



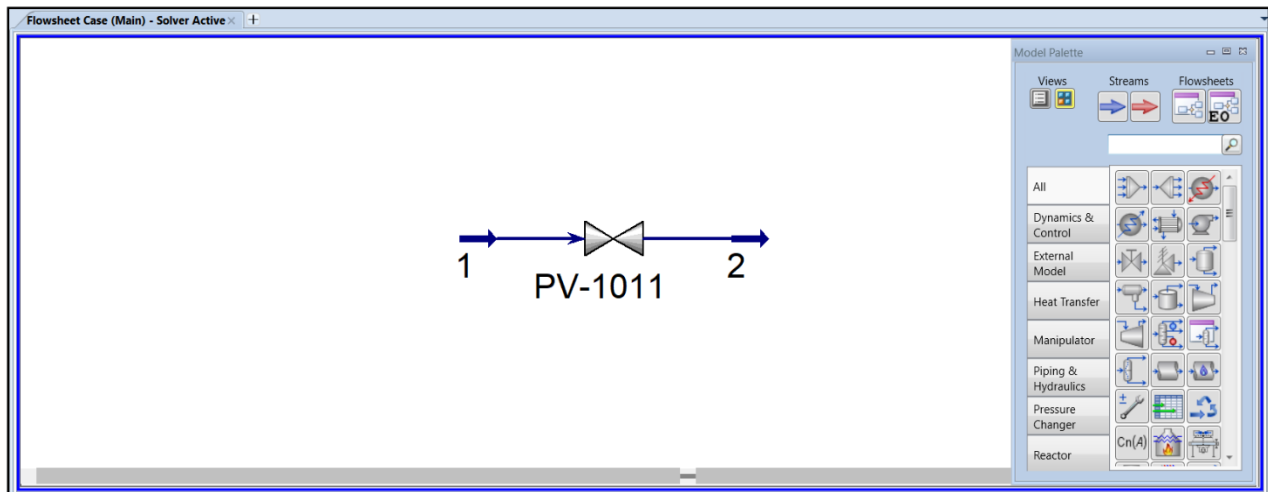
## Relief Load Calculation Note



## 1.PSV-1013/1014

Process description:

For fired heaters, one of the primary fuels is NG since it is more reliable and available. For a specific fired heater, 16000 kg/hr. of NG with operating pressure of 50 barg and temperature of 40C is let-down to operating pressure of 4barg via PV-1011 and later to 1 barg via another control valve to make it suitable for firing.

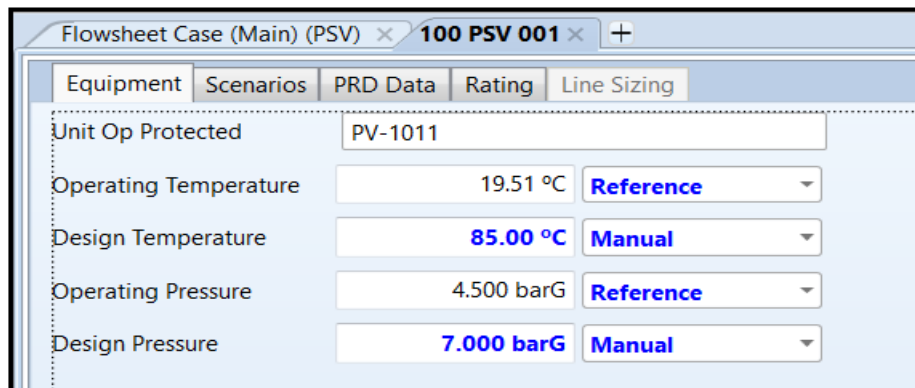


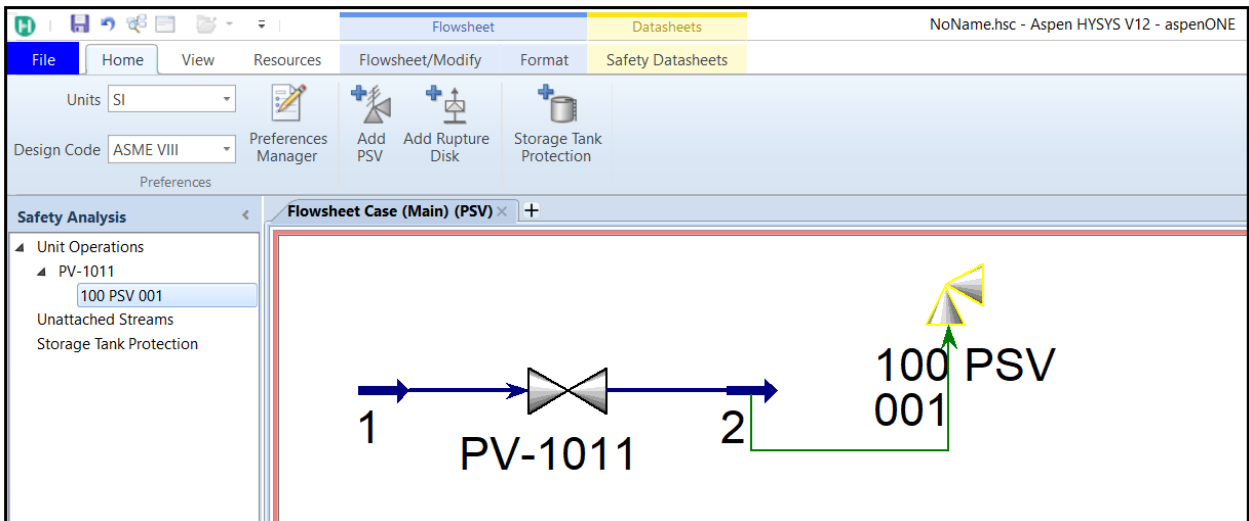
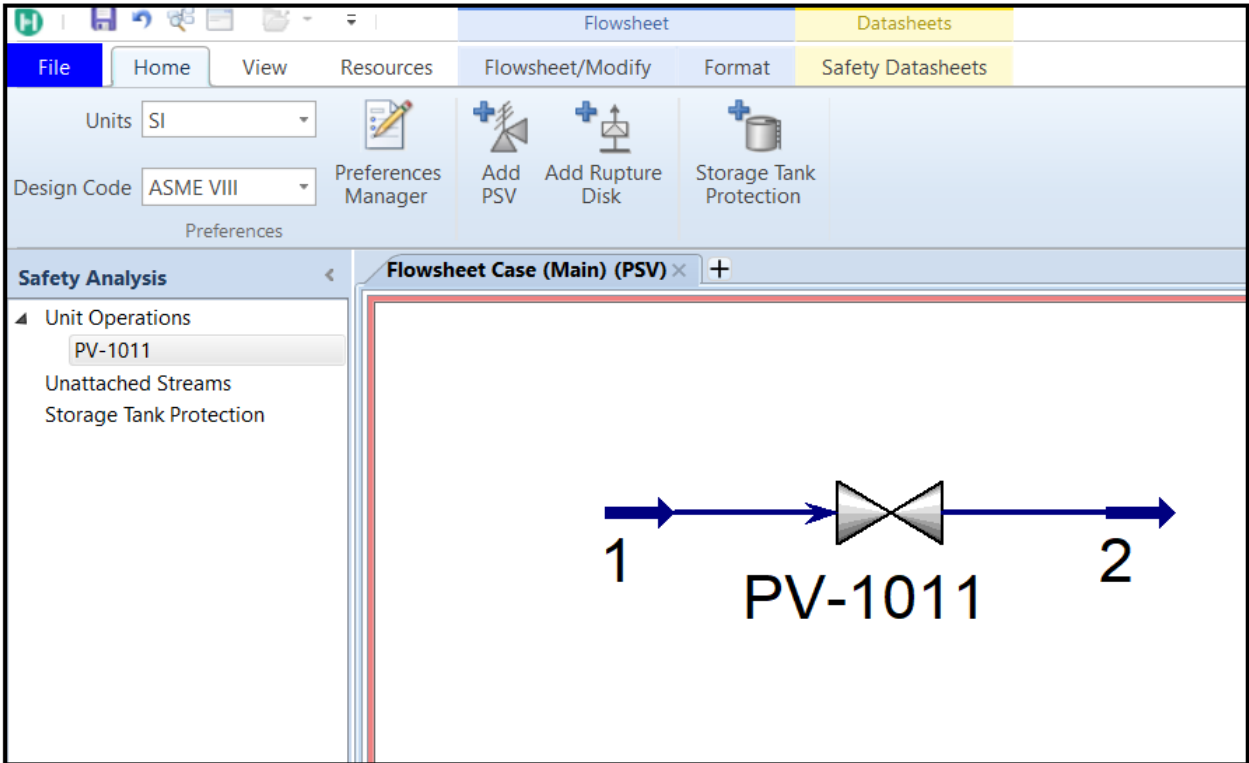
First Step: Let's check if we need a PSV

Since the difference between design pressure of high-pressure side, which is 55 barg and that of low-pressure side, which is 7 barg is high. So, we need a PSV in case of control valve failure and the possibility of high flow passage from high-pressure side to low-pressure side.

Second Step: Safety Analysis Environment

- 1.Go to safety analysis environment and add PSV on the outlet of control valve.
- 2.Double-click on PSV icon to see the following tab.







Manual means you are supposed to specify the matter while reference means the information is taken from the line, which just provides operating conditions.

