External Fire Liquid Vaporization

External Fire B	oiling	Liquid - AP	I STD 521									
Equipment Data:												
Equipment Tag Num	bar:	EqTag				Equipmen	t Type:		EqType		-	
Drawing:		Drawing				MAWP:			MAWP	psig	1	
Description		Description		<u> </u>		MAWT:			MAWT	F		
							•••••					
Scenario Input Da	ta;					Scenario	Output I	Data:				
Length:		Length	LengthU 🗸			Wetted A	ea:		WettedArea	ft2]	
Diameter:		Diameter	Diamete			Fire:Heat	nput:		HeatInput	МM	Btu/hr	1
Orientation		Orientation				Total Hea	/lb Vapori	zed	Qtotal	Btu/	1b	
Наад Тура:		Head1Type				Sensible	eat/lb/va	porized:	QSensible	Btu/	1b	
Additional Wetted A	reat	UserArea	ft2			Latent He	BT:		LHV	Btu/	lb	
Level:		Level				Initial Rel	ef Temper	atura:	Tinit	F		
Level Basis:		LevelBasis				Temp: at S	tart:Quali	ty:	T1	F		
Bottom Elevation:		Height	ft:			Cp at Star	Quality:		Cp1	Btu/	IB/F	
Area Exponent:		AreaExp	,			Cp at Fina	Quality:		Cp2	Btu/	IB/F	
Adequate:Drainage:						Critical:Pr	essure:		Pc	psig	T	
Insulation Factor:::		InsulationF				Liguid Dei	sity:		LiquidDensity	lb/ft	3	
Required Relief Rate	Units:	RateUnit	1			Required	Mass Rate		liredRateMass	15/h	r	
Start Mass % Vapor:		PercentVap1				Required	std.:Vol.:Ra	ite:	JuiredRateMM	MM	CFD	
Finish Mass %Vapor		PercentVap2				Required:	Air:Rate: : :		quiredRateAir	scfh	air	
Subtract Out Sensib	le Heat:					ReliefMa	s:Flux::::		Flux2	lb/s	sc/ft2	
Set Pressure:		Set	psig:			ReliefStre	am:Nama			Stre	eamlD	5
Allowable Overpres	sure:	OverF	,									
Constant Back Press	ure:	P3	DSIE									
Correct for Densities									Open Stream			
UseThermodynamic	s					Scenario	Bescription	n:	Scenario Descr	iptio		
Thermodynamic Pac	kaza		ThermoP	ackage		1]			
		<u> </u>	1			<u></u>						
FireLiquidStreamID		~										
Open Stream Ne Relief Device Kd:	w Stream)	1									
Outstan Diana Cindered	Sizing											
wutiet ripe sizing:	OutPipeS	izing Calculate	Preview		Prir	nt	Close					

Equipment Data:

The six fields under Equipment Data are specified on the Overpressure Scenario Form.

Input Data:

The form fields for inputs are blue and organized under the Scenario Input column. The are described below:

Length – Vessel seam-to-seam length for horizontal and vertical orientations. Not required for spheres.

LengthUnits – Units (ft, in or mm) associated with the Length.

Diameter – Vessel diameter generally taken as the outer diameter.

DiameterUnits - Units (ft, in or mm) associated with the Diameter.

Orientation - Vessel orientation (horizontal, vertical or spherical.

Head1Type – Both vessel heads assumed the same (2:1 ellipsoidal, hemispherical or flat).

UserArea – Any wetted area beyond normal geometry calculation to be added such as a boot or piping.

Level – Vessel liquid level for use in determining wetted area.

LevelBasis – Source for input liquid level such as LSHH, LSH, Upper LG Tap.

Height - Elevation above grade of vessel bottom for use only when considering maximum fire height

AreaExp – Typically 0.82 unless an air cooler or fire in confined space in which case 1.0..

