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EURISG

European Industrial Sizing Group

EURISG Sizing Case Report

ESC_107

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Sizing of a safety valve to protect a reactor filled with acetone against impermissible overpressure due to external heating

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1 Task description

In the chemical and pharmaceutical Industry reactors and vessels are often cleaned with solvents. Pressurized vessels are typically protected by means of a safety valve. In case of a vessel relief, either a pure vapour or a vapour-liquid two-phase mixture will be discharged.

In this report a safety valve to protect a steam jacketed agitated vessel against impermissible overpressure should be sized. The worst-case scenario to be considered is the abnormal maximum heating of the vessel due to control valve failure in the steam network.

A specification of the pressurized vessel, as well as the operating conditions are given in **Table 1** through **Table 4**. The determination of the remaining material property data is part of the task.

Table 1: Process Parameters **-** Agitated Vessel

▪ Medium:	acetone
▪ Filling temperature	20 °C
▪ Filling pressure	1 bar
▪ Initial filling level (height from bottom):	80%vol
▪ Operating pressure:	2 bar g
▪ Operating temperature:	91.8 °C
▪ Maximum allowable pressure:	6 bar g
▪ Maximum allowable temperature:	150 °C
▪ Set pressure safety valve SV-107-1:	6 bar g
▪ Back pressure:	1 bar
▪ Ambient pressure	1 bar
▪ Ambient temperature	20 °C

Table 2: Geometric Parameters - Agitated Vessel

▪ Safety valve SV-107-1	DN 50 x 80, Full stroke
▪ Seat diameter SV-107-1	46 mm
▪ Rated discharge coefficient, gas:	0.7
▪ Rated discharge coefficient, liquid:	0.45
▪ Vessel volume:	10 m^3
▪ Vessel configuration:	cylindrical, vertical
▪ Vessel head configuration:	torispherical
▪ Internal diameter	1.9 m
▪ Heigth to diameter ratio, H/D	2
▪ Vessel material:	stainless steel, 1.4401
▪ Thickness of the vessel wall	6.3 mm
▪ Stirring system:	Impeller
▪ Stirrer diameter:	0.63 m
▪ Stirrer Rotary frequency	2.4 s^{-1}

▪ Stirrer torque:	20 Nm
▪ Number of stirrer blades:	3
▪ Stirrer height above the bottom:	0.9 m

Table 3: Process Parameters - Steam Network

▪ Heating system:	Vessel jacket
▪ Heating medium:	Saturated steam
▪ Steam operating pressure:	16 bar g
▪ Control Valve CV-107-1, K_{vs}	25 m^3/h
▪ Control Valve CV-107-1, F_L	0.95
▪ Control Valve, CV-107-1 x_T	0.75
▪ Set Pressure safety valve SV-107-2:	18 bar g

Table 4: Geometric Parameters - Steam Network

▪ Steam line nominal diameter:	DN 80
▪ Safety valve SV-107-2	DN 80 x 100, Fullstroke

Common assumptions / boundary conditions for the calculation are:

- Blocked outlet valves.
- No further feed into the reactor.
- Maximum initial filling of acetone, 80%.
- The safety valve SV-107-1 is mounted directly on the dome of the vessel.