3. Go to scenario tab, create a scenario and select control valve failure.

Sizing Case	Scenario Name	Type	Stream		Phase - Method	Flow Rate [kg/h]		Orifice Area [cm <sup>2</sup> ]		Capacity Used [%]	Pressure Drop [% of Set]		Notes
			Name	MW		Required	Rated	Calculated	Selected		Inlet	Outlet	
	Scenario100	User Defined	<empty>	<empty>	<empty>	<empty>	<empty>	<empty>	<empty>	<empty>	<empty>	<empty>	<empty>
		General	Control Valve Related			Heaters and Coolers							
		Fire	Blocked Outlet			Exch. Tube Rupture							
		Thermal Expansion	Control Valve Failure			Cold Side of Exchanger Blocked-In							
		Overfilling	Abnormal Flow through Valve			Blocked-In Fired Heater							
		User Defined	Failure of Automatic Controls			Fan Failure							
		Flare	Reaction/Mixing			Distillation Column/Tower							
		General Power Failure	Chemical Reaction			Reflux Failure							
		Local Power Failure	Accidental Mixing			Reflux Failure (Side Stream)							
		Cooling Water Failure	Inadvertent Loss of Segregation			Abnormal Heat or Vapor Input							
		Coolant Failure (Other than CW)	Pressure Surge or Internal Explosion			Accumulation of Non-Condensables							
		Loss of Heat				Loss of Absorbent							

4. Now open scenario.

Scenario Name: Scenario100  
Scenario Type: Control Valve Failure

Scenario Reference Stream: 1 @ Main

Relieving Temperature: 21.13 °C  
Relieving Pressure: 7.700 barG  
Total Backpressure: 0.7000 barG  
Relieving Phase - Method: Vapor  
Viscosity Correction (Kv): 1.000

Required Relieving Flow: 2.778E+004 kg/h  
Relieving Flow Method: Calculated

Process Data:  
Credit for Flow to Process: 0.0000 kg/h  
Calculated Mass Flow: 2.778E+004 kg/h

	Upstream	Upstream Method	Downstream @ Relief
Pressure	50.00 barG	Reference	7.700 barG
Temperature	40.00 °C	Reference	21.13 °C
Phase	Vapor		Vapor

Sizing Case Results:

PSV Results	Value
Calculated Orifice [cm <sup>2</sup> ]	52.49
Selected Orifice [cm <sup>2</sup> ]	71.290 (Q)
Fraction of Full Lift	1.000
Rated Capacity [kg/h]	3.773E+004
Capacity Used [%]	73.62
Orifice Designation	6 Q 8
In/Out Flanges	150 x 150
Discharge Coefficient (Kd)	0.9750

Orifice Calculation Completed



Required Relieving Flow 2.778E+004 kg/h

Relieving Flow Method  Manual  Reference  Calculated

Process Data

Credit for Flow to Process 0.0000 kg/h

Calculated Mass Flow 2.778E+004 kg/h

	Upstream	Upstream Method	Downstream @ Relief
Pressure	50.00 barG	Reference	7.700 barG
Temperature	40.00 °C	Reference	21.13 °C
Phase	Vapor		Vapor

Calculation Method PSV Plus

Valve Parameters

Vapor Flow Model N/A

Valve Type N/A

FI	0.9000
Cv [USGPM(60F,1psi)]	44.00

Handle multi-phase flows rigorously

Orifice Calculation Completed

Under scenario reference stream select stream 1:

Select Reference Stream

Flowsheet Case (Main)

Object

1  
2

Object Filter

All  
 Streams  
 UnitOps  
 Logicals  
 ColumnOps  
 Custom

Custom...

OK



You can also change total backpressure like below:

**Backpressure (BP) Parameters**

Atmospheric Pressure: 1.013 barA

Constant Superimposed BP: 1.013 barA

Variable Superimposed BP: 0.0000 bar

Built-up Backpressure: 0.7000 bar

Total Backpressure: 0.7000 barG

---

Maximum Allowable BP %: 10.00

Maximum Allowable BP: 0.7000 barG

---

Backpressure (BP) Factor (Kb)

Calculated

Specified: 1.000

OK Cancel

Select relieving method to be calculated and also choose PSV plus as the calculation method. Specify the CV to be 44.

Required Relieving Flow: 2.778E+004 kg/h

Relieving Flow Method:  Manual  Reference  Calculated

Process Data

Credit for Flow to Process: 0.0000 kg/h

Calculated Mass Flow: 2.778E+004 kg/h

	Upstream	Upstream Method	Downstream @ Relief
Pressure	50.00 barG	Reference	7.700 barG
Temperature	40.00 °C	Reference	21.13 °C
Phase	Vapor		Vapor

Calculation Method: PSV Plus

Valve Parameters

Vapor Flow Model: N/A

Valve Type: N/A

FI	0.9000
Cv [USGPM(60F,1psi)]	44.00

Handle multi-phase flows rigorously

Orifice Calculation Completed



Select a bigger orifice area than calculated orifice which is 52.49 cm<sup>2</sup>.

PSV Results	Value
Calculated Orifice [cm <sup>2</sup> ]	52.49
<b>Selected Orifice [cm<sup>2</sup>]</b>	<b>71.290 (Q)</b>
Fraction of Full Lift	1.000
Rated Capacity [kg/h]	3.773E+004
Capacity Used [%]	73.62
Orifice Designation	6 Q 8
In/Out Flanges	150 x 150
Discharge Coefficient (Kd)	<b>0.9750</b>

Based on the calculation, the orifice designation should be 6Q8.

5. Now go to line sizing tab

Equipment | Scenarios | PRD Data | Rating | Line Sizing - 100 PSV 001

Design | Rating

State/Phase - Method: Direct Integration (HEM)

Flow Rate Method: Required

Sizing Method: Rigorous Line Sizing Using Aspen Hydraulics

Current Scenario: Scenario100 [Calculated]

Run Line Sizing | Run For All Scenarios | Configure

Line Sizing Inputs	In Line	Out Line
PSV Flange Size [in]	6.000	8.000
Schedule	40	40
N.D. [in]	6.000	8.000
I.D. [in]	6.065	7.981
Material	Mild Steel	Mild Steel
Roughness [mm]	4.572E-002	4.572E-002
Specified Equivalent Length [m]	50.00	50.00
Elevation [m]	0.0000	0.0000
Flow Rate [kg/h]	2.778E+004	2.778E+004

Line Sizing Results	In Line	Out Line
Calculated DP [bar]	0.7471	1.226
Maximum DP [bar]	0.2100	0.7000
Average Rho*v <sup>2</sup> [kg/m <sup>2</sup> s <sup>2</sup> ]	3.202E+004	7.764E+004
Outlet Velocity [m/s]	<empty>	324.7
Critical Velocity [m/s]	<empty>	424.4
Critical Pressure [barA]	<empty>	0.7755
Reaction Forces [N]	<empty>	3214

INLET Line Pressure Drop check ... ERROR: Maximum Pressure Drop exceeded  
Outlet Line: Pressure Drop check ... ERROR: Back Pressure exceeds the maximum allowable by PSV  
OUTLET Line Pressure Drop check ... ERROR: Calculated pressure drop (1.226 bar) is higher than specified built-up backpressure (0.7 bar). Modify your specifications.  
OUTLET Line Velocity @ Exit check ... OK

INLET Line Pressure Drop check ... ERROR: Maximum Pressure Drop exceeded

Based on calculation, the pressure drop for both inlet and outlet has exceeded the criteria. In order to resolve the issue, let's select a line with bigger size for inlet and outlet.



Equipment | Scenarios | PRD Data | Rating | Line Sizing - 100 PSV 001

State/Phase - Method Direct Integration (HEM)

Flow Rate Method Required

Sizing Method Rigorous Line Sizing Using Aspen Hydraulics

Current Scenario Scenario100 [Checked] Calculated

Run Line Sizing Run For All Scenarios Configure

Line Sizing Results	In Line	Out Line
Calculated DP [bar]	0.2062	0.3087
Maximum DP [bar]	0.2100	0.7000
Average $\rho v^2$ [kg/m <sup>2</sup> ]	3.036E+004	6.152E+004
Outlet Velocity [m/s]	<empty>	216.5
Critical Velocity [m/s]	<empty>	434.3
Critical Pressure [barA]	<empty>	0.5052
Reaction Forces [N]	<empty>	3211

Line Sizing Inputs

	In Line	Out Line
PSV Flange Size [in]	6.000	8.000
Schedule	40	STD
N.D. [in]	8.000	10.00
I.D. [in]	7.981	10.02
Material	Mild Steel	Mild Steel
Roughness [mm]	4.572E-002	4.572E-002
Specified Equivalent Length [m]	50.00	50.00
Elevation [m]	0.0000	0.0000
Flow Rate [kg/h]	2.778E+004	2.778E+004

INLET Line Pressure Drop check ... OK  
 OUTLET Line Velocity @ Exit check ... OK  
 Outlet Line: Pressure Drop check ... OK

INLET Line Pressure Drop check ... OK

The problem solved!

Here is the summary of what we have obtained.

Relief load	27780 kg/hr.
Scenario	Control Valve Failure
Calculation Method	PSV Plus
Selected Orifice	71.29-Q
Orifice Designation	6Q8
Inlet Line Size	8 inch
Outlet Line Size	10 inch





## 2.PSV-1031

### 1.Determine the scenario, using API-521

Since it is R-1001 and exposed to fire then a fire scenario is defined.

Parameters	Value	Parameters	Value
Diameter	4.45 m	M	16.54
Height	3.1 m	Set Pressure	55 barg
Fluid	Natural Gas	Relieving Pressure	67.55 bara
Z	1.01	Accumulation	0.21
Cp/Cv	1.18	Material	CS

### 2.Calculate the relief load, using API-520 Part1

$$A = \frac{F' \times A'}{\sqrt{p_1}} \quad (9)$$

where

$A$  is the effective discharge area of the valve, expressed in mm<sup>2</sup> (in.<sup>2</sup>);

$A'$  is the exposed surface area of the vessel, expressed in m<sup>2</sup> (ft<sup>2</sup>);

$p_1$  is the upstream relieving absolute pressure, expressed in kPa (psi);

NOTE  $p_1$  is the set pressure plus the allowable overpressure plus the atmospheric pressure.

