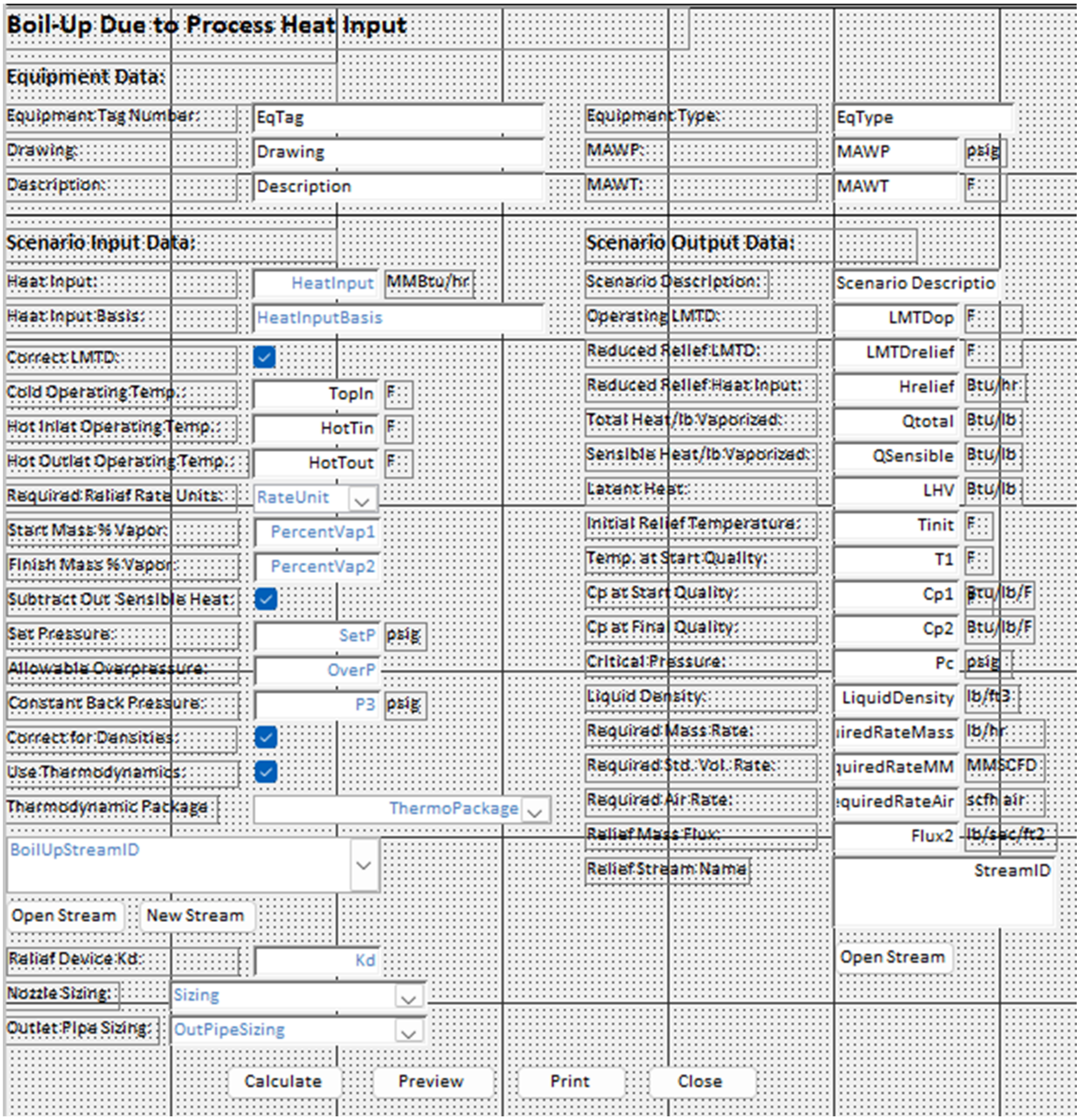
Boil-Up Due to Process Heat Input



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:

HeatInput – Maximum heat input during normal operation

HeatInputBasis – Basis for HeatInput such as design duty or 110% design duty

Correct LMTD – If yes, TopIn, HotIn and HotOut temperatures are used to determine a reduced LMTD and heat input at the relief pressure and temperature.

TopIn – Operating inlet temperature for cold side – only required for Correct LMTD

HotIn – Operating inlet temperature for hot side - only required for Correct LMTD

HotOut – Operating outlet temperature for hot side - only required for Correct LMTD

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 – 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 typically 21% used to determine relief pressure.

