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Management • Engineering
Inspection

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

Fire Case 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:	15: Exterior Fire

INPUTS

Flowrate, **W** (lb/hr) =	1836.2	
Relieving Temperature, **T** (deg F) =	387.7	
Ratio of Specific Heats, **k** =	1.20	
Coefficient of the ratio of specific heats[1], **C** =	336.8	$C = 520\sqrt{k\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$
Compressibility Factor, **Z** =	0.9088	
Molecular Weight, **M** =	18.02	
Ratio of P_2/P_1, **r** =	0.0721	
Coefficient of Subcritical Flow[2], $\mathbf{F_2}$ =	0.1683	$F_2 = \sqrt{\left(\frac{k}{k-1}\right)(r)^{\frac{2}{k}}\left[\frac{1-r^{\frac{(k-1)}{k}}}{1-r}\right]}$
Critical Flow Pressure Ratio[3], $\mathbf{P_{cf} / P_1}$ =	0.565	
Set Pressure, P (psig) =	165	
PSV Type (conv, pilot, bellows) =	Conventional	
Back Pressure, **P2** (psig) =	0.75	
Back Pressure Correction Factor, $\mathbf{K_b}$ =	1.0	K_b=1.0 for conventional
Manufacturer Coefficient of Discharge[5], $\mathbf{K_d}$ =	0.8	
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) =	199.65	Set pressure + 21% allowable overpressure
Critical Flow Area Calculation[2], **A** =	0.208	in^2
Sub-critical Flow Area Calculation[4], **A** =	Critical Flow	in^2
Available Orifice Area, $\mathbf{A_v}$ =	0.221	in^2
Valve Maximum Flowrate = W * (Av / A)	1952.3	lbs/hr

$$A = \frac{W}{CK_d P_1 K_b K_c}\sqrt{\frac{TZ}{M}}$$

$$A = \frac{W}{735 * F_2 K_d K_c}\sqrt{\frac{ZT}{MP_1(P_1 - P_2)}}$$

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

Engineering Analysis: HYSYS Properties: Inlet Piping

PSV INFORMATION

PSV Number:	PSV-XX2
Valve Type:	Conventional
Relieving State:	Vapor
Sizing Basis:	15: Exterior Fire

Material Stream: 1

Worksheet | Attachments | Dynamics

Worksheet
Conditions
Properties
Composition

Stream Name	1	Vapour Phase
Vapour / Phase Fraction	1.0000	1.0000
Temperature [F]	387.7	387.7
Pressure [psig]	199.6	199.6

Material Stream: 1

Worksheet | Attachments | Dynamics

Worksheet
Conditions
Properties
Composition
Oil & Gas Feed
Petroleum Assay
K Value
User Variables
Notes
Cost Parameters
Normalized Yields

Stream Name	1	Vapour Phase	Aqueous Phase
Molecular Weight	18.02	18.02	18.02
Z Factor	<empty>	0.9088	7.844e-003
Mass Density [lb/ft3]	0.4673	0.4673	54.14
Mass Heat of Vap. [Btu/lb]	837.7	<empty>	<empty>
Cp/(Cp - R)	1.196	1.196	1.115
Viscosity [cP]	1.556e-002	1.556e-002	0.1355

Notes

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

Engineering Analysis: HYSYS Properties: Outlet Piping

PSV INFORMATION

PSV Number:	PSV-XX2
Valve Type:	Conventional
Relieving State:	Vapor
Sizing Basis:	15: Exterior Fire

Material Stream: 1

Worksheet | Attachments | Dynamics

Worksheet: Conditions, Properties, Composition

Stream Name	1	Vapour Phase
Vapour / Phase Fraction	1.0000	1.0000
Temperature [F]	212.0	212.0
Pressure [psig]	0.0000	0.0000

Material Stream: 1

Worksheet | Attachments | Dynamics

Worksheet: Conditions, Properties, Composition, Oil & Gas Feed, Petroleum Assay, K Value

Stream Name	1	Vapour Phase	Aqueous Phase
Molecular Weight	18.02	18.02	18.02
Z Factor	<empty>	0.9846	6.142e-004
Mass Density [lb/ft3]	3.730e-002	3.730e-002	59.80
Cp/(Cp - R)	1.294	1.294	1.123
Viscosity [cP]	1.203e-002	1.203e-002	0.2790

Notes

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

Fire Case Relief Requirement Calculation for Vessels - Inadquate Drainage/Fire Fighting Equipment

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:	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 =	E		F = Flat, H = Hemispherical, E = Elliptical
D =	1.96	ft	Vessel diameter
HLL =	16.00	ft	High liquid level
L =	16.00	ft	Length of vessel, T/T [1]
H =	5	ft	Vessel elevation
F =	1.00		Environmental factor[2]
Latent Heat of Vap., λ =	837.7	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
$E_{vertical}$ =	16.0	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} =		ft²	[3]Total Wetted Area of a Vertical Vessel with HEMISPHERICAL Ends
Vertical Vessel, A_{Vws} =	102.6	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} =	103	ft²	Total wetted surface area
Q =	1,538,219	Btu/hr	Total heat absorption (input) to the wetted surface[4] $Q = 34{,}500 * F * A_{ws}^{0.82}$
W =	1,836	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 (without 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 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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Athlon Bayport, TX	Date: 10/29/19 Revision: A Relief Valve No.: PSV-XX2	Created By: CJM Checked By:

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, 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, 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, Ma_2 = 0.493
Set Outlet Line Outlet Pressure, P_o = 14.70 psia

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

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

Liquid Density in Outlet Line, ρ_L = lb/ft3
Vapor Average Density in Outlet Line, ρ_V = 0.08 lb/ft³
Viscosity in Outlet Line = 0.012 cp
[a]Reynolds Number (Re) in Outlet Line = 511,933.50 (Laminar flow occurs when Re ≤ 2000.)

