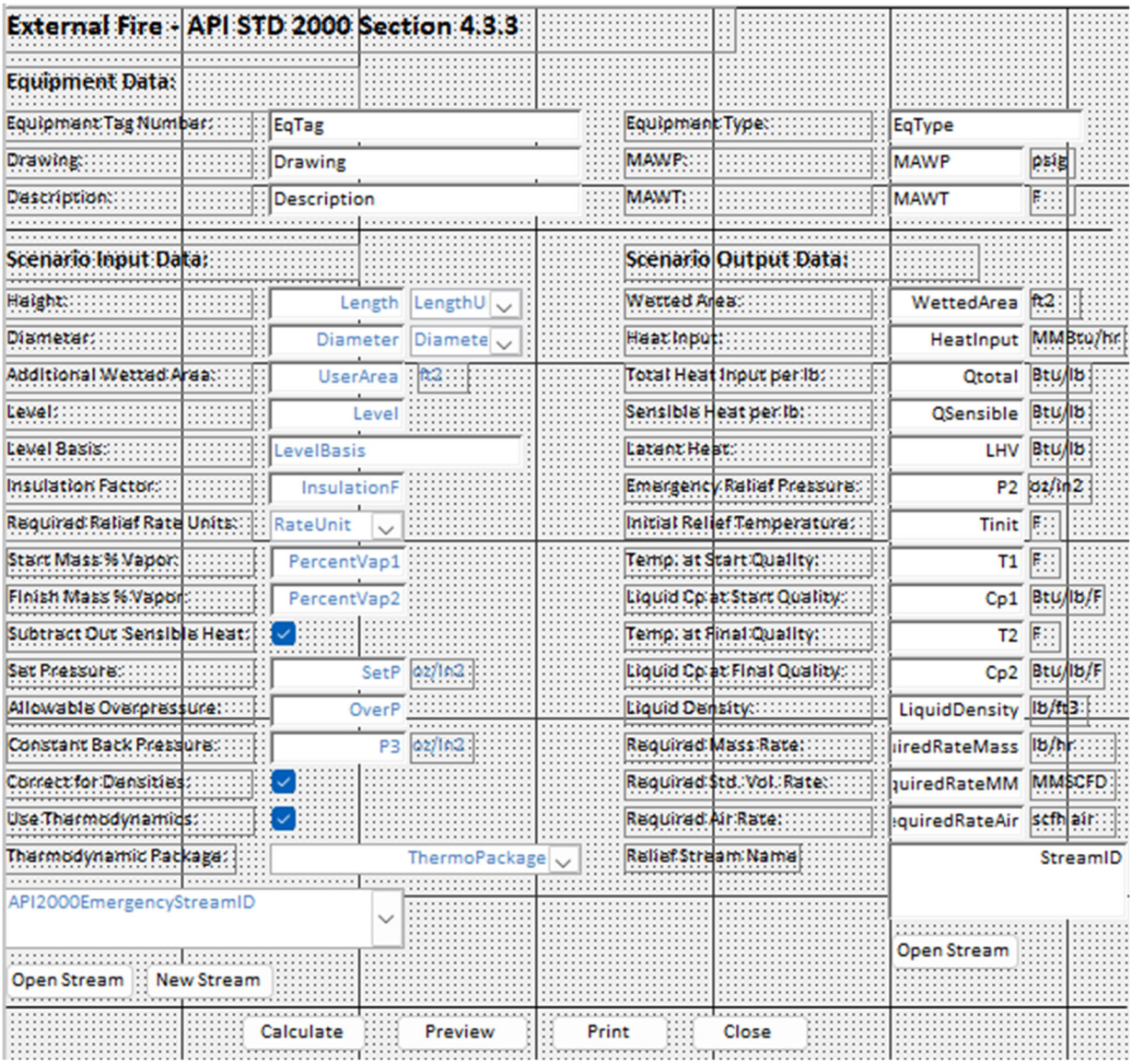
API STD 2000 External Fire Liquid Vaporization



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. These are described below:

Length – Tank floor to liquid level assumes vertical orientation.

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.

Level – Vessel liquid level for use in determining wetted area.

LevelBasis – Source for input liquid level such as LSHH, LSH, Upper LG Tap.

UserArea – Any wetted area beyond normal geometry calculation to be added such as piping.

InsulationF – Insulation factor used to reduce total heat input. 1.0 unless fireproof insulation is present then either 0.3 or calculated per API STD 521.

RateUnit – Units that the required relief rate will be reported back to the scenario sheet.

PercentVap1 –Starting mass % vapor for determined the latent heat.

PercentVap2 – Final mass % vapor for determined the latent heat. Must be higher than Start Mass %.

Subtract Out Sensible Heat – Typically yes and sensible heat will be removed from latent heat calculation.

