ReCon Management • Engineering Inspection

Athlon Bayport, TX	Date: 10/29/19 Revision: A Relief Valve No.: PSV-XX2	Created By: CJM Checked By:

INLET PIPING CALCULATIONS

Inlet Piping Segments

Sizing Basis: **01: Closed Outlet on Vessels**

Pipe Size (nominal diameter) =	2.00 inches				
Pipe Inside Diameter, **d** =	1.939 inches				
Pipe Spec =	CS				
Pipe Schedule =	Sch 40				
[5]Moody Friction Factor, ***f*** =	0.019				
Total Length of Straight Pipe, **L** =	2.0 ft				
[1]Equivalent Length of 90º Elbows =		# Elbows=		L_{eq}/d = 30	
[1]Equivalent Length of 90º Long Radius Elbows =		# Elbows=		L_{eq}/d = 20	
[1]Equivalent Length of 45º Elbows =		# Elbows=		L_{eq}/d = 16	
[1]Equivalent Length of Side Flow Tee =		# Tees=		L_{eq}/d = 60	
[1]Equivalent Length of Thru Flow Tee =		# Tees=		L_{eq}/d = 20	
[1]Equivalent Length of Gate Valve=		# Valves=		L_{eq}/d = 8	
[1]Equivalent Length of Ball Valve =		# Valves=		L_{eq}/d = 3	
[4]Equivalent Length of Rupture Disc =		K-factor=			
[1]Equivalent Length of Entrance Loss =	8.6 ft	K-factor=	1	Crane pg. A-29	
Equivalent Length of Reducer =	35.3 ft	[6]K-factor=	4.15	Reduced id =	1.048
Equivalent Length of Enlarger =		[6]K-factor=		Enlarged id =	
Other Fitting: Equivalent Length=		# Fittings=		[8]Cv =	
Other Fitting: Equivalent Length=		# Fittings=		L_{eq}/d =	
Total Equivalent Length of Valves and Fittings, $\mathbf{L_{eq}}$ =	**43.9 ft**	as 2 in. pipe			

Inlet Piping Stream Properties

Relief Rate of Liquid or Vap Valve Capacity, **W** =	1,952	lb/hr	
Set Pressure =	165	psig	
Inlet Piping Temperature =	387.7	ºF	847.7 ºR
Molecular Weight =	18.02	lb/lbmol	
Density in Inlet Line =	0.47	lb/ft^3	
Viscosity in Inlet Line =	0.02	cp	
[7]Reynolds Number (Re) in Inlet Line =	397,074.89	(Laminar flow occurs when Re ≤ 2000.)	

Inlet Line Pressure Drop Calculation

Total Equivalent Length (valves & fittings), L_{eq} =	43.9	ft
Friction Factor, ***f*** =	0.019	
Total Straight Pipe Length, L =	2.0	ft
Friction Factor (straight pipe), ***f*** =	0.019	
Inside Diameter of Piping, d =	1.939	in
Inlet Piping, Total Pressure Drop, ΔP_{psi} =	0.87	psi
ΔP_{psi}, Percent of Set Pressure =	0.53	%[a]

For valves and fittings[2]:

$$\Delta P_{psi} = 0.00000336 \frac{f\, L_{eq} W^2}{\rho d^5}$$

For valves and fittings[2]:

$$\Delta P_{psi} = 0.00000336 \frac{f L W^2}{\rho d^5}$$

Note: Resistance coefficient K =

f_T(L_{eq}/D) for valves and fittings*

f(L/D) for straight pipe*

NOTES

[a]Per API 520 5th Edition Part II, Sect. 4.2.2, inlet piping is not to exceed a pressure drop of 3% of the set pressure.

The current inlet piping is adequate.

REFERENCES

[1] Crane Co., "Flow of Fluids" Technical Paper No. 410, "Resistance Coefficients for Valves and Fittings" pages A-26 thru A-30

[2] Phil Leckner, "Equivalent Length of Valves and Fittings in Pipeline Pressure Drop Calculations" article Cheresources.com

[3] Crane Co., "Flow of Fluids" Technical Paper No. 410, "Pressure Drop in Straight Pipe" pg. 3-2, Eq. 3-5

[4] API STD 521, 5th edition, "Typical K-factors for pipe fittings and reducers", pg. 110 Table 13 and Table 14

[5] This calculation is valid for steel pipe, for all other pipe material see Crane pg. A-26 or pg. A-23, to determine the correct Friction Factor, f.

