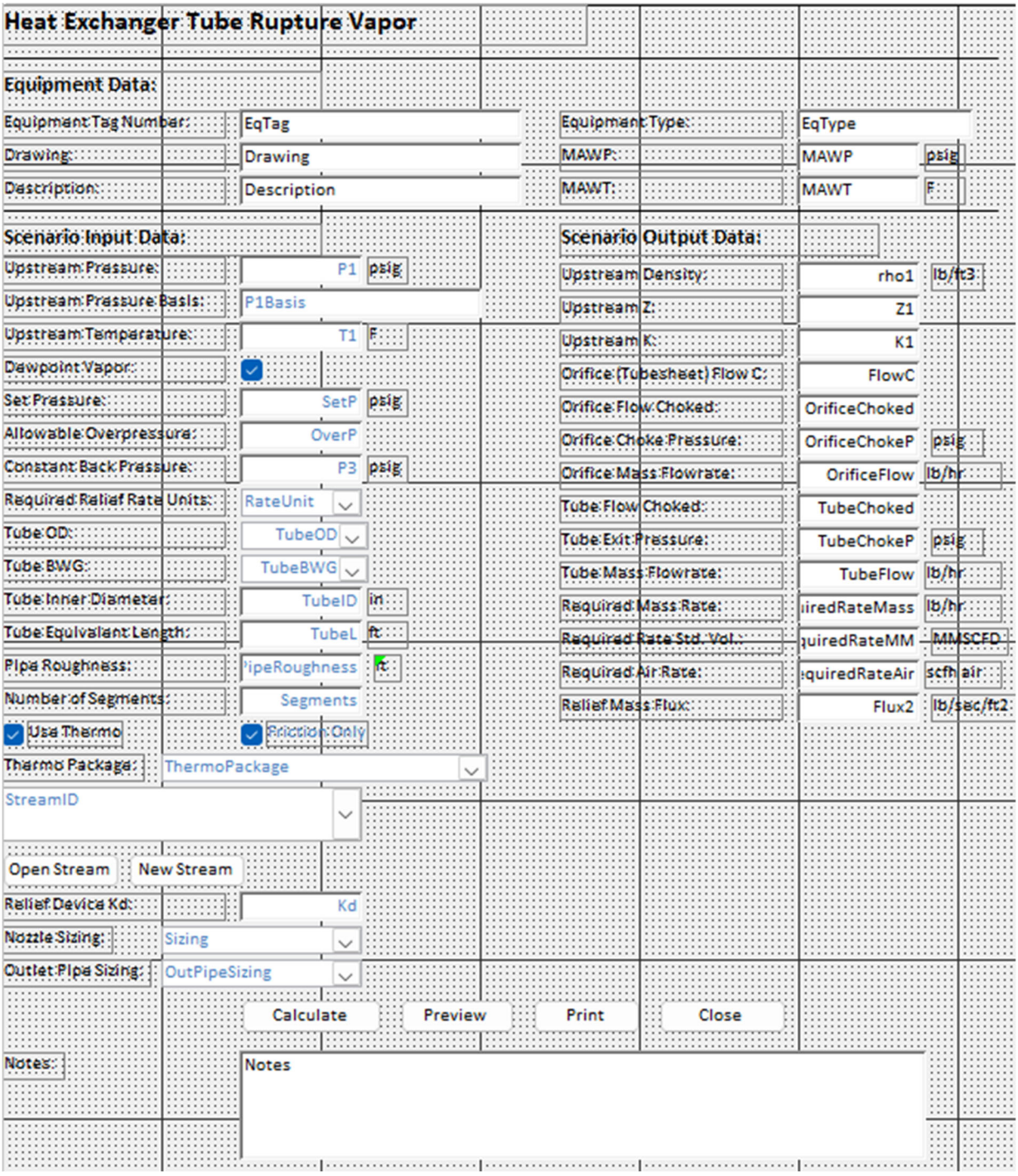
Tube Rupture – Vapor



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:

P1 – Pressure upstream of restriction orifice. From most to least conservative: MAWP, PSV Set, PSHH, Max Operating

P1Basis – Description for choice of P1. PSV-100 Set Pressure, PSHH Setpoint, etc.
T1 – Temperature at inlet to pipe for PT Flash Only. Calculated for PQ (Dewpoint) Flash.

