carried out at or near ground level. A burn pit differs from a flare in that it is primarily designed to handle liquids.

Flare Blow Off/Flame Lift-up - Is the lifting of flame front from the flare tip.

Flare Blow Out - Is the extinguishing of flare flame.

Mach Number - Is the ratio of vapor velocity to sonic velocity in that vapor at flowing conditions.

Open Disposal System - Is a disposal system that discharges directly from the relieving device to the atmosphere with no containment other than a short tail pipe.

Quenching - Is the cooling of a hot vapor by mixing it with another fluid or by partially vaporizing another liquid.

Super Imposed Back Pressure - Is the static pressure that exists at the outlet of a pressure relief device at the time the device is required to operate. It is the result of pressure in the discharge system coming from other sources and may be constant or variable.

Vent Stack - Is the elevated vertical termination of a disposal system that discharges vapors into the atmosphere without combustion or conversion of the relieved fluid.

SYMBOLS AND ABBREVIATIONS

SYMBOL/ABBREVIATION	DESCRIPTION
A	Cross-sectional area, in (m^2).
A_{L1}	Vessel segment area occupied by slops and drain, in (m^2).
A_{L2}	Vessel segment area occupied by condensed liquid, in (m^2).
A_p	Pit area required to vaporize and burn liquid, in (m^2).
A_t	Total vessel cross-sectional area, in (m^2).
A_V	Vessel cross-section area available for vapor flow, in (m^2).
C	Drag coefficient.
D	Flare tip diameter (m)
f	Moody Friction Factor, f=fD=4fF
f_F	Fanning Friction Factor
f_D	Darcy Friction Factor.
F	Fraction of heat radiated.
g	Acceleration due to gravity,9.8 in (m/s^2).
G	Design mass flow, in ($kg/s.\ m^2$).
G_{ci}	Critical mass flux, in ($kg/s.m^2$).
h	Depth (maximum distance, that the inlet pipe is submerged), in (m).
H	Flare stack height, in (m).
h_{L1}	Vessel depth occupied by slops and drain, in (m).
h_{L2}	Vessel depth occupied by condensed liquid, in (m).
h_v	Vertical space for vapor flow, in (cm).
k	Ratio of specific heats, C_p/C_v for the vapor being relieved.

K_1	Dimensional constant equal to 0.076 mm/min.
K	Maximum allowable radiation (kilowatts per square meter).
K_2	Unit conversion factor equal to 60,000.
L	Flame length, in (m).
L_{min}	Flare knockout drum minimum length required, in (m).
LH	Level high
LHA	Level high alarm
M	Molecular mass (weight) of the vapor or gas.
M_w	Average molecular weight of the vapour
N	Line resistance factor, (dimensionless).
n	Polytrophic exponent.
P_1	Upstream pressure, in (kPa absolute).
P_0	Upstream pressure, in (kPa absolute)
P_2	Pressure in the pipe at the exit or at any point or distance L downstream from the source, in (kPa absolute).
P_3	Pressure in reservoir into which pipe discharges, in [101 kPa (absolute) with atmospheric discharge].
P_{CF}	Critical flow pressure, in (kPa absolute)
q_l	Rate of vaporization and burning of liquid, in (kg/s) (selected as equal to the rate of flashed liquid entering the pit).
Q	Heat liberated (kilowatts).
Q_v	Heat required to vaporize liquid, in (kJ/kg).
W	Flow rate (kg/hour)
w_s	Steam flow rate, in (kg/s).
w_{HC}	Vapor relief rate, in (kg/s).
R	Surface distance from the center of flare stack to the object under consideration, in (m).
Re	Reynolds number.
r	Relative humidity, in (percent).
S_R	Linear regression rate of liquid surface, in (mm/min).
T	Flowing temperature (K)
T_1	Upstream temperature, in (K).
U_c	Particle dropout velocity, in (m/s).
U_j	Exit gas velocity, in (m/s).
U_v	Vapor velocity, in (m/s).
U_∞	Lateral wind velocity, in (m/s)
z	Compressibility factor.

Greek Letters

δ (Gama)	Fraction of heat intensity transmitted through the atmosphere.
θ (theta)	Liquid particle dropout time, in (s).
μ (mu)	Viscosity of gas, in (cP=1m Pa. s)
π (pi)	Constant figure equal to 3.1416.
ρ_L (rho)	Density of liquid at operating conditions, in (kg/m^3)
ρ_V (rho)	Density of vapor at operating conditions , in (kg/m^3).
τ (tau)	Fraction of heat intensity transmitted

UNITS

This Standard is based on International System of Units (SI) except where otherwise specified.

