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Athlon Solutions Bayport Texas	Date: 05/01/19 Revision: A	Created By: DES Checked By: 0

Relief Requirements Summary

PSV Number	New PSV	
P&ID	New P&ID	
Set Pressure	30 psig	
Manufacturer	Consolidated	
Model #	1905QC-32	
Orifice	P	
Area	6.380	Multivalve
Style	Conventional	YES

Protected Equipment

Equipment #	Equipment Description	MAWP				
T-31	Storage Tank	30	psig	@	250	°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							0.00%		0.00%	
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	Nitrogen	275		0.045	21,262		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	HCl	12,932		5.912	13,957	0.09	0.29%	0.37	1.23%	
14: Hydraulic Expansion							0.00%		0.00%	
15: Exterior Fire	Product Vapor	40,756		7.621	34,121	0.20	0.67%	0.02	0.08%	
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 Solutions Bayport Texas	Date: 05/01/19 Revision: A	Created By: DES Checked By: 0

Orifice Calculation - Vapor Relief

PSV INFORMATION

PSV Number:	New PSV	
Vessel Item #	T-31	
Vessel Description:	Storage Tank	
Flow Sheet Reference #:	New P&ID	
Relieving State:	Vapor	
Sizing Basis:	13: Chemical Reaction	

INPUTS

Flowrate, **W** (lb/hr) =	12932.3	
Relieving Temperature, **T** (deg F) =	212	
Allowable Overpressure =	10	%
Ratio of Specific Heats, **k** =	1.38	
Coefficient of the ratio of specific heats[1], **C** =	354.6	$C = 520\sqrt{k\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$
Compressibility Factor, **Z** =	1	
Molecular Weight, **M** =	36.46	
Ratio of P_2/P_1, **r** =	0.3711	
Coefficient of Subcritical Flow[2], $\mathbf{F_2}$ =	0.5733	$F_2 = \sqrt{\left(\frac{k}{k-1}\right)(r)^{\frac{2}{k}}\left[\frac{1-r^{\frac{(k-1)}{k}}}{1-r}\right]}$
Critical Flow Pressure Ratio[3], $\mathbf{P_{cf} / P_1}$ =	0.531	
Set Pressure, P (psig) =	30	
PSV Type (conv, pilot, bellows) =	Conventional	
Back Pressure, **P2** (psig) =	3	
Back Pressure Correction Factor, $\mathbf{K_b}$ =	1.0	K_b=1.0 for conventional
Manufacturer Coefficient of Discharge[5], $\mathbf{K_d}$ =	0.617	
Combination Correction Factor for Rupture Disks, $\mathbf{K_c}$ =	0.9	Kc=1.0 if rupture disk not installed, else 0.9, if MFG not available

CALCULATIONS:

Upstream Relieving Pressure: $\mathbf{P_1}$ (psig) =	33	Set Pressure + Allowable Overpressure
Critical Flow Area Calculation[2], **A** =	5.912	in^2
Sub-critical Flow Area Calculation[4], **A** =	Critical Flow	in^2
Available Orifice Area, $\mathbf{A_v}$ =	6.380	in^2
Valve Maximum Flowrate = W * (Av / A)	13956.6	lbs/hr

$$A = \frac{W}{CK_dP_1K_bK_c}\sqrt{\frac{TZ}{M}}$$

$$A = \frac{W}{735 * F_2K_dK_c}\sqrt{\frac{ZT}{MP_1(P_1-P_2)}}$$

NOTES

Decomposition reaction. Based on rate in the 5/21/2008 BASF memo from Greg Roginski.
The rate is adjusted for the larger inventory in the new tank. Original 7,000 gallons Benzyl Chloride. New tank 15,000 gallons
New rate = 8,510 X 15/7 = 18,236 lb/hr.

