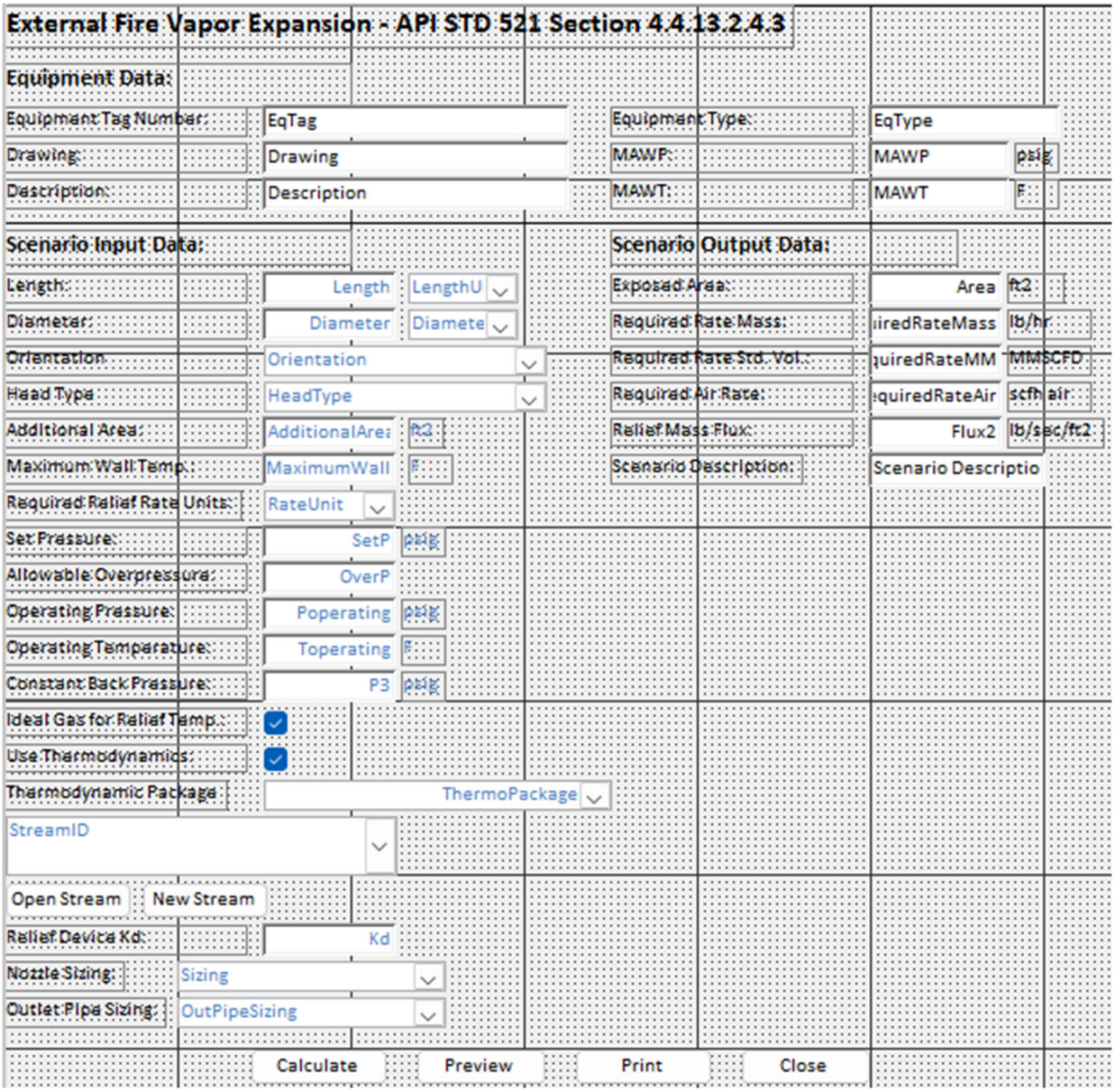
External Fire Vapor Expansion



Equipment Data:

The six fields under Equipment Data are specified on the Overpressure Scenario Form.

Input Data:

The form fields for inputs are blue and organized under the Scenario Input column. The are described below:

Length – Vessel seam-to-seam length for horizontal and vertical orientations. Not required for spheres.

LengthUnits – Units (ft, in or mm) associated with the Length.

Diameter – Vessel diameter generally taken as the outer diameter.

DiameterUnits – Units (ft, in or mm) associated with the Diameter.

Orientation – Vessel orientation (horizontal, vertical or spherical.

Head1Type – Both vessel heads assumed the same (2:1 ellipsoidal, hemispherical or flat).