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

OverP – Allowable overpressure which is dependent on tank design code.

P3 – Constant back pressure when vent is closed.

Correct for Densities – If yes, accounts for the relative densities of the liquid and vapor in rate calculation

UseThermo – If false, additional property inputs are required.

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

API2000EmergencyStreamID – The liquid stream to be vaporized determining latent heat and relief composition. A new stream can be added here. See Stream Definition Form.

Calculation Method:

The calculation method for external fire with vaporizing liquid is well established in API STD 2000. The first step in determining the required relief rate is calculation of the wetted area based on the input dimensions of the tank, standard geometric equations based on a vertical orientation and exclusion of the floor and/or roof. The heat input is subsequently calculated based on the wetted area using the following equations from API STD 2000:

Table 4 — Heat input, Q
(expressed in USC units)

Wetted surface area A_{TWS} ft^2	Design pressure psig	Heat input Q Btu/h
< 200	≤ 15	20 000A_{TWS}
≥ 200 and < 1 000	≤ 15	199 300 × ($A_{TWS}^{0,566}$)
≥ 1 000 and < 2 800	≤ 15	963 400 × ($A_{TWS}^{0,338}$)
≥ 2 800	> 1 and ≤ 15	21 000 × ($A_{TWS}^{0,82}$)
≥ 2 800	≤ 1	14 090 000

The second step is quantification of the latent heat by first determining the total heat required to increase the mass percent vaporized from PercentVap1 to PercentVap2 which is done by comparing the staring and ending enthalpies. The sensible heat is determined by using the average of Cp1 and Cp2 along with the temperature rise from T1 to T2. The heat used to calculate the latent heat is then easily determined based on the selection to subtract out the sensible heat (normal procedure) or not which yields Q in the following equation:

$$LHV = Q/(PercentVap1 - PercentVap2)$$

Once the LHV is known the required relief rate in mass terms is simply:

$$RequiredRateMass = HeatInput/LHV$$

The required mass rate can then be converted to scfh air (typically used for LP Vents) as follows:

$$q_{scfh\ air} = \frac{379.5\ scf/lbmole}{M_{air}}\ x\ \sqrt{\frac{M_{air}}{T_{air}}}\ x\ \sqrt{\frac{T_{act}}{M_{act}}}$$

Scenario Output Data:

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

WettedArea – Surface area calculated using level assuming vertical plus UserArea.

HeatInput – Calculated total heat input based on WettedArea per API STD 2000.

QTotal – Total heat required to vaporize from PercentVap1 to PercentVap2

QSensible – Amount of QTotal used to increase the fluid temperature.

LHV – Heat per lb vaporized with or without sensible heat excluded based on selection

P2 – Emergency relief pressure in oz/in2

Tinit – Temperature of fluid at initial relief of dewpoint temperature at relief pressure

T1 – Temperature at PercentVap1 which would equal Tinit if PercentVap1 = 0%

Cp1 – Mass heat capacity at T1 or PercentVap1

T2 - Temperature at PercentVap2

Cp2 – Mass heat capacity at T2 or PercentVap2

LiquidDensity – Liquid density at T1 or Percent Vap1

RequiredRateMass – Calculated required relief rate of actual relief fluid in lb/hr.

RequiredRateMM – Required rate of actual fluid in MMSCFD

RequiredRateAir – Required rate converted to scfh air

StreamID – Vapor relief stream at T2 or PercentVap2

QA/QC Benchmarks:

As the calculation of the wetted area relies on simple geometric calculations and the heat input calculation is very straightforward as detailed in the calculation section, the primary benchmark for the external fire scenario is the quantification of the latent heat and relief composition. These two calculations were benchmarked against a commercial simulation (Symmetry) for a typical gasoline product in a storage tank. The latent heats were within 1.2% (146.9 Btu/lb vs. 145.1 Btu/lb) which resulted in a similar difference in the required relief rates of 1.2% (56,851 lb/hr vs. 57,571 lb/hr).

External Fire - API STD 2000

T-6000 External Fire

Equipment Data:

Equipment Tag:	**T-6000**	Type:	API 12F Tank
Drawing:	PID-6000	MAWP:	1 psig
Description:	Gasoline Storage Tank	MAWT:	120 F

Scenario Description:

The 400 BBL storage tank contains gasoline that could vaporize in the event of an external fire potentially resulting in overpressure. The required relief rate was quantified in accordance with API STD 2000 using the normal gasoline product composition at the emergency relief pressure of 32 oz/in2. The liquid level was based on the 19' - 6" height of the liquid overflow or 97.5%..

