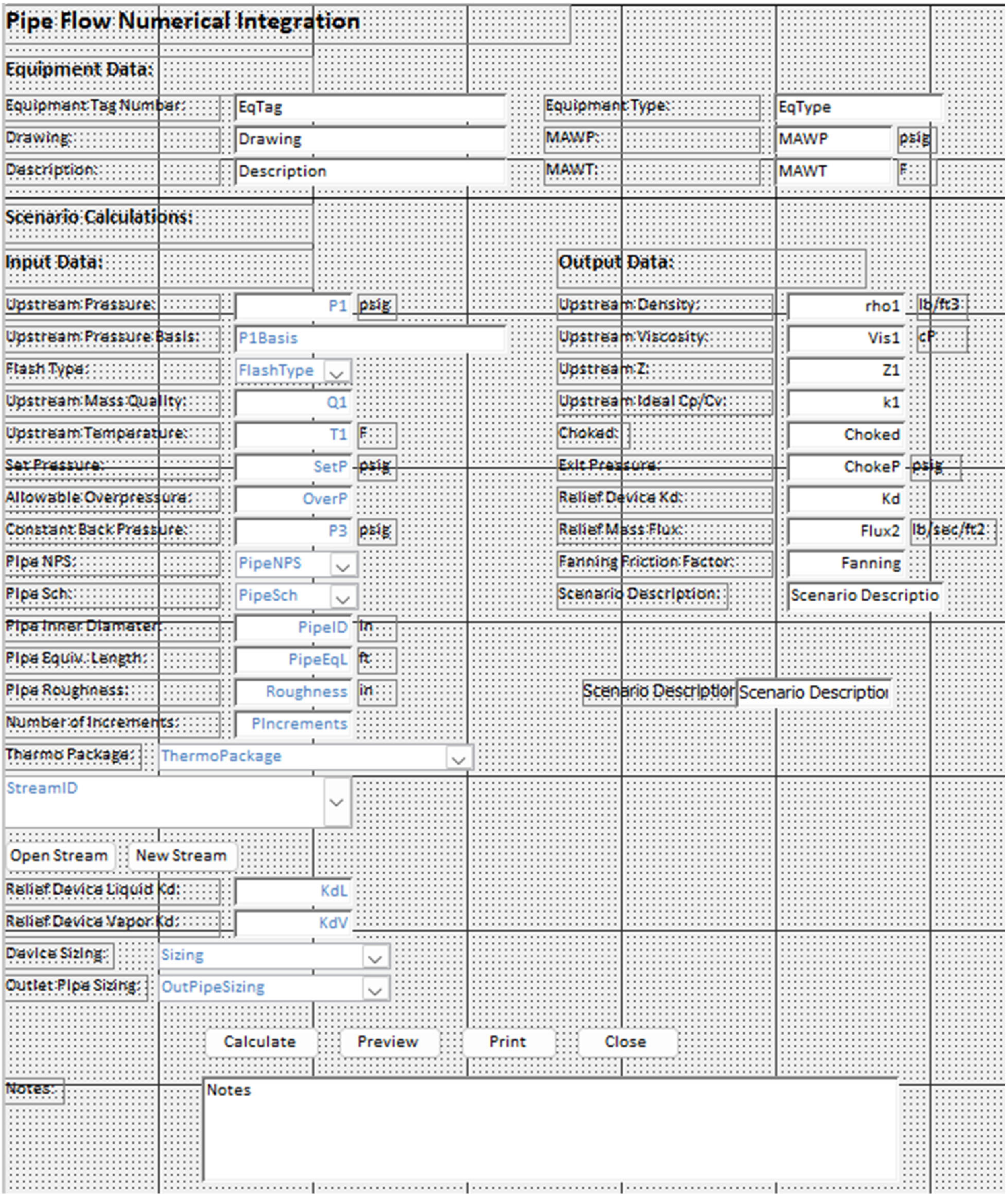
Pipe Flow – Numerical Integration



Pipe Flow Numerical Integration

Equipment Data:

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

Scenario Calculations:

Input Data:

Upstream Pressure:	P1	psig
Upstream Pressure Basis:	P1Basis	
Flash Type:	FlashType	
Upstream Mass Quality:	Q1	
Upstream Temperature:	T1	F
Set Pressure:	SetP	psig
Allowable Overpressure:	OverP	
Constant Back Pressure:	P3	psig
Pipe NPS:	PipeNPS	
Pipe Sch:	PipeSch	
Pipe Inner Diameter	PipeID	in
Pipe Equiv. Length:	PipeEqL	ft
Pipe Roughness:	Roughness	in
Number of Increments:	PIncrements	
Thermo Package:	ThermoPackage	

StreamID

Open Stream | New Stream

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

Output Data:

Upstream Density:	rho1	lb/ft3
Upstream Viscosity:	Vis1	cP
Upstream Z:	Z1	
Upstream Ideal Cp/Cv:	k1	
Choked:	Choked	
Exit Pressure:	ChokeP	psig
Relief Device Kd:	Kd	
Relief Mass Flux:	Flux2	lb/sec/ft2
Fanning Friction Factor:	Fanning	
Scenario Description:	Scenario Descriptio	

Scenario Descriptior Scenario Descriptior

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.

