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PRESSURE RELIEF DEVICE EVALUATON

FOR:

PRV-01288, 01388 & 01488 Rev F

FL0001A, B and C

Southern Company Services

In accordance with ASME Section VIII Division I - 2010

Equipment is protected from overpressure: ☑ Yes ☐ No

PRD is installed correctly: ☐ Yes ☐ No

Corrective Action Required: ☐ Yes ☑ No

Comments: It is assumed that the pipe is designed for at least 150 psig and that the inlet water pump cannot exceed 150 psig. Surface area of top head has been included in fire case calculations based on the assumption that the candles will allow flow between the two parts of the vessel during the fire case.
Set pressure is at vessel MAWP, 150 psig. Relief area has been increased to next larger size to provide safety factor for valves involving two phase flow. This results in a "K" orifice in a 3"x4" valve or 4"x6" valve. Valve to be installed with minimum length inlet piping (4") and reducer at valve inlet.

Engineer:	William J. Heron	Date:	9-Nov-11
Checked By:	Gordon F. Wilson	Date:	12-Dec-11
Revised/Checked:	Gordon F. Wilson	Date:	26-Jan-12

Revision D - confirmed set point to be 114 psig for all sheets.
Revision E - corrected discharge piping backpressure labelling and incorporated piping sketches
Revision F - changed set pressure to 150 psig which changed fluid properties. Deleted page of Flash calculations as it is not applicable.

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PRD SCENARIO SUMMARY

Client and Location	Southern Company Services	Perigon project no.	109874
Project	Gasifier Island Coal Candle Filter	By/date	WJH/Nov 9 2011
Pressure Relief Device No.	PRV-01288, 01388 & 01488	Checked by/date	GFW/1/26/12
P&ID Number	600179925 Rev F	Revised by/date	WJH/1/26/12
Equipment Number	FL0001A, B and C	Revision Number	F
Equipment Drawing Number	2011-WC-8068		
Vessel Decription	Candle Filter		
Design Pressure	150 psig		
Design Temperature	350 Deg F		
Set Pressure	150 psig		
Fluid Relieved by PRD	Water		

CAUSES OF RELIEF	EVALUATED	PERCENT OVER-PRESSURE	RELIEF LOAD VAPOR FLOW LB/HOUR	RELIEF LOAD LIQUID FLOW LB/Hour	RELIEF (2) CONDITIONS PRESSURE PSIG	RELIEF (2) CONDITIONS TEMP. DEG F	VAPOR AREA SQ IN.	LIQUID AREA SQ IN.	REQUIRED AREA SQ IN.
1. BLOCKED DISCHARGE	Not App.								
2. COOLANT SUPPLY FAILURE	Not App.								
3. REFLUX FAILURE TO TOP OF TOWER	Not App.								
4. REFLUX FAILURE TO SIDE OF TOWER	Not App.								
5. ACCIDENTAL MIXING	Not App.								
6. POWER FAILURE	No Relief								
7. ACCUMULATION OF NON-CONDENSIBLES	Not App.								
8. FAILURE OF AUTOMATIC CONTROLS	No Relief								
9. ABNORMAL HEAT OR VAPOR INPUT	Not App.								
10. INADVERTENT VALVE OPENING	No Relief								
11. CHEMICAL REACTION	See Fire								
12. THERMAL EXPANSION	Not App.								
13. JACKET EXTERIOR FIRE	Not App.								
14. SHELL EXTERIOR FIRE	Yes	21%	3274		196	380			0.446
15. COIL RUPTURE	Not App.								
16. UTILITY FAILURE	No Relief						See Note Below		
17. CLOSED OUTLET ON FIRED HEATER	Not App.								
18. LOSS OF ABSORBENT	No Relief								
19. ABNORMAL FLOW THROUGH VALVE	No Relief								
20. Other (Specify)	None								

SIZING BASIS: Fire Case DESCRIPTION:

Comments:		Req'd Size	
	This relief valve will operate under three separate conditions in the fire case.		
	Liquid Flow (while liquid is cleared from the inlet nozzle)	1.162	
	Vapor Flow (when liquid carryover ceases)	0.446	
	Two Phase Flow (while liquid is carried over by vapor))	0.467	
	Generally recommended practice is to use twice the required size	**1.162**	This requires a **"J"** orifice USE NEXT SIZE UP DUE TO UNCERTAINTY AROUND TWO PHASE FLOW

Prepared For: **Southern Company Services**

Location
Project Title 109874
Project # 109874
Specification #

C = Change
A = Addition
D = Deletion

Spring-Loaded Pressure Relief Valve Specification

Originated By 12/21/2011 — Origin Date 12/21/2011
Revision # F — Revision Date 1/26/2012