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

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Athlon Solutions Bayport Texas	Date: 05/01/19 Revision: A	Created By: DES Checked By: 0

Control Valve Calculation - Vapor

PSV INFORMATION

PSV Number:	New PSV
Vessel Item #	T-31
Vessel Description:	Storage Tank
Flow Sheet Reference #:	New P&ID
Relieving State:	Vapor
Sizing Basis:	09: Failure of Automatic Control

Control Valve Data

Control Valve Number:	New Nitrogen
Manufacturer:	
Model:	Y690A
Size:	1/8"
Flow Characteristic:	Linear

INPUT DATA

Cg =	12.3		Gas Sizing Coefficient (from Valve Manufacturer)
MW =	29		Gas Molecular Weight
C_1 =	35		Ratio of gas to liquid sizing coefficients (=Cg/Cv)
T =	535	°R	Absolute Temperature of Gas at Inlet (=°F+460)
P_1 =	164.7	psia	Valve Inlet Pressure (=psig+14.7)
P_2 =	47.7	psia	Valve Outlet Pressure (=psig+14.7)
Q_N =	0	lb/hr	Normal flow rate through the valve

CALCULATED RESULTS

G =	1.000		Gas Specific Gravity = MW / 29
deltaP =	117	psi	Pressure Drop Across Valve
Q_{SCFH}[1] =	1979.1	SCFH	Vapor Relieving Requirement

$$Q_{SCFH} = Cg \times \sqrt{\frac{520}{G \times T}} \times P_1 \times \sin\left\{\pi \times \left(\frac{3417}{C_1} \times \sqrt{\frac{\Delta P}{P_1}}\right) \times \frac{1}{180}\right\} - \left\{Q_N \frac{379}{MW}\right\}$$

82.29 °

When this value equals or exceeds 90°, critical flow is indicated. This quantity must be limited to 90°. This then becomes unity since sin(90°) =1.

$Q_{LB/HR}$ = 151.4 lb/hr (=Q_{SCFH}*MW/379)

NOTES

REFERENCES

[1] "Rules of Thumb for Chemical Engineers", C.R. Branan, Copyright 1994, Section 1, page 13.

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Athlon Solutions Bayport Texas	Date: 05/01/19 Revision: A	Created By: DES Checked By: 0

Orifice Calculation - Vapor Relief

PSV INFORMATION

PSV Number:	New PSV
Vessel Item #	T-31
Vessel Description:	Storage Tank
Flow Sheet Reference #:	New P&ID
Relieving State:	Vapor
Sizing Basis:	09: Failure of Automatic Control

INPUTS

Flowrate, **W** (lb/hr) =	151.4	
Relieving Temperature, **T** (deg F) =	100	
Allowable Overpressure =	10	%
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** =	28	
Ratio of P_2/P_1, **r** =	0.3711	
Coefficient of Subcritical Flow[2], $\mathbf{F_2}$ =	0.5771	$F_2 = \sqrt{\left(\frac{k}{k-1}\right)(r)^{\frac{2}{k}}\left[\frac{1-r^{\frac{(k-1)}{k}}}{1-r}\right]}$
Critical Flow Pressure Ratio[3], $\mathbf{P_{cf} / P_1}$ =	0.528	
Set Pressure, P (psig) =	30	
PSV Type (conv, pilot, bellows) =	Conventional	
Back Pressure, **P2** (psig) =	3	
Back Pressure Correction Factor, $\mathbf{K_b}$ =	1.0	K_b=1.0 for conventional
Manufacturer Coefficient of Discharge[5], $\mathbf{K_d}$ =	0.975	
Combination Correction Factor for Rupture Disks, $\mathbf{K_c}$ =	0.9	Kc=1.0 if rupture disk not installed, else 0.9, if MFG not available

CALCULATIONS:

Upstream Relieving Pressure: $\mathbf{P_1}$ (psig) =	33	Set Pressure + Allowable Overpressure
Critical Flow Area Calculation[2], **A** =	0.045	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, $\mathbf{A_v}$ =	6.380	in^2
Valve Maximum Flowrate = W * (Av / A)	21261.5	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

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Athlon Solutions Bayport Texas	Date: 05/01/19 Revision: A	Created By: DES Checked By: 0

