Equipment & Process Design



MEKPCO FLARE NETWORK DESIGN ASPEN FLARENET



Equipment & Process Design



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2 Design Procedure

- 2.1 Select proper Orientation
- 2.2 Select and Size proper Inlet Device, Inlet and Outlet ID
- 2.3 Calculate Vessel Diameter
- 2.4 Calculate Vessel Height
- 2.5 Select and Size Manholes, Vent, Drain, Vortex Breaker
- 2.6 Select a well-designed mist eliminator pad

Equipment & Process Design



Flare System Design Procedure

In order to design a flare package, the following procedure is taken:

- 1. Determination of worst-case scenarios
- 2. Flare network line sizing using Aspen flarenet and API-527
- 3. Flare K.O.D sizing using API-527 excel sheet
- 4. Stack height and diameter calculation by API-527

System Description

The overall Flare system consists of three parts:

1. The first part is made of flare network and K.O.D inside MEKPCO plant. The second part is made of flare main pipes between the tie-in point of the plant and flare area at the northeast. The third part consists of flare stack package which will be located on the north mountain. The stack will be located at X:652388, Y:3051685, Z:135.

2. The flare main header approximate length is considered 2715 for hydraulic analysis implementation, including the flare piping length 305m between the starting point and the tie-in point in methanol plant and the flare piping length 2410 between the tie-in point and the actual flare site.

3. For the flare piping routing, one stress expansion loop is set at about 60 m distance, about

27 stress expansion loops between the tie-in point and the flare stack.

4. For the flare piping routing, the elevation changes between the tie-in location of methanol plant and the actual flare site is about 111m.

5. The backpressure at the flare stack is 1.4 bara.







In Site Flare Header





Criteria and Design Basis

The sizing of relief discharge piping can usually be simplified by starting at the system outlet, where the pressure is known, and working back through the system to verify acceptable backpressure at each PRD Calculations is performed in a stepwise manner for each pipe segment of constant diameter.

Several methods for calculating the size of discharge piping have been developed using isothermal or adiabatic flow equations. Actual flow conditions in relief systems are normally somewhere between isothermal and adiabatic conditions. For most cases, the slightly more conservative isothermal equations are recommended.

- For both header and tailpipes, the Mach number of both 0.1 and 0.5 are taken into account.
- The maximum pv2 for the whole piping should be 150000 kg/m/s2
- The sound/ noise level should not exceed the recommended value of 100 DBA

Determination of worst-case scenario

All possible sources of relief load are summarized below and the worst-case scenario is

detected.

PID	Tag No.	Fluid	Contingency	Flow rate	MW	Т	LHV	HHV	Reference
				(kg/hr)	(g/mole)	(°C)	(kJ/Nm ³)	(kJ/Nm ³)	stream no."
P01	PSV-1008 / PSV-1009	Natural gas	Inadvertent valve opening of PV-1006	2000	16.74	40	34496	38260	2005
P01	PSV-1013 / PSV-1014	Natural gas	Inadvertent valve opening of PV-1011	27700	16.74	35	34496	38260	7005
P01	PSV-1015	Natural gas	Fire around D 1001	800	16.74	85	34496	38260	2000
P04	PSV-1031	Process gas	Fire around R 1001	1200	16.54	410	33834	37542	2030
P04	PSV-1038	Process gas	Fire around R 1002 1	1200	16.54	410	33834	37542	2040
P04	PSV-1043	Process gas	Fire around R 1002 2	1200	16.54	410	33834	37542	2040
P04	PV-1045	Process gas	Valve failure at normal operating pressure/start-up	63000	16.54	365	33834	37542	2040
P07	PSV-6053	Steam + natural gas	Fire around D 6001	3800	13.14	283	7350	8900	2200
P09	PV-2073	Process gas	Valve failure at normal operating pressure/start-up	165300	17.47	262	13565	16226	2090
P09	PSV-2078	Recycle gas from C 2002	Inadvertent valve opening of FV-2079	1500	11.44	48	10367	11751	3000
P17	PSV-2354 / PSV-2355 / PSV-2356 / PSV-2357 / PSV-2358 / PSV-2359 / PSV-2360 /	Reformed gas	Blocked outlet	510000	13.14	360	7350	8900	2200
P19	PV-2406	Reformed gas	Valve failure at normal operating pressure/trip of downstream units	222400	13.17	165	7350	8900	2200



PID	Tag No.	Fluid	Contingency	Flow rate	MW	T	LHV	HHV	Reference
				(kg/hr)	(g/mole)	(°C)	(kJ/Nm³)	(kJ/Nm ³)	stream no.'
P21	PV-2481	Reformed gas	Valve failure at normal operating pressure/trip of methanol synthesis	282200	11.44	48	10367	11751	3000
P21	USV-2482	Reformed gas	Reformer Trip	29700	11.44	48	10367	11751	3000
P22	HV-3011	Synthesis gas	Small purge (short duration)	4000	11.44	48	10367	11751	3000
P22	PSV-3021	Synthesis gas	Fire around R 3001 1/2/3	5600	9.81	120	10426	12029	3110
P27	PSV-3163	Synthesis gas	Fire around D 3001	19000	9.37	100	10441	12132	3190
P27	PV-3166	Recycle gas	Valve failure at normal operating pressure/start-up	51000	11.4	48	10441	12132	3190
P27	HV-3166	Recycle gas	Maximum flow	51000	11.4	48	10441	12132	3190
P27	PSV-3173 / PSV-3174	Purge gas	Inadvertent valve opening of FV-3169	41800	9.37	48	10441	12132	3190
P28	PSV-3196 / PSV-3197 / PSV-3206	Purge gas	Gas breakthrough from LV-3161	66900	9.37	48	9598 Full-screen Snip	10975	3340
P30	PSV-5058 / PSV-5059 / PSV-5060 / PSV-5061	Methanol vapour	Reflux failure	118800	29.92	116	22076	25549	5030
P32	PV-5109	Off-gas	Maximum case	2400	43.59	48	20664	23009	5145
P34	PSV-5179 / PSV-5180	Methanol vapour	Fire around T 5002	5200	29.08	121	22077	25554	5240
P38	PSV-5250 / PSV-5251 / PSV-5261	Methanol vapour	Reflux failure	100200	27.1	141	16524	19619	5430
P40	HV-5338	Methanol vapour	Manual vent on D 5003	220	32.04	101	28473	32389	5500

Table 2 - Summary of flaring scenarios cases.