$F'$  can be determined using Equation (10). If calculated using Equation (10) and the result is less than 182 in SI units (<0.01 in USC units), then use a recommended minimum value of  $F' = 182$  in SI units ( $F' = 0.01$  in USC units). If insufficient information is available to use Equation (10), then use  $F' = 821$  in SI units ( $F' = 0.045$  in USC units).

$$F' = \frac{C_9}{C \times K_D} \left[ \frac{(T_w - T_1)^{1.25}}{T_1^{0.6506}} \right] \quad (10)$$

where

$C_9$  is a constant [= 0.2772 in SI units (0.1406 in USC units)];

$K_D$  is the coefficient of discharge (obtainable from the valve manufacturer);

NOTE A  $K_D$  value of 0.975 is typically used for preliminary sizing of PRVs (see API 520, Part 1).

$T_w$  is the maximum wall temperature of vessel material, expressed in K (°R);

$T_1$  is the gas absolute temperature, at the upstream relieving pressure, determined from Equation (12), expressed in K (°R).



The coefficient,  $C$ , is given by Equation (11):

$$C = C_{10} \sqrt{k \left( \frac{2}{k+1} \right)^{\frac{k+1}{k-1}}} \quad (11)$$

where

$C_{10}$  is a constant [= 0.0395 (kg-mole-K)<sup>0.5</sup>/(mm<sup>2</sup>-kPa-h) in SI units [520 (lb-mole-°R)<sup>0.5</sup>/(lb<sup>2</sup>-h) in USC units];

$k$  is the ideal gas specific heat ratio ( $C_p/C_v$ ) of gas or vapor at relieving temperature.

$$T_1 = \frac{p_1}{p_n} \times T_n \quad (12)$$

where

$p_n$  is the normal operating gas absolute pressure, expressed in kPa (psia);

$T_n$  is the normal operating gas absolute temperature, expressed in K (°R).

The recommended maximum vessel wall temperature,  $T_w$ , for the usual carbon steel plate materials is 593 °C (1100 °F). If vessels are fabricated from alloy materials, the value for  $T_w$  should be based on the stress rupture data for that material. See 4.4.13.2.3, 4.4.13.2.6, 4.6.1, and Annex A for guidance on the potential for vessel failure from overtemperature due to fire exposure.

If  $F' \geq 182$  in SI units ( $F' \geq 0.01$  in USC units), the relief load,  $q_{m,relief}$ , expressed in kg/h (lb/h), can be calculated directly by rearranging the critical vapor equation and substituting Equation (9) and Equation (10), which results in Equation (13):

$$q_{m,relief} = C_{12} \sqrt{M \times p_1} \left[ \frac{A'(T_w - T_1)^{1.25}}{T_1^{1.1506}} \right] \quad (13)$$

where

$M$  is the relative molecular mass of the gas;

$C_{12}$  is a constant [= 0.2772 in SI units (0.1406 in USC units)].

The minimum relief load recommended for sizing where  $F' < 182$  in SI units ( $F' < 0.01$  in USC units) is calculated by setting  $F' = 182$  in SI units ( $F' = 0.01$  in USC units), which results in Equation (14):

$$q_{m,relief} = C_{13} C A' \sqrt{\frac{M p_1}{T_1}} \quad (14)$$

where

$C_{13}$  is a constant [= 182 in SI units (0.01 in USC units)].

NOTE To derive Equation (13) and Equation (14),  $Z$ ,  $K_b$ , and  $K_c$  in API 520, Part 1, Equation (3) have each been assumed to have a value of 1. For Equation (14),  $K_D$  is conservatively assumed to have a value of 1.



Calculation

Parameters	Value	Parameters	Value
Aw	65 m <sup>2</sup>	KD	0.975
C9	0.2772	F'	116
C10	0.0395	Relief Load	3874 kg/hr
C	0.0254		

$$W_s = 182 \times C \times A_w \times \sqrt{\left(\frac{M \times P \times 100}{T + 273}\right)}$$

$$W_s = 182 \times 0.0254 \times 65 \times \sqrt{\frac{16.54 \times 67.5 \times 100}{400 + 273}} = 3874 \frac{\text{kg}}{\text{hr}}$$

Note that since F' is less than 182 the corresponding equation has been used in which F' is set to 182. Remember that in F' calculation T1 is set to max 400 C.

Note : Relieving Temperature Calculation

$$\text{Relieving Temperature(K)} = \frac{\text{Relieving Pressure (bara)}}{\text{Operating Pressure (bara)}} \times \text{Operating Temperature (K)}$$

$$\text{Relieving Temperature (K)} = \frac{67.55}{49.8} \times (380 + 273) = 885.74 \text{ K} = 612.74 \text{ C}$$

since the ratio between operating pressure and PSV relieving pressure is very high, the relieving temperature calculated is not consistent (it would exceed the maximum vessel wall temperature for carbon steel, &co). The relieving temperature for PSV design has been assumed equal to 400°C (considered the max allowable value for carbon steel). The actual relieving mass flow has been calculated keeping the discharge capacity of the valve (volumetric flow rate) constant and scaling the temperature down to 400°C.

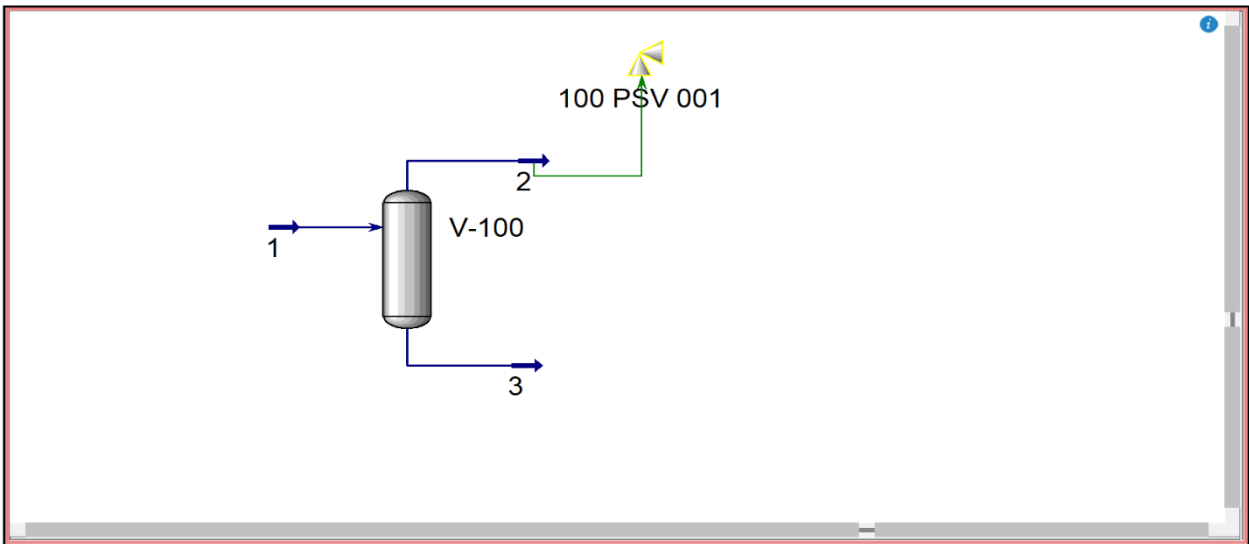


### Simulation

The screenshot displays a process simulation window. On the left, a distillation column labeled 'V-100' is shown with three streams: an inlet stream '1' on the left, a top vapor outlet stream '2' on the right, and a bottom liquid outlet stream '3' on the right. On the right side, a 'Material Stream: 1' properties window is open, showing the following data:

Worksheet	Stream Name	1	Vapour Phase
Conditions	Vapour / Phase Fraction	1.0000	1.0000
Properties	Temperature [C]	380.0	380.0
Composition	Pressure [bar_g]	47.60	47.60
Oil & Gas Feed	Molar Flow [kgmole/h]	7685	7685
Petroleum Assay	Mass Flow [kg/h]	1.233e+005	1.233e+005
K Value	Std Ideal Liq Vol Flow [m3/h]	411.8	411.8
User Variables	Molar Enthalpy [kJ/kgmole]	-5.904e+004	-5.904e+004
Notes	Molar Entropy [kJ/kgmole-C]	185.4	185.4
Cost Parameters	Heat Flow [kcal/h]	-1.084e+008	-1.084e+008
Normalized Yields	Liq Vol Flow @Std Cond [m3/h]	1.813e+005	1.813e+005
Emissions	Fluid Package	Basis-1	
	Utility Type		

Step 1:





Step 2:

Equipment	Scenarios	PRD Data	Rating	Line Sizing
Unit Op Protected	V-100			
Operating Temperature	380.0 °C	Reference	▼	
Design Temperature	410.0 °C	Manual	▼	
Operating Pressure	47.60 barG	Reference	▼	
Design Pressure	55.00 barG	Manual	▼	

Step 3:

Equipment   Scenarios   PRD Data   Rating   Line Sizing														
Create Scenario   Open Scenario   Duplicate & Rename   Delete Scenario														
Sizing Case	Scenario		Stream		Phase - Method		Flow Rate [kg/h]		Orifice Area [cm <sup>2</sup> ]		Capacity Used [%]	Pressure Drop [% of Set]		Notes
	Name	Type	Name	MW			Required	Rated	Calculated	Selected		Inlet	Outlet	
▶	Scenario 100	Fire	1 @Main	16.04	Vapor	Direct Integr.	3734	<empty>	1.700	<empty>	<empty>	<empty>	<empty>	<empty>
			General	Control Valve Related	Heaters and Coolers									
			Fire	Blocked Outlet	Exch. Tube Rupture									
			Thermal Expansion	Control Valve Failure	Cold Side of Exchanger Blocked-In									
			Overfilling	Abnormal Flow through Valve	Blocked-In Fired Heater									
			User Defined	Failure of Automatic Controls	Fan Failure									
			Flare	Reaction/Mixing	Distillation Column/Tower									
			General Power Failure	Chemical Reaction	Reflux Failure									
			Local Power Failure	Accidental Mixing	Reflux Failure (Side Stream)									
			Cooling Water Failure	Inadvertent Loss of Segregation	Abnormal Heat or Vapor Input									
			Coolant Failure (Other than CW)	Pressure Surge or Internal Explosion	Accumulation of Non-Condensables									
			Loss of Heat		Loss of Absorbent									