Adequate Drainage - If yes then 21,000 used in heat equation, if no 34,500 used in heat equation

Insulation F – Insulation factor used to reduce total heat input. 1.0 unless fireproof insulation is present then either 0.3 or calculated per API STD 521.

RateUnit – Units that the required relief rate will be reported back to the scenario sheet.

PercentVap1 – Starting mass % vapor for determined the latent heat.

PercentVap2 – Final mass % vapor for determined the latent heat. Must be higher than Start Mass %.

Subtract Out Sensible Heat - Typically yes and sensible heat will be removed from latent heat calculation.

SetP – Set pressure that will be used along with overpressure to determine relief pressure.

OverP – Allowable overpressure typically 10% used to determine relief pressure.

P3 – Constant back pressure when PSV is closed.

Correct for Densities - If yes, accounts for the relative densities of the liquid and vapor in rate calculation

UseThermo – If false, additional property inputs are required.

ThermoPackage – Thermo package used for properties. VMG (Symmetry) packages or REFPROP 10.0 from NIST

FireLiquidStreamID – The liquid stream to be vaporized determining latent heat and relief composition. A new stream can be added here. See <u>Stream Definition Form</u>.

Kd – Manufacturer's certified vapor Kd or 0.975 for API STD 520 default.

Sizing – PSV sizing method: API 520 Vapor or Numerical Integration (recommended when Z <= 0.8).

OutPipeSizing – Outlet pressure drop method: Adiabatic, Omega Method or Numerical Integration.

Calculation Method:

The calculation method for external fire with vaporizing liquid is well established in API STD 521. The first step in determining the required relief rate is determination of the wetted area which is done based on the input dimensions and orientation of the vessel using standard geometric equations. The heat input is then calculated based on the wetted area using the following equations depending on the presence of adequate drainage and firefighting equipment:

Adequate drainage and firefighting equipment:

 $HeatInput = 21,000 \times InsulationF \times WettedArea^{AreaExp}$

No adequate drainage and firefighting equipment:

 $HeatInput = 34,500 \times InsulationF \times WettedArea^{AreaExp}$

The latent heat is quantified by first determining the total heat required to increase the mass percent vaporized from PercentVap1 to PercentVap2 which is done by comparing the staring and ending enthalpies. The sensible heat is determined by using the average of Cp1 and Cp2 along with the temperature rise from T1 to T2. The heat used to calculate the latent heat is then easily determined based on the selection to subtract out the sensible heat (normal procedure) or not yielding Q in the following equation:

LHV = Q/(PercentVap1 - PercentVap2)

Once the LHV is known the required relief rate in mass terms is simply:

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RequiredRateMass = HeatInput/LHV
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Scenario Output Data:

The form fields for scenario-specific outputs are organized under the Scenario Output column. These are described below:

WettedArea – Surface area calculated using level plus UserArea.

HeatInput - Calculated total heat input based on WettedArea, AreaExp and Adequate Drainage.

QTotal – Total heat required to vaporize from PercentVap1 to PercentVap2

QSensible – Amount of QTotal used to increase the fluid temperature.

LHV - Heat per lb vaporized with or without sensible heat excluded based on selection

Tinit – Temperature of fluid at initial relief of dewpoint temperature at relief pressure

T1 – Temperature at PercentVap1 which would equal Tinit if PercentVap1 = 0%

Cp1 – Mass heat capacity at T1 or PercentVap1

Cp2 – Mass heat capacity at T2 or PercentVap2

Pc – Critical pressure reported to ensure relief pressure is below Pc

LiquidDensity - Liquid density at T1 or Percent Vap1

RequiredRateMass - Calculated required relief rate in lb/hr.

RequiredRateMM – Required rate in MMSCFD RequiredRateAir – Required rate converted to scfh air Flux2 – RequiredRateMass · RequiredArea * 144 / 3600 StreamID – Vapor relief stream at T2 or PercentVap2

Scenario Calculation Results:

The form fields for overall scenario results are organized in the Scenario Calculation Results Section. These outputs are typical of most of the scenario calculations and are detailed under Typical Scenario Calculation Results.