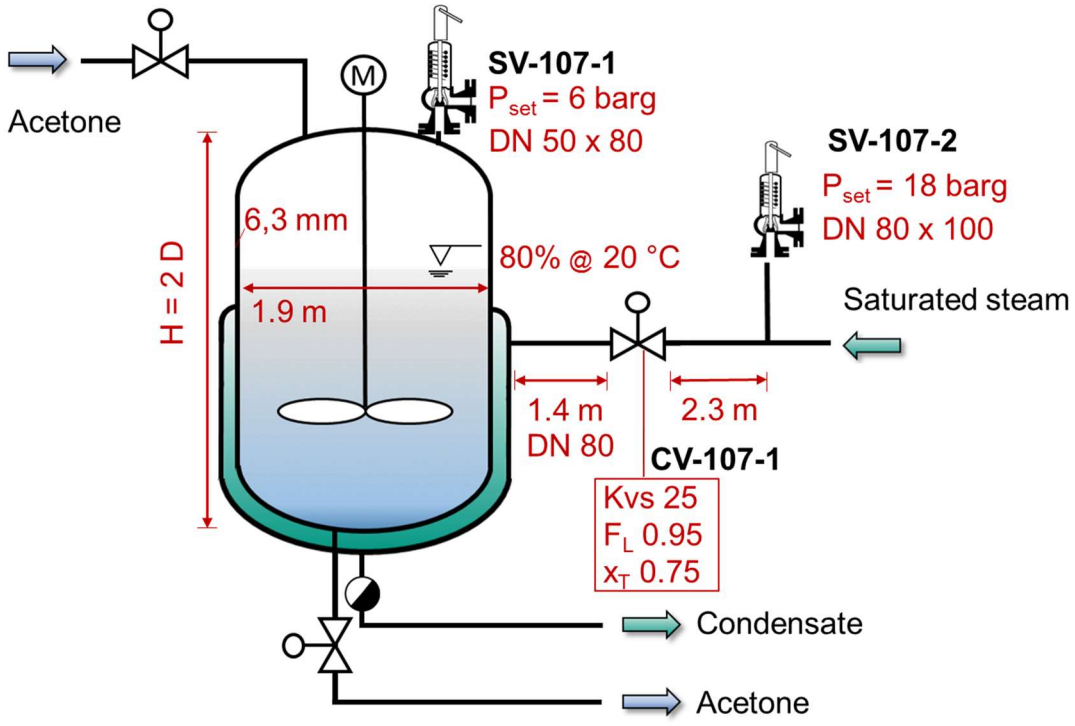

Figure 1-1: Jacketed agitated pressure vessel with steam heating system, common data for the calculation.

The following calculation cases shall be considered:

CASE 1

Sizing Task: Size a sufficient safety valve to protect the vessel against overpressure and compare the result to the installed safety valve.

Additional assumptions / boundary conditions:

- The malfunction of the control valve CV-107-1 delivers a steam flow of 3700 kg/h.
- The calculation shall be done neglecting the heat transfer resistance of the vessel jacket and wall.

CASE 2

Sizing Task: Size a restriction orifice to limit the maximum heating power into the vessel such that only pure vapour is released through the existing safety valve.
Verify, if the initial filling level of 80% can still be maintained.

Additional assumptions / boundary conditions:

- The calculation shall be done neglecting the heat transfer resistance of the vessel jacket and wall.

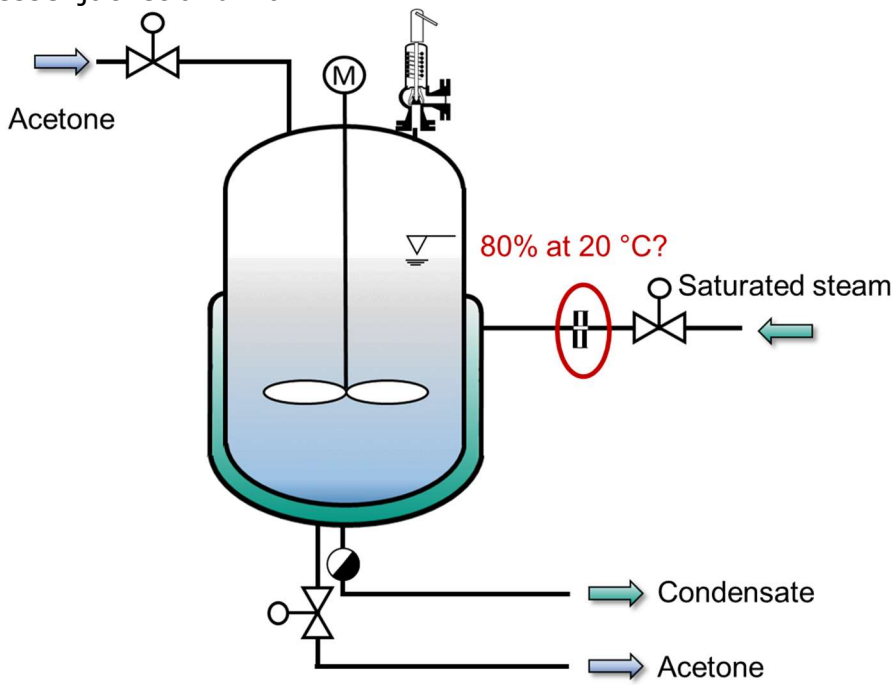

Figure 1-2 Jacketed agitated pressure vessel with steam heating system, CASE 2

CASE 3

Sizing task: Size a restriction orifice to limit the maximum heat imput into the vessel such that only pure vapour is released through the existing safety valve.