Identification				
1	Valve Tag #		**PRV-01288, 01388 & 01488**	
2	System Name		Gasifier Island Coal Candle Filter	
3	P&ID Drawing #	Vendor Drawing #		2011-WC-8068
4	Project #	Site	109874	
5	Manufacturer			
6	Manufacturer's Model No.			
7	Conventional or Balanced Bellows	Auxiliary Nameplate (Yes or No)	Conventional	No
8	Size: Inlet	Outlet inches	3" x 4"	
9	Inlet Connection Type - Class	Outlet Connection Type - Class	150#RF	150# RF
10	Orifice Letter (if applicable)	Area (Sq in)	K	2.042
Service Conditions				
11	System Design Pressure (psig)	Design Temperature °F	150	350
12	System Allowable Accumulation %		21%	
13	Fluid	State (Gas, Liquid or Two-phase)	Water	Two Phase
14	Operating Pressure, Minimum	Maximum Psig	75.0	90
15	Operating Temperature, Minimum	Maximum °F	70	90
16	Relief Temperature	°F	380	
17	Molecular Weight (Gas or Vapor)	Ratio of Specific Heats	18.02	1.29
18	Specific Gravity at Relieving Conditions (Liquid)		0.937	
19	Viscosity at Relieving Conditions, cp	Compressibility Factor	0.130	1.000
20	Valve Set Pressure	Cold Differential Test Pressure Psig	**150**	150.0
21	Built-Up Back Pressure,	psi	4.50	
22	Superimposed Back Pressure, Min	Maximum psig	0.0	1.7
23	Back Pressure Correction Factor Kb		1.00	
24	Device Required Relief Rate	lbs/hr	3274.0	Note 5 of Water
25	Rated Capacity @ 21%	% Overpressure lbs/hr	*	of Water
26	Name Plate Capacity 21%	% Overpressure lbs/hr	*	
27	Rupture Disc (Yes/No)	Combination Capacity Factor Kc	NA	NA
28	Actual Capacity @ Maximum Allowable Relieving Pressure (Units & Fluid)			Water
29	ASME & N.B. Stamp (Yes/No)	Applicable Section	Yes	VIII
30	ASME Code Case Number, if applicable		NA	
31	Test Frequency (specify months or years)		Once per year	
Materials of Construction				
32	Body or Base	Bonnet	CS	CS
33	Nozzle	Disc	CS	CS
34	Bellows	Coating	NA	NA
35	Spring	Button or Washer	17-7PH	
36	O-Ring	Durometer	Teflon	
37	Inlet Flange	Outlet Flange	CS	CS
38	Cap		CS	
Auxiliary				
39	Test Lever (Yes or No)	Type (Open or Packed)	Yes	Packed
40	Gag (With or Without)	Field Test Connection (Yes or No)	Without	No
41				

Notes
1. ** indicates information to be provided by vendor
2. Name Plate capacity to be stamped in GPM of water, PPH of Steam, or Scfm of Air at indicated overpressure
3. Vendor shall attach a SS nameplate, 1/16" thick, with 3/16" stamped, etched or pressed letters with following information: Plant - , Project # , EN# , Model #, Serial #, Manufacturer, date of Manufacture, Purchase Order #.
4. Vendor shall provide 3 copies of dimensional drawings, installation, operation, and maintenance Manuals.
5. Size for given flow then use next larger size standard orifice.

Quality Record

Approved

FIRE CASE

C = Change
A = Addition
D = Deletion

PROJECT #	**109874**	TITLE:	DEVICE #	PRV-01288, 01388 and 01488
WHICH FIRE CODE IS TO BE USED? (NFPA, API, ASHRAE, NA)				**API**
Are the fire case calculations needed **ONLY** in order to get heat up rate for liquid expansion case (Y/N)				**N**
Are these calculations needed **ONLY** for surface areas, volumes of equipment or 2 phase flow check (Y/N)				**Y**

DATA REQUIRED FOR EXTERNAL FIRE CASE

	1st Section	2nd Section	3rd Section	4th Section
Description of section	Tank			
Diameter in feet (D1)	5.500			
Straight Length in feet (L1)	8.469			
Hor/Vert/Sphere (H/V/S)	V			
% of Total Vessel Height that is wetted	100.00			
1st/Top Head (1=Elip,2=Hem,3=ASME dish,4=Cone,5=Flat,6=Std dish	1			
2nd/Bot Head (1=Elip,2=Hem,3=ASME dish,4=Cone,5=Flat,6=Std dish	4			
Bottom Cone Length (if applicable), ft	4.750			
Angle of cone from vertical (for conical heads only)	60.00			
Percentage of the top (end) that is exposed	100			
Percentage of bottom (end) that is exposed	100			
Percentage of shell that is exposed	100			
How many segments of this vessel are identical to = #Seg =	1			

section #1. I.E. a spinning machine would have several blocks that are interconnected to form one large tank. UG133.c

Note 1 Percentage of liquid height is not equal to volume % full except at 50% full.
Note 2 A condenser would be 100% filled because entire surface is wetted.
Note 3 For air cooled condensers: Fins are destroyed early in fire, wetted surface area is .3 times bare tube area for sections without subcooling, wetted surface area = bare tube area for subcooling sections.
Per API 521 sect 3.15.17.1. Q= 21,000 or 34,000 * F * A .
Is 1st Section an air cooled condenser (Y/N)? N
Note 3 The jacketed portion of a vessel or pipe is not normally counted as exposed.
Note 4 Program automatically corrects exposed area for vessels taller than 25'.
Note 5 For Ashrae cases do not enter data for associated piping.

CALCULATON OF VAPOR AND LIQUID VOLUMES Volume of partially filled dished ends is approximation

	HEAD #1	HEAD #2	CONE	SHELL	TOTAL
V1 = Volume of First Section, ft^3	21.8	12.6	37.6	201.2	273.1
V2 = Volume of Second Section, ft^3					
V3 = Volume of Third Section, ft^3					
V4 = Volume of Fourth Section, ft^3					

	LIQ VOL, cu ft	% Full	VAP VOL, cu ft
V1 =	273.1	100.0%	0.0
V2 =			
V3 =			
V4 =			
VL = Liquid Volume = VL1 + VL2 + VL3			273.15
VG = Vapor volume = Total Volume - Liquid Volume			0.00

IF Heat up Time is desired, Enter wall thickness

	Sec 1 Thickness, I	Sec 2, Thick, In
Shell	0.375	
Top or End 1	0.333	
Bottom or End 2	0.375	

A = EXPOSED WETTED SURFACE AREA (FT^2)
NFPA-30 assumes vessels are 90% full and uses factors below. OSHA 1910.106 follows NFPA and both apply only to "Storage Tanks".

EWS = 55% of total exposed surface area of sphere is wetted surface
EWS = 75% of total exposed surface area of horizontal tank is wetted surface
EWS = First 30' of surface area of vertical tank is wetted surface (API 520 uses 25'.)