Dewpoint – If true, a PQ Flash is performed with quality = 1.0. Otherwise superheated with PT Flash.

SetP – PSV set pressure used to determine relief pressure.

OverP – Allowable overpressure typically 10% used to determine relief pressure.

P3 – Constant back pressure when PSV is closed.

TubeOD – Tube outer diameter (used along with TubeBWG to get TubeID)

TubeBWG – Tube Birmingham Wire Gauge (used along with TubeOD to get TubeID)

TubeID - Tube inner diameter (calculated if TubeOD and TubeBWG entered, otherwise must be input)

TubeL - Tube equivalent length

PipeRoughness - Roughness used to quantify tube friction factor (default = 0.0018 in for carbon steel)

Segments – Number of segments to be analyzed. 10 segments with 20' tubes will be analyzed 2' at a time.

UseThermo – If false, additional property inputs are required.

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

StreamID – The stream to be used for properties. 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:

This form supports flow of a vapor through a tube rupture in a shell and tube heat exchanger. The tube break is assumed to occur at the tube sheet such that fluid will flow directly through the tubesheet which is treated as an orifice and through the tube which is quantified based on pipe flow. The orifice flow calculation is identical to the Vapor Orifice Flow calculation and the pipe flow calculation is identical to the Vapor Pipe Flow. Reference those individual forms for the detailed calculation method for each.

Scenario Output Data:

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

rho1 - Upstream density in lb/ft3 typically from thermo engine.

Z1 - Upstream compressibility typically from thermo engine.

K1 - Upstream ideal C_p/C_v typically from thermo engine.

FlowC – Orifice discharge coefficient corrected for the velocity of approach.

OrificeChoked – Applicable to flow through the tubesheet, Yes for critical flow, no for subcritical flow

OrificeChokeP – Applicable to flow through the tubesheet. Calculated choke pressure or downstream pressure if not choked

OrificeFlow – Calculated flow through the tubesheet

TubeChoked – Applicable to flow through the tube, Yes for critical flow, no for subcritical flow

TubeChokeP – Applicable to flow through the tube. Calculated choke pressure or downstream pressure if not choked

TubeFlow – Calculated flow through the tube

RequiredRateMass – Sum of OrificeFlow and TubeFlow 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 described under the Calculation Method Section, the tube rupture calculation is the sum of orifice flow and pipe flow both of which have been benchmarked individually. As such, the Tube Rupture Numerical Integration was benchmarked against these two individual sheets to ensure consistency. As the following reports show the two flows calculated by the Tube Rupture Numerical Integration method are essentially identical to the individual flows calculated by the Orifice Numerical Integration and Pipe Flow Numerical Integration forms.

Tube Rupture Vapor

HX-2000 Tube Rupture

Equipment Data:

Equipment Tag:	**V-1000**	Type:	Pressure Vessel
Drawing:	PID-1000	MAWP:	150 psig
Description:	Slug Catcher	MAWT:	250 F

Scenario Description:

The MAWP of the high pressure side of HX-2000 is 350 psig, therefore a tube rupture could result in overpressure. The required relief rate was based on the residue gas composition at 800 psig and 120 F. The tubes were selected as 1" BWG 24 to closely match 1" Sch 80 from the pipe flow benchmark case.