[6] Crane Co., page A-26 and 2-11.

[7] Crane Co., "Flow of Fluids" Technical Paper No. 410, pages 1-6 thru 1-7. Friction factor for straight pipe in laminar flow is equal to 64/Re.

[8] Cv converted to L_{ed}/d by combining Crane Co. Technical Paper No. 410 (08/11 Reprint) equations 2-11 and 2-4 as follows:

$$\frac{L_{eq}}{D} = 890.4256 \frac{d^4}{f * Cv^2}$$

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OUTLET PIPING CALCULATIONS

Outlet Piping Segments

Sizing Basis:

01: Closed Outlet on Vessels

Pipe Size (nominal diameter) =	2.00	inches				
Pipe Inside Diameter, **d** =	2.000	inches				
Pipe Spec =	CS					
Pipe Schedule =	Sch 40					
[5]Moody Friction Factor, ***f*** =	0.019					
Total Length of Straight Pipe, **L** =	3.0 ft					
[1]Equivalent Length of 90º Elbows =	5.0 ft	# Elbows=	1	L_{eq}/d = 30		
[1]Equivalent Length of 90º Long Radius Elbows =		# Elbows=		L_{eq}/d = 20		
[1]Equivalent Length of 45º Elbows =		# Elbows=		L_{eq}/d = 16		
[1]Equivalent Length of Side Flow Tee =		# Tees=		L_{eq}/d = 60		
[1]Equivalent Length of Thru Flow Tee =		# Tees=		L_{eq}/d = 20		
[1]Equivalent Length of Gate Valve=		# Valves=		L_{eq}/d = 8		
[1]Equivalent Length of Ball Valve =		# Valves=		L_{eq}/d = 3		
[4]Equivalent Length of Rupture Disc =		K-factor=				
[1]Equivalent Length of Exit Loss =		K-factor=		Crane pg. A-29		
Equivalent Length of Reducer =		[6]K-factor=		Reduced id =		
Equivalent Length of Enlarger =		[6]K-factor=		Enlarged id =		
Other Fitting: Equivalent Length=		# Fittings=		[9]Cv =		
Other Fitting: Equivalent Length=		# Fittings=		L_{eq}/d =		
Total Equivalent Length of Valves and Fittings, $\mathbf{L_{eq}}$ =	**5.0 ft**	as 2 in. pipe				

Outlet Piping Stream Properties

Relief Rate of Liquid or Vap Valve Capacity, **W** =	1,952	lb/hr		
Relief Valve Set Pressure =	165	psig		
[c]Header Pressure, $\mathbf{P_H}$ =	14.70	psia		psig
Outlet Piping Temperature, **T** =	672	ºR	212.00	ºF
Ratio of Specific Heats at Outlet Conditions, **k** =	1.3			
Gas Compressibility Factor, **Z** =	0.98			
Gas Relative Molecular Weight, **M** =	18.0	lb/lbmol		
[2]Mach Number at Pipe Outlet, $\mathbf{Ma_2}$ =	0.493			
Set Outlet Line Outlet Pressure, $\mathbf{P_o}$ =	14.70	psia		
Liquid Density in Outlet Line, $\boldsymbol{\rho_L}$ =		lb/ft3		
Vapor Average Density in Outlet Line, $\boldsymbol{\rho_V}$ =	0.08	lb/ft^3		
Viscosity in Outlet Line =	0.012	cp		
[8]Reynolds Number (Re) in Outlet Line =	511,933.50	(Laminar flow occurs when Re ≤ 2000.)		

$$Ma_2 = 1.702x10^{-5}\left(\frac{W}{p_H d_H^{\,2}}\right)\left(\frac{ZT}{M}\right)^{0.5}$$