Step 4:

Scenario Setup | Fluid Properties | Relief Composition

Scenario Name: **Scenario100**

Scenario Type: **Fire**

Scenario Reference Stream

Stream: **2 @Main**

Relieving Temperature: **634.6 °C** Unwetted (API)

Relieving Pressure: **66.55 barG**

Total Backpressure: **10.00 barG**

Relieving Phase - Method: Vapor **Direct Integration (HEM)**

Viscosity Correction (Kv): **1.000**

Step 5:

Number of Vessels: **1**

Vessel Parameters	Vessel 1
Specify Equipment Dimensions?	<b>Yes</b>
Exposed Area [m <sup>2</sup> ]	<b>74.52</b>
Vessel Type	<b>Vertical (incl. bot</b>
Head Type	<b>2:1 Ellipsoidal</b>
Diameter [m]	<b>4.450</b>
Vessel Tan/Tan [m]	<b>3.100</b>
Liquid Level [m]	<empty>
Elevation [m]	<b>0.0000</b>
Maximum Flame Height [m]	<b>7.620</b>
Additional Area %	<b>15.00</b>
Relieving Flow [kg/h]	<b>3734</b>



Required Relieving Flow

Relieving Flow Method  Manual  Reference  Calculated

Calculation Method **Unwetted (API)**

Calculation Parameters	Value
▶ Max. Wall Temp. [°C]	<b>635.0</b>

Relief Temperature Calculation Option

Ideal Gas Assumption (API 521)  Ref Stream Equation of State

Step 6:

PSV Results	Value
▶ Calculated Orifice [cm <sup>2</sup> ]	1.700
▶ Selected Orifice [cm <sup>2</sup> ]	<b>1.980 (F)</b> ▼
▶ Fraction of Full Lift	1.000
▶ Rated Capacity [kg/h]	4350
▶ Capacity Used [%]	85.84
▶ Orifice Designation	1.5 F 2
▶ In/Out Flanges	600 x 150
▶ Discharge Coefficient (Kd)	<b>0.9750</b>

Here is the gist of what we have obtained:

Parameters	Results	Unit
Relief Load-API	3874	kg/hr.
Relief Load-Hysys	3734	kg/hr.
Selected Orifice	1.98	cm <sup>2</sup>
Orifice Designation	1.5 F 2	



### 3.PSV-1038/1043

#### 1.Determine the scenario, using API-521

Since it is R-1002 and exposed to fire then a fire scenario is defined.

Parameters	Value	Parameters	Value
Diameter	4 m	M	16.54
Height-TT	2.9 m	Set Pressure	55 barg
Fluid	Natural Gas	Relieving Pressure	67.55 bara
Z	1.01	Accumulation	0.21
Cp/Cv	1.18	Material	CS

#### 2.Calculate the relief load, using API-520 Part1

$$A = \frac{F' \times A'}{\sqrt{P_1}} \quad (9)$$

where

$A$  is the effective discharge area of the valve, expressed in mm<sup>2</sup> (in.<sup>2</sup>);

$A'$  is the exposed surface area of the vessel, expressed in m<sup>2</sup> (ft<sup>2</sup>);

$p_1$  is the upstream relieving absolute pressure, expressed in kPa (psi);

NOTE  $p_1$  is the set pressure plus the allowable overpressure plus the atmospheric pressure.

$F'$  can be determined using Equation (10). If calculated using Equation (10) and the result is less than 182 in SI units (<0.01 in USC units), then use a recommended minimum value of  $F' = 182$  in SI units ( $F' = 0.01$  in USC units). If insufficient information is available to use Equation (10), then use  $F' = 821$  in SI units ( $F' = 0.045$  in USC units).

$$F' = \frac{C_9}{C \times K_D} \left[ \frac{(T_w - T_1)^{1.25}}{T_1^{0.6506}} \right] \quad (10)$$

where

$C_9$  is a constant [= 0.2772 in SI units (0.1406 in USC units)];

$K_D$  is the coefficient of discharge (obtainable from the valve manufacturer);

NOTE A  $K_D$  value of 0.975 is typically used for preliminary sizing of PRVs (see API 520, Part 1).

$T_w$  is the maximum wall temperature of vessel material, expressed in K (°R);

$T_1$  is the gas absolute temperature, at the upstream relieving pressure, determined from Equation (12), expressed in K (°R).





The coefficient,  $C$ , is given by Equation (11):

$$C = C_{10} \sqrt{k \left( \frac{2}{k+1} \right)^{\frac{k+1}{k-1}}} \quad (11)$$

where

$C_{10}$  is a constant [= 0.0395 (kg-mole-K)<sup>0.5</sup>/(mm<sup>2</sup>-kPa-h) in SI units [520 (lb-mole-°R)<sup>0.5</sup>/(lbf-h) in USC units];

$k$  is the ideal gas specific heat ratio ( $C_p/C_v$ ) of gas or vapor at relieving temperature.

$$T_1 = \frac{P_1}{P_n} \times T_n \quad (12)$$

where

$P_n$  is the normal operating gas absolute pressure, expressed in kPa (psia);

$T_n$  is the normal operating gas absolute temperature, expressed in K (°R).

The recommended maximum vessel wall temperature,  $T_w$ , for the usual carbon steel plate materials is 593 °C (1100 °F). If vessels are fabricated from alloy materials, the value for  $T_w$  should be based on the stress rupture data for that material. See 4.4.13.2.3, 4.4.13.2.6, 4.6.1, and Annex A for guidance on the potential for vessel failure from overtemperature due to fire exposure.

If  $F' \geq 182$  in SI units ( $F' \geq 0.01$  in USC units), the relief load,  $q_{m,relief}$ , expressed in kg/h (lb/h), can be calculated directly by rearranging the critical vapor equation and substituting Equation (9) and Equation (10), which results in Equation (13):

$$q_{m,relief} = C_{12} \sqrt{M \times P_1} \left[ \frac{A'(T_w - T_1)^{1.25}}{T_1^{1.1506}} \right] \quad (13)$$

where

$M$  is the relative molecular mass of the gas;

$C_{12}$  is a constant [= 0.2772 in SI units (0.1406 in USC units)].

The minimum relief load recommended for sizing where  $F' < 182$  in SI units ( $F' < 0.01$  in USC units) is calculated by setting  $F' = 182$  in SI units ( $F' = 0.01$  in USC units), which results in Equation (14):

$$q_{m,relief} = C_{13} C A' \sqrt{\frac{M P_1}{T_1}} \quad (14)$$

where

$C_{13}$  is a constant [= 182 in SI units (0.01 in USC units)].

NOTE To derive Equation (13) and Equation (14),  $Z$ ,  $K_b$ , and  $K_c$  in API 520, Part 1, Equation (3) have each been assumed to have a value of 1. For Equation (14),  $K_D$  is conservatively assumed to have a value of 1.



Calculation

Parameters	Value	Parameters	Value
Aw	53.84 m <sup>2</sup>	KD	0.975
C9	0.2772	F'	116
C10	0.0395	Relief Load	3215 kg/hr
C	0.0254		

$$W_s = 182 \times C \times A_w \times \sqrt{\left(\frac{M \times P \times 100}{T + 273}\right)}$$

$$W_s = 182 \times 0.0254 \times 53.84 \times \sqrt{\frac{16.54 \times 67.5 \times 100}{400 + 273}} = 3215.1 \frac{\text{kg}}{\text{hr}}$$

Note that since F' is less than 182 the corresponding equation has been used in which F' is set to 182. Remember that in F' calculation T1 is set to max 400 C.

Note : Relieving Temperature Calculation

$$\text{Relieving Temperature(K)} = \frac{\text{Relieving Pressure (bara)}}{\text{Operating Pressure (bara)}} \times \text{Operating Temperature (K)}$$

$$\text{Relieving Temperature (K)} = \frac{67.55}{49.3} \times (375 + 273) = 887 \text{ K} = 614 \text{ C}$$

since the ratio between operating pressure and PSV relieving pressure is very high, the relieving temperature calculated is not consistent (it would exceed the maximum vessel wall temperature for carbon steel, & o). The relieving temperature for PSV design has been assumed equal to 400°C (considered the max allowable value for carbon steel). The actual relieving mass flow has been calculated keeping the discharge capacity of the valve (volumetric flow rate) constant and scaling the temperature down to 400°C.