API requires calculations to determine the actual wetted surface area and applies to all tanks. Engineering judgement can exclude top or portion of top of vertical tanks in API calcs.
NFPA, API & OSHA do not comment on whether the jacketed area of jacketed vessels is considered to be "Exposed Wetted Suface Area". Use engineering judgment

CALCULATION OF SURFACE AREA

	A = Area 1st Section (A1) + Area 2nd Section (A2) + Area 3rd Section (A3)						NFPA TOTAL EXP. AREA TIMES EWS%	
	NFPA EWS %	NFPA EXPOSED SHELL	API 520 SHELL EXPOSED	API 520 SHELL WETTED	HEAD ACTUAL AREA TOP/1ST HD	HEAD ACTUAL AREA BOT/2ND HD		
1st	1	146.3	146.3	146.3	36.0	27.4	209.8	
2nd								
3rd								
4th								
	WETTED AREA TOP/1ST HD	WETTED AREA BOT/2ND HD	EXPOSED & WET AREA TOP/1ST HD	EXPOSED & WET AREA BOT/2ND	TOT EXP. WET AREA	EXPOSED AREA		
1st	36.0	27.4	36.0	27.4	209.8	209.8		
2nd								
3rd							Calculated Areas	Area to be Used in Calcs
4th								
Exposed Wetted Surface Area Per OSHA 1910.106 & NFPA 30 = A =						1x209.8 =	209.8	209.8
Exposed Dry Area For Vapor Pres. Rise (API-520) = Exp. Area - Exp. Wet Area =						209.8 - 209.8 =	0.0	0.0
Exposed Wetted Surface Area Per API 520 (At % Full) = A =						209.8 =	209.8	209.8

HEAT INPUT FROM FIRE

8/15/2011

From NFPA 30 Appendix B — **NFPA Equations**

For Areas <200 Ft^2	Q= 20,000 * F * A
For Areas >200 but <1000 Ft^2	Q= 199,300 * F * A^.566
For Areas >1000 but <2800 Ft^2	Q= 963,400 * F * A^.338
For Areas > 2800 Ft^2 and Pressure > 1 Psig	Q= 21,000 * F * A^.82
For Areas > 2800 Ft^2 and Pressure < 1 Psig	Q= 963,400 * F * A^.338with A set at 2800

From API 521 — **API 521 Equat. (Sect 3.15.2.1.1)**

For areas with good drainage and near fire fighting equipment	Q= 21,000 * F * A^.82
For areas without good drainage and fire fighting equipment	Q= 34,500 * F * A^.82

Q = Total heat absorption (input) to the wetted surface, in BTU/HR

F = Environment factor for tanks containing stable liquids:
Stable liquids will not react due to shock, temp, or pressure changes
Good drainage means slope of >=1% away from tank for at least 50 ft.
Insulation must remain in place during fire when hoses directed at it
Can only use one factor for each vessel.

NFPA 30 Factors (Section 2-3.5.7)

F = 1 for unprotected vessels
F = .5 for vessels protected by good drainage and with wetted area > 200 Ft^2. Good drainage is defined as having at least 1% slope from tank to collection area at least 50' away which has capacity >= to the tank.
F = .3 for vessels protected by water spray and good drainage
F = .3 for vessels protected by insulation with conductivity <=4 at mean insulation temp of 1000F
F = .15 for vessels protected by insulation, water spray and good drainage
Divide F above by 2 **IF**:
Heat of Combustion AND burn rate are <= ethanol
And liquid is miscible with water
And Only fire potential is spillage of this liquid

API Factors

F = 1 for bare vessels
F = 1 for vessels with water spray
For insulated vessels (from Table 5):
(Insulation must be nonflammable and must be secured with **Steel or SS** metal jacket)

API-521 Table 5

F	Conductivity/thickness at Relieving Temp
F=.3	4 BTU/Hr Ft^2 F
F=.15	2
F=.075	1
F=.05	.67
F=.0376	.6
F=.03	.4
F=.026	.33

F = .03 for above grade earth covered.
F=.00 for below grade earth covered

Section #1	Section #2	Section #3
Conductivity (BTU In/ Hr Sq Ft Deg F) at Rel		
1.3		
Insulation Thickness (Inches)		
1		

	Heat of Combustion Btu/Lb	Burn Rate Ft / Min
Relieved fluid			
Comparison Fluid	Ethanol	11,932.5	0.0049

Heat of Combustion and Burn Rate Qualify for reduction in F

	F = k (1660-Tf)/(21000 * Thickness)		
Calculated F =	0.1028	1.0000	1.0000
Average F =	0.1028	Lowest F used in API is .026	

Is Drainage good? Y/N	**N**
Will insulation jacket melt? Y/N	**N**

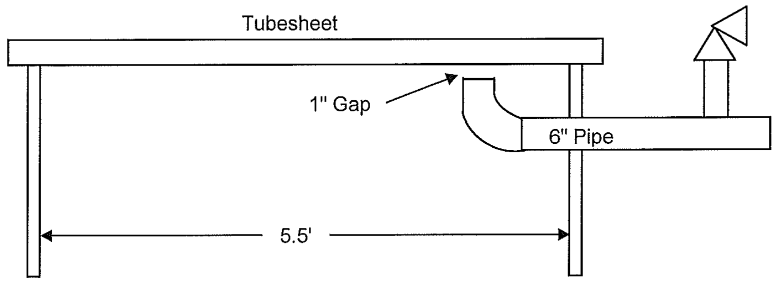
NFPA-30 F= **1.000** Minimum is .15

API-521 Table 5 F = **1.000**

LH = Latent Heat of Evaporated Fluid at relieving temperature			844.4	BTU/LB
Per API	Q= 34,500 * F * A^.82	= 34,500 * 1 * 209.8^.82 =	2,764,604	BTU/HR
Per NFPA	Q= 20,000 * F * A	= 20,000 * 1 * 209.8 =	1,667,610	BTU/HR
RELIEF CAPACITY REQUIRED PER NFPA		Wr = Q/LH (for wet surfaces)	1975	Lbs/Hr
RELIEF CAPACITY REQUIRED PER API		Wr = Q/LH	3274	Lbs/Hr

Note: Fire case assumes all input and output streams stop flowing and all internal heat sources stop. (API 521 Sect 3.19.2.2)