Scenario Input Data:

Height:	20	ft
Diameter:	12	ft
Level Basis:	Liquid Overflow	
Additional Wetted Area:	0	ft2
Level:	98%	
Insulation Factor:	1	
Required Relief Rate Units:	scfh air	
Start Mass % Vapor:	0.00%	
Finish Mass % Vapor:	5.00%	
Subtract Out Sensible Heat:	☑	
Set Pressure:	16	oz/in2
Allowable Overpressure:	50.0%	
Constant Back Pressure:	0	oz/in2
Correct for Densities:	☐	
Use Thermodynamics:	☑	
Thermo Package:	Advanced_Peng-Robinson	

Scenario Output Data:

Wetted Area:	735.1	ft2
Heat Input:	8.35	MMBtu/hr
Latent Heat:	145.1	Btu/lb
Initial Relief Temperature:	117.2	F
Temp. at Start Quality:	117.2	F
Liquid Cp at Start Quality:	0.562	Btu/lb/F
Liquid Cp at Final Quality:	0.556	Btu/lb/F
Liquid Density:	39.207	lb/ft3
Required Mass Rate:	57570.8	lb/hr
Required Std. Vol. Rate:	7.17	MMSCFD
Required Air Rate:	501092.9	scfh air

External Fire - API STD 2000

T-6000 External Fire

Equipment Data:

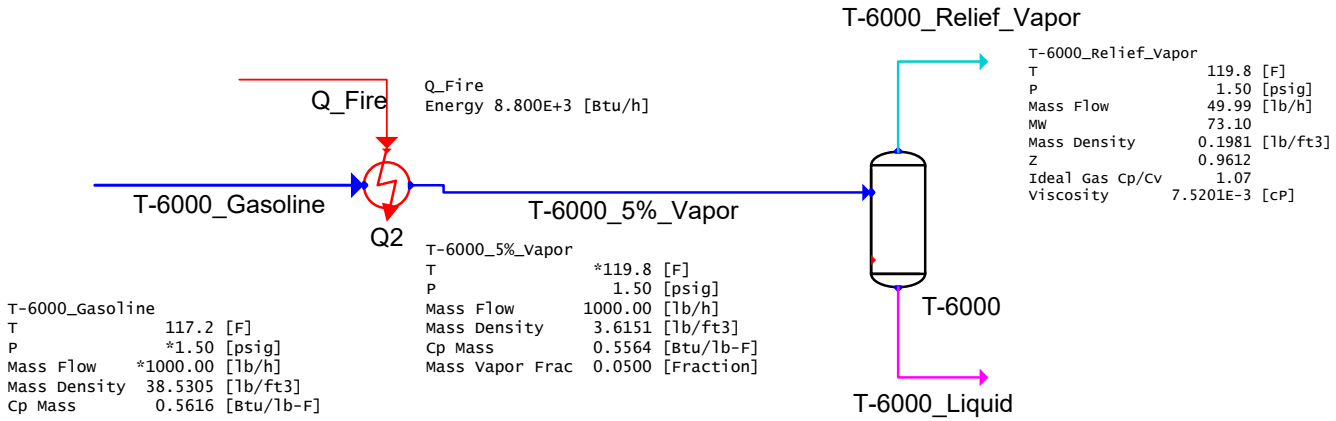
Equipment Tag:	**T-6000**	Type:	API 12F Tank
Drawing:	PID-6000	MAWP:	1 psig
Description:	Gasoline Storage Tank	MAWT:	120 F

Liquid Stream Description: **Gasoline Product**

Relief Stream Description: **T-6000 Fire Gasoline Vapor**

Component	Liquid Stream Mole Fraction	Relief Stream Mole Fraction
methane		0.0000
ethane		0.0000
propane		0.0000
butane	0.0450	0.1536
isobutane	0.0032	0.0141
pentane	0.1796	0.2450
isopentane	0.2317	0.3841
hexane	0.3603	0.1713
heptane	0.1802	0.0319
octane		0.0000
nonane		0.0000
decane		0.0000
carbon dioxide		0.0000
hydrogen sulfide		0.0000
methanol		0.0000
water		0.0000

T-6000 Fire Liquid Vaporization



LHV = (8800 Btu/hr – (1,000 lb/hr x (119.8 – 117.2) F x (0.562 +.556) / 2 Btu/lb/F)) / 50 lb/hr) = 146.9 Btu/lb
Heat Input = 199,300 x (735.1 ft2) ^ 0.566 = 8.35 MMBtu/hr
Required Mass Rate = 8,350,000 Btu/hr / 146.9 Btu/lb = 56,851 lb/hr
Rate SCFH Air = 379.5 Btu/scf / 29.0 lb/lbmole x 56,851 lb/hr x (29 lb/lbmole / 520 R)^.5 x (579.8 R/73.1 lb/lbmole) = 494,800 scfh air