P3 – Constant back pressure when PSV 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

BoilUpStreamID – The liquid stream to be vaporized determining latent heat and relief composition. 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 heat input with vaporizing liquid (boil-up) is essentially identical to the external fire scenario with the exception of the method used to determine the heat input which is entered directly and can be corrected for the reduced LMTD at relief conditions, if desired. The heat input is generally the design duty or design duty plus some percentage over design. This operating heat input can be corrected for relief conditions using the operating and reduced LMTDs using the following formulae.

$$LMTD_{op} = \frac{[(HotTin - TopIn) - (HotTout - TopIn)]}{\log\left[\frac{(HotTin - TopIn)}{(HotTOut - TopIn)}\right]}$$

$$LMTD_{relief} = \frac{[(HotTin - T2) - (HotTout - T2)]}{\log\left[\frac{(HotTin - T2)}{(HotTOut - T2)}\right]}$$

$$Hrelief = HeatInput\ x\ \frac{LMTD_{relief}}{LMTD_{op}}$$

The latent heat is quantified by first determining the total heat required to increase the mass percent vaporized from PercentVap1 to PercentVap2 which is done by comparing the starting 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 or not yielding Q in the following equation:

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

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

$$RequiredRateMass = Hrelief/LHV$$

Scenario Output Data:

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

LMTDOp – Calculated LMTD based on cold side operating temperature

LMTDrelief – Calculated LMTD based on cold side relief temperature

Hrelief – Heat input at relief for use in required relief rate determination

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

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

Cp2 – Mass heat capacity at T2 or PercentVap2

Pc – Critical pressure reported to ensure relief pressure is below Pc

LiquidDensity – Liquid density at T1 or Percent Vap1

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

StreamID – Vapor relief stream at T2 or PercentVap2

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:

The calculations were benchmarked against a commercial simulator (Symmetry) for a Depropanizer Reboiler using the normal reboiler liquid composition. The latent heats were nearly identical (89.7 Btu/lb vs. 89.6 Btu/lb) which resulted in required relief rates within 1.5% (28,568 lb/hr vs. 29,000 lb/hr) for Pressio and Symmetry, respectively.

Boil-Up Due to Heat Input

Blocked with Continued Heat Input

Equipment Data:

Equipment Tag:	**E-6000**	Type:	Shell and Tube Exchanger
Drawing:	PID-6000	MAWP:	350 psig
Description:	Depropanizer Reboiler (Shell)	MAWT:	300 F

Scenario Description:

The Depropanizer Reboiler shell side contains hydrocarbon liquids that are vaporized by heat input from the hot oil on the tube side. In the event that the reboiler outlet is blocked overpressure could occur due to continued heat input. The required relief rate was based on the design duty of the reboiler corrected for the decreased LMTD associated with the higher shell side temperature at the relief pressure of 385 psig.

Scenario Calculation Results:

Required Rate:	28568.2	lb/hr	Device Choke Pressure:	192.5	psig
Actual Capacity:	79987	lb/hr	Outlet Temperature:	259.6	F
Required Area:	1.089	in2	Outlet Mass Quality:	1.000	
Actual Area:	3.043	in2	Outlet Density:	0.124	lb/ft3
Relief Pressure:	385.0	psig	Outlet Ideal Cp/Cv:	1.065	
Relief Temperature:	319.7	F	Outlet Viscosity:	0.010	cP
Relief MW:	63.93		Inlet Non-Recoverble dP:	3.4	psi
Relief Mass Quality:	1.000		Inlet dP % Set:	1.0	% Set
Relief Density:	5.23	lb/ft3	Built-Up Back Pressure:	60.2	psig
Relief SG:	2.204		Built-Up Back P % Set:	17.2	% Set
Relief Z:	0.58		Total Back Pressure:	60.2	psig
Relief Ideal Cp/Cv:	1.06		Total Back P % Set:	17.2	% Set
Relief Viscosity:	0.010	cP			

Boil-Up Due to Heat Input

Blocked with Continued Heat Input

OIL & GAS

Equipment Data:

Equipment Tag:	**E-6000**	Type:	Shell and Tube Exchanger
Drawing:	PID-6000	MAWP:	350 psig
Description:	Depropanizer Reboiler (Shell)	MAWT:	300 F

Scenario Input Data:

Heat Input:	5	MMBtu/hr
Heat Input Basis:	Design Duty	
Start Mass % Vapor:	0.00%	
Finish Mass % Vapor:	100.00%	
Remove Sensible Heat:	☐	
Correct for Densities:	☐	
Set Pressure:	350	psig
Allowable Overpressure:	10.0%	
Constant Back Pressure:	0	psig
Use Thermodynamics:	☑	
Thermo Package:	Advanced_Peng-Robinson	
Relief Device Kd:	0.627	
Nozzle Sizing:	API Numerical Integration Vapor	
Outlet Pipe Sizing:	Numerical Integration	
Notes:		

Scenario Output Data:

Total Heat/lb Vaporized:	89.7	Btu/lb
Sensible Heat/lb Vaporized:	0.0	Btu/lb
Latent Heat:	89.7	Btu/lb
Initial Relief Temperature:	290.3	F
Temp. at Start Quality:	290.3	F
Cp at Start Quality:	1.032	Btu/lb/F
Cp at Final Quality:	0.755	Btu/lb/F
Liquid Density:	25.39	lb/ft3
Required Mass Rate:	28568.2	lb/hr
Required Std. Vol. Rate:	4.07	MMSCFD
Required Air Rate:	308322.3	scfh air
Relief Mass Flux:	1049.3	lb/sec/ft2

Boil-Up Due to Heat Input

Blocked with Continued Heat Input

Equipment Data:

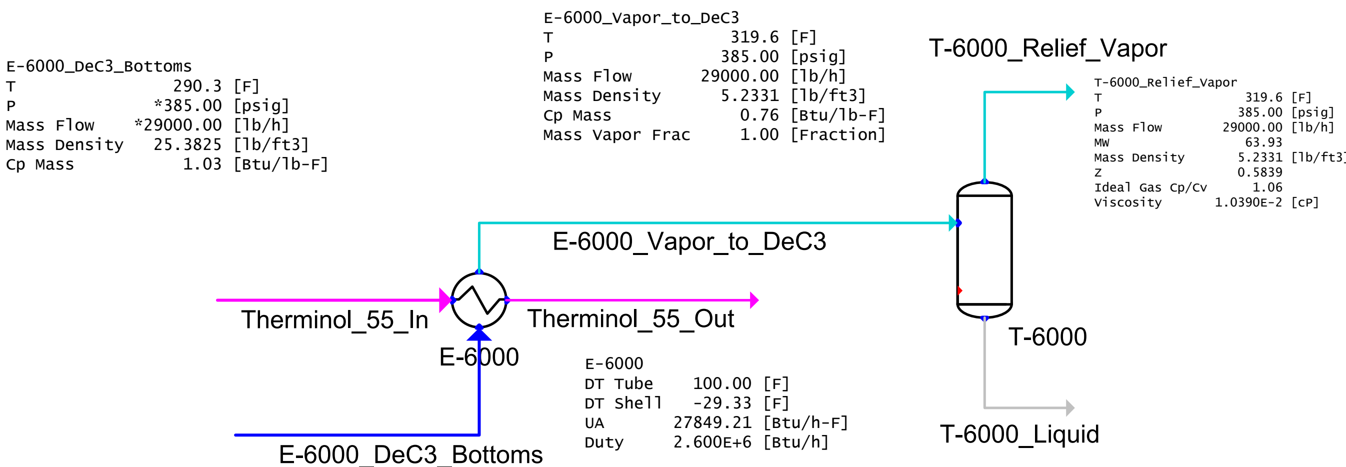
Equipment Tag:	**E-6000**	Type:	Shell and Tube Exchanger
Drawing:	PID-6000	MAWP:	350 psig
Description:	Depropanizer Reboiler (Shell)	MAWT:	300 F

Liquid Stream Description: **Depropanizer Reboiler Liquid**

Relief Stream Description: **V-6000 Blocked Vapor Relief**

Component	**Liquid Stream Mole Fraction**	**Relief Stream Mole Fraction**
nitrogen	0.0000	0.0000
methane	0.0000	0.0000
carbon dioxide	0.0000	0.0000
ethane	0.0000	0.0000
hydrogen sulfide	0.0000	0.0000
propane	0.0212	0.0212
isobutane	0.1963	0.1963
butane	0.5157	0.5157
isopentane	0.0704	0.0704
pentane	0.0880	0.0880
hexane	0.0694	0.0694
heptane	0.0262	0.0262
octane	0.0081	0.0081
nonane	0.0012	0.0012
decane	0.0035	0.0035
methanol		0.0000
water		0.0000

E-6000 Boil Up



LHV = 2.60 MMBtu/hr / 29,000 lb/hr = 89.6 Btu/lb