SET PRESSURE REDUCTION CALCULATIONS



6" vent pipe is installed with inlet near tubesheet in order to aid vapor removal during filter fill

Volume above Gap =	1.98 cu ft
Vapor generation rate at 10% overpressure	
3252 / 18.03 * 379.3 / 60 * 14.7 / 179.7 * (460 + 373) / 530 =	147 cu ft/min
Time required to fill the gap with vapor	0.81 seconds

$$Ar = \frac{Q*(G^{.5})}{38.0 * Kd * Kw * Ku * (P1-Pb)^{.5}}$$

Assume Ar is "H" orifice =	0.873 in^2	Assumption during initial release
Q =	435.3 gpm	Based on back pressure of 1 psig
	58.20 cuft/min	
	0.97 cuft/sec	

Volume in pipe before relief inlet (assume 3 ft) 0.59 cu ft

Valve must relieve 1.98 + 0.59 cu ft of liquid before it will begin to relieve vapor
Time Required 2.65 seconds

Vapor generated in the time required to clear liquid = 6.47 cuft

P1V1 = P2V2 Volume of vessel = V1 273.1 cuft
(273.1 + 6.5 - 2.57) * 179.7 / 273.1 = 182.3 psia

This is less than the 196.2 psia allowed by the code for the fire case (21% overpressure)
Therefore the liquid will be cleared from the nozzle before the vessel reaches 196.2 psia.

PERIGON ENGINEERING

				Section 1	Section 2	Section 3	Section 4	
File Name where flow data is located >		Two Phases		PRV to Hdr	Header	Tank to PRV	0.00	
TUBING, PIPE-English or Metric? (Tubing, Pipe E, Pipe M)				Pipe E	Pipe E	Pipe E		
Pipe Sch (5S, 10, 10S, 20, 30, 40S, 40, >> STD, XS, 60, 80, 100, 120, 160, XXS) For Non standard sizes Use A - Z)		Nominal Pipe Size	INCHES	4	6	4		
		Schedule or Tube ID		40	40	40		
		PIPE ID	INCHES	4.026	6.065	4.026		
		ABS. ROUGHNESS	INCHES	0.00015	0.00015	0.00015	0.00015	0.00015
PIPING EXCLUDING FITTING LENGTH		STRAIGHT RUN	FEET	6.00	50.00	3.00		
EQUIVALENT LENGTH OF PIPE FROM COLUMN K			FEET	0.00	0.00	0.00	0.00	
ELBOW	90 DEGREE	ST'D SCREWED (R/D = 1)						
		ST'D FLANGED OR WELDED (R/D=1)						
		LONG RADIUS (R/D = 1.5) ALL TYPES		2	1	1	1	
		OTHER R/D =						
	90 DEGREE (Pipe size smaller than main line)	ST'D SCREWED (R/D = 1)						
		ST'D FLANGED OR WELDED (R/D=1)						
		LONG RADIUS (R/D = 1.5) ALL TYPES						
		ID of smaller pipe, In.						
	90 DEGREE MITERED (R/D = 1.5)	1 BEND (90 Deg Angle)						
		2 BENDS (45 Deg Angle)						
		3 BENDS (30 Deg Angle)						
		4 BENDS (22.5 Deg Angle)						
		5 BENDS (18 Deg Angle)						
	45 DEGREE	STANDARD (R/D=1), all types						
		LONG RADIUS (R/D=1.5), all types						
	45 DEGREE MITERED	1 BEND						
		2 BENDS						
RETURN BEND	180 DEGREE	SCREWED (R/D=1)						
		FLANGED OR WELDED (R/D=1)						
		LONG RADIUS (R/D = 1.5) all types						
TEE	SIDE OUTLET	SCREWED						
		SCREWED, LONG RAD.						
		STD., FLANGED OR WELDED				1		
		STUB-IN BRANCH		1				
	RUN THROUGH	SCREWED						
		FLANGED OR WELDED						
		STUB-IN BRANCH						
VALVE	GATE/BALL OR PLUG	FULL-PORT						
		10% REDUCED PORT						
		20% REDUCED PORT						
	GLOBE	STANDARD						
		ANGLE OR Y-TYPE						
	DIAPHRAGM							
	BUTTERFLY							
	CHECK	LIFT-TYPE						
		SWING-TYPE						
		TILTING-DISK						
ENTRANCE LOSS		NORMAL				1		
		BORDA						
EXIT LOSS					1			
CHANGE IN PIPE SIZE		INLET ID	EXIT ID					
		6.000	3.000 # Rqd>			1		
		3.000	4.000 # Rqd>	1				
		4.000	6.000 # Rqd>		1			
			# Rqd>					
			# Rqd>					
		NUMBER OF FITTINGS >				1		
Rupture Disk	In Column 4	K (liquid) FACTOR FOR FITTING >				0.59		
		K (vapor) FACTOR FOR FITTING >				0.43		