Fire Case Relief Requirement Calculation for Vessels - Adequate Drainage & Fire Fighting Equipment

PSV INFORMATION

PSV Number:	New PSV
Vessel Item #	T-31
Vessel Description:	Storage Tank
Flow Sheet Reference #:	New P&ID
Relieving State:	Vapor
Sizing Basis:	15: Exterior Fire

INPUTS

Spherical Vessel Code:

Vessel Orientation =	V		H = Horizontal, V = Vertical, S = Spherical
Number of Ends(Heads) =	1		Number of Ends (Heads) exposed to the Fire.
Type of Ends =	H		F = Flat, H = Hemispherical, E = Elliptical
D =	10.00	ft	Vessel diameter
HLL =	26.00	ft	High liquid level
L =	26.00	ft	Length of vessel, T/T [1]
H =	5	ft	Vessel elevation
F =	1.00		Environmental factor[2]
Latent Heat of Vap., λ =	122	btu/lb	From process simulation calculations (at relieving conditions)

CALCULATIONS

Spherical Vessel, A_{Sws} =		ft²	Total Wetted Area of a Spherical Vessel Per API 521
Spherical Vessel, A_{Sws} =		ft²	Total Wetted Area of a Spherical Vessel Per API 2000
$E_{vertical}$ =	20.0	ft	Effective liquid level (up to 25 ft from the flame source)
Vertical Vessel, A_{Vws} =		ft²	[3]Total Wetted Area of a Vertical Vessel with FLAT Ends
Vertical Vessel, A_{Vws} =	785.4	ft²	[3]Total Wetted Area of a Vertical Vessel with HEMISPHERICAL Ends
Vertical Vessel, A_{Vws} =		ft²	[5]Total Wetted Area of a Vertical Vessel with ELLIPTICAL Ends
$E_{horizontal}$ =		ft	Effective liquid level (up to 25 ft from the flame source)
F_{wp}=			
Horizontal Vessel, A_{Hws} =		ft²	[3]Total Wetted Area of a Horizontal Vessel with FLAT Ends
Horizontal Vessel, A_{Hws} =		ft²	[3]Total Wetted Area of a Horizontal Vessel with HEMISPHERICAL Ends
Horizontal Vessel, A_{Hws} =		ft²	[5]Total Wetted Area of a Horizontal Vessel with ELLIPTICAL Ends
A_{ws} =	785	ft²	Total wetted surface area
Q =	4,968,131	Btu/hr	Total heat absorption (input) to the wetted surface[4] $Q = 21{,}000 * F * A_{ws}^{0.82}$
W =	40,756	lb/hr	Required Relief Rate (=Q/λ)

NOTES

REFERENCES

[1] This spreadsheets calculates the wetted area for a HORIZONTAL or VERTICAL vessel.
[2] API STD 521, 5th edition, Table 6 "Environmental Factor", pg. 41
[3] Wetted Surface Area Calculations taken from page VS22 in the Consolidated Relief Valve Databook, Valve Sizing Section.
[4] API STD 521, 5th edition, "Heat Absorption to Liquids", Equation 6, pg. 40 (with adequate draining and firefighting equipment)
[5] Wetted Surface Area Calculations taken from page 439 in the Pressure Vessel Handbook, 13th Ed. By Eugene F. Megyesy.

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Athlon Solutions Bayport Texas	Date: 05/01/19 Revision: A	Created By: DES Checked By: 0

Fire Case Orifice Calculation - Vapor Relief

PSV INFORMATION

PSV Number:	New PSV
Vessel Item #	T-31
Vessel Description:	Storage Tank
Flow Sheet Reference #:	New P&ID
Relieving State:	Vapor
Sizing Basis:	15: Exterior Fire