If Ma_2 < 1.0, P_o = P_H; however, if Ma_2 > 1.0, set P_o = P_{crit}

$$\rho_V = \frac{pM}{ZTR}$$

Outlet Line Pressure Drop Calculation

Critical absolute pressure, $\mathbf{P_{crit}}$ =	7.25	psia
Total Equivalent Length (valves and fittings), $\mathbf{L_{eq}}$ =	5.0	ft
Moody Friction Factor, ***f*** =	0.019	
Line Diameter, **d** =	2.00	in
Total Straight Pipe Length, **L** =	3.0	ft
Friction Factor (straight pipe), ***f*** =	0.019	
Inside Diameter of Piping at Header, $\mathbf{d_H}$=	2.000	in
Valve Design Backpressure Allowed =	21%	
Max Back Pressure Allowed, P_B=	49.40	psia
Outlet Line Avg. Press. at Max BP Allowed, P_{AVG}=	32.05	psia [b]
[3]Outlet Piping Pressure Drop, ΔP_{psi} =	0.75	psi
Calculated Outlet Piping Back Pressure, BP_C=	0.75	psig
Pressure Drop, Percent of Set Pressure =	**0.45%**	[a]
[7]Reaction Force for **Atmospheric Relief Valves,** F=	**26.82**	lbf

(Reaction force calculation is not applicable for non atmospheric relief devices)

Critical absolute pressure: set Ma_2=1.0 (sonic flow); if the critical pressure is less than the pipe outlet pressure then the flow is subsonic.

$$P_{crit} = 1.702x10^{-5}\left(\frac{W}{d^2}\right)\left(\frac{Z\cdot T}{M}\right)^{0.5}$$

$$P_{AVG} = \frac{P_o + P_B}{2}$$

$$\Delta P_{psi} = 0.00000336\frac{fLW^2}{\rho d^5}$$

$$BP_c = \Delta P_{PSI} + P_o - 14.7$$

$$F = \frac{W}{366}\sqrt{\frac{kT}{(k+1)M}} + (AP)$$

NOTES

[a]Outlet piping built-up pressure drop not to exceed 10% of the set pressure for conventional valves (API STD 521, Sect. 7.3.1.3 pg. 103).

The current outlet piping is adequate.

[b]P_{AVG}, Outlet Line Average Pressure, is used in calculating the outlet line average density, in order to more closely represent the fluid density in the outlet piping.

[c]In calculating multiple pipe segments, i.e., changes in diameter, the header pressure in the second segment should be equal to the "Calculated Outlet Piping Back Pressure", BPc, in the first segment.

REFERENCES

[1] Crane Co., "Flow of Fluids" Technical Paper No. 410, "Resistance Coefficients for Valves and Fittings" pages A-26 thru A-30

[2] API STD 521, 5th edition, "Design of relief device discharging piping", pg. 105 Equation #28: Isothermal outlet Mach number

[3] Crane Co., "Flow of Fluids" Technical Paper No. 410, "Pressure Drop in Straight Pipe" pg. 3-2, Eq. 3-5

[4] API STD 521, 5th edition, "Typical K-factors for pipe fittings and reducers", pg. 110 Table 13 and Table 14

[5] This calculation is valid for steel pipe, for all other pipe material see Crane pg. A-26 or pg. A-23, to determine the correct Friction Factor, f.

[6] Crane Co., page A-26 and 2-11.

[7] This calculation should be used as a reference only, a competent mechanical engineer should determine the required support design. API RP 520 Part II, 5th edition, "Determining Reaction Forces" Section 4.4.1.1 - for any gas, vapor, or steam discharging to the atmosphere.

[8] Crane Co., "Flow of Fluids" Technical Paper No. 410, pages 1-6 thru 1-7. Friction factor for straight pipe in laminar flow is equal to 64/Re.

[9] Cv converted to L_{eq}/d by combining Crane Co. Technical Paper No. 410 (08/11 Reprint) equations 2-11 and 2-4 as follows: $\frac{L_{eq}}{D} = 890.4256\frac{d^4}{f * Cv^2}$

Athlon Bayport, TX	Date: 10/29/19 Revision: A	Created By: CJM Checked By: 0

Relief Requirements Summary

PSV Number	PSV-XX2	
P&ID	SK-19282010-001 Rev.A	
Set Pressure	165 psig	
Manufacturer	Emerson Crosby	
Model #	JOS-H-E	
Orifice	E	
Area	0.221	Multivalve
Style	Conventional	

Protected Equipment

Equipment #	Equipment Description	MAWP				
E-778 Shell S	E-778 Shell	165	psig	@		°F
			psig	@		°F
			psig	@		°F
			psig	@		°F