PipeNPS – Nominal pipe size (used along with PipeSch to get PipeID)

PipeSch – Pipe schedule (used along with PipeNPS to get PipeID)

PipeID = Pipe inner diameter (calculated if PipeNPS and PipeSch entered, otherwise must be input)

PipeEql = Pipe equivalent length

PipeRoughness = Pipe roughness used to quantify 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 pipe of constant diameter and fixed length. The iterative solution is based on the procedure and equations below presented at a Design Institute of Emergency Relief Systems meeting.

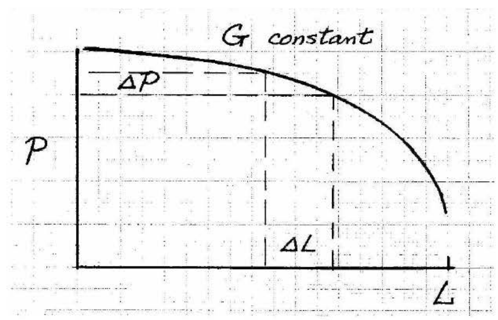
Pipe-Segment Numerical Integration

$$\Delta L = -\frac{\overline{v}\,\Delta P + G^2\,\overline{v}\,\Delta v}{\frac{2f}{D}\,G^2\,\overline{v}^2}$$

where ΔP is pressure increment

Δv is incremental specific volume over ΔP

$\overline{v}$ is average specific volume in ΔP



DIERS Users Group Orlando Mtg./March 23-25, 2009

Numerical Integration Steps

1. G is known or guessed.
2. Increments of pressure are taken from the initial to the final pressure.
3. $\overline{v}$ and Δv are obtained for each increment for a constant-enthalpy process.
4. ΔL for each ΔP taken is computed from Eq. in previous slide.
5. Total length of pipe L is $\sum \Delta L$.
6. If ΔL is negative, then ΔP is too large.
7. A critical flow condition corresponds to $\Delta L = 0$, and the final pressure corresponds to choked pressure.
8. If $\sum \Delta L > L$, then G was guessed too small and Steps 1-7 are repeated with a larger G. If $\sum \Delta L < L$, then G was guessed too large; Steps 1-7 are repeated with a smaller G.
9. A converged solution is obtained when $\sum \Delta L = L$ to within a given tolerance.

Ref.: Perry's ChE Hdb, "Fluid Dynamics" section,7th ed., also Leung, CEP article, 1996. -20-

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.

Vis1 = Upstream viscosity in cP from thermo engine

Z1 - Upstream compressibility typically from thermo engine.

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

Choked – Yes for critical flow, no for subcritical flow

ChokeP – Calculated choke pressure or downstream pressure if not choked

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

Flux2 – RequiredRateMass · RequiredArea * 144 / 3600

Fanning – Fanning friction factor

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 pipe flow numerical integration calculation was benchmarked against CCFlow from DIERs which utilized the three point projection method to develop the density versus pressure relationship resulting in a flowrate of 25,906 lb/hr. In addition, the same case was evaluated using a commercial simulator which does not check for choked flow at the pipe segment exit but in this case yielded a very similar result of 28,938 lb/hr. Pressio calculated the pipe flow rate as 28,880 lb/hr. The deviation from CCFlow is believed to be due to the density versus pressure relationship interpolation. Finally, the calculation was performed in an internal RKR spreadsheet which quantified an identical result to Pressio.

Pipe Flow Numerical Integration
1" Drain Valve Open

OIL & GAS

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
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 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 NPS:	1"	
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
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: **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	

RKR Engineering and Consulting
Gas Plant XYZ
Pressio 2024 Help Benchmarks
2024-1000

CCPS - CCflow

TWO-PHASE FLOW THROUGH PIPING

File Name: C:\Users\Administrator\OneDrive\2022 VMG Relief DB Development\Pressio 2024 Pipe Flow

Save Date: 7/11/2024 2:11:00 PM   Print Date: 7/11/2024 2:11:25 PM

Project: Plant: Pressio Pipe Flow

Calc. Option: 3 Point HEM

PHYSICAL PROPERTIES ENTERED-

-Three-Point Interpolation (Model F):

Pressure, psia, States A,B,C	364.7	289.7	179.7
Mass Fraction Vapor	0	0.1101	0.266
Vapor Specific Volume, ft^3/lb	0.343	0.446	0.743
Liquid Specific Volume, ft^3/lb	0.0346	0.033	0.031
Liquid Viscosity, cp	0.065	0.077	0.01
Vapor Viscosity, cp	0.0094	0.0091	0.0086