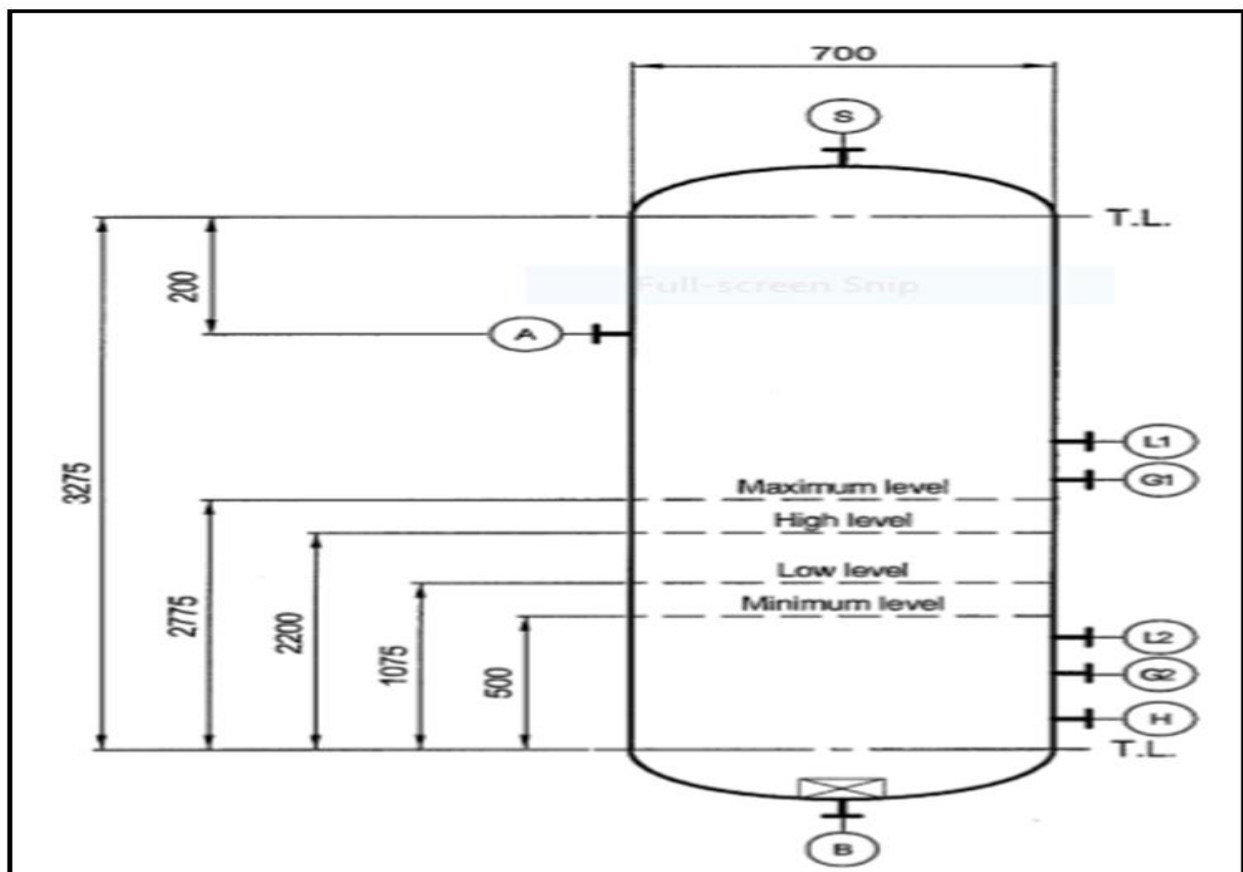


PSV-2019

1. Determine the scenario, using API-521

Since it is exposed to fire then a fire scenario is defined.

Parameters	Value	Parameters	Value
Diameter	0.7 m	M	18.02
Height	3.275 m	Set Pressure	52 barg
Fluid	Steam Condensate	Relieving Pressure	63.9 bara
Z	0.78	Accumulation	0.21
Cp/Cv	1.09	Material	CS





2. Calculate the relief load, using API-520 Part1

$$Q = C_1 \times F \times A_{ws}^{0.82} \quad (7)$$

where

$Q$  is the total heat absorption (input) to the wetted surface, expressed in W (Btu/h);

$C_1$  is a constant [= 43,200 in SI units (21,000 in USC units)];

$F$  is an environment factor (see Table 5);

$A_{ws}$  is the total wetted surface, expressed in m<sup>2</sup> (ft<sup>2</sup>).

NOTE 1 See 4.4.13.2.2 and Table 4.

NOTE 2 The expression,  $A_{ws}^{0.82}$ , is the area exposure factor or ratio. This ratio recognizes that large vessels are less likely than small ones to be completely exposed to the flame of an open fire.

Where adequate drainage and firefighting equipment do not exist, Equation (8) should be used

$$Q = C_2 \times F \times A_{ws}^{0.82}$$

$C_2$  is a constant [= 70,900 in SI units (34,500 in USC units)].

Calculation

Parameters	Value
Aw	7.73 m2
C2	70900
F	1
λ	2880
Relief load	474 kg/h

$$W_s = \frac{C_2 \times F \times (A_w^{0.82})}{\lambda} = \frac{70900 \times 1 \times (7.73^{0.82}) \times 3.6}{2880} = 474 \frac{kg}{hr}$$

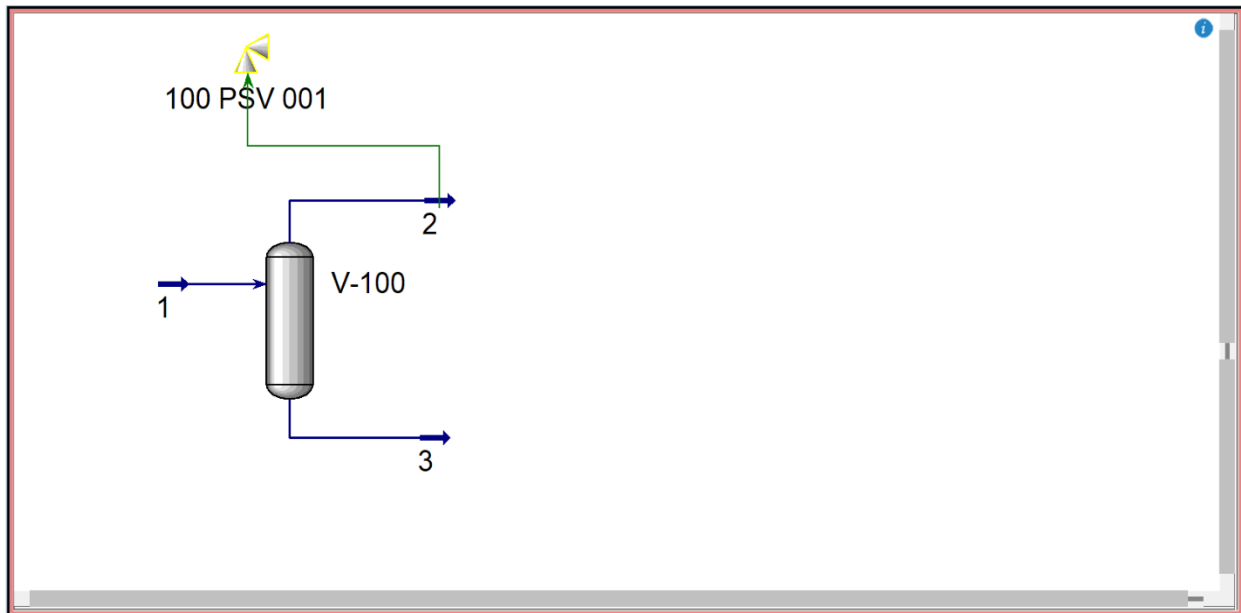


### Simulation in Aspen Hysys

The screenshot displays the Aspen Hysys interface. On the left, a process flow diagram shows a vertical vessel labeled 'V-100'. An inlet stream '1' enters from the left, and two outlet streams, '2' and '3', exit from the top and bottom respectively. On the right, the 'Material Stream: 1' properties window is open, showing a table of stream data.

Worksheet	Stream Name	1	Aqueous Phase
Conditions	Vapour / Phase Fraction	0.0000	1.0000
Properties	Temperature [C]	257.0	257.0
Composition	Pressure [bar_g]	43.50	43.50
Oil & Gas Feed	Molar Flow [kgmole/h]	557.9	557.9
Petroleum Assay	Mass Flow [kg/h]	1.005e+004	1.005e+004
K Value	Std Ideal Liq Vol Flow [m3/h]	10.07	10.07
User Variables	Molar Enthalpy [kJ/kgmole]	-2.667e+005	-2.667e+005
Notes	Molar Entropy [kJ/kgmole-C]	101.3	101.3
Cost Parameters	Heat Flow [kcal/h]	-3.556e+007	-3.556e+007
Normalized Yields	Liq Vol Flow @Std Cond [m3/h]	9.903	9.903
Emissions	Fluid Package	Basis-1	
	Utility Type		

Step 1:





Step 2:

Flowsheet Case (Main) (PSV) x 100 PSV 001 x 100 PSV 001-Scenario100 x +

Equipment Scenarios PRD Data Rating Line Sizing

Unit Op Protected V-100

Operating Temperature 257.0 °C Reference

Design Temperature 290.0 °C Manual

Operating Pressure 43.50 barG Reference

Design Pressure 52.00 barG Manual

Step 3:

Equipment Scenarios PRD Data Rating Line Sizing

Create Scenario Open Scenario Duplicate & Rename Delete Scenario

Sizing Case	Scenario		Stream		Phase - Method	Flow Rate (kg/h)		Orifice Area (cm <sup>2</sup> )		Capacity Used (%)	Pressure Drop (% of Set)		Notes
	Name	Type	Name	MW		Required	Rated	Calculated	Selected		Inlet	Outlet	
Scenario100	Fire	2 @Main	18.02	Vapor	Direct Integr:	511.7	<empty>	0.1639	<empty>	<empty>	<empty>	<empty>	<empty>
General			Control Valve Related		Heaters and Coolers								
Fire			Blocked Outlet		Exch. Tube Rupture								
Thermal Expansion			Control Valve Failure		Cold Side of Exchanger Blocked-In								
Overfilling			Abnormal Flow through Valve		Blocked-In Fired Heater								
User Defined			Failure of Automatic Controls		Fan Failure								
Flare			Reaction/Mixing		Distillation Column/Tower								
General Power Failure			Chemical Reaction		Reflux Failure								
Local Power Failure			Accidental Mixing		Reflux Failure (Side Stream)								
Cooling Water Failure			Inadvertent Loss of Segregation		Abnormal Heat or Vapor Input								
Coolant Failure (Other than CW)			Pressure Surge or Internal Explosion		Accumulation of Non-Condensables								
Loss of Heat					Loss of Absorbent								

100 PSV 001: Please select a Sizing Case



Step 4:

Scenario Setup Fluid Properties Relief Composition

Scenario Name **Scenario100**

Scenario Type **Fire**

Scenario Reference Stream

Stream **2 @Main**

Relieving Temperature **279.0 °C**

Relieving Pressure **62.92 barG**

Total Backpressure **0.5000 barG**

Relieving Phase - Method **Vapor**

Viscosity Correction (Kv) **1.000**

Select Reference Stream

Flowsheet Object

Case (Main)