Relief Condition	Relief Description	Required Relief			Capacity	Inlet Pressure Loss		Outlet Pressure Loss		Mitigation required
		Mass (lb/hr)	Volume (gpm)	Area (in^2)	(lb/hr)	(psi)	(%)	(psi)	(%)	
01: Closed Outlet on Vessels		1,100			34,798	0.87	0.53%	0.75	0.45%	
02: Cooling-water Failure							0.00%		0.00%	
03: Top-tower Reflux Failure							0.00%		0.00%	
04: Sidestream Reflux Failure							0.00%		0.00%	
05: Lean-oil Failure to Absorber							0.00%		0.00%	
06: Accumulation of Noncondensables							0.00%		0.00%	
07: Entrance of Highly Volatile Material							0.00%		0.00%	
08: Overfilling Storage or Surge Vessel							0.00%		0.00%	
09: Failure of Automatic Control							0.00%		0.00%	
10: Abnormal Heat or Vapor Input							0.00%		0.00%	
11: Split Exchanger Tube							0.00%		0.00%	
12: Internal Explosions							0.00%		0.00%	
13: Chemical Reaction							0.00%		0.00%	
14: Hydraulic Expansion							0.00%		0.00%	
15: Exterior Fire							0.00%		0.00%	
16: Power Failure (steam, electric, air, or other)							0.00%		0.00%	
17: Inadvertent Valve Operation							0.00%		0.00%	
18: Other							0.00%		0.00%	
							0.00%		0.00%	
							0.00%		0.00%	
							0.00%		0.00%	

NOTES

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Athlon Bayport, TX	Date: 10/29/19 Revision: A	Created By: CJM Checked By: 0

Orifice Calculation - Liquid Relief

PSV INFORMATION

PSV Number:	PSV-XX2
Vessel Item #	E-778 Shell Side
Vessel Description:	E-778 Shell
Flow Sheet Reference #:	SK-19282010-001 Rev.A
Relieving State:	Liquid
Sizing Basis:	01: Closed Outlet on Vessels

INPUT DATA

Flowrate, **Q** =	2.53	gpm	= 1100.2 lbs/hr
Set Pressure, $\mathbf{P_s}$ =	165.0	psig	
Allowable Overpressure =	21	%	
Relieving Pressure, $\mathbf{P_R}$ =	199.7	psig	
Back Pressure $\mathbf{P_B}$=	-	psig	
Specific Gravity at oper temp, **G** =	0.87		
Viscosity, **μ** =	0.1355	cP	
Density, ρ =	54.22690209	lb/ft^3	
Manufacturer Coefficient of Discharge[1], $\mathbf{K_d}$ =	0.65	Default K_d=0.65 certified, Kd=0.62 for non-certified	
Reynolds Number[2], **R** =	96,635	$R = \dfrac{Q(2800 \times G)}{\mu\sqrt{A_v}}$	
Capacity Correction Factor due to Back Pressure[3], $\mathbf{K_w}$ =	1.000	If back pressure is atm., K_w=1 otherwise see API 520, Fig 31.	
Capacity Correction Factor due to Viscosity[4], $\mathbf{K_v}$ =	0.997	$K_v = \left(0.9935 + \dfrac{2.878}{R^{0.5}} + \dfrac{342.75}{R^{1.5}}\right)^{-1.0}$	
Combination Correction Factor for Rupture Disks[5], $\mathbf{K_c}$ =	1.0	K_c=1.0 if rupture disk not installed, else 0.9, if MFG not available	
Correction Factor due to Overpressure[6], $\mathbf{K_p}$ =	0.6	At 25%, K_p = 1.0; at 10% K_p= 0.6	

CALCULATED RESULTS

PSV Liquid Capacity Certification Required? Y or N =	Y		
Required Orifice Area for a *Liquid Certified* Relief Valve[7], $\mathbf{A_{cert}}$ =	0.007	in^2	$A_{cert} = \dfrac{Q}{38K_dK_wK_cK_v}\sqrt{\dfrac{G}{p_1 - p_2}}$
Required Orifice Area for a *Non-Certified* Liquid Relief Valve[8], $\mathbf{A_{non\text{-}cert}}$ =	N/A	in^2	$A_{non\text{-}cert} = \dfrac{Q}{38K_dK_wK_cK_vK_p}\dfrac{G}{1.25p - p_b}$
Available Orifice Area, $\mathbf{A_v}$ =	0.221	in^2	
Relief Valve Maximum Flow Rate = Q (A_v / A) =	80	gpm	
Relief Valve Maximum Mass Flowrate =	34,798	lb/hr	

