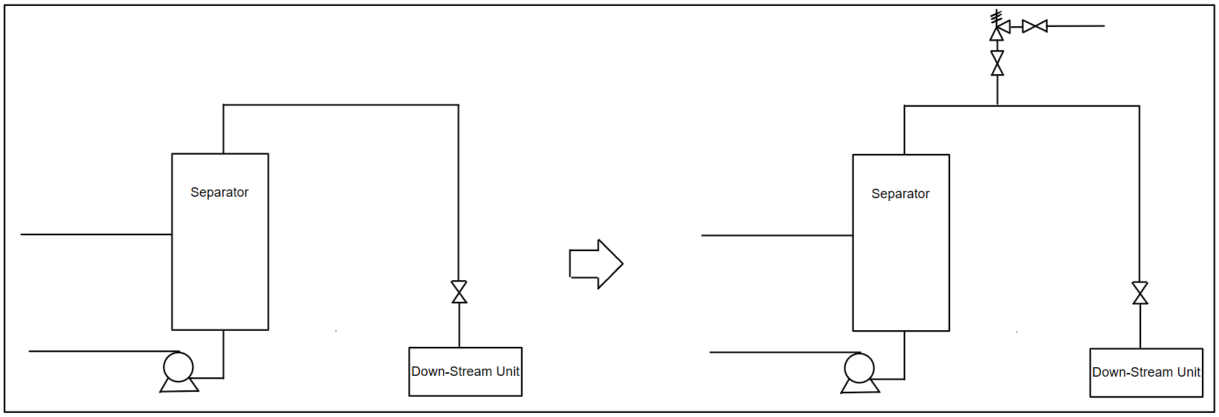
Educational Institute for Equipment and Process Design

Flare Header Summary

Suppose we have the following conditions:

1.The mixture enters the separators and the separator simply separate the liquid from the gas stream. The liquid by means of a pump is sent to another unit to be reused in the plant. The gas stream passes through a PV and its pressure is controlled or regulated, which now becomes suitable for downstream unit. Now imagine that for any reasons, which is not important, the control valve fails and closes. What will happen? Let's check the consequence! The pressure before the valve increases, which means the pipe connecting separator to control valve is pressurized, which means the separator pressure increases. Now you know the meaning of design pressure which was explained in second offline video, right? In a simple way, the pressure inside the vessel increases until it becomes equal to the design pressure of the vessel. What do you expect now? The explosion and damage to the vessel.

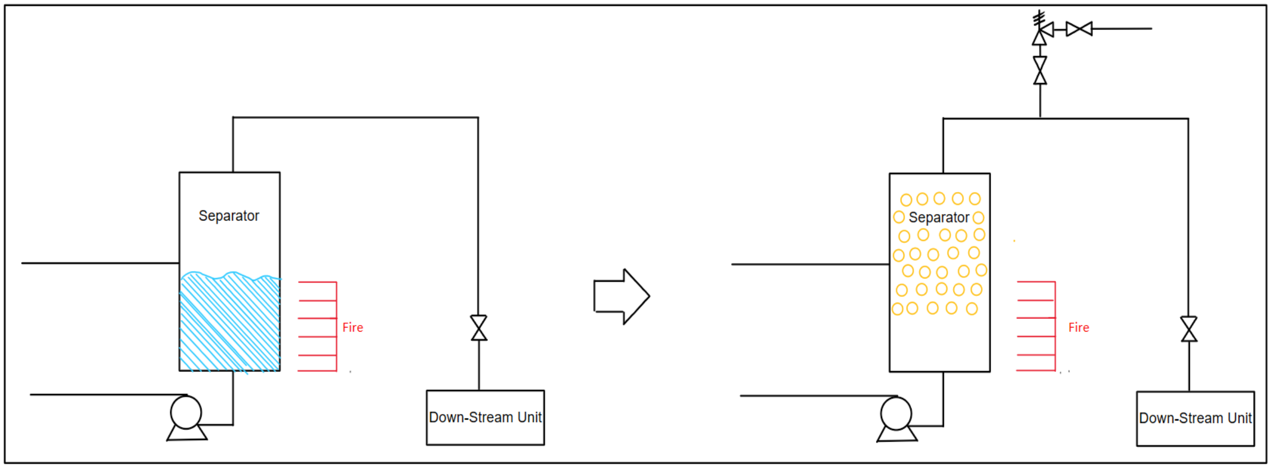


How to prevent it? Using a PSV in our design. The PSV should be mechanically designed in a way that when **the pressure in the vessel reaches design pressure**, it should open and **relieve the pressure and excess flow.**