Scenario	Case A	Case B	Case C: Plant Trip
Case Explanation	Reformed gas blocked outlet and overpressure (Maximum discharge case)	Plant Start-up/Shut Down Failure	Valve failure at normal operating pressure/trip of methanol synthesis
Total Mass Flow (Kg/h)	510000	343700	282206
Release source	PSV-2354 PSV-2355 PSV-2356 PSV-2357 PSV-2358 PSV-2359 PSV-2360	PV-2481 USV-2482 PV-2536 B	PV-2481



Flare network line sizing using Aspen flarenet and API-527

Procedure: The discharge load of each release point, the backpressure of flare stack, the diameter and length of each pipe segment is given to seek the Mach number and backpressure alongside each pipe segment.

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2nd Step: Checking "Calculation Setting"

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Note: There is no need to change PSV sizing, Solver, Initialization and AIV tabs in calculation setting.

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Equipment & Process Design



3rd Step: Create the layout





 4^{th} Step: Definition of Scenarios

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In order to define a scenario, at first "clone" a new scenario from default scenario and then complete the Scenario. Also, in "sources" tab, do not select the PSVs included in the scenario.

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	PSV-2357						
	PSV-2358						
	PSV-2360						
	PSV-2359						
			All	None			
		n/s		ОК			
				1			
	P8V-2358			Pipeaa		~	
					,		
Edit					66% Θ		•



🔞 Pipe Editor				177		×	
Connections Specification Fitt	ings Heat Transfer	Methods	Summary				
Property	/			Value			
Mass flow(kɑ/hr)		595000.0					
Rated flow(kg/hr)		595000.0					
Calculation Basis		Mass flow	v			111	
Molar flow(kgmole/hr)		45281.57					
Static pressure drop(bar d)		140.3319	7				M
Total pressure drop(bar)		133.4421	3				UBV:2482
Noise(dB)		118.7					
Friction factor		0.01298					
Reynolds number		12408955	50				
						*	107
Property		Upstream		Downstre	am		
Static pressure(bar_g)	151.77872			11,44675			PV-2481
Total pressure(bar_g)	152.48786			19.04574			
Temperature(C)	357.54			297.21			
Velocity(m/s)	61.968			664.035			
Mach number	0.088			1.000			
Rho V2(kg/m/s2)	141828			1519798			0 0
Energy flow(kJ/hr)	1.053e+00	9		1.053e+009			
Flow regime	Single Pha	se		Single Phase			
SPL(dB)							
					10		Connectors
						OK	







Equipment & Process Design



Results

🔕 . 🖉 🖬 😂 🕨 🔳 🜆 🖶 🗸	My MEKPCO	FIARE NETWORK	M0.5 - Copy.fnwx - Aspen Fla	re System Analyzer V12 - aspenC	NE	_	o x
File Home View Custo	mize Resources						۵ 🔞
X Cut Metric_g Image: Copy Image: Copy Image: Paste Image: Copy Image: Copy Image: Copy	Check Model Calculation Mode: Rating	culation Settings * *	Import All Sources +	Source Tools +	Components Components	*	
Navigation 4	Process Flowsheet × N	Messages × +	importy export	10013	Dunu	Palette	≁ å ×
Inputs Components	Excel						1
C Pipes	Problems Data Ec	ho Solver	Sizing Loops			-	+1
Sources Nodes	No. 🍸			Message		5	A
A Results	1	Choked Flow de	tected at exit of following flare	etip: FlareTip1 in Scenario: CaseA		T.	_
Ressages	2	MABP Exceeded	For Source 'PSV-2354' (164.9'	7767 / 2.90000 bar_g) in Scenaric	'CaseA'		U
R Physical Properties	F 3	MABP Exceeded For Source 'PSV-2355' (164.95737 / 2.90000 bar_g) in Scenario 'CaseA'					
Compositions 4 MABP Exceeded For Source 'PSV-2356' (164			For Source 'PSV-2356' (164.8	-2356' (164.88485 / 3.04000 bar_g) in Scenario 'CaseA'			
No Profile	Profile 5 MABP Exceeded For Source 'PSV-2357' (164.79666 / 3.04000 bar q) in Scenario 'CaseA'			'CaseA'			
K Flow Map	6	MABP Exceeded	For Source 'PSV-2358' (164.6	8115 / 3.04000 bar_g) in Scenaric	'CaseA'		
Scenario Summary	▶ 7	MABP Exceeded For Source 'PSV-2360' (164.49322 / 2.90000 bar_g) in Scenario 'CaseA'					
Source Summary	8	MABP Exceeded	For Source 'PSV-2359' (164.3)	0562 / 3.04000 bar_g) in Scenaric	'CaseA'		
Databases	9	Choked Flow Fo	r Pipe Segment 'Pipe57' in Sce	enario 'CaseA'			
	10	Mach Number \	/iolation For Pipe Segment 'Pip	pe57' (0.088 / 1.000) in Scenario '	CaseA'		
	E 11	Noise Violation	For Pipe Segment 'Pipe57' (11	8.7 dB) in Scenario 'CaseA'			
	12	RhoV2 Violation	For Pipe Segment 'Pipe57' (14	41828 / 1519798 kg/m/s2) in Sce	nario 'CaseA'		
- Done					100% O		• • .::

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Solution

In order to resolve the warnings, pipe diameters (all 12') are increased till the constrains are met. The Starting point is from last pipe segment. When the pipe ID is increased to 54' then the Mach number for last segment is decreased to 0.46. it was observed that only last pipe has experience Mach number violation.