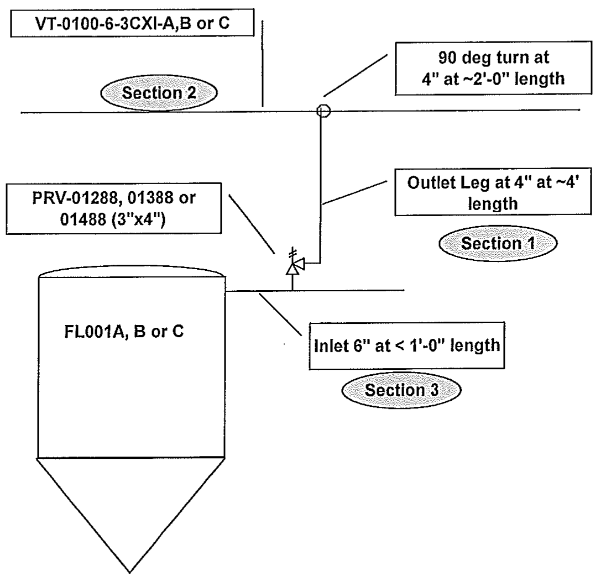
EQUIPMENT	Section 1 or 2?	LOSS, PSI	@ GIVEN, lbs/hr	K	Eq. Len. Ft	Eq. Len. Ft			To which column should N values below be added (G,H,I or J)?
					0.0	0.0			
For Liquids					0.00	0.00	0.00	0.00	
For Gases					0.00	0.00	0.00	0.00	
For **Gases:** W =19.3Cv P_1 Y((dP/P_1)Mw/(T_1Z))^.5			Cv =		Xt =		Column >		
For **Liquids:** W = 63.3 Cv Cf (S.G. dP)^.5			Cv =		Cf or Fl =		Column >		
For **Liquids** Total "N" for pipe and fittings =					2.43	11.22	2.82	0.00	0.00
For **Liquids** "N" for all fittings & equipment =					2.13	9.70	2.67	0.00	0.00
For **Gases** Total "N" for pipe and fittings =					2.51	4.44	2.57	0.00	0.00
For **Gases** "N" for all fittings & equipment =					2.24	2.82	2.42	0.00	0.00

Friction Factor by Churchill Equation - Chem Eng 11/7/77 pg 91-92: Kinetic energy Factor - Chem Eng 10/13/75 pg 128
2K Friction Losses (K=K1/Re + Kinf (1 + 1/d)) CHEM. ENG., AUG 24, 1981 PP 96-100- Chem Eng 11/7/88 pg 90 Change in Pipe Size

Quality Record

Approved

PIPING SKETCH FOR PRV-01288, 01388 & 01488



NOTES:

1. Not all piping and/or flanges shown.
2. Estimated at 4 feet of additional head on discharge of relief devices to connect to main vent line header.
3. Section descriptions apply only to the flow case described for this scenario.

PERIGON ENGINEERING

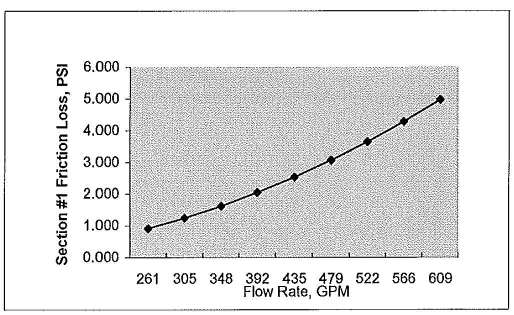
PRV-01288 Rev F calcs 1 26 12 | 1/26/2012

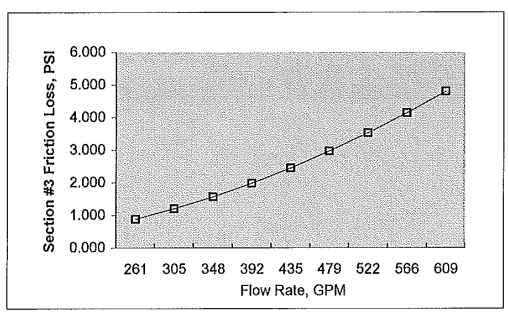
PRESSURE LOSS - LIQUID FLOW

DEVICE #	PRV-01288, 01388 & 01488		PROJECT NUMBER	109874
CLIENT/LOCATION	Sask	Charlotte	PROJECT TITLE	Gasifier Island Coal Candle Filter
CALCULATION BY/DATE	WJ Heron	1/26/2012	REVISION	
PROBLEM DESCRIPTION	SECTION #1	Relief Valve Discharge (Section of pipe right after valve outlet)		
	SECTION #2	Relief Valve Discharge (Section of pipe after section #1)		
	SECTION #3	Relief Valve Inlet (Section of pipe up to valve inlet)		
	SECTION #4	Relief Valve Inlet (Section of pipe up to section #3)		
COMMENTS / DISCUSSION				

		SECT #1	SECT #2	SECT #3	SECT #4
LINE DESCRIPTION		PRV to Hdr	Header	Tank to PRV	
NOMINAL PIPE SIZE, INCHES (.5, 1, 1.5, 2 ETC.)		4.00	6.00	4.00	
PIPE SCHEDULE (5S, 10, 10S, 20, 30, 40S, 40		40	40	40	
STD, XS, 60, 80, 100, 120, 160, XXS)		4.026	6.065	4.026	
ROUGHNESS (STEEL=.00018 IN.)	INCHES	0.00015	0.00015	0.00015	0.00015
FLUID NAME		Water	Water	Water	Water
FLOW RATE	GPM	435.33	435.33	435.33	
SPECIFIC GRAVITY AT RELIEVING TEMPERATURE OF	380	0.94	0.94	0.94	0.96
DENSITY	LB/CU FT	58.52	58.52	58.52	59.74
VISCOSITY	CENTIPOISE	55.59	55.59	55.59	0.00
FLOW RATE	LBS/HR	204195	204195	204195	
VELOCITY	FT/SEC	10.96	4.83	10.96	
PRESSURE DROP	PSI/100 E.FT	8.22	1.20	8.22	
TOTAL EQUIVALENT LENGTH	FEET	48.2	369.2	3.0	
FRICTION FACTOR		0.0364	0.0412	0.0364	
REYNOLDS NUMBER		5757	3822	5757	
TOTAL FRICTION LOSSES (PIPE + FITTINGS)	PSI	**2.54**	**2.05**	**2.45**	
FRICTION LOSS FROM OTHER SECTIONS OF PIPE	PSI				
TOTAL FRICTION LOSSES (PIPE + FITTINGS)	FT OF FLUID	**6.24**	**5.05**	**6.03**	**0.00**
INCREASE IN ELEVATION FROM END TO END	FT OF FLUID		4.00	0.00	0.00
TOTAL CHANGE IN PRESSURE FROM END TO END	FT OF FLUID	6.24	9.05	6.03	0.00
TOTAL CHANGE IN PRESSURE FROM END TO END	PSI	2.54	3.68	2.45	0.00
TOTAL	PSI		**6.21**		2.45

