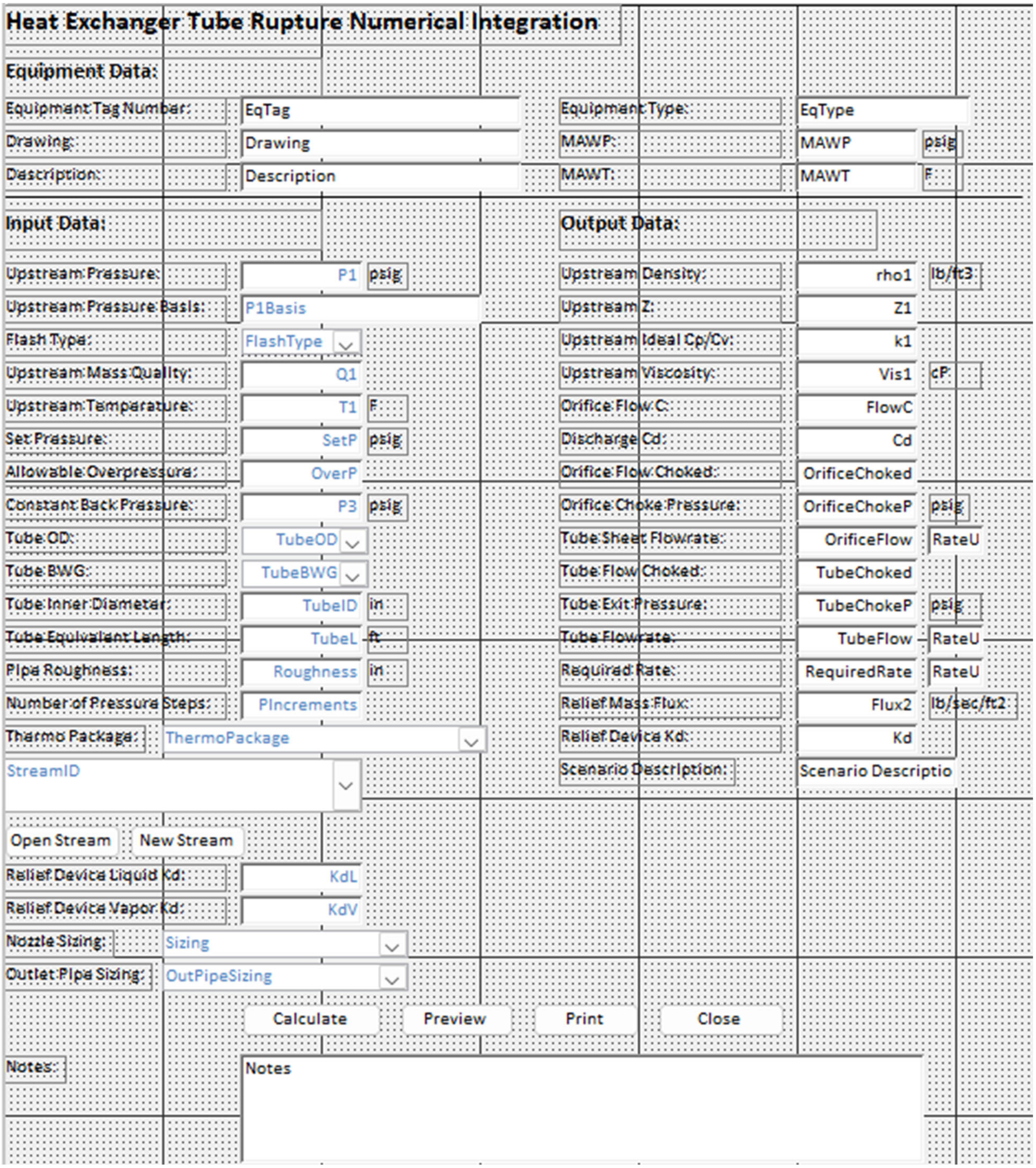
Tube Rupture – Numerical Integration



Heat Exchanger Tube Rupture Numerical Integration

Equipment Data:

Equipment Tag Number:	EqTag	Equipment Type:	EqType
Drawing:	Drawing	MAWP:	MAWP psig
Description:	Description	MAWT:	MAWT F