Imagine the operating pressure of the vessel is 25 barg and its design pressure is 30 barg. The PSV should open at 30 barg. In PSV terminology, we say the set pressure should be 30 barg. Also, the amount of flow which is excess-accumulated- and discharged so that again the pressure is less than the design pressure is called relief load.

2. Imagine the above scenario again. This time everything is in perfect condition and the valve works properly. But this time, a fire breaks out near the vessel; the fire radiates the heat to the vessel and as a result the water inside the vessel receives the heat via convection heat transfer and expands. What does it mean? It means the pressure inside the vessel increases as a result of expansion. Now you know the meaning of design pressure which was explained in second offline video, right? In a simple way, the pressure inside the vessel increases until it becomes equal to the design pressure of the vessel. What do you expect now? The explosion and damage to the vessel.

How to prevent it? Using a PSV in our design.

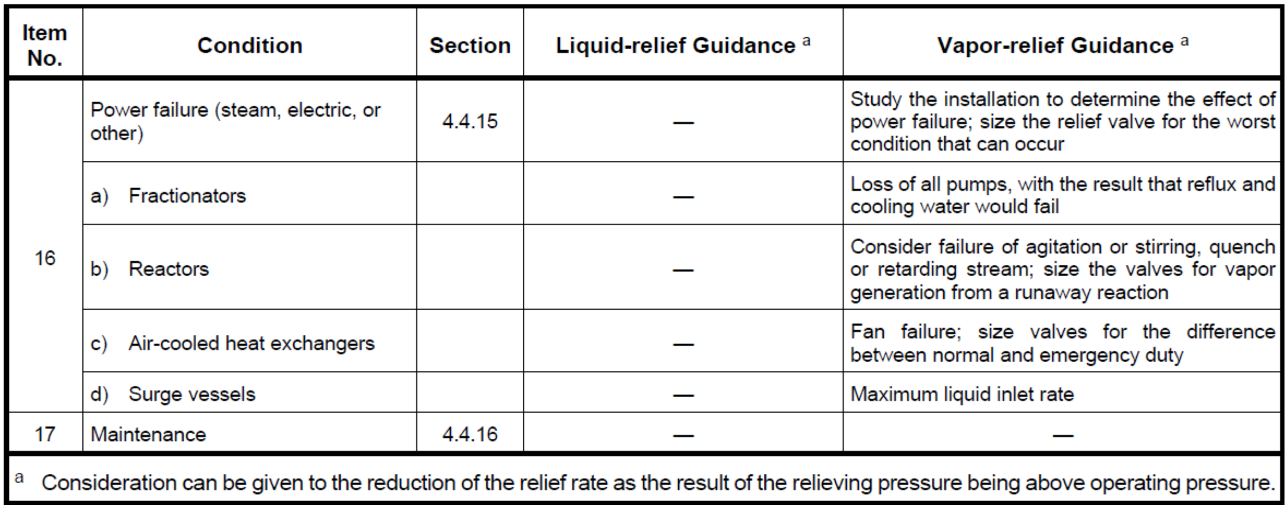


In first condition, we have to design and size a PSV due to valve failure case. In second condition, we have to design and size a PSV due to fire case.

In PSV terminology, we call each **case**, a **scenario**.

For a real process plant design, we have different scenarios based on API-521, which is shown on next page.