PIPING PROPERTIES-

Pipe Diameter, in	0.957
Piping Length, ft	20
Pipe Roughness, in	0.0018
Fittings Loss Coeff., turbulent	0
Fittings Loss Coeff., laminar	0
Change in Elevation, ft	0

PROCESS CONDITIONS-

Relieving Pressure, psia	364.7
Downstream Pressure, psia	179.7

CALCULATED RESULTS-

Pipe Exit Pressure, psia	179.7
Mass Velocity, $lb/(s \cdot ft^2)$	1440.6
Flow Rate, lb/hr	25,906.
Vapor Flow Rate at pipe exit, lb/hr	6,891.
Vapor Flow Rate at downstream pressure, lb/hr	6,891.
Flow Resistance	5.783

Pipe Exit Conditions:

Viscosity, cp	0.0158
Reynolds Number	1.08E+07
Fanning friction factor	0.00577
Thrust, lbf	71.0
Exit Velocity, ft/s	317.5

Name **Pipe1** Description

S1 → S2

Pressure Drop Corr.	Colebrook	Filter	All

Summary | Pipe Detail | Profiles | Heat Transfer | Sizing | Settings | Equilibrium Results | Report | Notes

Main Data

Name	Value
Delta P [psi]	185.00
OutQ [Btu/h]	0.000E+0
U [Btu/h-ft2-F]	**0.00**
Heat Transfer Calc Type	**Simple**
Outside Data	**Ambient**
External T [F]	77.0
Number of Sections	**10**
Slip Exponent	**0.00**
Friction Factor Tuning	**1.00**

Pipe Data

Name	Value
Total Length [ft]	**20.00**
Elevation	Profile...
Elevation In [ft]	**0.00**
Elevation Out [ft]	**0.00**
Schedule	**80**
Nominal Size (in)	**1**
Inner Diameter [in]	0.957
Outer Diameter [in]	1.315
Thickness [in]	0.179
Roughness [in]	**0.0018**

Results

Name	Value
Velocity In [ft/s]	55.69
Velocity Out [ft/s]	287.68
Max Mach	0.75
Max RhoV2 [psi]	99.92
Inventory	
Line Pack [SCF]	1.06
Liquid [ft3]	0.055
Oil [ft3]	0.055
Water [ft3]	0.000
Bulk Std Liq Vol [ft3]	0.060

Material

PortName	In	Out
Is Recycle Port	☐	☐
Connected Stream/Unit Op	**/S1.Out**	**/S2.In**
VapFrac	0.0001	0.25597
T [F]	90.0	43.6
P [psia]	364.70	179.70
Mole Flow [lbmol/h]	696.15	696.15
Mass Flow [lb/h]	28938.09	28938.09
Volume Flow [ft3/s]	0.278	1.437
Std Liq Volume Flow [ft3/s]	0.279	0.279
Std Gas Volume Flow [MMSCFD]	6.3403E+0	6.3403E+0

Pipe Flow Numerical Integration
Based on Curve Fit from PV Data Tab
Solve for Flow Based on P1 and P2

P increment	18.5	psi
Mass Flow	28880	lb/hr
Pipe ID	0.957	in
Pipe Area	0.004995	ft^2
G	1606.001	lb/sec/ft2
Pipe Length Specified	20	ft
Fanning F	0.00576	
P_1	350	psig
P_{bubble}	350	psig
P_2	165	psig

Goal Seek G11 to Equal B11 by Changing B7

Pipe Length Calculated	20.00	
Choke P	165	psig

Increment	P_1	P_2	v_1	v_2	Δv	v_{avg}	Term 1	Term 2	Term 3	L
1	350	332	0.03460	0.04158	0.00698	0.03809	(3,264.12)	685.62	540.47	4.7708
2	332	313	0.04158	0.04965	0.00807	0.04561	(3,909.02)	949.48	775.14	3.8181
3	313	295	0.04965	0.05889	0.00924	0.05427	(4,650.77)	1,293.26	1,097.22	3.0600
4	295	276	0.05889	0.06942	0.01053	0.06415	(5,497.94)	1,742.46	1,533.35	2.4492
5	276	258	0.06942	0.08146	0.01205	0.07544	(6,465.33)	2,343.78	2,120.43	1.9437
6	258	239	0.08146	0.09542	0.01395	0.08844	(7,579.32)	3,182.45	2,914.09	1.5088
7	239	221	0.09542	0.11190	0.01648	0.10366	(8,883.35)	4,406.07	4,003.10	1.1185
8	221	202	0.11190	0.13179	0.01989	0.12184	(10,441.92)	6,251.17	5,530.99	0.7577
9	202	184	0.13179	0.15615	0.02436	0.14397	(12,338.03)	9,044.61	7,722.08	0.4265
10	184	165	0.15615	0.18575	0.02960	0.17095	(14,650.34)	13,053.04	10,887.75	0.1467
11	165	147	0.18575	0.21974	0.03399	0.20275	(17,375.55)	17,776.35	15,315.10	-