Assumptions / boundary conditions:

- The maximum steam flow rate for the normal plant operation shall not be less than 1850 kg/h.
- The effective area for the heat exchange between the jacket and the reactor content is 13 m².
- The resistance of the vessel wall has to be considered for the heat transfer calculation.

CASE 4

Sizing Task: Size a sufficient safety valve to protect the vessel against overpressure and compare the result to the installed safety valve.

Additional assumptions/boundary conditions:

- The maximum steam temperature is 250 °C.
- The maximum steam flow rate for the normal plant operation shall not be less than 1850 kg/h.
- The effective area for the heat exchange between the jacket and the vessel content is 13 m².
- The resistance of the vessel wall has to be considered for the heat transfer calculation.

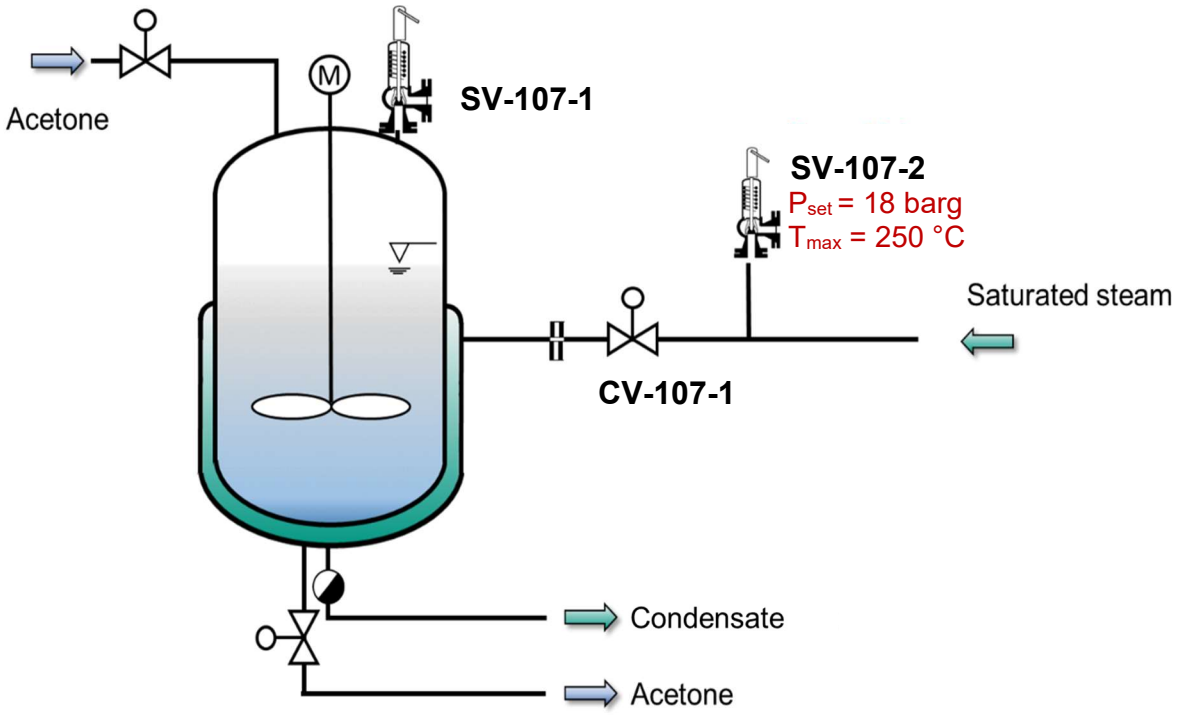

Figure 1-3 Jacketed agitated pressure vessel with steam heating system, CASE 4