INPUTS

Flowrate, **W** (lb/hr) =	40755.8	
Relieving Temperature, **T** (deg F) =	459	
Ratio of Specific Heats, **k** =	1.06	
Coefficient of the ratio of specific heats[1], **C** =	322.0	$C = 520\sqrt{k\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$
Compressibility Factor, **Z** =	1	
Molecular Weight, **M** =	126.6	
Ratio of P_2/P_1, **r** =	0.3471	
Coefficient of Subcritical Flow[2], $\mathbf{F_2}$ =	0.4612	$F_2 = \sqrt{\left(\frac{k}{k-1}\right)(r)^{\frac{2}{k}}\left[\frac{1-r^{\frac{(k-1)}{k}}}{1-r}\right]}$
Critical Flow Pressure Ratio[3], $\mathbf{P_{cf} / P_1}$ =	0.594	
Set Pressure, P (psig) =	30	
PSV Type (conv, pilot, bellows) =	Conventional	
Back Pressure, **P2** (psig) =	3	
Back Pressure Correction Factor, $\mathbf{K_b}$ =	1.0	K_b=1.0 for conventional
Manufacturer Coefficient of Discharge[5], $\mathbf{K_d}$ =	0.975	
Combination Correction Factor for Rupture Disks, $\mathbf{K_c}$ =	0.9	Kc=1.0 if rupture disk not installed, else 0.9, if MFG not available

CALCULATIONS:

Upstream Relieving Pressure: $\mathbf{P_1}$ (psig) =	36.3	Set pressure + 21% allowable overpressure
Critical Flow Area Calculation[2], **A** =	7.621	in^2
Sub-critical Flow Area Calculation[4], **A** =	Critical Flow	in^2
Available Orifice Area, $\mathbf{A_v}$ =	6.380	in^2
Valve Maximum Flowrate = W * (Av / A)	34121.3	lbs/hr

$$A = \frac{W}{CK_dP_1K_bK_c}\sqrt{\frac{TZ}{M}}$$

$$A = \frac{W}{735 * F_2K_dK_c}\sqrt{\frac{ZT}{MP_1(P_1 - P_2)}}$$

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

Athlon Solutions Bayport Texas	Date: 05/01/19 Revision: A Relief Valve No.: New PSV	Created By: DES Checked By:

INLET PIPING CALCULATIONS

Inlet Piping Segments

Sizing Basis:

15: Exterior Fire

Pipe Size (nominal diameter) =	8.00	inches				
Pipe Inside Diameter, **d** =	7.981	inches				
Pipe Spec =						
Pipe Schedule =	Sch 40					
[5]Moody Friction Factor, ***f*** =	0.014					
Total Length of Straight Pipe, **L** =	1.0 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=	5.4 ft	# Valves=	1	L_{eq}/d = 8		
[1]Equivalent Length of Ball Valve =		# Valves=		L_{eq}/d = 3		
[4]Equivalent Length of Rupture Disc =	17.6 ft	K-factor=	0.37			
[1]Equivalent Length of Entrance Loss =	23.8 ft	K-factor=	0.5	Crane pg. A-29		
Equivalent Length of Reducer =	30.1 ft	[6]K-factor=	0.63		Reduced id =	6.065
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, L_{eq} =	**76.9 ft**	as 8 in. pipe				

Inlet Piping Stream Properties

Relief Rate of Liquid or Vap Valve Capacity, **W** =	34,121	lb/hr	
Set Pressure =	30	psig	
Inlet Piping Temperature =	459	ºF	919.0 ºR
Molecular Weight =	126.60	lb/lbmol	
Density in Inlet Line =	0.65	lb/ft^3	
Viscosity in Inlet Line =	0.01	cp	
[7]Reynolds Number (Re) in Inlet Line =	2,584,025.88	(Laminar flow occurs when Re ≤ 2000.)	