1  
2  
3

Object Filter

All  
 Streams  
 UnitOps  
 Logicals  
 ColumnOps  
 Custom



Scenario Setup | Fluid Properties | Relief Composition

Scenario Name **Scenario100**

Scenario Type **Fire**

Scenario Reference Stream

Stream **2 @Main**

Relieving Temperature **279.0 °C** **Wetted (API)**

Relieving Pressure **62.92 barG**

Total Backpressure **0.5000 barG**

Relieving Phase - Method **Vapor** **Direct Integration (HEM)**

Viscosity Correction (Kv) **1.000**

Step 5:

Required Relieving Flow **511.7 kg/h**

Relieving Flow Method  Manual  Reference  Calculated

Calculation Method **Wetted (API)**

Calculation Parameters	Value
▶ Wetted Area Exponent	<b>0.8200</b>
▶ Drainage & Firefighting	<b>Absent</b>
▶ Calculate Latent Heat	<b>Yes</b>
▶ Latent Heat [kJ/kg]	1600
▶ Initial % Vaporized [mol%]	<b>0.0000</b>
▶ Final % Vaporized [mol%]	<b>10.00</b>
▶ Sensible Heat	<b>Exclude</b>
▶ Calculate Vapor/Liquid Disengagement	<b>No</b>
▶ Vessel Flow Model	<empty>
▶ Disengagement Regime	<empty>
▶ C0	<empty>





Step 6:

Number of Vessels <b>1</b>	
Vessel Parameters	Vessel 1
> Specify Equipment Dimensions?	<b>Yes</b>
> Exposed Area [m <sup>2</sup> ]	4.138
> Vessel Type	<b>Vertical (incl. bot</b>
> Head Type	<b>2:1 Ellipsoidal</b>
> Diameter [m]	<b>0.7000</b>
> Vessel Tan/Tan [m]	<b>3.275</b>
> Liquid Level [m]	<b>1.640</b>
> Elevation [m]	<b>0.0000</b>
> Maximum Flame Height [m]	<b>7.620</b>
> Additional Area %	<b>0.0000</b>
>	
> Calculate F Factor?	<b>No</b>
> Environment Factor F	<b>1.000</b>
> Insulation k [W/m/°C]	<empty>
> Insulation Thickness [mm]	<empty>
>	
> Heat Input [kJ/h]	8.186E+005
> Relieving Flow [kg/h]	511.7



#### 4.PSV-2121/2122

The rated capacity of FT-2002 is 27180 kg/h, so the relief load is 27180 kg/h.

#### 5.PSV-2171/2172

The rated capacity of FT-2001 is 48000 kg/h, so the relief load is 48000 kg/h.

#### 6.PSV-2354/2360

Heat Exchanger E-2020 tube rupture

Please check Appendix A.

#### 7.PSV-2485

### 1. Heat Exchanger Data Input

High pressure side	Reformed Gas
Low pressure side	DMW
Design Pressure of high-pressure side	29 barg
Design Pressure of low-pressure side	14 barg
Operating Pressure	24.5 barg
M	12.06
Cp/Cv	1.36
Z	1
Relieving Temperature	138
Tube OD	25.4
Tube Thk.	1.65

### 2. Check if a PSV is needed

In order to perform this step, do the calculation below:

multiply design pressure of high-pressure side by 10/13:

$$29 * 10/13 = 22.3 \text{ barg}$$

So, design pressure of low-pressure side should be at least 22.3 barg in order not to need a PSV. Here it is 7.5 bars, thereby requiring a PSV.



3. Use the formula below to calculate Relief Load

$K_G$ : 2.93 (Metric), 385 (USC)	Vapors	$W_G = K_G d^2 P_1 \sqrt{\frac{M}{zT}}$
$K_L$ : 1.77 (Metric), 2645 (USC)	Liquids	$W_L = K_L d^2 \sqrt{\rho_L (P_1 - P_2)}$
$W_G$	:	gas flow through tube break, kg/hr or lb/hr
$W_L$	:	liquid flow through tube break, kg/hr or lb/hr
$d$	:	tube inside diameter, mm or inch
$P_1(*)$	:	HP side normal pressure, bara or psia (alternatively the HP side design pressure may be considered for $P_1$ , as required by some clients).
$P_2(*)$	:	relieving pressure of the low pressure side, usually 1.1 x gauge set pressure, bara or psia
$M$	:	molecular weight
$z$	:	compressibility factor
$T(*)$	:	vapor temperature, °K or °R
$\rho_L(*)$	:	liquid density, kg/m <sup>3</sup> or lb/ft <sup>3</sup>

4. Relief Load Result

$$W_s = K_G \times (d^2) \times P_1 \times ((M/ZT) ^{0.5})$$

$$W_s = 2.93 \times (22.1^2) \times (24.5 + 1.013) \times \frac{12.06}{1 \times 411} = 6254.12 \text{ kg/hr.}$$

PSV 2376/2377/2378/2379/2380

The total capacity is 430000kg/h (Normal capacity is 388329 considering 1.1 times) which is shared by PSV-2376, PSV-2377, PSV-2378, and PSV-2379; PSV-2380 is spare and its capacity is the same as PSV-2376~79.



PSV-2494

1. Heat Exchanger Data Input

High pressure side	Reformed Gas
Low pressure side	CW
Design Pressure of high-pressure side	29 barg
Design Pressure of low-pressure side	7.5 barg
Operating Pressure	24.2 barg
M	11.24
Cp/Cv	1.39
Z	1
Relieving Temperature	56.4
Tube OD	19.05
Tube Thk.	1.65

2. Check if a PSV is needed

In order to perform this step, do the calculation below:

multiply design pressure of high-pressure side by 10/13:

$$29 * 10/13 = 22.3 \text{ barg}$$

So, design pressure of low-pressure side should be at least 22.3 barg in order not to need a PSV. Here it is 7.5 bars, thereby requiring a PSV.



3. Use the formula below to calculate Relief Load

$K_G$ : 2.93 (Metric), 385 (USC)	Vapors	$W_G = K_G d^2 P_1 \sqrt{\frac{M}{zT}}$
$K_L$ : 1.77 (Metric), 2645 (USC)	Liquids	$W_L = K_L d^2 \sqrt{\rho_L (P_1 - P_2)}$
$W_G$	:	gas flow through tube break, kg/hr or lb/hr
$W_L$	:	liquid flow through tube break, kg/hr or lb/hr
$d$	:	tube inside diameter, mm or inch
$P_1(*)$	:	HP side normal pressure, bara or psia (alternatively the HP side design pressure may be considered for $P_1$ , as required by some clients).
$P_2(*)$	:	relieving pressure of the low pressure side, usually 1.1 x gauge set pressure, bara or psia
$M$	:	molecular weight
$z$	:	compressibility factor
$T(*)$	:	vapor temperature, °K or °R
$\rho_L(*)$	:	liquid density, kg/m <sup>3</sup> or lb/ft <sup>3</sup>

4. Relief Load Results

$$W_s = K_G \times (d^2) \times P_1 \times ((M/ZT)^{0.5})$$

$$W_s = 2.93 \times (15.75^2) \times (24.2 + 1.013) \times \frac{11.24}{1 \times 329} = 3387.18 \text{ kg/hr.}$$



PSV-2494

1. Heat Exchanger Data Input

High pressure side	Syngas
Low pressure side	CW
Design Pressure of high-pressure side	99 barg
Design Pressure of low-pressure side	7.5 barg
Operating Pressure	83.7 barg
M	10.07
Cp/Cv	1.37
Z	1
Relieving Temperature	43.6
Tube OD	25.4
Tube Thk.	1.65

2. Check if a PSV is needed

In order to perform this step, do the calculation below:

multiply design pressure of high-pressure side by 10/13:

$$99 * 10/13 = 76.15 \text{ barg}$$

So, design pressure of low-pressure side should be at least 76.15 barg in order not to need a PSV. Here it is 7.5 bars, thereby requiring a PSV.



3. Use the formula below to calculate Relief Load

$K_G$ : 2.93 (Metric), 385 (USC)	Vapors	$W_G = K_G d^2 P_1 \sqrt{\frac{M}{zT}}$
$K_L$ : 1.77 (Metric), 2645 (USC)	Liquids	$W_L = K_L d^2 \sqrt{\rho_L (P_1 - P_2)}$
$W_G$	:	gas flow through tube break, kg/hr or lb/hr
$W_L$	:	liquid flow through tube break, kg/hr or lb/hr
$d$	:	tube inside diameter, mm or inch
$P_1$ (*)	:	HP side normal pressure, bara or psia (alternatively the HP side design pressure may be considered for $P_1$ , as required by some clients).
$P_2$ (*)	:	relieving pressure of the low pressure side, usually 1.1 x gauge set pressure, bara or psia
$M$	:	molecular weight
$z$	:	compressibility factor
$T$ (*)	:	vapor temperature, °K or °R
$\rho_L$ (*)	:	liquid density, kg/m <sup>3</sup> or lb/ft <sup>3</sup>

4. Relief Load Result

$$W_s = K_G \times (d^2) \times P_1 \times ((M/ZT) ^{0.5})$$

$$W_s = 2.93 \times (22.1^2) \times (83.7 + 1.013) \times \frac{10.07}{1 \times 323} = 21620 \text{ kg/hr.}$$



## Simulation

The screenshot shows a software interface for simulating a heat exchanger. On the left, a process flow diagram shows a central heat exchanger labeled 'E-100'. It has four streams: '1' (top), '2' (bottom), 'CWS' (left), and 'CWR' (right). On the right, a data table for 'Heat Exchanger: E-100' is displayed. The table has columns for 'Name', 'CWS', 'CWR', '1', and '2'. The 'Worksheet' tab is active, showing various properties and specifications.