NOTES

REFERENCES

[1] API RP 520, 7th Edition, "Rated Coefficient of Discharge, K_d" pg. 52 (certified) and pg. 54 (non-certified)
[2] API RP 520, 7th Edition, "Sizing for Liquid Relief", Equation 3.10, pg. 53
[3] API RP 520, 7th Edition, "Capacity Correction Factor due to Backpressure", pg. 52; Figure 31, pg. 38
[4] API RP 520, 7th Edition, "Capacity Correction Factor due to Viscosity", pg.52; Figure 36, pg. 54
[5] API RP 520, 7th Edition, "Capacity Correction Factor for Rupture Disks", pg.52
[6] API RP 520, 7th Edition, "Capacity Correction Factor due to Overpressure", Figure 37, pg.55
[7] API RP 520, 7th Edition, "Sizing for Liquid Relief: Pressure Relief Valves Requiring Capacity Certification", Equation 3.9, pg. 52
[8] API RP 520, 7th Edition, "Sizing for Liquid Relief: Pressure Relief Valves Not Requiring Capacity Certification", Equation 3.12, pg. 54

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Athlon Bayport, TX	Date: 10/29/19 Revision: A	Created By: CJM Checked By: 0

Orifice Calculation - Vapor Relief

PSV INFORMATION

PSV Number:	PSV-XX2
Vessel Item #	E-778 Shell Side
Vessel Description:	E-778 Shell
Flow Sheet Reference #:	SK-19282010-001 Rev.A
Relieving State:	Vapor
Sizing Basis:	01: Closed Outlet on Vessels

INPUTS

Flowrate, **W** (lb/hr) =	1100.2	
Relieving Temperature, **T** (deg F) =	387.7	
Allowable Overpressure =	21%	%
Ratio of Specific Heats, **k** =	1.40	
Coefficient of the ratio of specific heats(1), **C** =	356.1	$C = 520\sqrt{k\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$
Compressibility Factor, **Z** =	1	
Molecular Weight, **M** =	18.015	
Ratio of P_2/P_1, **r** =	0.0816	
Coefficient of Subcritical Flow(2), $\mathbf{F_2}$ =	0.2332	$F_2 = \sqrt{\left(\frac{k}{k-1}\right)(r)^{\frac{2}{k}}\left[\frac{1-r^{\frac{(k-1)}{k}}}{1-r}\right]}$
Critical Flow Pressure Ratio(3), $\mathbf{P_{cf} / P_1}$ =	0.528	
Set Pressure, P (psig) =	165	
PSV Type (conv, pilot, bellows) =	Conventional	
Back Pressure, **P2** (psig) =	0	
Back Pressure Correction Factor, $\mathbf{K_b}$ =	1.0	K_b=1.0 for conventional
Manufacturer Coefficient of Discharge(5), $\mathbf{K_d}$ =	0.9	
Combination Correction Factor for Rupture Disks, $\mathbf{K_c}$ =	1	Kc=1.0 if rupture disk not installed, else 0.9, if MFG not available

CALCULATIONS:

Upstream Relieving Pressure: $\mathbf{P_1}$ (psig) =	165.3465	Set Pressure + Allowable Overpressure
Critical Flow Area Calculation(2), **A** =	0.131	in^2 $A = \frac{W}{CK_dP_1K_bK_c}\sqrt{\frac{TZ}{M}}$
Sub-critical Flow Area Calculation(4), **A** =	Critical Flow	in^2 $A = \frac{W}{735 * F_2K_dK_c}\sqrt{\frac{ZT}{MP_1(P_1-P_2)}}$
Available Orifice Area, $\mathbf{A_v}$ =	0.221	in^2
Valve Maximum Flowrate = W * (Av / A)	1858.8	lbs/hr

NOTES

REFERENCES

(1) API RP 520, 7th Edition, "Coefficient C" Equation taken from Figure 32, pg. 44
(2) API RP 520, 7th Edition, "Sizing for Critical Flow" Equation 3.2, pg. 42
(3) API RP 520, 7th Edition, "Critical Flow Pressure Ratio" Equation 3.1, pg. 41
(4) API RP 520, 7th Edition, "Sizing for Subcritical Flow: Gas or Vapor" Equation 3.5, pg. 45
(5) API RP 520, 7th Edition, "Sizing for Critical Flow" pg. 42