TOTAL NON RECOVERABLE INLET PRESSURE LOSS / SET PRESSURE	2.45 / 150.00	=	1.63%
TOTAL NON RECOVERABLE DISCHARGE PRESSURE LOS / SET PRESSURE	4.59 / 150.00	=	3.06%





Quality Record

Approved

PRESSURE RELIEF DEVICE SIZING FOR VAPORS

9/20/2011

For Gases and Vapors

ASME and API-520 Sect. 3.6.2

Critical Flow

Av = W * [T Z / Mw]^.5 / (Cg * Kb * Kd * P1)

P1 = Set Pressure + Accumulation +14.7

API-520 Sect 3.6.3.1

Sub-Critical Flow

Av = W * (Z * T/(MW * P1 * (P1-Pb)))^.5 / (735 * F_2 * Kd)

F2 = ((k-1)/k * r^(2/k) * ((1-r^((k-1)/k))/ (1-r))^.5

If ASME flow coefficient units = Scfm/Psia:
Wr = Scfm/Psia x P1 and Av is unique for each selected model

If ASME flow coefficient units = Scfm: P1 and Av are predetermined for the selected model

For Steam

API-520 Sect 3.7.1

Av = Wr / (51.5 * P1 * Kd * Kn * Ksh * Kb)

Ksh = 1 for saturated steam

If ASME flow coefficent units = pph steam: P1 and Av are predetermined for the selected model

If ASME flow coefficient units = pph/psia:
Wr = pph/psia x P1 and Av is unique for each selected model

			3274		
Wr =	Required relieving capacity divided by # of devices at same set pressure	Lbs/Hr	3274		
Z =	Compressibility Factor at relieving pressure		1.00		
MW =	Molecular Weight		18.0		
k -	Cp/Cv		1.294		
Pb =	Back Pressure against valve = 14.7 + 0	Psia	14.70		
Pcf =	Max Press * (2/(k+1)^(k/(k-1)) = 269.9 (2 / (1.294 + 1)^(1.294 / (1.294 - 1))	Psia	144.6		
Determine if Flow is Critical or SubCritical (Critical if Pcf > Pb)			Critical		
F_2=	Coefficient of Sub-Critical Flow		1.0000		
Kb =	Back pressure correction factor equal to 1.0 for standard valve if back pressure <60% of inlet pressure. Looku tables for standard valves, curve fit for Bellows valves (Consolidated, Crosby, Farris)	Alternative Kb =	1.000		
Kd =	Coefficient of Discharge per ASME Redbook		0.9		
Kn =	Napier correction factor for steam (For P1<1500 psig, Kn =1), For P1>1500, Kn =(.1906P1 - 1000) / (.2292P		1.00		
Kc =	PSV-Factor for rupture disk in combination with relief valve. Use Certified Combination Factors		1		
Ksh=	Superheated Steam Correction Factors from API-520 Table 9		1.00		
Cg =	Gas Constant based on Cp/Cv, (dimensionless) = 520 (k (2/(k+1)^((k+1)/(k-1)))^.5		394		
P1	Relieving pressure (including allowable overpressure)	Psia	144.6		
T =	Relieving Temperature	Deg R	800.0		
		Deg F	340.0		
Determine Required Area with Kd value					
Av =	ASME Area Required for Critical Flow	In^2	0.4462		
Av =	Area Required for Subcritical Flow	In^2			
Av =	Area Required for Steam (Assumes critical flow)	In^2	NA		
Maximum required area (assuming no rupture disk)		In^2	0.4462		
Maximum required area (with rupture disk) = Av/Kc = 0.446 / 1 =		In^2			
Minimum standard orifice for selected vendor		In^2	0.559		
			G		

REQUIRED ORIFICE ASME AREA	**0.446**	**In^2**	NonAPI means orifice does not follow the API designations		
Min. Vendor Orifice Size	**0.559**	**In^2**	of D through T		
Orifice Designation	**G**		Lbs/Hr	ACFM	SCFM
EXISTING Valve Orifice Designation or Size =		In^2			
For Existing Valve, convert SCFM to lbs/hr of fluid	W = SCFMair x C x MW^.5 / (18.4 x (T x Z)^.5) =				
Maximum Capacity of selected orifice with this fluid			4101	120.6	1437.5
Max. std. AIR Capacity of this standard Orifice at 60 deg F = 356 KAP (28.97/(60+460))^.5 =			5827		1271
Max. STEAM Capacity of the selected Orifice = 51.5 KAP			3571	where KAP = W/(C(M/T)^.5) = 69.3	
Flow Rate to be used for pressure drop calcs, if rated capacity is not used.					

PRESSURE RELIEF DEVICE SIZING FOR LIQUIDS

WJH/1/26/12

REQUIRED FLOW RATE FROM TABLE DIVIDED BY # OF RELIEF DEVICES OPERATING SIMULTANEOUSLY	**435.3**	GPM
FLOW RATE TO BE USED IN CALCULATIONS IF DIFFERENT FROM ABOVE		GPM
	204194.7	Lbs/hr

Based on brief time until inlet nozzle is no longer submerged

ASME & API-520 Sect 3.8

$$Ar = \frac{Q*(G^{.5})}{38.0 * Kd * Kw * Ku * (P1-Pb)^{.5}}$$

			Water	NA
Q =	Flow rate	gpm	435.335	
Wr =	Required relieving capacity	lbs/hr	204194.7	
T =	Relieving Temperature	°F	380	
Pb =	Back pressure at outlet of valve = Max Static Pressure + Pressure Drop =	Psia	100.6	100.6
υ =	Viscosity of Liquid	cp	0.130	
Ku =	Viscosity correction factor = 1/(.9935 + 2.878/Rey^.5 + 342.75/Rey^1.5) = 1 if required flow is very low but viscosity is normal		1.00	
Kw =	Liquid flow factor for variable back pressure Kw = 1 for standard valves. Kw for bellows valves varies		1.000	
Kd =	Coefficient of discharge for the valve		0.878	
G =	Specific Gravity of the liquid		0.873	
P1 =	Relieving Pressure (including allowable overpressure)	Psia	210.7	