AdditionalArea – Any wetted area beyond normal geometry calculation to be added such as a boot or piping.

MaximumWall – Maximum wall metal temperature which is typically 1,100 ° F for carbon steel.

RateUnit – Flow units in which the required relief rate will be reported.

SetP – Set pressure that will be used along with overpressure to determine relief pressure.

OverP – Allowable overpressure typically 21% used to determine relief pressure.

Poperating – Operating pressure used to quantify initial density and initial relief temperature. Higher value results in higher density and lower initial relief temperature.

Toperating – Only required if Bubblepoint is false, otherwise calculated. Higher value results in lower density and higher initial relief temperature.

P3 – Constant back pressure when PSV is closed.

Ideal Gas for Relief Temperature – If yes, the ideal gas law is used to predict initial relief temperature, if no (typical) thermodynamics is used keeping density constant from operating to relief to determine relief temperature.

Use Thermodynamics - If false, additional property inputs are required.

ThermoPackage – Thermo package used for properties. VMG (Symmetry) packages or REFPROP 10.0 from NIST

StreamID – The vapor stream contained in the vessel. A new stream can be added here. See Stream Definition Form.

Kd – Manufacturer's certified vapor Kd or 0.975 for API STD 520 default.

Sizing – PSV sizing method: API 520 Vapor or Numerical Integration (recommended when Z <= 0.8).

OutPipeSizing – Outlet pressure drop method: Adiabatic, Omega Method or Numerical Integration.

Calculation Method:

The calculation method for external fire with vapor expansion is well established in API STD 521. The total surface area is then calculated based on the input dimensions and orientation of the vessel using standard geometric equations. The initial relief composition and temperature are quantified by placing the vapor

stream at the relief pressure and adjusting the temperature to achieve a density equal to the density at the operating conditions or the ideal gas law is used if that option is selected. Based on the operating and relief conditions, the following equation from API STD 521 is applied to determine the required mass relief rate.

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

q_{relief} is the required mass relief rate (lb/hr)

C_{12} is a constant = 0.1406

T_w is the maximum wall temperature (°R) of vessel material, typically 1,100 °F (1,560 °R) for carbon steel

T_1 is the gas absolute temperature (°R) at the upstream relieving pressure

M is the gas molecular weight

p_1 is the absolute relief pressure (psia)

Scenario Output Data:

The form fields for scenario-specific outputs are organized under the Scenario Output column. These are described below:

ExposedArea – Total surface area calculated using dimensions plus AdditionalArea

RequiredRateMass – Calculated required relief rate in lb/hr.

RequiredRateMM – Required rate in MMSCFD

RequiredRateAir – Required rate converted to scfh air

Flux2 – RequiredRateMass · RequiredArea * 144 / 3600

Scenario Calculation Results:

The form fields for overall scenario results are organized in the Scenario Calculation Results Section. These outputs are typical of most of the scenario calculations and are detailed under Typical Scenario Calculation Results.

QA/QC Benchmarks:

As the calculation of the surface area relies on simple geometric calculations and the required relief rate calculation is very straightforward as detailed in the calculation section, the primary benchmark for the external fire with vapor expansion is the quantification of the initial relief temperature. This calculation was benchmarked against a commercial simulation (Symmetry) for a typical residue gas filter. The initial relief temperatures were both found to be 267° F and the required relief rates were 3,615 lb/hr and 3,597 lb/hr in Pressio and based on the fluid properties from the simulator, respectively. Finally, the entire calculation was benchmarked against an internal RKR spreadsheet which determined an overall required relief rate of 3,686 lb/hr with similar intermediate results. The very minor deviations are attributable to rounding.

External Fire Vapor Expansion - API STD 521

External Fire F-3000

Equipment Data:

Equipment Tag:	**F-3000**	Type:	Pressure Vessel
Drawing:	PID-3000	MAWP:	1000 psig
Description:	Residue Gas Filter Separator	MAWT:	200 F

Scenario Description:

The Residue Gas Filter Separator is expected to be free of liqudis, therefore in the event of an external fire overpressure could occur due to expansion of the vapor. The required relief rate was based on the normal recovery residue gas compsition with operating conditions of 900 psig (PSHH-3000 setting) and 120 F. The relief pressure is 1210 psig.