Name	CWS	CWR	1	2
Conditions				
Vapour	0.0000	0.0000	0.9146	0.9080
Temperature [C]	38.00	48.62	65.00	48.00
Properties				
Pressure [bar_g]	4.500	3.500	83.70	83.20
Composition				
PF Specs				
Molar Flow [kgmole/h]	9.548e+004	9.548e+004	9.037e+004	9.037e+004
Mass Flow [kg/h]	1.720e+006	1.720e+006	9.006e+005	9.006e+005
Std Ideal Liq Vol Flow [m3/h]	1723	1723	2935	2935
Molar Enthalpy [kJ/kgmole-C]	-2.852e+005	-2.844e+005	-4.461e+004	-4.549e+004
Molar Entropy [kJ/kgmole-C]	57.01	59.63	100.4	97.83
Heat Flow [kcal/h]	-6.508e+009	-6.489e+009	-9.636e+008	-9.824e+008

Step 1:

The screenshot shows the 'Rating' tab for Heat Exchanger E-100. The 'Unit Op Protected' is set to 'E-100'. The 'Operating Temperature' is 48.62 °C, with a 'Reference' dropdown. The 'Design Temperature' is 100.0 °C, with a 'Manual' dropdown. The 'Operating Pressure' is 3.500 barG, with a 'Reference' dropdown. The 'Design Pressure' is 7.500 barG, with a 'Manual' dropdown.

Equipment	Scenarios	PRD Data	Rating	Line Sizing
Unit Op Protected		E-100		
Operating Temperature		48.62 °C	Reference	
Design Temperature		100.0 °C	Manual	
Operating Pressure		3.500 barG	Reference	
Design Pressure		7.500 barG	Manual	





Step 2:

Sizing Case		Scenario		Stream		Phase - Method		Flow Rate (kg/h)		Orifice Area (cm <sup>2</sup> )		Capacity Used (%)	Pressure Drop (% of Set)		Notes
	Name	Type	Name	MW			Required	Rated	Calculated	Selected		Inlet	Outlet		
<input checked="" type="checkbox"/>	Scenario100	Exch. Tube Rupture	1 @Main	9966	Two phase	Direct Integr	2.153E+004	<empty>	58.53	<empty>	<empty>	<empty>	<empty>	<empty>	<empty>
General		Control Valve Related		Heaters and Coolers											
Fire		Blocked Outlet		Exch. Tube Rupture											
Thermal Expansion		Control Valve Failure		Cold Side of Exchanger Blocked-In											
Overfilling		Abnormal Flow through Valve		Blocked-In Fired Heater											
User Defined		Failure of Automatic Controls		Fan Failure											
Flare		Reaction/Mixing		Distillation Column/Tower											
General Power Failure		Chemical Reaction		Reflux Failure											
Local Power Failure		Accidental Mixing		Reflux Failure (Side Stream)											
Cooling Water Failure		Inadvertent Loss of Segregation		Abnormal Heat or Vapor Input											
Coolant Failure (Other than CW)		Pressure Surge or Internal Explosion		Accumulation of Non-Condensables											
Loss of Heat				Loss of Absorbent											

Step 3:

Scenario Setup	Fluid Properties	Relief Composition
Scenario Name <b>Scenario100</b>		
Scenario Type <b>Exch. Tube Rupture</b>		
Scenario Reference Stream		
Stream	1 @Main	Select...
Relieving Temperature	43.61 °C	Calculated
Relieving Pressure	8.250 barG	Edit
Total Backpressure	0.7500 barG	Edit
Relieving Phase - Method	Two phase	Direct Integration (HEM)
Viscosity Correction (Kv)	1.000	



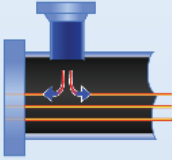
Step 4:

Required Relieving Flow

Relieving Flow Method  Manual  Reference  Calculated

Direction of Flow  From Tube to Shell  From Shell to Tube

	High Pressure Side	High Pressure Side Method	Choking Condition	Low Pressure Side @ Relief
▶ Pressure	83.70 barG	Reference ▾	43.97 barG	8.250 barG
▶ Temperature	65.00 °C	Reference ▾	60.40 °C	43.61 °C
▶ Phase	Two phase		Two phase	Two phase



Tube I.D.

Flow Coefficient (C)

ΔP  (choked flow)

Vapor Density (ρV)

Vapor k

Liquid Density (ρL)

Vapor Ratio (R)

Step 5:

	PSV Results	Value
▶	Calculated Orifice [cm <sup>2</sup> ]	58.53
▶	Selected Orifice [cm <sup>2</sup> ]	<b>71.290 (Q)</b> ▾
▶	Fraction of Full Lift	1.000
▶	Rated Capacity [kg/h]	2.622E+004
▶	Capacity Used [%]	82.10
▶	Orifice Designation	6 Q 8
▶	In/Out Flanges	150 x 150
▶	Discharge Coefficient (Kd)	<b>0.8500</b>



Here is all we have obtained:

Parameters	Values	Units
Relief Load-API	21620	kg/hr.
Relief Load-Hysys	21530	kg/hr.
Selected Orifice	71.29	Cm <sup>2</sup>
Orifice Designation	6Q8	



PSV-3047/3048/3057

Steam Drum D-3003

The normal capacity of steam is about 251000 kg/h and the rated capacity is achieved by multiplying the normal capacity by 1.1 which equals to 276000 kg/h.

PSV-3163

1. Determine the scenario, using API-521

Since it is D-3001 and exposed to fire then a fire scenario is defined.

Parameters	Value	Parameters	Value
Diameter	4.9 m	M	9.37
Height	4.8 m	Set Pressure	99 barg
Fluid	Methanol + Syng	Relieving Pressure	120.79 bara
Z		Accumulation	0.21
Cp/Cv	1.37	Material	SS



2. Calculate the relief load, using API-520 Part1

$$A = \frac{F' \times A'}{\sqrt{P_1}} \quad (9)$$

where

$A$  is the effective discharge area of the valve, expressed in mm<sup>2</sup> (in.<sup>2</sup>);

$A'$  is the exposed surface area of the vessel, expressed in m<sup>2</sup> (ft<sup>2</sup>);

$P_1$  is the upstream relieving absolute pressure, expressed in kPa (psi);

NOTE  $P_1$  is the set pressure plus the allowable overpressure plus the atmospheric pressure.

$F'$  can be determined using Equation (10). If calculated using Equation (10) and the result is less than 182 in SI units (<0.01 in USC units), then use a recommended minimum value of  $F' = 182$  in SI units ( $F' = 0.01$  in USC units). If insufficient information is available to use Equation (10), then use  $F' = 821$  in SI units ( $F' = 0.045$  in USC units).

$$F' = \frac{C_9}{C \times K_D} \left[ \frac{(T_w - T_1)^{1.25}}{T_1^{0.6506}} \right] \quad (10)$$

where

$C_9$  is a constant [= 0.2772 in SI units (0.1406 in USC units)];

$K_D$  is the coefficient of discharge (obtainable from the valve manufacturer);

NOTE A  $K_D$  value of 0.975 is typically used for preliminary sizing of PRVs (see API 520, Part 1).

$T_w$  is the maximum wall temperature of vessel material, expressed in K (°R);

$T_1$  is the gas absolute temperature, at the upstream relieving pressure, determined from Equation (12), expressed in K (°R).



The coefficient,  $C$ , is given by Equation (11):

$$C = C_{10} \sqrt{k \left( \frac{2}{k+1} \right)^{\frac{k+1}{k-1}}} \quad (11)$$

where

$C_{10}$  is a constant [= 0.0395 (kg-mole-K)<sup>0.5</sup>/(mm<sup>2</sup>-kPa-h) in SI units [520 (lb-mole-°R)<sup>0.5</sup>/(lb<sup>2</sup>-h) in USC units];

$k$  is the ideal gas specific heat ratio ( $C_p/C_v$ ) of gas or vapor at relieving temperature.

$$T_1 = \frac{p_1}{p_n} \times T_n \quad (12)$$

where

$p_n$  is the normal operating gas absolute pressure, expressed in kPa (psia);

$T_n$  is the normal operating gas absolute temperature, expressed in K (°R).

The recommended maximum vessel wall temperature,  $T_w$ , for the usual carbon steel plate materials is 593 °C (1100 °F). If vessels are fabricated from alloy materials, the value for  $T_w$  should be based on the stress rupture data for that material. See 4.4.13.2.3, 4.4.13.2.6, 4.6.1, and Annex A for guidance on the potential for vessel failure from overtemperature due to fire exposure.

If  $F' \geq 182$  in SI units ( $F' \geq 0.01$  in USC units), the relief load,  $q_{m,relief}$ , expressed in kg/h (lb/h), can be calculated directly by rearranging the critical vapor equation and substituting Equation (9) and Equation (10), which results in Equation (13):

$$q_{m,relief} = C_{12} \sqrt{M \times p_1} \left[ \frac{A'(T_w - T_1)^{1.25}}{T_1^{1.1506}} \right] \quad (13)$$

where

$M$  is the relative molecular mass of the gas;

$C_{12}$  is a constant [= 0.2772 in SI units (0.1406 in USC units)].

The minimum relief load recommended for sizing where  $F' < 182$  in SI units ( $F' < 0.01$  in USC units) is calculated by setting  $F' = 182$  in SI units ( $F' = 0.01$  in USC units), which results in Equation (14):

$$q_{m,relief} = C_{13} C A' \sqrt{\frac{M p_1}{T_1}} \quad (14)$$

where

$C_{13}$  is a constant [= 182 in SI units (0.01 in USC units)].

NOTE To derive Equation (13) and Equation (14),  $Z$ ,  $K_b$ , and  $K_c$  in API 520, Part 1, Equation (3) have each been assumed to have a value of 1. For Equation (14),  $K_D$  is conservatively assumed to have a value of 1.