This could be justified by the fact that the pressure in other pipe is too high that the volumetric flow has reduced dramatically in a way that Mach number is not a problem for these pipes. Interesting!!

Then other pipe segment diameter were increased and when other pipe ID, one by one, reached 46', the whole header and tail pipes Mach number met the constraints. By the way for smaller diameters like 42' the tests were carried out but the pipes in the middle of header could not bear and Mach number criterion was not met.

Also, tail pipe ID were increased to 20' but the backpressure on PSV-2356-60 was higher than the set value, therefore, the PSV type were changed to balanced type and their compatibility to system backpressure was increased and as a result, the warning disappeared. The final diameter for tail pipes were 12' and smaller diameter were tested but the Mach number criterion failed. So, 12' was selected.

Also, case B and C were tested and for PV-2481, the pipe ID of 28' was suitable. For PV-2536B the pipe ID of 8' was found suitable.

All above calculation are based on Mach number of max 0.5. It is interesting to notice that in Marjan Project the main header before K.O.D is 48' and the header after K.O.D to flare site is expanded to 64'. It seems that in Marjan Project the max Mach number of 0.5 has been considered as basis of design.

In MEKPCO Project, the max Mach number of 0.1 has been regarded as design basis and as a result, the main header before K.O.D is 56' and the header after K.O.D to flare site is expanded to 64'. Also ,in next page the comparison between IMPLANT and ASPEN FLARENET results for Mach number of 0.1 is shown.



Case A

PSV- 2354	PSV- 2355	PSV- 2356	PSV- 2357	PSV- 2358	PSV- 2359	P-52- in	P-52- out	P-57- in Mach	P-57- ou Mach
2.836	2.837	2.838	2.845	2.849	2.85	2.474	2.427	0.11	0.129
2.02	2.05	2.12	2.17	2.17	2.13	1.55	1.48	0.18	0.33

Case B

PV-2481	USV-2482	PV-2536	P-52-in	P-52-out	P-57-in Mach	P-57-out Mach
1.37	1.36	1.34	1.22	1.20	0.08	0.09
0.87	0.99	0.78	0.67	0.65	0.11	0.14

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It sounds that TCC has set Mach number of 0.1 as the criterion in order to have noise level within reasonable limits. Furthermore, Implant and Aspen Flarenet results are compared which shows good Compatibility.

Also, the deviation might stem from different composition because in absence of exact composition, MW Of each source were given to Aspen Flarenet and aspen flarenet estimates the composition.

Flare K.O.D Sizing

1.Knockout drums are typically located on the main flare line upstream of the flare stack or any liquid seal. If there are particular pieces of equipment or process units within a plant that release large amounts of liquid to the flare header, it is desirable to have knockout drums inside the battery limits to collect these liquids. This reduces the sizing requirements for the main flare knockout drum, as well as facilitates product recovery.

The economics of drum design can influence the choice between a horizontal and a vertical drum. If a large liquid storage capacity is desired and the vapor flow is high, a horizontal drum is often more economical. Also, the pressure drops across horizontal drums is generally the lowest of all the designs. Vertical knockout drums are typically used if the liquid load is low or limited plot space is available. They are well suited for incorporating into the base of the flare stack.
 Among disparate configurations proposed in API-527, a combination of a vertical drum in the base of the flare stack and a horizontal drum upstream to remove the bulk of the liquid entrained in the vapor has been selected for MEKPCO. Horizontal drum with the vapor entering one end of the vessel and exiting at the top of the opposite end (no internal baffling);

4.A split-entry or split-exit configuration can be used to reduce the drum diameter (but increase the length) for large flow rates and should be considered if the vessel diameter exceeds 3.66 m (12 ft). Careful consideration should be given to the hydraulics of split-entry configurations to ensure the flow is indeed split in the desired proportion. Inlet nozzles should include means such as baffles or long sweep elbows to prevent re-entrainment of liquid. Long sweep elbows are typically used up to DN 300 (NPS 12) inlet diameter. Baffles are typically used for larger

Equipment & Process Design



inlet diameters. Neither of these rules has been applied for MEKPCO application.

5. In general, vapor outlet nozzles should not be fitted with any devices (e.g. deflection plates, baffles, demister pads, vane packs, etc.), because of the potential for such devices to fail or plug and obstruct the outlet. Such devices should be used only if the drum is equipped with an alternate outlet nozzle sized for the drum's design vapor flow rate and fitted with a rupture disk (or pin-actuated device) whose burst pressure is selected both to protect the drum against overpressure and to permit proper operation of the drum and relief system in the event the normal vapor outlet becomes obstructed.

6. Liquid droplets 300 um and larger may drop out of the gas stream at less than 2 m/s. If liquids are not drained from the system, flare flows with gas velocities exceeding about 3 m/s or 4 m/s can entrain liquid droplets up to 1000 μ m in size. Liquid droplets exceeding 1000 μ m can readily lead to burning rain regardless of flare type.

7. Among different flare burner types alluded to in API-527 steam and air-assisted flare burner has been selected for MEKPCO project. For this design, Flare gases containing less than 1 % by mass of liquids up to a liquid droplet size of 600 µm can be handled smokeless and without burning rain. Some air assisted burners with small ports and operated at significant pressures can handle larger amounts, and with larger droplet size, without smoke.

8. The liquid holdup capacity of a flare knockout drum is based on consideration of the amount of liquid that can be released during an emergency situation without exceeding the maximum level for the intended degree of liquid disengagement. The holdup times vary between users, but the basic requirement is to provide sufficient volume for a 20 min to 30 min emergency release. Longer holdup times might be required if it takes longer to stop the flow. This holdup should also consider any liquid that can have previously accumulated within the drum that was not pumped out. If there has been a liquid discharge to the knockout drum whereby the liquid level exceeds the maximum level required for adequate vapor-liquid separation, then liquid shall be removed to reduce the level back below this maximum level.