Item No.	Condition	Section	Liquid-relief Guidance [a]	Vapor-relief Guidance [a]
1	Closed outlets	4.4.2	Maximum liquid pump-in rate	Total incoming steam and vapor plus that generated therein at relieving conditions
2	Cooling-water failure to condenser	4.4.3	—	Total vapor to condenser at relieving conditions
3	Top-tower reflux failure	4.4.3	—	Total incoming steam and vapor plus that generated therein at relieving conditions less vapor condensed by sidestream reflux
4	Sidestream reflux failure	4.4.3	—	Difference between vapor entering and leaving equipment at relieving conditions
5	Lean-oil failure to absorber	4.4.4	—	None, normally
6	Accumulation of noncondensables	4.4.5	—	Same effect in towers as found for Item 2; in other vessels, same effect as found for Item 1
7	Entrance of highly volatile material	4.4.6	—	Use alternative means of protection to avoid scenario; see Item 15 for heat exchanger tube rupture guidance
	a) Water into hot oil	4.4.6.1	—	
	b) Light hydrocarbons into hot oil	4.4.6.2	—	
8	Overfilling	4.4.7	Maximum liquid pump-in rate	—
9	Failure of automatic controls	4.4.8	—	Analyze on a case-by-case basis
	a) Inlet control devices and bypasses	4.4.8.3		
	b) Outlet control devices	4.4.8.4		
	c) Fail-stationary valves	4.4.8.5		
	d) Choke valves	4.4.8.6		
10	Abnormal process heat or vapor input	4.4.9	—	
	a) Abnormal process heat input	4.4.9.1		Estimated maximum vapor generation including noncondensables from overheating
	b) Inadvertent valve opening	4.4.9.2		
	c) Check valve failure	4.4.9.3		
11	Internal explosions or transient pressure surges (e.g. water, steam, or condensate hammer)	4.4.10	Not controlled by conventional PRDs but by avoidance of circumstances	Not controlled by conventional PRDs but by avoidance of circumstances
12	Chemical reaction	4.4.11	—	Estimated gas/vapor generation from both normal and uncontrolled conditions; consider two-phase effects
13	Hydraulic expansion	4.4.12		
	a) Cold-fluid shut-in	4.4.12	See 4.4.12	—
	b) Lines outside process area shut-in	4.4.12	See 4.4.12	—
14	Exterior fire	4.4.13		Estimated by the methods given in 4.4.13.2 or Annex A
15	Heat transfer equipment failure	4.4.14		
	a) Heat exchanger tube rupture	4.4.14.2	Liquid flowing across a rupture equal to twice the cross-sectional area of one tube	Steam or vapor flowing across a rupture equal to twice the cross-sectional area of one tube
	b) Double pipe	4.4.14.3		
	c) Plate and frame	4.4.14.4		



Item No.	Condition	Section	Liquid-relief Guidance [a]	Vapor-relief Guidance [a]
16	Power failure (steam, electric, or other)	4.4.15	—	Study the installation to determine the effect of power failure; size the relief valve for the worst condition that can occur
	a) Fractionators		—	Loss of all pumps, with the result that reflux and cooling water would fail
	b) Reactors		—	Consider failure of agitation or stirring, quench or retarding stream; size the valves for vapor generation from a runaway reaction
	c) Air-cooled heat exchangers		—	Fan failure; size valves for the difference between normal and emergency duty
	d) Surge vessels		—	Maximum liquid inlet rate
17	Maintenance	4.4.16	—	—

[a] Consideration can be given to the reduction of the relief rate as the result of the relieving pressure being above operating pressure.

Let’s convert API-521 table into more practical approach toward PSV scenario detection in a process plant.

1.Heat exchanger
  - Whenever there is a cooled-water heater exchanger, consider the case of hydraulic expansion.
  - When the difference between design pressure of High-pressure side and low-pressure side is high, consider tube rupture scenario.

2.Valves
  - When the difference between design pressure of High-pressure side and low-pressure side is high, consider inadvertent valve opening.
  - If a valve closes and causes high pressure, then consider closed outlet.

3.Pumps
  - We can install a PSV at the discharge of a pump and whenever the discharge pressure in abnormal conditions reaches shut-off pressure, PSV can handle it and relieve the pressure.
  - In modern design, we simply increase the design pressure of pipe connected to discharge of the pump equal to shut-off pressure and as a result, there is no need to consider any PSV at the outlet of pumps.