QA/QC Benchmarks:

As the calculation of the wetted area relies on simple geometric calculations and the heat input calculation is very straightforward as detailed in the calculation section, the primary benchmark for the external fire scenario is the quantification of the latent heat and relief composition. These two calculations were benchmarked against a commercial simulation (Symmetry) for a typical rejection NGL product in a storage tank. The latent heats were within 1.7% (102.4 Btu/lb vs. 104.1 Btu/lb) The entire external fire required relief rate calculation was then benchmarked against an internal RKR spreadsheet which determined required relief rates within 1.2% (29,667 lb/hr vs. 29,305 lb/hr).

External Fire Boiling Liquid API STD 521

External Fire Liquid



Equipment Data:

Equipment Tag:	V-1000	Туре:	Pressure Vessel
Drawing:	PID-1000	MAWP:	150 psig
Description:	Slug Catcher	MAWT:	250 F

Scenario Description:

The Slug Catcher contains liquid hydrocarbon that could vaporize in the event of an external fire potentially resulting in overpressure. The required relief rate was based on the composition of the inlet liquids from the simulation at the relief pressure of 181.5 psig. The liquid level was based on the location of LAHH-1000 which is located at 75%.

Scenario Calculation Results:

Required Rate:	29661.9	lb/hr	Device Choke Pressure:	101.5	psig
Actual Capacity:	60881.8	lb/hr	Outlet Temperature:	226.8	F
Required Area:	1.390	in2	Outlet Mass Quality:	1.000	
Actual Area:	2.853	in2	Outlet Density:	0.132	lb/ft3
Relief Pressure:	181.5	psig	Outlet Ideal Cp/Cv:	1.066	
Relief Temperature:	255.9	F	Outlet Viscosity:	0.009	сР
Relief MW:	64.99		Inlet Non-Recoverble dP:	3.3	psi
Relief Mass Quality:	1.000		Inlet dP % Set:	2.2	% Set
Relief Density:	2.18	lb/ft3	Built-Up Back Pressure:	37.5	psig
Relief SG:	2.241		Built-Up Back P % Set:	25.0	% Set
Relief Z:	0.76		Total Back Pressure:	37.5	psig
Relief Ideal Cp/Cv:	1.06		Total Back P % Set:	25.0	% Set
Relief Viscosity:	0.010	сР			



External Fire Liquid

Equipment Data:

Equipment Tag:	V-1000	Туре:	Pressure Vessel
Drawing:	PID-1000	MAWP:	150 psig
Description:	Slug Catcher	MAWT:	250 F

Scenario Input Data:

Length:		12	ft	
Diameter:		6	ft	
Orientation:		Horizontal		
Head Type:		2:1 Ellipsoidal		
Level Basis:		LSHH-1000		
Additional Wetted Are	ea:	0	ft2	
Level:		85%		
Bottom Elevation:		3	ft	
Area Exponent:		0.82		
Adequate Drainage				
Insulation Factor:		1		
Start Mass % Vapor:		0.00%		
Finish Mass % Vapor:		5.00%		
Remove Sensible Hea	t: 🗹	Correct for Dens	ities:	
Set Pressure:		150	psig	
Allowable Overpressu	ire:	21.0%		
Constant Back Pressu	re:	0	psig	
Use Thermodynamics:		\checkmark		
Thermo Package: Advanced_		Peng-Robinson		
Relief Device Kd:		0.975		
Nozzle Sizing: API 520 Var		por		
Outlet Pipe Sizing:	Isothermal	l		
Notes:				

Scenario Output Data:		
Wetted Area:	235.3	ft2
Fire Heat Input:	3.04	MMBtu/hr
Total Heat/lb Vaporized:	144.0	Btu/lb
Sensible Heat/lb Vaporized:	41.6	Btu/lb
Latent Heat:	102.4	Btu/lb
Initial Relief Temperature:	253.1	F
Temp. at Start Quality:	253.1	F
Cp at Start Quality:	0.739	Btu/lb/F
Cp at Final Quality:	0.732	Btu/lb/F
Liquid Density:	31.36	lb/ft3
Required Mass Rate:	29661.9	lb/hr
Required Std. Vol. Rate:	4.16	MMSCFD
Required Air Rate:	304243.3	scfh air
Relief Mass Flux:	853.6	lb/sec/ft2