9. It is important to realize as part of the sizing considerations that the maximum vapor release case might not necessarily coincide with the maximum liquid. Therefore, the knockout drum size

Equipment & Process Design



should be determined through consideration of both the maximum vapor release case as well as the release case with the maximum amount of liquid. If no valid liquid case exists and the vapor is either condensable or has a condensable component, then the design liquid case should be a minimum of 2 wt. % of the maximum gas rate to the flare knockout drum.





1st Step: Nozzle Sizing

The criterion for inlet nozzle sizing is velocity limitation which should be 7-13 m/s. The criterion for gas outlet nozzle sizing is velocity limitation which should be 15-30 m/s. The criterion for inlet nozzle sizing is velocity limitation which should be 2-4 m/s.

Parameter	Inlet Nozzle	Gas Outlet Nozzle	Water Outlet Nozzle
Mass	540000 kg/h	510000 kg/h	30000 kg/h
Density		6.82 kg/m3	988 kg/m3
Qv	20.25m3/s	20.24 m3/s	0.01 m3/s
ID-TCC	64'	72'	4'
Velocity	9.76 m/s	7.7 m/s	1.04 m/s
My ID	64'	64'	3'
Velocity	9.76 m/s	9.76 m/s	1.85 m/s

Note that according to API-521, when there is no criterion stipulating the exact amount of water which should be separated a minimum of 2% by weight of total vapor mass could be selected as basis for calc.

But TCC has assumed 30000 m3/h as the rated capacity of K.O.D pump which is Another matter is that the vendor has selected 72' as outlet nozzle ID which is a bit bigger than what the criterion stipulates. Perhaps the vendor was more concerned with droplet sizing so that the higher the outlet nozzle ID, the lower particle sizing. Probably maximum 300 um has been taken for Design Basis.

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2nd Step: K.O.D Diameter and Length Sizing

- 1. Assume Diameter and consider L= 2.5 or 3 D
- 2. Calculate AL and AT according to the following equation:

AL = Q.t/(L.N) $AT = \Pi(D^2)/4$ t = Hold-up time

3. Calculate AL/AT and calculate hL/D from the following equation:

 $A_L/A_T = (\theta - \sin \theta)/(2 \pi)$ and $\theta = 2 \arccos(1-2 h_L/D)$, θ in radians

4. Calculate hV = D.(1 - hL/D)

Parameters	Values
Vapor mass kg/h	510000
Liquid mass kg/h	30000
ρν Kg/m3	6.8
ρl Kg/m3	990
Dp um	300
Hold-up time minute	30
L/D	3
D meter	3.5
L meter	10.5



5.Calculate uc by following equation:

$$u_{\rm c} = 1.15 \sqrt{\frac{g \times D(\rho_{\rm l} - \rho_{\rm v})}{\rho_{\rm v} \times C}}$$

where

- g is the acceleration due to gravity [= 9.8 m/s² (32 ft/s²)];
- D is the particle diameter, expressed in m (ft);
- ρ is the density of the liquid at operating conditions, expressed in kg/m³ (lb/ft³);
- ρ_V is the density of the vapor at operating conditions, expressed in kg/m³ (lb/ft³);







- 6. Calculate $\varphi = hv/uc$
- 7. Calculate AV = AT-AL
- 8. Calculate Uv = Qv / (Av.N)
- 9. Calculate Lreq = Uv. ϕ .N

Parameters	Value
AL	1.44
AT	9.62
AL/AT	0.15
hL/D	0.21
ERROR	Goal Seek Function
hV/D	0.79
hV	2.77
Uc	0.75
φ	3.7
AV	



Parameters	Value
Uv	2.55
Lmin m	9.42
Inlet ID inch	64
Outlet ID inch	72
LT	14.6

If initial volume is not zero and is about 50 m3

Parameters	Value
AL	6.2
AT	9.62
AL/AT	0.64
hL/D	0.61
ERROR	Goal Seek
	Function
hV/D	0.39
hV	1.35



Parameters	Value
Uc	0.75
φ	1.8
AV	3.42
Uv	6.1
Lmin m	10.98
Inlet ID inch	64
Outlet ID inch	72
L	10.5

10.Verification: If L _{Req} is greater than L, increase the drum diameter and repeat the L _{Req} calculations again until L _{Req} is less than L. Also, hl/D should be max 0.5.

Since L $_{Req}$ is less than L then, we ought to increase K.O.D ID to 4 meter and repeat the procedure.

So for doing this, we use Goal seek function in Excel to help us reach exact point of hL/D.



Parameters	Value
D	4
L/D	3
L	12
Uc	0.75

Parameters	Value
AL	5.43
AT	12.57
AL/AT	0.43
hL/D	0.44
ERROR	Goal Seek Function
hV/D	0.55
hV	2.21



Parameters	Value
φ	2.95
AV	7.14
Uv	2.92
Lmin m	8.62
Inlet ID inch	64
Outlet ID inch	72

TCC has ordered a K.O.D with the following sizing which is oversized in my opinion but

appears to be good in handling such amount of gas and condensate.

Parameters	TCC	API-521	Sabalan
Diameter	5.8 m	4 m	5m
Length	18 m	14 m	10m



Flaresim Design

KODrum 1			
d Data Composition N/	A Vessel Data	Nozzle Data Results	Vessel Report
ow Data			
ias Flow			
lass Flow	kg/h	510000	
ctual Volume Flow	m3/h	73912	
iquid Flow			
lass Flow	kg/h	29700	
ctual Volume Flow	m3/h	30.00	
ump Out Flow			
lass Flow	kg/h	29700	
ctual Volume Flow	m3/h	30.00	
clude Pump Out Flow		No	~
uid Properties			
luid Properties			
roperty Source	User Specified		
ias Density	kg/m3	6.900	
ias Viscosity	cP	0.02500	
iquid Density	kg/m3	990.0	
iquid Viscosity	cP		
iquid Surface Tension	N/m		
			Calculate



id Data Composition N//	4 Vessel Data	Nozzle Data Results	s Vessel Report
Calculation Options			
Calculation Options			
Calculation Type	Sizing		~
Vessel Type	Horizontal		
Vessel End Type	Ellipsoidal		
Settling Velocity Method	API		
Vessel Input Data			
Vessel Input Data - Sizing	1	- Anna anna	
Initial Liquid Level	%	10.00	
Max.Allowed Liq.Level	%	75.00	
Liquid Holdup Time	S	1800	
Droplet Diameter	mm	0.3000	
L/D Ratio		3.100	
Diameter	m		
Summary Results Calculated Vessel Result	S		
Diameter	m	4.153	
Tan Tan Length	m	12.87	
L/D Ratio		3.100	
			Calculate