Input Data:		Output Data:	
Upstream Pressure:	P1 psig	Upstream Density:	rho1 lb/ft3
Upstream Pressure Basis:	P1Basis	Upstream Z:	Z1
Flash Type:	FlashType	Upstream Ideal Cp/Cv:	k1
Upstream Mass Quality:	Q1	Upstream Viscosity:	Vis1 cP
Upstream Temperature:	T1 F	Orifice Flow C:	FlowC
Set Pressure:	SetP psig	Discharge Cd:	Cd
Allowable Overpressure:	OverP	Orifice Flow Choked:	OrificeChoked
Constant Back Pressure:	P3 psig	Orifice Choke Pressure:	OrificeChokeP psig
Tube OD:	TubeOD	Tube Sheet Flowrate:	OrificeFlow RateU
Tube BWG:	TubeBWG	Tube Flow Choked:	TubeChoked
Tube Inner Diameter:	TubeID in	Tube Exit Pressure:	TubeChokeP psig
Tube Equivalent Length:	TubeL ft	Tube Flowrate:	TubeFlow RateU
Pipe Roughness:	Roughness in	Required Rate:	RequiredRate RateU
Number of Pressure Steps:	PIncrements	Relief Mass Flux:	Flux2 lb/sec/ft2
Thermo Package:	ThermoPackage	Relief Device Kd:	Kd
StreamID		Scenario Description:	Scenario Descriptio

Open Stream | New Stream

Relief Device Liquid Kd:	KdL
Relief Device Vapor Kd:	KdV
Nozzle Sizing:	Sizing
Outlet Pipe Sizing:	OutPipeSizing

Calculate | Preview | Print | Close

Notes: Notes

Note: Thermodynamics are required for this form.

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.

Flash Type – PT or PQ flash.

Q1 – Quality at inlet to pipe for PQ Flash Only. Calculated for PT Flash.

T1 – Temperature at inlet to pipe for PT Flash Only. Calculated for PQ 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

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

Pincrements – Number of pressure increments to be analyzed. (P1 - P2) / Pincrements = Pressure Step

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.

KdL – Manufacturer's certified liquid Kd or 0.65 for API STD 520 default.

KdV – 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 liquid, vapor or two phase flow 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 Orifice Flow Numerical Integration calculation and the pipe flow calculation is identical to the Pipe Flow Numerical Integration calculation. 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.

Vis1 - Upstream viscosity in cP from thermo engine

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

Cd - Orifice discharge coefficient defaulted to 0.62.

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

RequiredRate – Sum of OrificeFlow and TubeFlow.

Flux2 – RequiredRateMass · RequiredArea * 144 / 3600

Kd – Overall relief valve Kd based on volumetric average of liquid and vapor values if two phase