Calculation

Parameters	Value	Parameters	Value
Aw	100 m <sup>2</sup>	KD	0.975
C9	0.2772	F'	328
C10	0.0395	Tw	593C
C	0.026	Relief Load	13236 kg/hr

$$W_s = \frac{2.722 \times (T_w - T)^{1.25} \times A \times \sqrt{MP}}{T^{1.1506}}$$

$$W_s = \frac{2.722 \times (866.5 - 478.6)^{1.25} \times 100 \times \sqrt{(120.7 \times 100 \times 9.37)}}{478.6^{1.1506}} = 13236 \frac{\text{kg}}{\text{hr}}$$

Note: Relieving temperature calculation:

$$T = \frac{\text{Relieving Pressure}}{\text{Operating Pressure}} \times \text{Operating Temperature}$$

$$T = \frac{120.79}{81} \times (48 + 321) = 478.7 \text{ C}$$



PSV-5370

Use the formula below to calculate Relief Load

$$q = \frac{\alpha_v \cdot \phi}{1000 d \cdot c}$$

$q$  is the volume flow rate at the flowing temperature, expressed in cubic metres per second;

$\alpha_v$  is the cubic expansion coefficient for the liquid at the expected temperature, expressed in  $1/^\circ\text{C}$ ;

$\phi$  is the total heat transfer rate, expressed in watts;

NOTE For heat exchangers, this can be taken as the maximum exchanger duty during operation.

$d$  is the relative density referred to water ( $d = 1,00$  at  $15,6^\circ\text{C}$ ), dimensionless;

NOTE Compressibility of the liquid is usually ignored.

$c$  is the specific heat capacity of the trapped fluid, expressed in  $\text{J/kg}\cdot\text{K}$ .

1.PSV-5370

Parameters	value
av (1/k)	0.000454
duty (watts)	160000
specific gravity	0.99
c (J/kg.C)	4176

Q (lit/m)	1.05
Q (kg/h)-API521	63





$$q = \frac{av \times \phi}{1000 \times d \times C}$$

$$q = \frac{0.000454 \times 160000 \times 60000}{1000 \times 0.99 \times 4176} = 1.05 \text{ lit/min}$$



2.PSV-5339

Use the formula below to calculate Relief Load

$$q = \frac{\alpha_v \cdot \phi}{1000 d \cdot c}$$

$q$  is the volume flow rate at the flowing temperature, expressed in cubic metres per second;

$\alpha_v$  is the cubic expansion coefficient for the liquid at the expected temperature, expressed in  $1/^\circ\text{C}$ ;

$\phi$  is the total heat transfer rate, expressed in watts;

NOTE For heat exchangers, this can be taken as the maximum exchanger duty during operation.

$d$  is the relative density referred to water ( $d = 1,00$  at  $15,6^\circ\text{C}$ ), dimensionless;

NOTE Compressibility of the liquid is usually ignored.

$c$  is the specific heat capacity of the trapped fluid, expressed in  $\text{J/kg}\cdot\text{K}$ .

Parameters	value
av (1/k)	0.000454
duty (watts)	3600000
specific gravity	0.99
c (J/kg.K)	4176

Q (lit/m)	23.71
Q (kg/h)-API521	1422



$$q = \frac{av \times \phi}{1000 \times d \times C}$$

$$q = \frac{0.000454 \times 3600000 \times 60000}{1000 \times 0.99 \times 4176} = 23.71 \text{ lit/min}$$



PSV-5058

Heat Exchanger E-2024 Tube Rupture

$$\text{Venting Required (Ws)} = 2.463 \times (d^2) \times (\Delta P \times \rho V / 10)^{0.5}$$

Parameter	Unit	Value
Tube ID (d)	mm	28.5
$\Delta P$	bar	9.5
Gas Density ( $\rho V$ )	Kg/m <sup>3</sup>	20.47

$$\text{Ws} = 2.463 \times (28.5^2) \times (9.5 \times 20.47 / 10)^{0.5} = 8822.15 \text{ kg/hr.}$$

PSV-5058

Heat Exchanger E-5001 Tube Rupture

$$\text{Venting Required (Ws)} = 2.463 \times (d^2) \times (\Delta P \times \rho V / 10)^{0.5}$$

Parameter	Unit	Value
Tube ID (d)	mm	27.53
$\Delta P$	bar	2.44
Gas Density ( $\rho V$ )	Kg/m <sup>3</sup>	3.37



$$W_s = 2.463 \times (27.53^2) \times (2.44 \times 3.37/10)^{0.5} = 1692.73 \text{ kg/hr.}$$

PSV-5179/5180

Heat Exchanger E-5002 Tube Rupture

$$\text{Venting Required (} W_s \text{)} = 2.463 \times (d^2) \times (\Delta P \times \rho V/10)^{0.5}$$

Parameter	Unit	Value
Tube ID (d)	mm	21.18
$\Delta P$	bar	1.71
Gas Density ( $\rho V$ )	Kg/m <sup>3</sup>	7.35

$$W_s = 2.463 \times (21.18^2) \times (1.71 \times 7.35/10)^{0.5} = 1239 \text{ kg/hr.}$$



PSV-5250/5261

Heat Exchanger E-5023 Tube Rupture

$$\text{Venting Required (Ws)} = 2.463 \times (d^2) \times (\Delta P \times \rho V / 10)^{0.5}$$

Parameter	Unit	Value
Tube ID (d)	mm	22.1
$\Delta P$	bar	18.84
Gas Density ( $\rho V$ )	Kg/m <sup>3</sup>	9.74

$$Ws = 2.463 \times (22.1^2) \times (18.84 \times 9.74 / 10)^{0.5} = 5153 \text{ kg/hr.}$$



PSV-5250/5261

Heat Exchanger E-5003 Tube Rupture

$$\text{Venting Required (Ws)} = 2.463 \times (d^2) \times (\Delta P \times \rho V / 10)^{0.5}$$

Parameter	Unit	Value
Tube ID (d)	mm	14.83
$\Delta P$	bar	0.5
Gas Density ( $\rho V$ )	Kg/m <sup>3</sup>	3.99

$$Ws = 2.463 \times (14.83^2) \times (0.5 \times 3.99 / 10)^{0.5} = 242 \text{ kg/hr.}$$



### Governing Scenarios

#### PSV-5058/5059/5060/5061

1. The overall relieve amount of the T5001 overhead is equal to the amount into condenser AE5004 which is 112490kg/h.
2. Tube rupture scenario for both heat exchangers E-5001 and E-5024 would result in venting flowrate of  $8822 + 1692 = 10514$  kg/hr.
3. By comparison between the relief load of these scenarios, the governing scenario is reflux failure.

#### PSV-5179/5180

1. The overall relieve amount of the T5002 overhead is equal to the amount into condenser AE5005 which is 418559kg/h,
2. Tube rupture scenario for heat exchangers E-5002 would result in venting flowrate 1239 kg/hr.
3. By comparison between the relief load of these scenarios, the governing scenario is reflux failure.

#### PSV-5250/5251/5261

1. The overall relieve amount of the T5003 overhead is equal to the amount into condenser E5002 1/2/3/4 which is 440751kg/h.
2. Tube rupture scenario for both heat exchangers E-5023 and E-5003 would result in venting flowrate of  $242 + 5153 = 5395$  kg/hr.
3. By comparison between the relief load of these scenarios, the governing scenario is reflux failure.

#### PSV-2494

1. The relief load for tube rupture scenario is 3387.18 kg/hr.
2. Also, the hydraulic expansion is an applicable scenario. Here is the calculation for the hydraulic expansion scenario.

Parameters	value
av (1/k)	0.000454
duty (watts)	6500000
specific gravity	0.99
c (J/kg.K)	4176





Q (lit/m)	42.82
Q (kg/h)-API521	

3. By comparison between the relief load of these scenarios, the governing scenario is tube rupture.

PSV-3143/3146/3149

1. The relief load for tube rupture scenario is 24000 kg/hr.
2. Also, the hydraulic expansion is an applicable scenario. Here is the calculation for the hydraulic expansion scenario.

Parameters	value
av (1/k)	0.000454
duty (watts)	44300000
specific gravity	0.99
c (J/kg.K)	4176

Q (lit/m)	291.88
Q (kg/h)-API521	

3. By comparison between the relief load of these scenarios, the governing scenario is tube rupture.



### Practice

In a HAZOP meeting tube rupture scenario was suggested for methanol reactors. Causes could be pressure drop differences, leak as a result of corrosion, or both. Investigate the matter and check if the existing PSVs could handle such relief load as a result of tube rupture.

Let's check if this scenario is applicable.

High-pressure operating pressure is 79.5 barg

Low-pressure operating pressure is 33.7 barg

Required Pressure =  $79.5 \times 10/13 = 61.15$  barg , So the low-pressure side pressure should be minimum 61.15 barg so that tube rupture does not occur. So this scenario is applicable.

Parameter	Value	Unit
Tube Inner Diameter (ID)	57.5	
Differential pressure of high-pressure side and low side ( $\Delta P$ )	45.8	
Gas density ( $\rho V$ )	17.9	Kg/m <sup>3</sup>

$$W_s = 2.463 \times (d^2) \times (\Delta P \times \rho V / 10)^{0.5}$$

$$W_s = 2.463 \times (57.5^2) \times (45.8 \times 17.9 / 10)^{0.5} = 73732 \text{ kg/hr.}$$

So the PSVs which are designed for blocked outlet with venting capacity of 281000 kg/hr. can handle such relief load and is in fact the governing scenario.



Appendix A

The equation for heat exchanger tube rupture for liquid is as follows:

$$Ws = 1.68 \times \rho \times d^2 \times \sqrt{\frac{\Delta P}{\rho}}$$

Parameter	Value	Unit
Heat Exchanger Inner tube Diameter (d)	48.26	mm
Liquid Density ( $\rho$ )	683	Kg/m <sup>3</sup>
Differential pressure of high-pressure side and low-side ( $\Delta P$ )	74.7	bar

$$Ws = 1.68 \times \rho \times d^2 \times \sqrt{\frac{\Delta P}{\rho}} = 1.68 \times 683 \times 48.26^2 \times \sqrt{\frac{74.7}{683}} = 883601 \frac{kg}{hr}$$