Determine Required Area with Kd value

Preliminary Area of Standard orifice (uncorrected for viscosity)		In^2	4.822	
Reynolds # for flow through preliminary standard orifice (Required to determine Ku)			3727324	
Maximum required area (assuming no rupture disk)	Ar =	In^2	1.1618	0.0000
Maximum required area (with rupture disk)	Ar / Kc =	In^2	1.1618	
	Min. Vendor Orifice Size =	**J**	**1.4300**	Sq In

	Lbs/Hr	GPM				
Calculated Capacity of required orifice	**234,052**	**535.8**	Existing Orifice Designation or Size =			Sq In
Calculated capacity of Selected orifice						
Capacity to be used for Selected orifice			Program will use the lesser of calculated capacity or existing nameplate capacity.			
Existing Valve Nameplate Capacity, gpm of water				Gpm of actual fluid which is		lbs/hr of actual fluid
Flow Rate to be used for pressure drops, lbs/hr				Gpm of actual fluid with Specific Gravity of 0.873		

Two Phase Flow Calculations

RELIEF DEVICE # **PRV-01288, 01388 & 01488**

Should two phase flow be considered (yes/no)?		Yes			
Fluid **Water**		Lbs/Hr	ACFM		
Vapor Flow Rate from Maximum Case		3274.0	23.4		
Input Vapor Flow Rate To be Used in 2 phase Flow Case		3274.05	139.1		
Liquid Flow Rate Based on User Input					
Input Liquid Flow To Be Used		3159.67	Lbs/Hr	7.2	Gpm
Relieving Temperature **380.0** Deg F Temperature Increment to be used >		2.00	Used in HEM Max & Two Phase		
Pa = Relieving Pressure = Set Pressure + Allowable Overpressure		196.2	Psia		
Pb = Critical Throat Pressure Estimated Value found by iteration		100.6	Psia	100.6	Revised Esti
Temperature in Throat (Corresponds to Relief Valve Throat Pressure)		319	Deg F	< Calculated to be 319	
Does flashing occur (Y/N)?		Y			
Xa = Weight Fraction of gas in Inlet to device (0 to 1.0)		0.5089	<zero if no vapor in upstream flow		
Xb = Weight Fraction of gas in throat		0.5089	Alternative Xb		
	Lbs/CuFt				
Liquid Density at inlet Conditions	54.47				
Liquid Density at throat conditions (Flashing may occur)	56.65				
Vapor Density at Inlet Conditions	0.4288		Density From Literature, if known	0.4288	
Vapor Density at Throat Conditions Assumes Z = 1	0.3210		Density From Literature, if known	0.321	

ORIFICE SIZING CALCULATIONS		
Are Physical Property equations to be used? Y or constants calculated below N?	**N**	Constants calculated below are alternative.
The Physical Property equations are more accurate than the constants calculated below.		
Adjust Pressure Increment when using constants.	**5.0**	<Not needed when using physical properties
Calculation for Constant $n = \ln(P_a/P_b) / \ln(VapDen_a/VapDen_b) =$	2.3070	Subscript "a" is properties at relieving cond.
Calculation for Constant $c = VapDen_a / (P_a\char`^(1/n) =$	0.043	Subscript "b" is at throat conditions
Calculation for Constant b = -T Cpliq (1/Gasden - 1/Liqden) / (5.404 Lat^2)	-5.25E-04	Phyical Properties at relieving pressure & temp.
Calculation for Constant $a = X_a - (b * P_a)$	6.12E-01	
Calculation for Constant $e = (LiqDen_a - LiqDen_b)/ (P_a - P_b)$	-0.0228	
Calculation for Constant $d = $ Liq den - (e P_a)	58.9468	
Maximum Mass Velocity (From Calculation Table)	648.9	Lb/s/Ft^2 At 86.2 psia
Combined Coefficient using Kd for Liquids = Kb*Kc*Kd =	0.85	Diers Project manual Session 3 Sect C-4
Required Relief Valve Area A = 144 * W /(3600 G Kd) =	**0.467**	In^2 based on G calculated below

PERIGON ENGINEERING

PRV-01288 Rev F calcs 1 26 12 1/26/2012

"Emergency Relief System Design Using Diers Technology" - by Fisher, Forrest...- page 120-130 Phys Prop File Name> RVData

CALCULATION TABLE USING CONSTANTS (HEM MODEL FOR TWO PHASE FLOW)