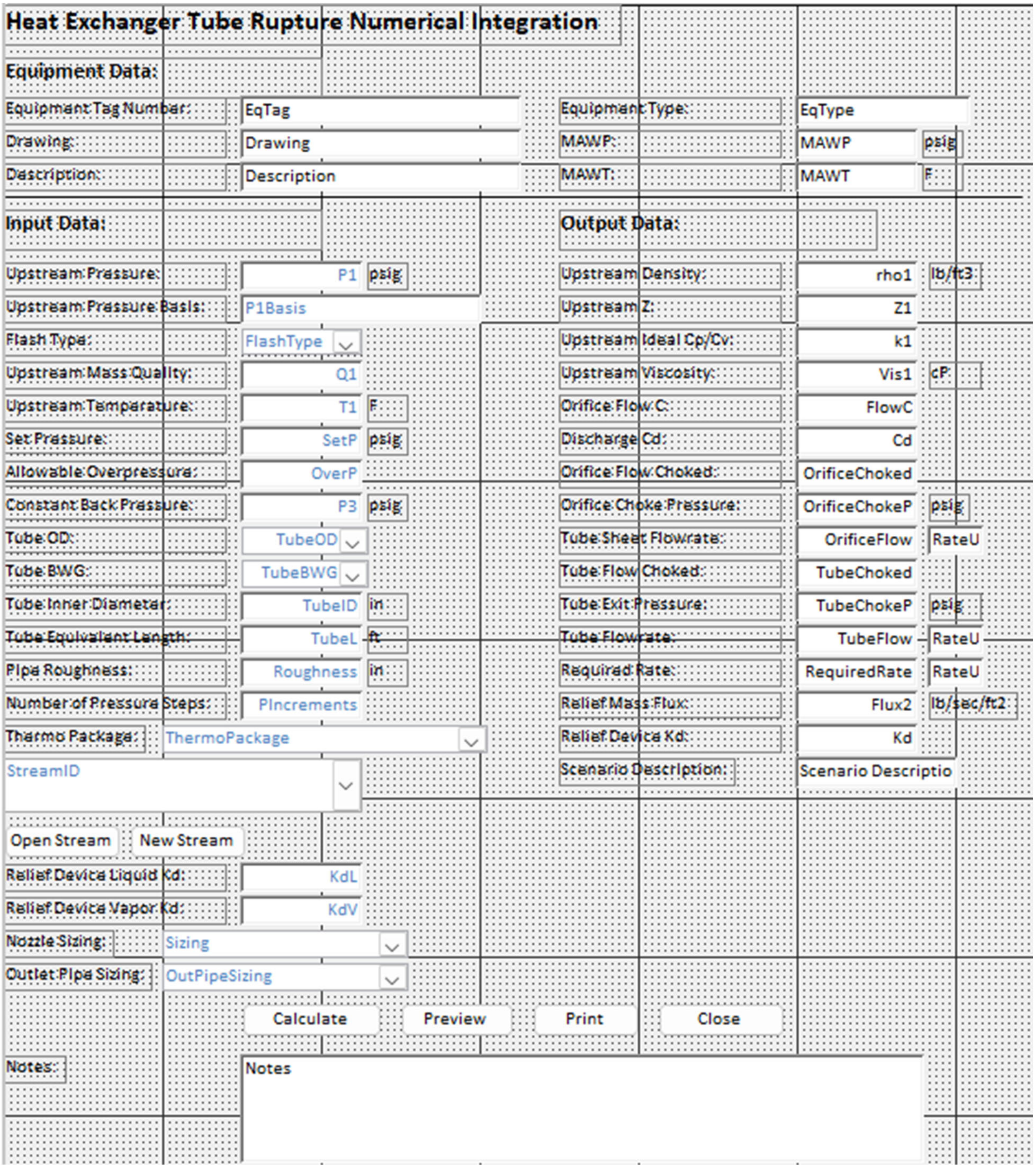
Scenario Calculation Results:

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 – Numerical Integration



Note: Thermodynamics are required for this form.

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Input Data:

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Q1 – Quality at inlet to pipe for PQ Flash Only. Calculated for PT Flash.

T1 – Temperature at inlet to pipe for PT Flash Only. Calculated for PQ Flash.

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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

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

Pincrements – Number of pressure increments to be analyzed. (P1 - P2) / Pincrements = Pressure Step

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.

KdL – Manufacturer's certified liquid Kd or 0.65 for API STD 520 default.

KdV – 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 liquid, vapor or two phase flow 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 Orifice Flow Numerical Integration calculation and the pipe flow calculation is identical to the Pipe Flow Numerical Integration calculation. Reference those individual forms for the detailed calculation method for each.

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Vis1 - Upstream viscosity in cP from thermo engine

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

Cd - Orifice discharge coefficient defaulted to 0.62.

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

RequiredRate – Sum of OrificeFlow and TubeFlow.

Flux2 – RequiredRateMass · RequiredArea * 144 / 3600

Kd – Overall relief valve Kd based on volumetric average of liquid and vapor values if two phase

Scenario Calculation Results:

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Heat Exchanger Tube Rupture - Numerical Integration

HX-1000 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-1000 is 350 psig, therefore a tube rupture could result in overpressure. The required relief rate was based on the recovery NGL composition at 350 psig and the associated bubblepoint temperature. The tubes were selected as 1" BWG 24 to closely match 1" Sch 80 from the pipe flow benchmark case.