4.Vessels
  - Consider the fire-unwetted surface scenario for reactor vessel which are filled with catalysts.
  - Consider the fire-wetted surface scenario for drums containing water.

5.Towers
  - When the reflux pump fails due to any reasons, the reflux flow is cut off. Before the cut-off, the reflux flow provides has a cooling effect on tower and when it is cut-off, the hot stream pressure increases in tower and causes over-pressure.
  - When the air cooler fails, again the overhead stream cannot be cooled, which finally causes the overpressure in tower.

To see the examples in a process plant, check the One Note File.
Now that we have founded possible scenarios, we need to determine some parameters for each PSVs which are explained below:

- Accumulation = Overpressure

The pressure increases over the MAWP of the vessel, expressed in pressure units or as a percentage of MAWP or design pressure. Maximum allowable accumulations are established by applicable codes for emergency operating and fire contingencies.

- Backpressure

The pressure that exists at the outlet of a pressure-relief device as a result of the pressure in the discharge system. Backpressure is the sum of the superimposed and built-up backpressures.

- Built-up backpressure

The increase in pressure at the outlet of a pressure-relief device that develops as a result of flow after the pressure-relief device opens.

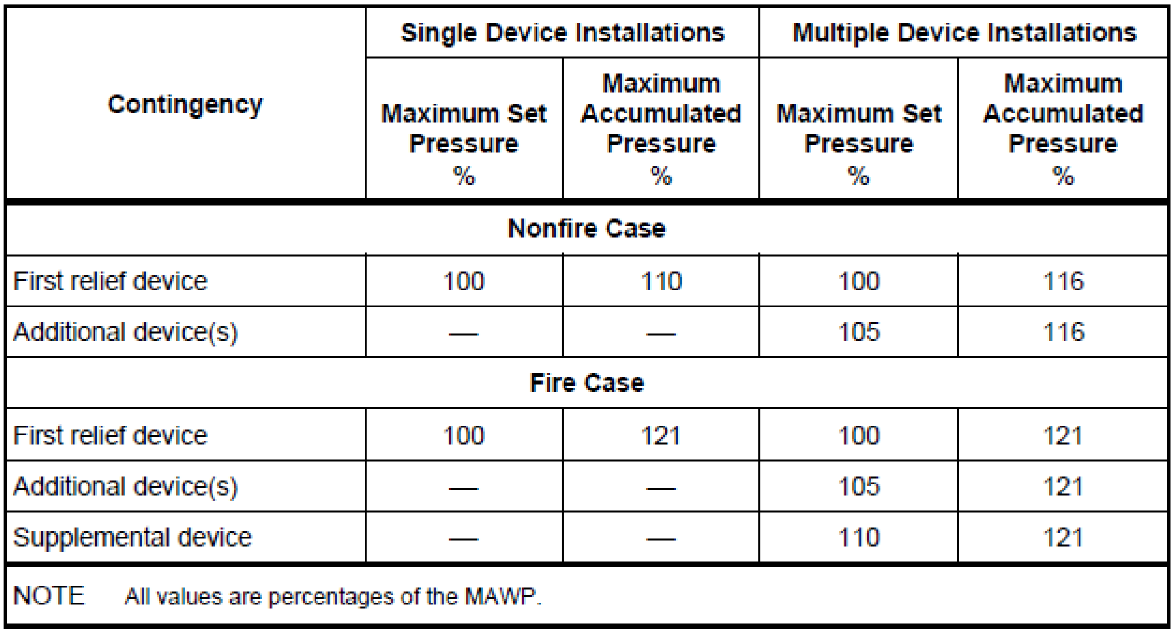
- Superimposed backpressure

The static pressure that exists at the outlet of a pressure-relief device at the time the device is required to operate. Superimposed backpressure is the result of pressure in the discharge system coming from other sources and may be constant or variable.