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External Fire Boiling Liquid API STD 521

External Fire Liquid



Equipment Data:

Equipment Tag:	V-1000	Туре:	Pressure Vessel
Drawing:	PID-1000	MAWP:	150 psig
Description:	Slug Catcher	MAWT:	250 F

Liquid Stream Description: Inlet Liquids

Relief Stream Description: V-1000 Fire Relief Vapor

Component	Liquid Stream Mole Fraction	Relief Stream Mole Fraction
carbon dioxide		0.0000
nitrogen		0.0000
methane		0.0000
ethane		0.0000
propane	0.0500	0.1306
isobutane	0.1000	0.1681
butane	0.1500	0.2171
isopentane	0.2000	0.1831
pentane	0.2000	0.1649
hexane	0.3000	0.1363
heptane		0.0000
octane		0.0000
nonane		0.0000
decane		0.0000
methanol		0.0000
water		0.0000
water		



V-1000 Latent Heat Evaluation



Total Heat = 7,264 Btu/hr

Sensible Heat = (.7387 + .7320) / 2 x (255.9 - 253.1) x 1,000 = 2,059 Btu/hr LHV = (7,264 - 2,059) Btu/hr / 50 lb/hr = 104.1 Btu/lb

External Fire Boiling Liquid Calculation Critical PSV Flow Only

Equipment:V-1000 Slug CatcherPSV:PSV-1000

User-Entered Inputs						
P _{relief}	181.50	psig				
P _{atm}	14.4	psia				
K _d	0.975					
Q _{fire}	3,040,000	Btu/hr				
x _{in}	0.00	Mass Quality				
x _{out}	0.05	Mass Quality				
	Thermo In	puts				
H _{in}	82.40	Btu/lb				
H _{out}	89.66	Btu/lb				
Cp _{in}	0.74	Btu/lb/F				
Cp _{out}	0.73	Btu/lb/F				
T _{in}	252.96	F				
T _{out}	255.79	F				
	Result	5				
M _v	0.05	lb				
Q _{total}	7.27	Btu/lb				
Q _{sensible}	2.08	Btu/lb				
LHV	103.7	Btu/lb				
W_{req}	29304.8	lb/hr				
С	322.8					
A _{req}	1.380	in ²				

External Fire Boiling Liquid Stream

Equipment:	V-1000 Slug Catcher
PSV:	PSV-1000

	Vessel Liquid	Vessel Liquid Heated	Vapor Relief Stream
Pressure (psig)	181.5	181.5	181.5
Temperature (F)	253.0	255.8	255.8
Cp (Btu/lb/F)	0.74	0.73	N/A
H (Btu/lb)	82.40	89.66	N/A
Mass Quality	0.00	0.05	1.00
MW	71.45	71.45	64.99
Z	N/A	N/A	0.77
Ideal Cp (Btu/lbmole/F)	N/A	N/A	32.98
Ideal Cp/Cv	N/A	N/A	1.064
Mole Fractions			
Carbon Dioxide	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000
Methane	0.0000	0.0000	0.0000
Ethane	0.0000	0.0000	0.0000
Propane	0.0500	0.0500	0.1306
Isobutane	0.1000	0.1000	0.1681
n-Butane	0.1500	0.1500	0.2171
Isopentane	0.2000	0.2000	0.1831
n-Pentane	0.2000	0.2000	0.1649
n-Hexane	0.3000	0.3000	0.1362
n-Heptane	0.0000	0.0000	0.0000
n-Octane	0.0000	0.0000	0.0000
Water	0.0000	0.0000	0.0000