Scenario Calculation Results:

Required Rate:	38,877.5	lb/hr	Device Choke Pressure:	83.6	psig
Actual Capacity:	19,755.4	lb/hr	Outlet Temperature:	80.3	F
Required Area:	3.632	in2	Outlet Mass Quality:	1.000	
Actual Area:	1.838	in2	Outlet Density:	0.043	lb/ft3
Relief Pressure:	165.0	psig	Outlet Ideal Cp/Cv:	1.296	
Relief Temperature:	89.4	F	Outlet Viscosity:	0.011	cP
Relief MW:	16.74		Inlet Non-Recoverble dP:	1.4	psi
Relief Mass Quality:	1.000		Inlet dP % Set:	1.0	% Set
Relief Density:	0.522	lb/ft3	Built-Up Back Pressure:	11.0	psig
Relief SG:	0.577		Built-Up Back P % Set:	7.4	% Set
Relief Z:	0.979		Total Back Pressure:	11.0	psig
Relief Ideal Cp/Cv:	1.293		Total Back P % Set:	7.4	% Set
Relief Viscosity:	0.011	cP	Reaction Force:	257	lbf

Tube Rupture Vapor

HX-2000 Tube Rupture

Equipment Data:

Equipment Tag:	**V-1000**	Type:	Pressure Vessel
Drawing:	PID-1000	MAWP:	150 psig
Description:	Slug Catcher	MAWT:	250 F

Scenario Input Data:

Upstream Pressure:	800	psig
Upstream Pressure Basis:	MAWP	
Upstream Temperature:	120	F
Dewpoint Vapor:	☐	
Set Pressure:	150	psig
Allowable Overpressure:	10.0%	
Constant Back Pressure:	0	psig
Required Relief Rate Units:	lb/hr	
Tube Inner Diameter:	0.954	in
Tube Equivalent Length:	20	ft
Pipe Roughness:	0.0018	ft
Use Thermo	☑	Friction Only ☐
Thermo Package:	REFPROP 10.0	
Relief Device Kd:	0.975	
Nozzle Sizing:	API 520 Vapor	
Outlet Pipe Sizing:	Isothermal	

Scenario Output Data:

Upstream Density:	2.364	lb/ft3
Upstream Z:	0.927	
Upstream K:	1.286	
Orifice (Tubesheet) Flow C:	0.6	
Orifice Flow Choked:	Yes	
Orifice Choke Pressure:	432	psig
Orifice Mass Flowrate:	21298.4	lb/hr
Tube Flow Choked:	Yes	
Tube Exit Pressure:	221.2	psig
Tube Mass Flowrate:	17579.1	lb/hr
Required Mass Rate:	38877.5	lb/hr
Required Rate Std. Vol.:	21.20	MMSCFD
Required Air Rate:	688297.5	scfh air
Relief Mass Flux:	428.2	lb/sec/ft2

Notes: Current relief valve is undersized for the tube rupture scenario.

Tube Rupture Vapor

HX-2000 Tube Rupture

Equipment Data:

Equipment Tag:	**V-1000**	Type:	Pressure Vessel
Drawing:	PID-1000	MAWP:	150 psig
Description:	Slug Catcher	MAWT:	250 F

Relief Stream Composition:

Stream Description: Residue Gas

Component	Mole Fraction
methane	0.9577
ethane	0.0320
propane	0.0008
butane	
isobutane	
pentane	
isopentane	
hexane	
heptane	
octane	
nonane	
decane	
carbon dioxide	0.0070
nitrogen	0.0025
methanol	
water	

Pipe Flow Vapor

1" Drain Valve Open

Equipment Data:

Equipment Tag:	**V-1000**	Type:	Pressure Vessel
Drawing:	PID-1000	MAWP:	150 psig
Description:	Slug Catcher	MAWT:	250 F

Scenario Description:

TThe maximum upstream pressure is 800 psig as dictated by the set point of PSHH-1000. As such, a failure open of PCV-1000 could result in overpressure and the required relief rate was based on the recovery residue gas compostion at 800 psig and 120 F upstream of control valve with the relief pressure of 165 psig downstream. Flow coefficients were based on a 1" Fisher D4 with 1/2" m-form trim and the control valve is installed in a 2" line.