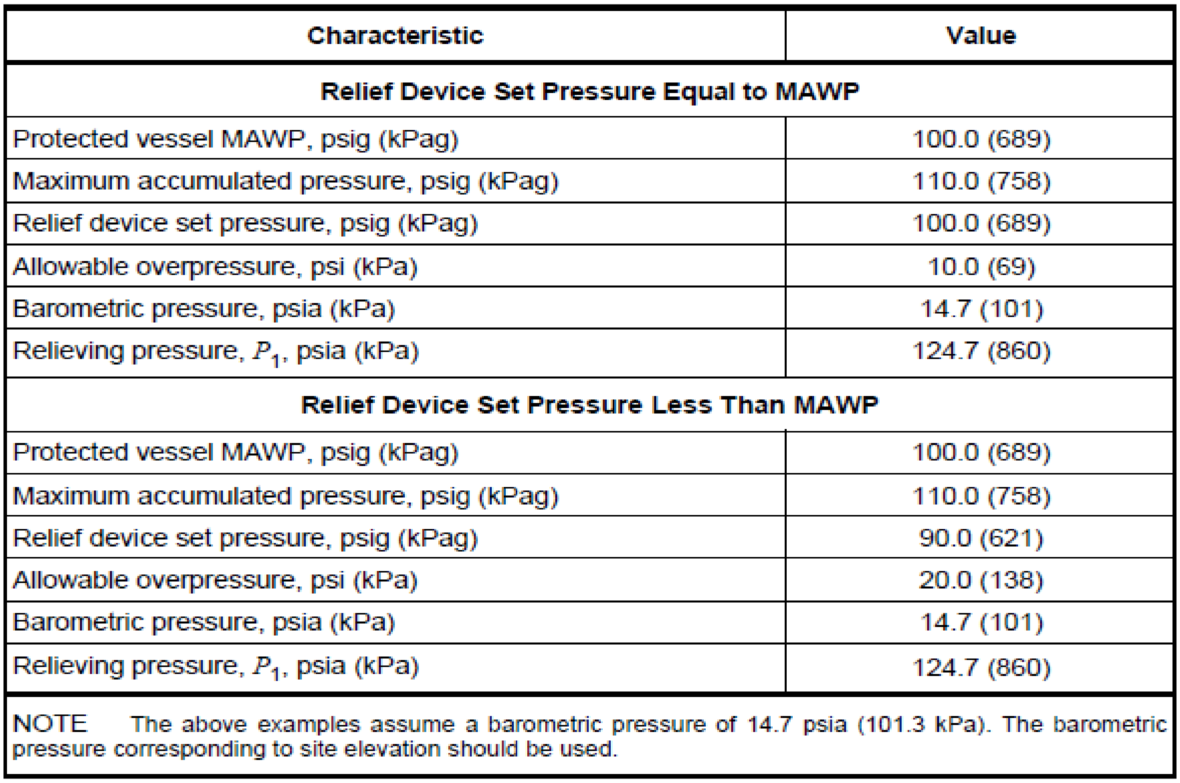
- Relieving conditions

Relieving pressure, shown as *P*1 in the various sizing equations, is the inlet pressure of the PRD at relieving conditions. The relieving pressure is the total of set pressure plus overpressure.

Examples:



Contingency	Single Device Installations		Multiple Device Installations	
	Maximum Set Pressure %	Maximum Accumulated Pressure %	Maximum Set Pressure %	Maximum Accumulated Pressure %
Nonfire Case				
First relief device	100	110	100	116
Additional device(s)	—	—	105	116
Fire Case				
First relief device	100	121	100	121
Additional device(s)	—	—	105	121
Supplemental device	—	—	110	121
NOTE All values are percentages of the MAWP.				