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

Outlet Line Pressure Drop Calculation

Critical absolute pressure, P_{crit} = 7.25 psia
Total Equivalent Length (valves and fittings), 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, 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_{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 Bayport, TX	Date: 10/29/19 Revision: A	Created By: CJM Checked By: 0

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

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:	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 =	E		F = Flat, H = Hemispherical, E = Elliptical
D =	1.96	ft	Vessel diameter
HLL =	16.00	ft	High liquid level
L =	16.00	ft	Length of vessel, T/T [(1)]
H =	5	ft	Vessel elevation
F =	1.00		Environmental factor[(2)]
Latent Heat of Vap., λ =	851	btu/lb	From process simulation calculations (at relieving conditions)

CALCULATIONS

Spherical Vessel, A_{Sws} =		ft^2	Total Wetted Area of a Spherical Vessel Per API 521
Spherical Vessel, A_{Sws} =		ft^2	Total Wetted Area of a Spherical Vessel Per API 2000
$E_{vertical}$ =	16.0	ft	Effective liquid level (up to 25 ft from the flame source)
Vertical Vessel, A_{Vws} =		ft^2	[(3)]Total Wetted Area of a Vertical Vessel with FLAT Ends
Vertical Vessel, A_{Vws} =		ft^2	[(3)]Total Wetted Area of a Vertical Vessel with HEMISPHERICAL Ends
Vertical Vessel, A_{Vws} =	102.6	ft^2	[(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} =		ft^2	[(3)]Total Wetted Area of a Horizontal Vessel with FLAT Ends
Horizontal Vessel, A_{Hws} =		ft^2	[(3)]Total Wetted Area of a Horizontal Vessel with HEMISPHERICAL Ends
Horizontal Vessel, A_{Hws} =		ft^2	[(5)]Total Wetted Area of a Horizontal Vessel with ELLIPTICAL Ends
A_{ws} =	103	ft^2	Total wetted surface area
Q =	936,307	Btu/hr	Total heat absorption (input) to the wetted surface[(4)] $Q = 21{,}000 * F * A_{ws}^{0.82}$
W =	1,100	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.

Athlon
Bayport, TX

Date: 10/29/2019
Revision: A

Created By: CJM
Checked By: 0

Fire Case Relief Requirement Calculation - Vapor Expansion

PSV CALCULATION SHEET

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:	Fire

INPUTS

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 =	E		F = Flat, H = Hemispherical, E = Elliptical
D =	1.96	ft	Vessel diameter
L =	16.00	ft	Length of vessel, T/T (1)
H =	5.00	ft	Vessel elevation
MW =	18.02		Molecular weight of the gas
P_n =	0	psig	Normal operating gas pressure
T_n =	70	^oF	Normal operating gas temperature
T_w =	1100	^oF	Max. vessel wall temp (Assume 1100 ^oF for Carbon Steel Vessel)
Set Pressure =	0	psig	
	21	%	Allowable overpressure (fire case)

CALCULATIONS

M =	18.0	lb/mol	Molecular weight of the gas or vapor
p_n =	14.7	psia	Normal operating gas absolute pressure
p_1 =	14.7	psia	Upstream relieving pressure (set pressure + allowable overpressure +atm. pressure)
T_n =	530	^oR	Normal operating gas absolute temperature
T_w =	1560	^oR	Recommended maximum vessel wall temperature
T_1 =	530	^oR	Gas absolute temperature, at the upstream relieving pressure T1 =(P1 / Pη) * Tη
A' =	102.6	ft²	Exposed surface area of the vessel
q_m =	**1,005.2**	lb/hr	Relief Load Vapor(2)

$$q_m = 0.1406\sqrt{M * p_1}\,\frac{A'(T_w - T_1)^{1.25}}{T_1^{1.1506}}$$

NOTES

REFERENCES

(1) This spreadsheets calculates the wetted area for a HORIZONTAL or VERTICAL vessel.

(2) API STD 521, 5th edition, "Heat Absorption Equations for Vessels", Equation 12, pg. 43. This calculation is used to determine the required relief rate for vapor expansion during a fire.

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

ReCon Management • Engineering Inspection

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	$R = \frac{Q(2800 \times G)}{\mu\sqrt{A_v}}$	
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	$K_v = \left(0.9935 + \frac{2.878}{R^{0.5}} + \frac{342.75}{R^{1.5}}\right)^{-1.0}$	
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	$A_{cert} = \frac{Q}{38K_dK_wK_cK_v}\sqrt{\frac{G}{p_1 - p_2}}$
Required Orifice Area for a *Non-Certified* Liquid Relief Valve [8], $\mathbf{A_{non\text{-}cert}}$ =	N/A	in^2	$A_{non\text{-}cert} = \frac{Q}{38K_dK_wK_cK_vK_p}\frac{G}{1.25p - p_b}$
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