Inlet Line Pressure Drop Calculation

Total Equivalent Length (valves & fittings), L_{eq} =	76.9	ft
Friction Factor, ***f*** =	0.014	
Total Straight Pipe Length, L =	1.0	ft
Friction Factor (straight pipe), ***f*** =	0.014	
Inside Diameter of Piping, d =	7.981	in
Inlet Piping, Total Pressure Drop, ΔP_{psi} =	0.20	psi
ΔP_{psi}, Percent of Set Pressure =	0.67	%[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:

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

ReCon Management • Engineering Inspection

Athlon Solutions Bayport Texas	Date: 05/01/19 Revision: A Relief Valve No.: New PSV	Created By: DES Checked By:

INLET PIPING CALCULATIONS

Inlet Piping Segments

Sizing Basis:

13: Chemical Reaction

Pipe Size (nominal diameter) =	8.00 inches			
Pipe Inside Diameter, **d** =	7.981 inches			
Pipe Spec =				
Pipe Schedule =	Sch 40			
[5]Moody Friction Factor, ***f*** =	0.014			
Total Length of Straight Pipe, **L** =	1.0 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=	5.4 ft	# Valves=	1	L_{eq}/d = 8
[1]Equivalent Length of Ball Valve =		# Valves=		L_{eq}/d = 3
[4]Equivalent Length of Rupture Disc =	17.6 ft	K-factor=	0.37	
[1]Equivalent Length of Entrance Loss =	23.8 ft	K-factor=	0.5	Crane pg. A-29
Equivalent Length of Reducer =	30.1 ft	[6]K-factor=	0.63	Reduced id = 6.065
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, L_{eq} =	**76.9 ft**	as 8 in. pipe		

Inlet Piping Stream Properties

Relief Rate of Liquid or Vap Valve Capacity, **W** =	13,957	lb/hr
Set Pressure =	30	psig
Inlet Piping Temperature =	212	ºF (672.0 ºR)
Molecular Weight =	36.46	lb/lbmol
Density in Inlet Line =	0.25	lb/ft^3
Viscosity in Inlet Line =	0.02	cp
[7]Reynolds Number (Re) in Inlet Line =	641,911.32	(Laminar flow occurs when Re ≤ 2000.)

Inlet Line Pressure Drop Calculation

Total Equivalent Length (valves & fittings), L_{eq} =	76.9	ft
Friction Factor, ***f*** =	0.014	
Total Straight Pipe Length, L =	1.0	ft
Friction Factor (straight pipe), ***f*** =	0.014	
Inside Diameter of Piping, d =	7.981	in
Inlet Piping, Total Pressure Drop, ΔP_{psi} =	0.09	psi
ΔP_{psi}, Percent of Set Pressure =	0.29	%[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]:

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

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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Athlon Solutions Bayport Texas	Date: 05/01/19 Revision: A Relief Valve No.: New PSV	Created By: DES Checked By:

OUTLET PIPING CALCULATIONS

Outlet Piping Segments

Sizing Basis:
15: Exterior Fire

Pipe Size (nominal diameter) =	8.00	inches			
Pipe Inside Diameter, **d** =	7.981	inches			
Pipe Spec =					
Pipe Schedule =	Sch 40				
[5]Moody Friction Factor, ***f*** =	0.014				
Total Length of Straight Pipe, **L** =	10.0 ft				
[1]Equivalent Length of 90º Elbows =	20.0 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 =	47.6 ft	K-factor=	1	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, L_{eq} =	**67.6 ft**	as 8 in. pipe			

Outlet Piping Stream Properties

Relief Rate of Liquid or Vap Valve Capacity, **W** =	34,121	lb/hr
Relief Valve Set Pressure =	30	psig
[c]Header Pressure, P_H =	14.70	psia
Outlet Piping Temperature, **T** =	668	ºR
Ratio of Specific Heats at Outlet Conditions, **k** =	1.1	
Gas Compressibility Factor, **Z** =	1.0000	
Gas Relative Molecular Weight, **M** =	126.6	lb/lbmol
[2]Mach Number at Pipe Outlet, Ma_2 =	0.205	
Set Outlet Line Outlet Pressure, P_o =	14.70	psia
Liquid Density in Outlet Line, ρ_L =	0.19	lb/ft3
Vapor Average Density in Outlet Line, ρ_V =		lb/ft^3
Viscosity in Outlet Line =	0.01011	cp
[8]Reynolds Number (Re) in Outlet Line =	2,668,370.94	(Laminar flow occurs when Re ≤ 2000.)