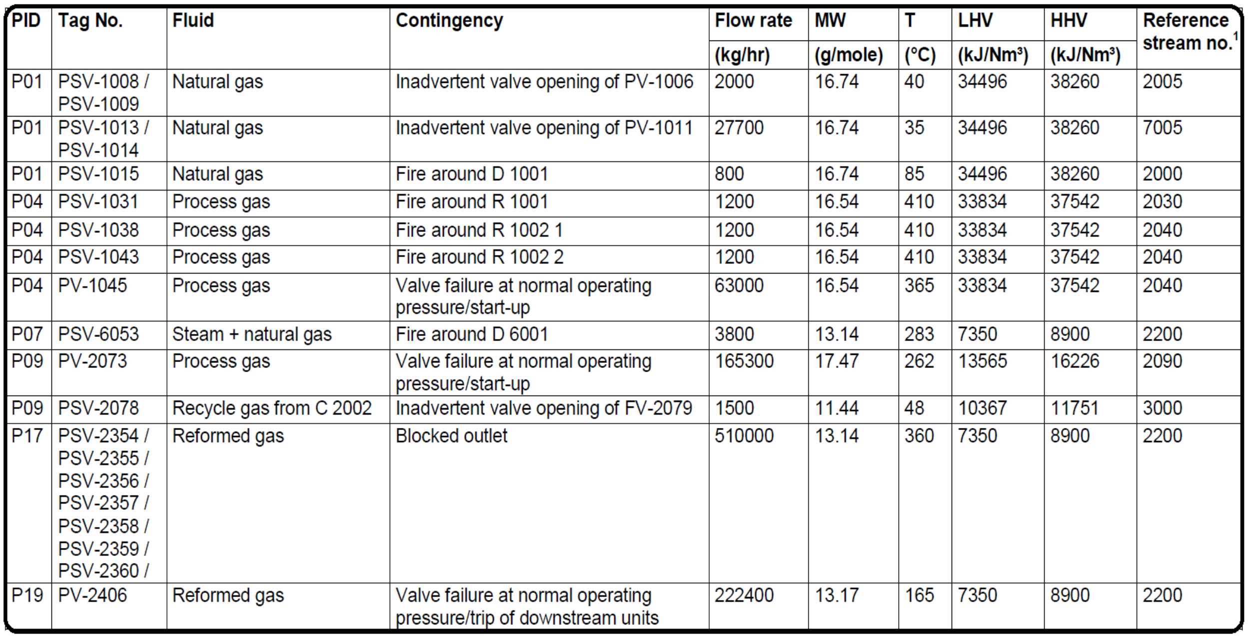
Characteristic	Value
Relief Device Set Pressure Equal to MAWP	
Protected vessel MAWP, psig (kPag)	100.0 (689)
Maximum accumulated pressure, psig (kPag)	110.0 (758)
Relief device set pressure, psig (kPag)	100.0 (689)
Allowable overpressure, psi (kPa)	10.0 (69)
Barometric pressure, psia (kPa)	14.7 (101)
Relieving pressure, P_1, psia (kPa)	124.7 (860)
Relief Device Set Pressure Less Than MAWP	
Protected vessel MAWP, psig (kPag)	100.0 (689)
Maximum accumulated pressure, psig (kPag)	110.0 (758)
Relief device set pressure, psig (kPag)	90.0 (621)
Allowable overpressure, psi (kPa)	20.0 (138)
Barometric pressure, psia (kPa)	14.7 (101)
Relieving pressure, P_1, psia (kPa)	124.7 (860)
NOTE The above examples assume a barometric pressure of 14.7 psia (101.3 kPa). The barometric pressure corresponding to site elevation should be used.	

At this stage, after obtaining above information, we need to determine relief load and orifice area sizing. To do so, we follow the following procedure:

1.Determine the scenario, using API-521
2.Calculate the relief load, using API-520 Part1
3.Calculate the orifice area, using API-520 Part1
4.Select proper PSV type by checking backpressure
5.Use API-526 to determine the designation and the inlet and outlet sizing
6.Use API-520 Part2 to detail its construction

To help you better understand how the procedure works, one example is provided in Appendix.