	Pressure P	Vap Wt Fract. X = a + bP	1/Vapden Vg=1/(cP^(1/n)	1/Liqden Vf=1/(d+eP)	Mix Vol V, cuft	Vol(Pin-Pout) Sum(Vol dP)	G^2 = 2V^(-2Sum)	Mass Vel G Lbs/sec/ft^2	Crit Flow Gc Lbs/sec/ft^2	Pressure P, Psia	
1	196.20	0.5089	2.3321	0.0184	1.1958	0	0	0.0		196.20	< Relieving F
2	191.20	0.5115	2.3583	0.0183	1.2153	6.028	8.2	194.5	1090.5	191.20	
3	186.20	0.5141	2.3856	0.0183	1.2354	12.154	15.9	271.6	1072.7	186.20	
4	181.20	0.5168	2.4139	0.0182	1.2562	18.383	23.3	328.5	1054.6	181.20	
5	176.20	0.5194	2.4433	0.0182	1.2778	24.718	30.3	374.5	1036.3	176.20	
6	171.20	0.5220	2.4740	0.0182	1.3002	31.163	36.9	413.3	1017.7	171.20	
7	166.20	0.5246	2.5060	0.0181	1.3234	37.722	43.1	446.7	998.9	166.20	
8	161.20	0.5273	2.5394	0.0181	1.3475	44.399	48.9	476.0	979.9	161.20	
9	156.20	0.5299	2.5743	0.0181	1.3726	51.200	54.4	501.8	960.6	156.20	
10	151.20	0.5325	2.6109	0.0180	1.3988	58.128	59.4	524.7	941.0	151.20	
11	146.20	0.5351	2.6492	0.0180	1.4261	65.190	64.1	545.0	921.1	146.20	
12	141.20	0.5378	2.6895	0.0179	1.4546	72.392	68.4	563.0	900.9	141.20	
13	136.20	0.5404	2.7319	0.0179	1.4845	79.740	72.4	579.0	880.4	136.20	
14	131.20	0.5430	2.7765	0.0179	1.5159	87.241	75.9	593.1	859.5	131.20	
15	126.20	0.5456	2.8237	0.0178	1.5488	94.903	79.1	605.5	838.4	126.20	
16	121.20	0.5483	2.8736	0.0178	1.5835	102.734	81.9	616.1	816.8	121.20	
17	116.20	0.5509	2.9266	0.0178	1.6202	110.743	84.4	625.2	795.0	116.20	
18	111.20	0.5535	2.9829	0.0177	1.6590	118.941	86.4	632.8	772.7	111.20	
19	106.20	0.5561	3.0430	0.0177	1.7002	127.339	88.1	638.9	750.0	106.20	
20	101.20	0.5588	3.1072	0.0177	1.7440	135.950	89.4	643.6	726.9	101.20	
21	96.20	0.5614	3.1762	0.0176	1.7909	144.787	90.3	646.8	703.3	96.20	
22	91.20	0.5640	3.2506	0.0176	1.8411	153.867	90.8	648.6	679.2	91.20	
23	86.20	0.5666	3.3310	0.0176	1.8951	163.207	90.9	648.9	654.7	86.20	< Choked Flo
24	81.20	0.5693	3.4184	0.0175	1.9536	172.829	90.6	647.8	629.6	81.20	
25	76.20	0.5719	3.5139	0.0175	2.0171	182.756	89.8	645.1	603.9	76.20	
26	71.20	0.5745	3.6188	0.0174	2.0865	193.015	88.7	640.9	577.6	71.20	
27	66.20	0.5772	3.7349	0.0174	2.1629	203.638	87.1	635.1	550.6	66.20	

Throat pressure providing max. velocity 86.20 Psia Corresponding throat temperature = 319 °F

Max. mass vel. (ignoring pipe) 648.9 lbs/(sec Ft^2) <G cannot exceed this. It is typically less than Gc.

MINIMUM REQUIRED AREA FOR TWO PHASE FLOW	Ar =	**0.467**	**IN^2**	**Orifice**
	Standard Orifice Size =	**0.559**	**IN^2**	G
Maximum orifice capacity (ignores pipe length)	= 3600 Kd G A/144 =	7708	lbs/hr	

Quality Record

Approved

DETERMINE MAXIMUM DISCHARGE PIPE CAPACITY FOR TWO PHASE FLASHING FLOW (HEM)

From "Easily Size Relief Devices For Two Phase Flow" by Leung, Chemical Engineering Progress Dec 1996

Po = Throat Pressure = Inlet Pressure of discharge pipe		100.6	Psia
Xo = Weight fraction of inlet vapor in Discharge Pipe		0.509	
Vgo = Specific volume of inlet vapor		2.332	ft^3/lb
Vfo = Specfic volume of inlet liquid		0.018	ft^3/lb
Vo = Specific volume of inlet mixture		1.196	ft^3/lb
Cpo = Heat capacity of inlet liquid		1.034	Btu/lbF
To = Inlet temperature	319.0 °F	779.0	°R
vfgo = Difference between specific gas volume & liquid volume		2.314	ft^3/lb
hfgo = latent heat at discharge pipe inlet conditions		870.10	Btu/lb
w = Xo vgo/vo + (Cpo 778 To 144 Po)/vo (vfgo/(hfgo 778))^2		1.17	
If w>4 then G/(Po/Vo)^.5 = (.6055 + .1356 ln w - .0131 ln w^2) / w^.5		0.576	
If w<4 then G/(Po/Vo)^.5 = .66 w^.39		0.7006	
K = Koutlet + Kout2 (IDout1/IDout2)^4 K = 11.22 x (6.065/4.026)^4 + 2.51 =		2.51	
Gc = G/(Po/Vo)^.5 (32.17* 144* Po/Vo)^.5		437.4	lbs/(sec Ft^2)
Graphs have been fitted to curves and interpolated			
Gc/Goc for horizontal pipe from figure VII-1 (Goc is nozzle flow)		0.62	
P2c/Po from figure VII-4		0.38	
P2c = Po P2c/Po		38.4	Psia
Since P2c is greater than final outlet pressure, these equations apply			
H = Elevation Increase from relief device to discharge point		10	Ft
Fi = Denliq g H /(K Po 144 32.17)		0.01	
G/Gc Vertical (from Figure VII-2) =		0.43	
G/Gc corrected for inclination = G/Goc - Fi (G/Goc-G/Gcvert)/.1 =		0.594	
Flow area of pipe used for determining K above		12.73	Sq In
Discharge Piping capacity = 3600 Gc Area/144 G/Gc(corrected)		**82,732**	lbs/hr

AICHE Journal Oct 1986 - Leung "A Generalized Correlation for One Component HEM Flashing Choked Flow"
AICHE Journal Mar 1987 - Leung "The Discharge of Two Phase Flashing Flow in a Horizontal Duct"
AICHE Journal May 1990 - Leung "The Discharge of Two Phase Flashing Flow From an Inclined Duct"

Maximum Flow through Inlet pipe =	276,819	lbs/hr	< Limited by maximum 3% pressure drop	4.5	psi
Maximum Flow through orifice =	7,708	lbs/hr			
Maximum Flow through discharge piping =	82,732	lbs/hr			
MAXIMUM FLOW =	**7,708**	lbs/hr			