SELECTION OF BLOWDOWN SYSTEMS

General

While the various systems for the disposal of voluntary or involuntary vapor or liquid are mentioned below, the actual selection of a disposal system shall be conducted in accordance with the expected frequency, duration of operation, required capacity and fluid properties.

Blowdown System for Vapor Relief Stream

Systems for the disposal for voluntary and involuntary vapor discharges are:

- To atmosphere
- To lower pressure process vessel or system
- To closed pressure relief system and flare
- Acid gas flare

1. Vapor discharge to atmosphere

   Vapor relief streams shall be vented directly to atmosphere if all of the following conditions are satisfied (for a complete discussion on the subject see API RP 521):

   a. Such disposal is not in conflict with the present regulations concerning pollution and noise.

b. The vapor is effectively non-toxic and non-corrosive.
c. Vapor which is lighter than air or vapor of any molecular mass that is non-flammable, non-hazardous and non-condensable.
d. There is no risk of condensation of flammable or corrosive materials.
e. There is no chance of simultaneous release of liquid, apart from water.
f. Relief of flammable hydrocarbons direct to the atmosphere should be restricted to cases where it can be assured that they will be diluted with air to below the lower flammable limit. This should occur well before they can come in contact with any source of ignition.

The above condition can most easily be met if the vapors to be released have a density less than that of air. However, with proper design of the relief vent adequate dilution with air can be obtained in certain cases with higher density vapors. Methods of calculation are given in API RP 521 section 4.3.

a. Vapor from depressuring valves shall be discharged to a closed pressure relief system.
b. Vapor which contains 1% H2S or more by volume, shall be discharged to a closed pressure relief system.

2. Vapor discharge to lower pressure process vessel or system

Individual safety/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

In all cases where the atmospheric discharge or release of vapor to a lower pressure system is not permissible or practicable, vapor shall be collected in a closed pressure relief system which terminates in a flare, namely flare system. Where the concentration of H2S is such that condensation of acid gas is probable, provision for a separate line, heat traced, shall be considered.
In all cases, the installation of a closed pressure relief system shall result in a minimum of air pollution and the release of combustion products.

4. Acid gas flare

In process plants where H2S free and H2S containing streams are to be flared, consideration should be given to the installation of a separate header and flare stack assembly for the H_2S containing streams. The following provisions should be studied for the acid gas flare assembly:

a. Automatic injection of fuel gas down stream of H_2S pot in order to make the combustion stable.
b. Steam injection for smokeless operation shall not be considered for H_2S flare tip.
c. A common pilot igniter may be used to ignite all flare stacks including the acid flare.
d. The H_2S flare header and subheaders may be heat traced in order to prevent the condensation acid gas.

Blowdown System for Liquid Relief Stream

Systems for the disposal of voluntary and involuntary liquid discharges are:
- To onsite 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 burning 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 onsite liquid blow down drum

   The liquid shall be discharged to an onsite liquid blow down drum which is capable of retaining the liquid discharged at the required liquid relief rate for a period of 20 minutes. This drum shall have a vapor discharge line to the closed pressure relief system.

2. Liquid discharge to lower pressure process vessel or system

   The liquid shall 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 shall be nonvolatile and nontoxic. The required liquid relief rate shall be within the oil removal capability of the oily water treating system.

4. Liquid discharge to pump suction

   Required liquid relief shall 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 safety/relief valve opens or when a constant displacement pump is used.

5. Liquid discharge to burning pit

   Liquid relief or voluntary liquid blow down which need not be returned to the process or discharged to an oily water sewer, shall be discharged to a burning pit, if environmentally accepted.

6. Liquid discharge to vaporizer

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

DESIGN OF DISPOSAL SYSTEM COMPONENTS

Depending on the process plant under consideration, a disposal system could consists of a combination of the following items: piping, knock-out drum, quench drum, seal drum, flare stack, ignition system, flare tip, and burning pit.

Piping

1. General

   In general, the design of disposal piping should conform to the requirements of ASME B31.3 Installation details should conform to those specified in API Recommended Practice 520, Part II.

2. Inlet piping

   The design of inlet piping should be in accordance with API-RP-521, Section 5.4.1.2 .

3. Discharge piping

   The sizing should be in accordance with API-RP-521, Section 5.4.1.3 in conjunction with Appendix A as a supplement to the above.