After doing for all PSVs, we get a table like below:



PID	**Tag No.**	**Fluid**	**Contingency**	**Flow rate (kg/hr)**	**MW (g/mole)**	**T (°C)**	**LHV (kJ/Nm³)**	**HHV (kJ/Nm³)**	**Reference stream no.**[1]
P01	PSV-1008 / PSV-1009	Natural gas	Inadvertent valve opening of PV-1006	2000	16.74	40	34496	38260	2005
P01	PSV-1013 / PSV-1014	Natural gas	Inadvertent valve opening of PV-1011	27700	16.74	35	34496	38260	7005
P01	PSV-1015	Natural gas	Fire around D 1001	800	16.74	85	34496	38260	2000
P04	PSV-1031	Process gas	Fire around R 1001	1200	16.54	410	33834	37542	2030
P04	PSV-1038	Process gas	Fire around R 1002 1	1200	16.54	410	33834	37542	2040
P04	PSV-1043	Process gas	Fire around R 1002 2	1200	16.54	410	33834	37542	2040
P04	PV-1045	Process gas	Valve failure at normal operating pressure/start-up	63000	16.54	365	33834	37542	2040
P07	PSV-6053	Steam + natural gas	Fire around D 6001	3800	13.14	283	7350	8900	2200
P09	PV-2073	Process gas	Valve failure at normal operating pressure/start-up	165300	17.47	262	13565	16226	2090
P09	PSV-2078	Recycle gas from C 2002	Inadvertent valve opening of FV-2079	1500	11.44	48	10367	11751	3000
P17	PSV-2354 / PSV-2355 / PSV-2356 / PSV-2357 / PSV-2358 / PSV-2359 / PSV-2360 /	Reformed gas	Blocked outlet	510000	13.14	360	7350	8900	2200
P19	PV-2406	Reformed gas	Valve failure at normal operating pressure/trip of downstream units	222400	13.17	165	7350	8900	2200

We are done with PSV sizing and datasheets.

Flare Package

Flare package components

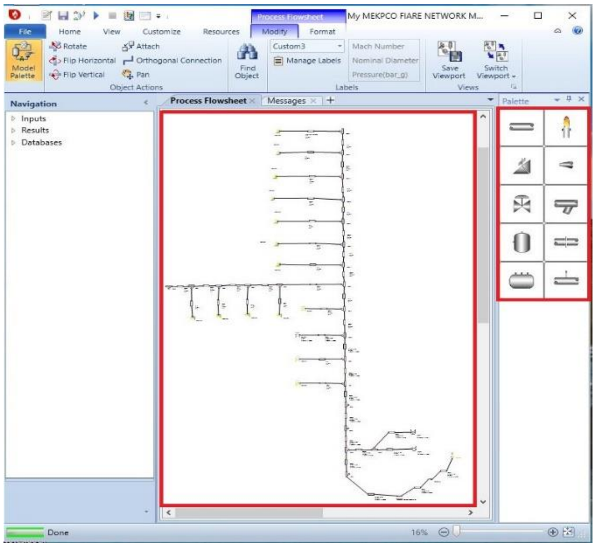
- Header network or simply piping network
- Knock-out drum
- Stack

Let’s detail it:

1.Header Network

- All PSVs are discharged to a header which is called flare header.
- We use Aspen Flarenet to size flare header Network. Here is the criteria:

1. For both header and tailpipes, the Mach number of both 0.1 and 0.5 are taken into account.
2. The maximum pv2 for the whole piping should be 150000 kg/m/s2
3. The sound/ noise level should not exceed the recommended value of 100 DBA



2.Knock-out drum sizing

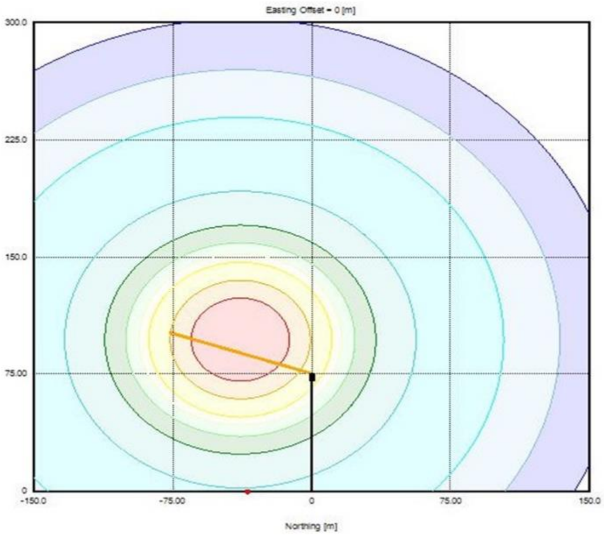
K.O.D is used to separate the water droplet from flare gas in order to avoid burning rain!