Scenario Results Summary:

Required Rate:	58954.6	lb/hr	Device Choke Pressure:	82.5	psig
Actual Capacity:	37083.4	lb/hr	Outlet Temperature:	-64.6	F
Required Area:	2.245	in2	Outlet Mass Quality:	0.501	
Actual Area:	1.838	in2	Outlet Density:	0.243	lb/ft3
Relief Pressure:	165.0	psig	Outlet Ideal Cp/Cv:		
Relief Temperature:	44.2	F	Outlet Viscosity:	0.046	cP
Relief Mass Quality:	0.216		Inlet Non-Recoverble dP:	0.5	psi
Relief Density:	5.42	lb/ft3	Inlet dP % Set:	0.3	% Set
Relief MW:	41.57		Built-Up Back Pressure:	6.1	psig
Relief Viscosity:	0.061	cP	Built-Up Back P % Set:	4.1	% Set
			Total Back Pressure:	6.1	psig
			Total Back P % Set:	4.1	% Set
			Reaction Force:	257	lbf

Heat Exchanger Tube Rupture - Numerical Integration

HX-1000 Tube Rupture

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:	350	psig
Upstream Pressure Basis:	MAWP	
Flash Type:	PQ	
Upstream Mass Quality:	0.000	
Upstream Temperature:	90.0	F
Set Pressure:	150	psig
Allowable Overpressure:	10.00%	
Constant Back Pressure:	0	psig
Tube Inner Diameter:	0.954	in
Tube Equivalent Length:	20	ft
Pipe Roughness:	0.0018	in
Number of Increments:	10	
Relief Device Liquid Kd:	0.650	
Relief Device Vapor Kd:	0.975	
Nozzle Sizing:	Numerical Integration	
Outlet Pipe Sizing:	Omega Method	

Output Data:

Upstream Density:	28.92	lb/ft3
Orifice Flow C:	0.620	
Discharge Cd:	0.620	
Orifice Flow Choked:	Yes	
Orifice Choke Pressure:	239	psig
Tube Sheet Flowrate:	30293.1	lb/hr
Tube Flow Choked:	No	
Tube Exit Pressure:	165	psig
Tube Flowrate:	28661.5	lb/hr
Required Rate:	58954.6	lb/hr
Relief Mass Flux:	1050.4	lb/sec/ft2
Relief Device Kd:	0.940	

Notes:

Heat Exchanger Tube Rupture - Numerical Integration

HX-1000 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: **Recovery NGL**

Component	Mole Fraction
nitrogen	0.0000
methane	0.0036
carbon dioxide	0.0073
ethane	0.4896
hydrogen sulfide	0.0000
propane	0.3102
isobutane	0.0502
butane	0.0666
isopentane	0.0193
pentane	0.0120
hexane	0.0275
heptane	0.0137
octane	
nonane	
decane	
methanol	
water	

Pipe Flow Numerical Integration

Equipment Data:

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

Scenario Description:

The maximum pressure upstream of the 1" ball valve drain is 350 psig as dictated by the MAWP of the NGL Tank. As such, inadvertent opening of this valve could result in overpressure. The required relief rate was based on the recovery NGL composition at 350 psig and the associated bubblepoint temperature. As the drain valve is a ball valve, the relief requirement was based on pipe flow through the 1" Sch 80 drain line that has an equivalent length of 20 ft.

Scenario Results Summary:

Required Rate:	28830.6	lb/hr	Device Choke Pressure:	82.5	psig
Actual Capacity:	48378.7	lb/hr	Outlet Temperature:	-64.5	F
Required Area:	1.098	in2	Outlet Mass Quality:	0.502	
Actual Area:	1.838	in2	Outlet Density:	0.243	lb/ft3
Relief Pressure:	165.0	psig	Outlet Ideal Cp/Cv:		
Relief Temperature:	44.3	F	Outlet Viscosity:	0.046	cP
Relief Mass Quality:	0.217		Inlet Non-Recoverble dP:	0.8	psi
Relief Density:	5.41	lb/ft3	Inlet dP % Set:	0.6	% Set
Relief MW:	41.57		Built-Up Back Pressure:	12.2	psig
Relief Viscosity:	0.061	cP	Built-Up Back P % Set:	8.1	% Set
			Total Back Pressure:	12.2	psig
			Total Back P % Set:	8.1	% Set
			Reaction Force:	257	lbf

Pipe Flow Numerical Integration

OIL & GAS

Equipment Data:

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

Scenario Calculations:

Input Data:

Upstream Pressure:	350	psig
Upstream Pressure Basis:	MAWP	
Flash Type:	PT	
Upstream Mass Quality:	0.001	
Upstream Temperature:	90.0	F
Set Pressure:	150	psig
Allowable Overpressure:	10.00%	
Constant Back Pressure:	0	psig
Pipe Nominal Pipe Size:	1"	
Pipe Nominal Pipe Schedule:	80	
Pipe Inner Diameter:	0.957	in
Pipe Equiv. Length:	20	ft
Pipe Roughness:	0.0018	in
Number of Increments:	10	
Relief Device Liquid Kd:	0.650	
Relief Device Vapor Kd:	0.975	
Thermo Package:	Advanced_Peng-Robinson	
Nozzle Sizing:	API Numerical Integration	
Outlet Pipe Sizing:	Omega Method	

Output Data:

Upstream Density:	28.74	lb/ft3
Upstream Z:	0.000	
Upstream Ideal Cp/Cv:	0.000	
Upstream Viscosity:	0.065	cP
Choked:	No	
Exit Pressure:	165	psig
Relief Device Kd:	0.940	
Relief Mass Flux:	1050.3	lb/sec/ft2
Fanning Friction Factor:	0.006	

Notes:

Pipe Flow Numerical Integration

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: Recovery NGL

Component	**Mole Fraction**
nitrogen	0.0000
methane	0.0036
carbon dioxide	0.0073
ethane	0.4896
hydrogen sulfide	0.0000
propane	0.3102
isobutane	0.0502
butane	0.0666
isopentane	0.0193
pentane	0.0120
hexane	0.0275
heptane	0.0137
octane	
nonane	
decane	
methanol	
water	

Orifice Flow - Numerical Integration

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-1000 tube rupture case.

Scenario Results Summary:

Required Rate:	30293.1	lb/hr	Device Choke Pressure:	82.5	psig
Actual Capacity:	48460.9	lb/hr	Outlet Temperature:	-64.6	F
Required Area:	1.154	in2	Outlet Mass Quality:	0.501	
Actual Area:	1.838	in2	Outlet Density:	0.243	lb/ft3
Relief Pressure:	165.0	psig	Outlet Ideal Cp/Cv:		
Relief Temperature:	44.2	F	Outlet Viscosity:	0.046	cP
Relief Mass Quality:	0.216		Inlet Non-Recoverble dP:	0.8	psi
Relief Density:	5.42	lb/ft3	Inlet dP % Set:	0.6	% Set
Relief MW:	41.57		Built-Up Back Pressure:	12.2	psig
Relief Viscosity:	0.061	cP	Built-Up Back P % Set:	8.1	% Set
			Total Back Pressure:	12.2	psig
			Total Back P % Set:	8.1	% Set
			Reaction Force:	257	lbf

Orifice Flow - Numerical Integration

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

Input Data:

RO Tag:	HX-1000 Tube Sheet	
Gas Type:	NGL	
Upstream Pressure:	350	psig
Upstream Pressure Basis:	MAWP	
Flash Type:	PQ	
Upstream Mass Quality:	0.000	
Upstream Temperature:	90.0	F
Set Pressure:	150	psig
Allowable Overpressure:	10.00%	
Constant Back Pressure:	0	psig
Pressure Increment:	10	
Pipe ID:	10	in
Orifice ID:	0.954	in
Relief Device Liquid Kd:	0.650	
Relief Device Vapor Kd:	0.975	
Thermodynamic Package:	Advanced_Peng-Robinson	
Nozzle Sizing:	Numerical Integration	
Outlet Pipe Sizing:	Omega Method	
Notes:		

Output Data:

Beta:	0.095	
Orifice Flow C:	0.620	
Discharge Cd:	0.620	
Upstream Density:	28.92	lb/ft3
Upstream Z:	0.00	
Upstream Ideal Cp/Cv:		
Upstream Viscosity:	0.065	cP
Choked:	Yes	
Exit Pressure (P2 for Sizing):	239	psig
Orifice Mass Flux:	1695.2	lb/sec/ft2
Required Mass Rate:	30,293.1	lb/hr
Relief Kd:	0.940	
Relief Mass Flux:	1050.0	lb/sec/ft2

Orifice Flow - Numerical Integration

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: **Recovery NGL**

Component	**Mole Fraction**
nitrogen	0.0000
methane	0.0036
carbon dioxide	0.0073
ethane	0.4896
hydrogen sulfide	0.0000
propane	0.3102
isobutane	0.0502
butane	0.0666
isopentane	0.0193
pentane	0.0120
hexane	0.0275
heptane	0.0137
octane	
nonane	
decane	
methanol	
water	