Table 1- Typical K Values For Pipe Fittings

FITTING	K	FITTING	K
Globe valve, open	9.7	90-degree double-miter elbow	0.59
Typical depressuring valve, open	8.5	Screwed tee through run	0.50
Angle valve, open	4.6	Fabricated tee through run	0.50
Swing check valve, open	2.3	Lateral through run	0.50
180 degree close-screwed return	1.95	90-degree triple-miter elbow	0.46
Screwed or fabricated tee through branch	1.72	45-degree single-miter elbow	0.46
90-degree single-miter elbow	1.72	180-degree welding return	0.43
Welding tee through branch	1.37	Welding tee through run	0.38
90-degree standard-screwed elbow	0.93	90-degree welding elbow	0.32
60-degree single-miter elbow	0.93	45-degree welding elbow	0.21
45-degree lateral through branch	0.76	Gate valve, open	0.21
90-degree long-sweep elbow	0.59		

Contraction or enlargement	0	0.2	0.4	0.6	0.8
Contraction (ANSI)	---	---	0.21	0.135	0.039
Contraction (sudden)	0.5	0.46	0.38	0.29	0.12
Enlargement (ANSI)	---	---	0.9	0.5	0.11
Enlargement (sudden)	1.0	0.95	0.74	0.41	0.11

Table 2 - Typical Friction Factors and Conversion Factors for Clean Steel Pipe (Based on Equivalent Roughness of 0.046 mm)

CONVERSION FACTOR FOR EQUIVALENT LENGTH PER UNIT OF K		
DIAMETER NOMINAL PIPE SIZE (mm)	**MOODY FRICITION FACTOR (f)**	**METERS**
DN 50 SCHEDULE 40	0.0195	2.7
DN 80 " "	0.0178	4.36
DN 100 " "	0.0165	6.25
DN 150 " "	0.0150	10.2
DN 200-6 mm WALL	0.0140	14.7
DN 250 " "	0.0135	19.2
DN 300 " "	0.0129	24.0
DN 350 " "	0.0126	27.3
DN 400 " "	0.0123	31.88
DN 500 " "	0.0119	41.45
DN 600 " "	0.0115	56.67
DN 750	0.0110	67.85
DN 900 " "	0.0107	83.33

Note:

The above friction factors and conversion factors apply at high Reynolds numbers, namely, above 1 × 106 for DN 600 and larger, scaling down to 2 × 105 for DN 50.

4. Liquid blow down header

In order to reduce relief header loads and prevent surges due to two-phase gas/liquid flow as much as possible, it is advisable to direct all disposable liquids into a separate blow down network.
In determination of back pressure the following shall be taken into consideration:

a. Flashing of liquid at relief/safety valve discharge or along the network due to pressure drop and/or warm-up to ambient temperatures should be analyzed.
b. Solids formation due to auto refrigeration and presence of high melting point liquids should be determined.
c. If flashing and auto refrigeration is possible, a temperature profile along the network should be established so that proper piping material selection and construction practices is undertaken.
d. The network should be self-draining and should not include pockets.

e. The network should be continuously purged by natural gas controlled through an orifice.

f. High liquid velocities should be watched for within the network.

5. Stress

The design should be in accordance with ASME B.31.3 Chapter II, Part 2,302.3.5.

6. Anchors, guides, and supports

The design should be in accordance with API-RP-521; and ASME B.31.3 Chapter II, Part 5, 321.2.

7. Drainage

Disposal system piping should be self-draining toward the discharge end. Pocketing of discharge lines should be avoided. Where pressure relief valves 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 can not be sloped continuously to the knockout or blow down drum. The use of traps or other devices with operating mechanisms should be avoided.

8. Details

a. Safety/relief valve connection to the header

Normally, the laterals from individual relieving devices should enter a header from above.

b. Safety/relief valves connection when installed below the relief header

Laterals leading from individual valves located at an elevation above the header should drain to the header. Locating a safety valve below the header elevation in closed systems should be avoided. Laterals from individual valves that must 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.

In this regard the following should be taken into consideration:

i) For the branch header which must be connected to the main header from a lower level than the main header, e.g., sleeper flare piping, a drain pot must be installed. This is shown in Fig. 1.

ii) If a safety/relief valve must be installed below the flare header, the outlet line leading to the flare header shall be heat-traced from the safety/relief valve to their highest point. But the arrangement of safety/relief valve must be reviewed, as such, an arrangement is not