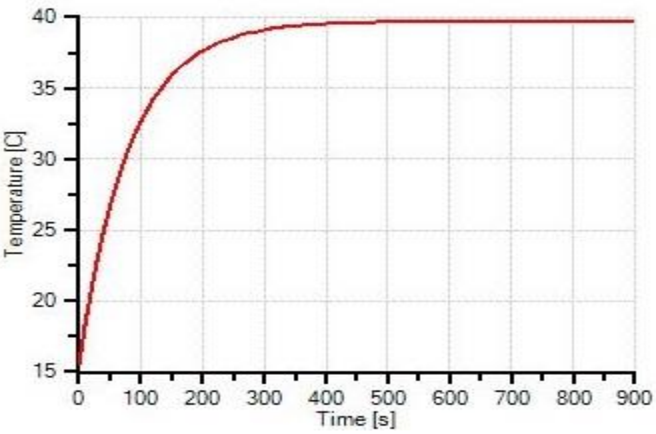
K.O.D is sized based on API-521 procedure. To verify API-521 excel sheet results, Flaresim software is used.

3.Stack

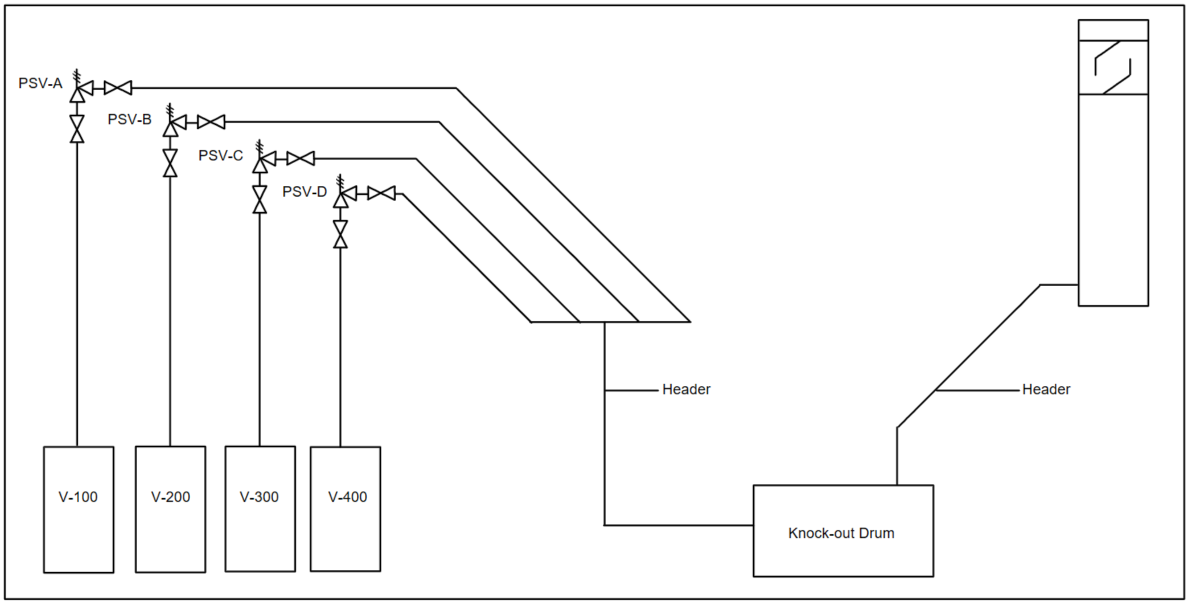
We use stack to not only combust flare gases, but also reduce the thermal radiation impact of the combusted gas.

Stacks are sized using Flaresim software. Flaresim provides its users with comprehensive report about thermal radiation, noise and temperature status in different radius.





Appendix


PSV-A
PSV-B
PSV-C
PSV-D
Header
Header
V-100
V-200
V-300
V-400
Knock-out Drum