Scenario Calculation Results:

Required Rate:	17,836.4	lb/hr	Device Choke Pressure:	98.5	psig
Actual Capacity:	19,675.0	lb/hr	Outlet Temperature:	75.9	F
Required Area:	1.66	in2	Outlet Mass Quality:	1.000	
Actual Area:	1.838	in2	Outlet Density:	0.043	lb/ft3
Relief Pressure:	165.0	psig	Outlet Ideal Cp/Cv:	1.288	
Relief Temperature:	86.2	F	Outlet Viscosity:	0.011	cP
Relief MW:	16.74		Inlet Non-Recoverble dP:	1.4	psi
Relief Mass Quality:	1.000		Inlet dP % Set:	1.0	% Set
Relief Density:	0.528	lb/ft3	Built-Up Back Pressure:	11.2	psig
Relief SG:	0.577		Built-Up Back P % Set:	7.5	% Set
Relief Z:	0.973		Total Back Pressure:	11.2	psig
Relief Ideal Cp/Cv:	1.286		Total Back P % Set:	7.5	% Set
Relief Viscosity:	0.011	cP	Reaction Force:	259	lbf

Pipe Flow Vapor

1" Drain Valve Open

Equipment Data:

Equipment Tag:	**V-1000**	Type:	Pressure Vessel
Drawing:	PID-1000	MAWP:	150 psig
Description:	Slug Catcher	MAWT:	250 F

Input Data:

Upstream Pressure:	800	psig
Upstream Pressure Basis:	MAWP	
Upstream Temperature:	120	F
Dewpoint Vapor:	☐	
Set Pressure:	150	psig
Allowable Overpressure:	10.00%	
Constant Back Pressure:	0	psig
Required Relief Rate Units:	lb/hr	
Friction Losses Only:	☐	
Pipe NPS:	1"	
Pipe Schedule:	80	
Pipe Inner Diameter:	0.957	in
Pipe Equivalent Length:	20	ft
Pipe Roughness:	0.0018	ft
Use Thermo	☑	
Thermo Package:	Advanced_Peng-Robinson	
Relief Device Kd:	0.975	
Nozzle Sizing:	API 520 Vapor	
Outlet Pipe Sizing:	Isothermal	

Output Data:

Upstream Density:	2.404	lb/ft3
Upstream Z:	0.912	
Upstream Ideal Cp/Cv:	1.279	
Moody Friction Factor:	0.0231	ft
Choked:	Yes	
Exit Pressure:	222.5	
Required Mass Rate:	17,836.4	psig
Required Rate Std Vol:	9.7	lb/hr
Required Air Rate:	314,853.7	MMSCFD
Relief Mass Flux:	429.8	scfh air
		lb/sec/ft2

Notes:

Pipe Flow Vapor

1" Drain Valve Open

Equipment Data:

Equipment Tag:	**V-1000**	Type:	Pressure Vessel
Drawing:	PID-1000	MAWP:	150 psig
Description:	Slug Catcher	MAWT:	250 F

Relief Stream Composition:

Stream Description: Residue Gas

Component	Mole Fraction
methane	0.9577
ethane	0.0320
propane	0.0008
butane	
isobutane	
pentane	
isopentane	
hexane	
heptane	
octane	
nonane	
decane	
carbon dioxide	0.0070
nitrogen	0.0025
methanol	
water	
	0.0070
	0.0025

Vapor Restriction Orifice

HX Tube Rupture RO

Equipment Data:

Equipment Tag:	**V-1000**	Type:	Pressure Vessel
Drawing:	PID-1000	MAWP:	150 psig
Description:	Slug Catcher	MAWT:	250 F

Scenario Description:

This calculation is the flow through the tubesheet, which is based on orifice flow, for comparison to the HX-2000 tube rupture case.