Scenario Calculation Results:

Required Rate:	3615.4	lb/hr	Device Choke Pressure:	668.8	psig
Actual Capacity:	7178.3	lb/hr	Outlet Temperature:	226.2	F
Required Area:	0.055	in2	Outlet Mass Quality:	1.000	
Actual Area:	0.110	in2	Outlet Density:	0.036	lb/ft3
Relief Pressure:	1210.0	psig	Outlet Ideal Cp/Cv:	1.2	
Relief Temperature:	267.0	F	Outlet Viscosity:	0.013	cP
Relief MW:	17.77		Inlet Non-Recoverble dP:	6.4	psi
Relief Mass Quality:	1.000		Inlet dP % Set:	0.6	% Set
Relief Density:	2.94	lb/ft3	Built-Up Back Pressure:	42.2	psig
Relief SG:	0.613		Built-Up Back P % Set:	4.2	% Set
Relief Z:	0.95		Total Back Pressure:	42.2	psig
Relief Ideal Cp/Cv:	1.23		Total Back P % Set:	4.2	% Set
Relief Viscosity:	0.014	cP			

External Fire Vapor Expansion - API STD 521

External Fire F-3000

Equipment Data:

Equipment Tag:	**F-3000**	Type:	Pressure Vessel
Drawing:	PID-3000	MAWP:	1000 psig
Description:	Residue Gas Filter Separator	MAWT:	200 F

Scenario Input Data:

Length:	8	ft
Diameter:	30	in
Orientation:	Horizontal	
Head Type:	2:1 Ellipsoidal	
Additional Area:	0	ft2
Maximum Wall Temp.:	1100	F
Set Pressure:	1000	psig
Allowable Overpressure:	21.0%	
Constant Back Pressure:	0.0	psig
Operating Pressure:	900	psig
Operating Temperature:	120	F
Thermodynamics Enabled:	☑	
Initial Relief T per Ideal Gas:	☐	
Thermo Package:	Advanced_Peng-Robinson	
Relief Device Kd:	0.975	
Nozzle Sizing:	API 520 Vapor	
Outlet Pipe Sizing:	Adiabatic	

Scenario Output Data:

Exposed Area:	76	ft2
Required Mass Rate:	3615.4	lb/hr
Required Rate Std. Vol.:	1.85	MMSCFD
Required Air Rate:	71465.0	scfh air
Required Mass Flux:	2610.3	lb/sec/ft2

Notes:

External Fire Vapor Expansion - API STD 521

External Fire F-3000

Equipment Data:

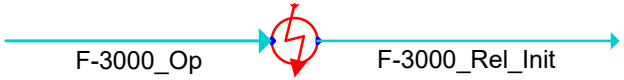
Equipment Tag:	**F-3000**	Type:	Pressure Vessel
Drawing:	PID-3000	MAWP:	1000 psig
Description:	Residue Gas Filter Separator	MAWT:	200 F

Relief Stream Composition:

Stream Description: Residue Gas

Component	Mole Fraction
carbon dioxide	0.0050
nitrogen	0.0010
methane	0.9300
ethane	0.0300
propane	0.0200
isobutane	0.0060
butane	0.0080
isopentane	
pentane	
hexane	
heptane	
octane	
nonane	
decane	
methanol	
water	

F-3000 Residue Gas Filter Fire Vapor Expansion



F-3000_Op	
T	*120.0 [F]
P	*900.00 [psig]
Mass Density	2.9430 [lb/ft3]

F-3000_Rel_Init	
T	*267.0 [F]
P	*1210.00 [psig]
Mass Density	2.9409 [lb/ft3]
MW	17.77
Ideal Gas Cp/Cv	1.23

Relief Rate = 0.1406*(17.77 x 1,224.7 psia)^.5 x (((76 ft2 * (1,560 R – 727 R)) ^ 1.25 / 727 F ^1.1506) = 3,597 lb/hr

External Fire Vapor Expansion Calculation
Critical PSV Flow Only

User-Entered Inputs		
P_{relief}	1210.0	psig
P_{atm}	14.7	psia
K_d	0.975	
$A_{exposed}$	76.0	ft^2
P_{op}	900.0	psig
T_{op}	120	F
T_w	1100	F
Thermo Inputs		
T_{relief}	268.0	F
Results		
C	340.5	
F'	0.026	
W_{req}	3585.8	lb/hr
A_{req}	0.055	in^2

	Vapor Operating	Vapor Relief Stream
Pressure (psig)	900.0	1210.0
Temperature (F)	120.0	268.0
Mass Density (lb/ft3)	2.943	2.936
MW	17.77	17.77
Z	0.886	0.947
Ideal Cp (Btu/lbmole/F)	9.52	10.52
Ideal Cp/Cv	1.264	1.233
Mole Fractions		
Carbon Dioxide	0.0050	0.0050
Nitrogen	0.0010	0.0010
Methane	0.9300	0.9300
Ethane	0.0300	0.0300
Propane	0.0200	0.0200
Isobutane	0.0060	0.0060
n-Butane	0.0080	0.0080