psig
208.00 ºF

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

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, P_{crit} =	3.02	psia
Total Equivalent Length (valves and fittings), L_{eq} =	67.6	ft
Moody Friction Factor, ***f*** =	0.014	
Line Diameter, **d** =	8.00	in
Total Straight Pipe Length, **L** =	10.0	ft
Friction Factor (straight pipe), ***f*** =	0.014	
Inside Diameter of Piping at Header, d_H=	7.981	in
Valve Design Backpressure Allowed =	10%	
Max Back Pressure Allowed, P_B=	17.70	psia
Outlet Line Avg. Press. at Max BP Allowed, P_{AVG}=	16.20	psia [b]
[3]Outlet Piping Pressure Drop, ΔP_{psi} =	0.69	psi
Calculated Outlet Piping Back Pressure, BP_C=	0.69	psig
Pressure Drop, Percent of Set Pressure =	**2.3000%**	[a]
[7]Reaction Force for **Atmospheric Relief Valves,** F=	**188.03**	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 Solutions Bayport Texas	Date: 05/01/19 Revision: A Relief Valve No.: New PSV	Created By: DES Checked By:

OUTLET PIPING CALCULATIONS

Outlet Piping Segments

Sizing Basis:

13: Chemical Reaction

Pipe Size (nominal diameter) =	8.00	inches				
Pipe Inside Diameter, **d** =	7.981	inches				
Pipe Spec =						
Pipe Schedule =	Sch 40					
[5]Moody Friction Factor, ***f*** =	0.014					
Total Length of Straight Pipe, **L** =	10.0 ft					
[1]Equivalent Length of 90° Elbows =	20.0 ft		# Elbows=	1	L_{eq}/d = 30	
[1]Equivalent Length of 90° Long Radius Elbows =			# Elbows=		L_{eq}/d = 20	
[1]Equivalent Length of 45° 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 =	47.6 ft		K-factor=	1	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, L_{eq} =	**67.6 ft**	as 8 in. pipe				

Outlet Piping Stream Properties

Relief Rate of Liquid or Vap Valve Capacity, **W** =	13,957	lb/hr		
Relief Valve Set Pressure =	30	psig		
[c]Header Pressure, P_H =	14.70	psia		psig
Outlet Piping Temperature, **T** =	907	°R	447.00	°F
Ratio of Specific Heats at Outlet Conditions, **k** =	1.4			
Gas Compressibility Factor, **Z** =	1.0000			
Gas Relative Molecular Weight, **M** =	36.5	lb/lbmol		
[2]Mach Number at Pipe Outlet, Ma_2 =	0.182			
Set Outlet Line Outlet Pressure, P_o =	14.70	psia		
Liquid Density in Outlet Line, ρ_L =		lb/ft3		
Vapor Average Density in Outlet Line, ρ_V =	0.06	lb/ft³		
Viscosity in Outlet Line =	0.01703	cp		
[8]Reynolds Number (Re) in Outlet Line =	647,942.20	(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, P_{crit} =	2.68	psia
Total Equivalent Length (valves and fittings), L_{eq} =	67.6	ft
Moody Friction Factor, ***f*** =	0.014	
Line Diameter, **d** =	8.00	in
Total Straight Pipe Length, **L** =	10.0	ft
Friction Factor (straight pipe), ***f*** =	0.014	
Inside Diameter of Piping at Header, d_H=	7.981	in
Valve Design Backpressure Allowed =	10%	
Max Back Pressure Allowed, P_B=	17.70	psia
Outlet Line Avg. Press. at Max BP Allowed, P_{AVG}=	16.20	psia [b]
[3]Outlet Piping Pressure Drop, ΔP_{psi} =	0.37	psi
Calculated Outlet Piping Back Pressure, BP_C=	0.37	psig
Pressure Drop, Percent of Set Pressure =	**1.2333%**	[a]
[7]Reaction Force for **Atmospheric Relief Valves,** F=	**163.53**	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: $\frac{L_{eq}}{D} = 890.4256\frac{d^4}{f * Cv^2}$