Equipment & Process Design



Flare Thermal Radiation Assessment Based on API-521 and Schlumberger Flaresim



Equipment & Process Design



Calculation of Flare Stack Diameter

In order to calculate Flare Diameter, the following equation between Mach number and Diameter is used.

In SI units:

$$Ma_2 = 3.23 \times 10^{-5} \left(\frac{q_{\rm m}}{p_2 \times d^2}\right) \left(\frac{Z \times T}{M}\right)^{0.5}$$

In USC units:

$$Ma_{2} = 1.702 \times 10^{-5} \left(\frac{q_{\rm m}}{p_{2} \times d^{2}}\right) \left(\frac{Z \times T}{M}\right)^{0.5}$$

According to TCC calculation a flare stack with diameter of 1.6 m and a height of 44.45 m Here according to API-521, the calculated diameter is about 2.46 m when the temperature is 273 K and when the temperature is 633 K for blocked outlet scenario then the calculated diameter is 3.04 m.



Parameters	Value
т	273.15 K
Z	1.33
Μ	13.44
P2	141 kpa
Mach	0.1
DD	2.46

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Calculation of Flame Length

1.Calculate liberated heat by following formula and then use next page Figure to determine

Flame Length.

 $Q = Mass (kg/h) \cdot LHV (kJ/kg) \cdot (1h/3600s)$

Q = 712342 Nm3/h . 7964 / $3600 = 1.57 \times 10^{6} \text{ kW}$

According to the next-page diagram the estimated Flame Length is round about 70 m.



Key

X heat release, expressed in watts

- Y flame length (including any lift-off), expressed in meters
- 1 fuel gas (508 mm stack)
- 2 Algerian gas well
- 3 catalytic reformer—recycle gas (610 mm stack)
- 4 catalytic reformer-reactor effluent gas (610 mm stack)
Equipment & Process Design



Calculation of Flame Distortion Caused by Wind Velocity

- 1. Calculate vapor volume flow rate
- 2. Divide wind velocity to flare tip velocity
- 3. Use next-page diagram to calculate ΔX and ΔY .
- 4. Use distance equation and plot to estimate flare stack height.

1st Step

T = 273K qv = $(51000/3600) \times \left(\frac{22.4}{13.4}\right) \times (273/273) = 236.8 \text{ m3/s}$ T = 633K qv = $(51000/3600) \times \left(\frac{22.4}{13.4}\right) \times (633/273) = 549 \text{ m3/s}$

2nd Step

In order to perform this step, at first, we need to calculate flare tip exit velocity according to following formula

$$u_{\rm j} = \frac{q}{\pi d^2 / 4}$$

T=273K uj = 49.6 m/s T=633K uj = 75 m/s



So now wind velocity to tip velocity is divided by taking into account 16 m/s as local wind velocity

T=273K

u/uj = 0.32

T=633K

u/uj = 0.21

T=633K

According to next-page diagram, $\Delta Y/L = 0.3$ therefore $\Delta Y = 21m$

According to next-page diagram, $\Delta X/L = 0.9$ therefore $\Delta X = 63$ m

T=273K

According to next-page diagram, $\Delta Y/L = 0.23$ therefore $\Delta Y = 16m$

According to next-page diagram, $\Delta X/L = 0.93$ therefore $\Delta X = 65m$



Figure F.3—Approximate Flame Distortion Due to Lateral Wind on Jet Velocity from Flare Stack

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A common approach to determining the flame radiation to a point of interest is to consider the flame to have a single radiant epicenter and to use the following empirical equation by Hajek and Ludwig. Equation (F.1) may be used for both subsonic and sonic flares, provided the correct F-factor is used.

$$D = \sqrt{\frac{\tau \times F \times Q}{4\pi \times K}}$$

Parameters	Values	Parameters	Values
т	0.8	т	1
F	0.15	F	0.2
Q	1.57 × 10^6	Q	1.57 × 10^6
К	3.13	К	3.13
D	70 m	D	89.5 m



F-factor

Table F.1—Radiation from Gaseous Diffusion Flames

Gas	Burner Diameter cm	Fraction of Heat Radiated
	0.51	0.095
	0.91	0.091
Hydrogen	1.90	0.097
	4.10	0.111
	8.40	0.156
	20.30	0.154
	40.60	0.169
	0.51	0.215
	0.91	0.253
	1.90	0.286
Butane	4.10	0.285
	8.40	0.291
	20.30	0.280
	40.60	0.299
	0.51	0.103
	0.91	0.116
Methane	1.90	0.160
	4.10	0.161
	8.40	0.147
Natural gas	20.30	0.192
(95 % CH4)	40.60	0.232





T=233K

In order to calculate flare height, the following equation is used.

$$h' = h + (0.5 \sum \Delta y)$$

$$r'=r-(0.5\sum \Delta x)$$

Parameters	Values
r	35
ΔΧ	65
r'	2.5

$$D^2 = r'^2 + h'^2$$

Parameters	Values	Values
D	89.5	70
r'	2.5	2.5
h'	89.4	69.9



Parameters	Values	Values
h'	89.4	69.9
ΔΥ	16	16
h	81.4 m	62 m

T=633K

In order to calculate flare height, the following equation is used.

$$h' = h + (0.5 \sum \Delta y)$$

$$r'=r-(0.5\sum\varDelta x)$$

Parameters	Values
r	35
ΔΧ	63
r'	3.5

$$D^2 = r'^2 + h'^2$$



Parameters	Values	Values
D	89.5	70
r'	3.5	3.5
h'	89.4	69.9

Parameters	Values	Values
h'	89.4	69.9
ΔΥ	21	21
h	78.4 m	59 m

An average Flare Stack Height of 70 m is accepted for preliminary design which should be confirmed by Flaresim.