Scenario Results Summary:

Required Rate:	21,424	lb/hr	Device Choke Pressure:	83.8	psig
Actual Capacity:	19,755	lb/hr	Outlet Temperature:	75.9	F
Required Area:	1.993	in2	Outlet Mass Quality:	1.000	
Actual Area:	1.838	in2	Outlet Density:	0.043	lb/ft3
Relief Pressure:	165.0	psig	Outlet Ideal Cp/Cv:	1.288	
Relief Temperature:	86.2	F	Outlet Viscosity:	0.011	cP
Relief MW:	16.74		Inlet Non-Recoverable dP:	1.4	psi
Relief Mass Quality:	1.000		Inlet dP % Set:	1.0	% Set
Relief Density:	0.528	lb/ft3	Built-Up Back Pressure:	11.0	psig
Relief SG:	0.577		Built-Up Back P % Set:	7.4	% Set
Relief Z:	0.973		Total Back Pressure:	11.0	psig
Relief Ideal Cp/Cv:	1.286		Total Back P % Set:	7.4	% Set
Relief Viscosity:	0.011	cP	Reaction Force:	257	lbf

Atmospheric Dispersion Screening (Constant Back Pressure = 0 and Hydrocarbons Only):

				Actual	Reseat	
Tail Pipe Exit Diameter:		in	Exit RE:			
Reset % Capacity:	0.0	%	Exit Velocity:			fps
Exit Minimum RE:			Exit/Wind Velocity:	0.0	0.0	
Horizontal Distance (x):	0	ft	Minimum Exit Velocity:	0.0	0.0	fps
Sonic Velocity:		fps	Horizontal Distance (x):			ft
Exit Quality Acceptable:	☐					
Lighter than Air:	☐					
Flammable::	☐					
Toxic:	☐					
Dispersion Screening Pass:						

Vapor Restriction Orifice

HX Tube Rupture RO

Equipment Data:

Equipment Tag:	**V-1000**	Type:	Pressure Vessel
Drawing:	PID-1000	MAWP:	150 psig
Description:	Slug Catcher	MAWT:	250 F

Scenario Input Data:

RO Tag Number:	HX-2000 Tubesheet	
Gas Type:	Residue Gas	
Upstream Pressure:	800	psig
Upstream Pressure Basis:	MAWP	
Upstream Temperature:	120	F
Dewpoint Vapor:	☐	
Set Pressure:	150	psig
Allowable Overpressure:	10.0%	
Constant Back Pressure:	0.0	psig
Pipe Inner Diameter:	10.02	in
Orifice Inner Diameter:	0.954	in
Thermodynamics Enabled:	☑	
Thermo Package:	Advanced_Peng-Robinson	
Relief Device Kd:	0.975	
Nozzle Sizing:	API 520 Vapor	
Outlet Pipe Sizing:	Adiabatic	

Scenario Output Data:

Beta:	0.095	
Orifice Flow C:	0.6	
Discharge Cd:	0.6	
Upstream Z:	0.912	
Upstream Density:	2.404	lb/ft3
Choked:	Yes	
Choke Pressure:	433	psig
Mach Number:	1	
Required Mass Rate.:	21423.6	lb/hr
Required Rate Std Vol:	11.7	MMSCFD
Required Air Rate:	378176.8	scfh air
Required Mass Flux:	429.9	lb/sec/ft2

Notes:

Vapor Restriction Orifice

HX Tube Rupture RO

Equipment Data:

Equipment Tag:	**V-1000**	Type:	Pressure Vessel
Drawing:	PID-1000	MAWP:	150 psig
Description:	Slug Catcher	MAWT:	250 F

Relief Stream Composition:

Stream Description: Residue Gas

Component	Mole Fraction
methane	0.9577
ethane	0.0320
propane	0.0008
butane	
isobutane	
pentane	
isopentane	
hexane	
heptane	
octane	
nonane	
decane	
carbon dioxide	0.0070
nitrogen	0.0025
methanol	
water	