In MEKPCO project there is one set of elevated flare in Flare system which is supported by derrick. The total height of flare is 70 m (Flare stack + K.O.D =60m and Molecular Seal and Flare tip each 5 meter)

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FS Flaresign and analysis software

Schlumberger

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1st Step: Click on "Fluid TAB" and "Add" a Fluid Table

(Click To Calculate	e	ft Fluid			
- 🖬 😡	i a 🛍	-	Name Blocked Outlet fl	ow		
View	Activate	Ignore				
Add	Сору	Delete	Properties Options Co	mposition Results	5	
-		<u></u>	Method			
Case	Summary		Calculation Method	Flaresim		
	luids Disoland Outla	t flow	Conditions			
	 Blocked Outle Invironments 	a now	Temperature	С	360.0	
	Environment	1	Ref. Pressure	bar	1.100	
🖕 🕜 S	itacks		Properties		-	
T(Stack 1		Mole Weight		13.14	
	ìps		Lower Heating Value	kJ/kg	12470	
	Tip 1		Cp/Cv		1.373	
	Receptor Points		LEL	%	7.398	
	Point 1		Saturation	%	100.0	
TY.	Grid 1		Critical Properties			
- A	ssist Fluids		Critical Pressure	bar	81.15	
- s	hields		Critial Temperature	С	-28.51	
- C	Dispersions					
— – K	O Drums					
- S	ieal Drums					
	ase Studies					
	Component Mana	gement	Delete		Ready	
	lotes	genora				



operties Options Cor	mposition Results	
Fluid Composition		Composition Basis
Component	Fraction	O Mass
Methane	0.004600	Mole
Hydrogen	0.488451	C Mole
Carbon monoxide	0.151685	
Water	0.294171	Add Component
Carbon dioxide	0.051695	
Argon	0.000200	Remove Component
Nitrogen	0.009199	
		Normalise Composition
		Calculate Last Fraction
Sum	1 000000	

Name Blocked Outlet flow		
Properties Options Composition Results	■ ■	
Options		
Options for Flaresim method		
Correct Temperatures	No	
Use RK Z Factor	Yes	



2nd Step: Click on "Environment TAB" and "Add" a Environment Table

lame Environmer	ıt 1		
verall Wind Rose	Dispersion Data		
Atmoonhorio Conditio			
Autospheric Conditio	ris -		
Wind			_
Speed	m/s	16.00	
Direction	•	0	
Atmosphere		and the second s	
Temperature	С	23.60	
Humidity	%	74.00	
Pressure	bar	1.100	
Background Data			
Background			
Solar Radiation	k\///m2	1.000	
Noise	dB	60.00	
Include Solar Rad	iation 🔽	Include Background N	oise
Transmissivity Metho	8		
Transmissivity			
Method	Calculated		~
Minimum Value			
Maximum Value			
D I I I		(Thomas in the second s	Longer d



Thermal Radiation and Noise Criteria

According to API-521, the followings are important to notice when designing a flare stack.

Recommended Design Thermal Radiation for Personnel.

Conditions
Maximum radiant heat intensity at any location where urgent emergency action by personnel is required. When personnel enter or work in an area with the potential for radiant heat intensity greater than 6.31 kW/m ² (2000 Btu/h·ft ²), radiation shielding and/or special protective apparel (e.g. a fire approach suit) should be considered.
Safety Precaution—It is important to recognize that personnel with appropriate clothing ^a cannot tolerate thermal radiation at 9.46 kW/m ² (3000 Btu/h·ft ²) for more than a few seconds.
Maximum radiant heat intensity in areas where emergency actions lasting up to 30 s can be required by personnel without shielding but with appropriate clothing. ^a
Maximum radiant heat intensity in areas where emergency actions lasting 2 min to 3 min can be required by personnel without shielding but with appropriate clothing. ^a
Maximum radiant heat intensity at any location where personnel with appropriate clothing can be continuously exposed.

The incident solar radiation for the site. Typical values for different geographical locations are given in the following table.

Location	Solar Radiation (W/m2)
North Sea	475-630
Middle East	945-1050
UKLand	630-800



The decision on whether to include solar radiation when designing flare systems is one for the user.

API 521 recommends that this be considered on a case-by-case basis. Some consider it more realistic to exclude solar radiation in calculations.

In deciding whether to include solar radiation consideration should be given to the frequency and duration of the flaring event, the probability of personnel being present in the exposed location, the possibility of sun and flare radiation impinging from the same general direction, the likelihood of protective clothing being worn and the ease or difficulty of escape from the exposed location.

Including solar radiation leads to more conservative designs and its impact can be significant if the flare system design is controlled by low total radiation limits at longer distances from the flare.

Determining whether solar radiation has been included or excluded is important when comparing flare system designs.

In MEKPCO Project, solar radiation has been included.



Noise

The background noise is used as a reference noise level to which the noise from the flare

system is added.

Intensity (dB)	Situation
0	Threshold of hearing
10	Virtual silence
20	Quiet room
30	Watch ticking at 1m
40	Quiet street
50	Quiet conversation
60	Quiet motor at 1m
70	Loud conversation
80	Door slamming
90	Busy typing room
100	Near loud motor horn
110	Pneumatic drill
120	Near aeroplane engine
130	Threshold of pain

In MEKPCO Project, a typical value of 60 dB has been selected for background noise.



Environment	
Name Environment 1	
Overall Wind Rose Dispersion Data	
Wind Rose Calculation Mode	
No wind rose calculations	
O Run calculations on all wind directions for specified wind speed	s
O Run each wind direction with a specified speed	
Delete	

Environment 1			
verall Wind Rose Dispers	ion Data		
Dispersion Data			
Atm. Stability Class	PasquillD		~
Terrain Class	Rural		
Atm. Surface Roughness	m	0.2000	
Wind Data			
Wind Reference Height	m	10.00	
Correct W.Speed For Height	t-	No	
"For radiation and temperature Correction always applies for o	e calc's. dispersion calc	s	
"For radiation and temperature Correction always applies for o	acalo's: dispersion calo	ŝ	
For radiation and temperature Correction always applies for o	acalo's. dispersion calo	ŝ	



Stability Class

PasquillA through PasquillF

This defines the atmospheric stability class to be used to characterize the atmospheric turbulence for both Gaussian and jet dispersion calculations.

Flaresim uses the widely used Pasquil stability class designation from A to F where A is the most turbulent or most unstable atmosphere and F the least turbulent or most stable. Here as typical, *PasquillD* is selected.

10-meter high is reference height at which the wind speed is specified. This will be used together with the atmosphere and terrain characterization information to calculate the wind speed at a given height when required.

etails	Sterile A	rea				
Locati	on	the later				
Relativ	ve To	Origi	n			~
Carte	sian Coo	rdinates	÷.			
North	ing		m	>	0	
Eastin	ng		m		0	
Eleva	tion		m		0	
Polar	Coordina	ates				
Radiu	IS		m		0	
Angle	To Horiz	contal	•		0	
Angle	From No	orth	1		0	
Stack	Dimensio	ns				
Dime	nsions					
Lengt	h		m		65.00	
Angle	To Horiz	contal	•		90.00	
Angle	From No	orth	1		0	
Siz	e This St	ack				

3rd Step: Click on "Stack TAB" and "Add" a Stack Table



Equipment & Process Design

etails Sterile Area	
Options	
Options	
Sterile Area Elevation m Noise Basis Calculate Sterile Area	0 NoiseA No
Sterile Area	
Radiation Limit Distance To Limit	Export
1.577	Radiation
3.155	O Noise
4.732	
6.309	Sterile Area is for this stack only and excludes shields.
	Distance is downwind distance from stack base; inclined stacks point into wind.

At first estimation, a stack length of 65 m is selected. Since the stack is vertical 90 degrees for

Horizontal angle is selected.

Notice that Noise A means Noise weighted for human ear sensitivity



Equipment & Process Design

4th Step: Click on "Tips TAB" and "Add" a Tip Table

ame IIp I			Harr
loise Results Flame Shap	pe Combustion Res	ults Purge Gas	
letails Noise Input Loc	ation & Dimensions	Fluids Emissions Results	
Details			
Tip Details			
Тір Туре	Pipe		
Number of Burners		-1	
Seal Type	Molecular 1		
Seal Diameter Basis	Stack		
Methods			
Radiation Method Detail	s		
Radiation Method	Global		
No. Flame Elements		1	
Element Position	%	50.00	
F Factor Details	-		
F Factor Method	Generic Pipe		
Calculated F Factor			
Flame Length Details			
Flame Length Method	Brzustowski		

For gases, either the pipe or sonic tip types may be selected. Pipe flares are the simplest type of tip and may be specified for both high- and low-pressure gases. If the pressure available is greater than 2 bar (30 psi) at the tip then a sonic tip can be utilized. Sonic flare tips have the advantage of low flame emissivities due to more efficient combustion of the flare gas. For lower pressures a pipe flare is generally used possibly with steam or air Assist fluid.

Where a combined HP/LP tips is selected the HP tip is assumed to be a sonic tip and the LP a sub-sonic one. The flow ratio of HP to LP fluids should be 3 or greater.

For liquids a *Welltest* tip type should be selected.

In MEKPCO Project, Pipe is selected.



Seal Type

There are two basic types of seal, Fluidic or Molecular. Seals are only appropriate for pipe and sonic flare tips. If the tip type is set to *Welltest* the seal type will be set to None automatically. The figure below shows the general design concept for the fluidic seal.



The type selection is a function of the opening as defined below

- Fluidic1: 50% of total area
- Fluidic2: 40% of total area
- Fluidic3: 35% of total area

The figure below shows the general design concept for the molecular seal.





The type selection is a function of the diameter as defined below:

Molec.1: Traditional design. Maximum diameter is 1.7 times the tip diameter. The pressure drop correlation is based on a design which gives a body length of 5.5m (18ft) regardless of the tip diameter.

Molec.2: Low pressure drop design. Maximum diameter is 2 times the tip diameter. The pressure drop correlation is based on a design which gives a body length which is a function of the tip diameter.

The fluidic seal has a number of advantages over the traditional molecular seal:-

- 1. Lower purge gas requirements and consequent operating costs.
- 2. The seal still operates with a high efficiency even if rain water or chunks of refractory material drops into the baffles. In fact, the water is quickly dissipated because the fluidic seal is located at a high temperature section of the flare stack.
- Lower cost due to the simple construction and light weight. A 48" fluidic seal will typically weigh less than half the weight of a 6" molecular seal.

In MEKPCO Project, Molecular 1 is selected.

Seal Diameter Basis

This entry defines whether the seal calculations are based on the tip diameter or stack diameter. effectively this specifies whether the seal is located within the tip or the stack. Here Stack has been selected.



F Factor

The fraction of the total net heat release from the flame which is radiated.

- Natural gas: Correlation based on tip exit velocity assuming a natural gas fluid of molecular weight 19.
- ✓ Tan: Correlation based on mole weight
- ✓ Kent: Correlation based on mole weight
- High Efficiency: Proprietary correlation between tip type, exit velocity, fluid molecular weight and degree of hydrocarbon saturation. Formally known as the Flaresim method in versions prior to 1.2.
- ✓ Cook: Correlation based on exit velocity.
- Generic Pipe: Correlation based on refitting Kent, Tan, Natural gas and Cook methods across a range of exit velocities and molecular weights.
- ✓ Modified. Chamberlain: Correlation based on mole weight and exit velocity.

Which one to select?

Where flare vendor data is available it should be used in preference to a correlation. In the absence of vendor data, the Generic Pipe method is recommended for a conservative design. For clean burning, smokeless flares from well-designed flare tips in good condition the High Efficiency method can be used.

In practice this means flares burning paraffinic hydrocarbons of low molecular weight fluid (<60) at reasonable exit velocities (> 0.2 Mach). For fluids other than paraffinic hydrocarbons vendor advice should be sought. In the absence of advice, user specified F Factors of 0.3 to 0.4 are generally reasonable.

If the Fraction Heat Radiated Method is set to User Specified then the required value for the fraction of heat radiated must be entered here. Otherwise, the calculated result for the selected calculation method will be displayed after the model has been run.

Here Generic Pipe is selected.



Tip Type	Fraction Heat Radiated	
Pipeflare	0.25 to 0.4	
Single Burner Sonic	0.10	
Multiple Burner Sonic	0.05 to 0.1	

Flame Length Method

- API Flame length is calculated from heat released according to equation presented in API 521.
- ✓ FLARESIM Flame length is calculated from heat released using following equation.
 Where

$$L = I_1 \left[\frac{Q}{N}\right]^{I_2}$$

Тір Туре	1	12
Pipefiare	0.00331	0.4776
Single Burner Sonic	0.00241	0.4600
Multiple Burner Sonic	0.00129	0.5000

L is flame length in m

Q is heat release in J/s N is number of tips The constants I1 and I2 take the following values for different tip types

✓ Brzustowski - Flame length is calculated from flammability limits using Brzustowski &

Sommer method

Here Brzustowski is selected by the Flaresim.



anne	Lub i		1 Miles
Results	Noise Results	Flame Shape Com	bustion Results Purge Gas
)etails	Noise Input Lo	ocation & Dimensions	Fluids Emissions
Fluids			
Prima	ry Fluid		
Fluid		Blocked Outlet f	low
Mass	Flow	kg/h	510000
Mole F	Flow	kgmole/s	10.78
Assist	t Fluid		
Fluid			
Mass	Flow	kg/h	
Flow	Ratio		
			Flow vs Time
Combu	istion Input		
Comb	ustion Input Data	8	
Comb	ustion Air Ratio		1.000
Flame	Temp. (opt)	С	1714
Clear F	lame Temperatur	e to allow it to be cal	culated





Purge Gas Input Data			
Purge Gas Input	Nitrogen		
Diameter Basis	Stack		
Fixed Velocity	m/s	0.06000	
Fixed Flow	m3/h	0.2830	
HUSA 02	%	6.000	
HUSA Height	m	7.620	
Defined Velocity	m/s	kg/h	
Defined Velocity	0.06000		
Defined Flow			
HUSA			
Reduced HUSA		-	
		Update Purge Calcs	



The physical length of the burner tip. The value is used in calculating the true gas exit point for flame Length calculations and gas dispersion calculations.

For Exit Diameter calculation, click "Size Me" and enter 0.11 as Design Mach number in order to allow the software to calculate proper exit diameter.

Sizing Data			
Fluid Data		Prev Size	New Size
Mass Flow	kg/h	510000	510000
Mole Flow	kgmole/s	10.78	10.78
Number of Burners		1	1
Design Mach No.		0.1100	0.1100
Diameter Data		Prev Size	New Size
Use Nominal Diam.		No	No
Schedule		STD	STD
Nominal Diameter		<not set=""></not>	<not set=""></not>
Tip Internal Diam.	mm	2956	2956
Calc, Mach No		0.1100	0.1100

On Stack Stack 1		~	
Dimensions			
Tip Dimensions			
Tip Length Angle to Horizontal	m •	5.000 90.00	
Angle from North	•	0	
Exit Diameter	mm	2956	
Burner Opening	%	100.0	
Riser Diameter	mm	2956	
Roughness	mm	0.02500	
Tip Exit Settings			
Contraction Coefficient	t	1.000	
Exit Loss Coefficient		1.000	
Outlet Pressure	bar	1.100	
Calculate Burner Op	ening	Size Me	

Equipment & Process Design



Noise input

Selects the noise calculation method to be used.

- 1. Acoustic Efficiency method
- 2. Reference Curve method

The Reference Curve method is based on a reference spectrum of noise at a known heat

release.

Select Noise Curve

- 1.Standard
- 2.Low Noise

The Standard and Low Noise reference data options are

proprietary data supplied by a flare system vendor.

Noise Method Details Comb'n Noise Method Reference Curve Noise Curve Low Noise Jet Noise Method Flaresim	
Noise Method Details Reference Curve Noise Curve Low Noise Jet Noise Method Flaresim	
Jet Noise Method Flaresim	
	~



5th Step: Click on "Calculation Option TAB" and "Add" a Table

Saloalation motification				
Methods	-			
Radiation Method	Brzus	towski		
No. Flame Elements			1	
Element Position	%		50.00	
Noise Method	Spectrum			
Wind Chill Jet Dispersion Run Dynamics		Atm.Noise A Gaussian D Run Case S	Attenuation ispersion tudies	
Buoyancy				
Buoyancy				
Pipe Burner	m/s		3.048	
Sonic Burner	m/s		4.572	
Well Test Burner	m/s		0.03048	_
Invironment				
Activo Environment	Financia	1000-000-00 - 0		
	Environment 1			



Select the method to be used to model the thermal radiation from the flame.

- ✓ The Flaresim API and Strict API methods model the single point source method of Hajek and Ludwig given in API RP-521. The difference between the methods is in the method of calculating the flame shape before finding the center point to act as the source. The Flaresim API method uses the vector-based flame shape method and allows multiple flame elements to be used to model the shape more accurately even though a single, center point will be used as the source. The Strict API method uses the graphical method presented in API 521 through a curve fit to the data presented there. The API method in DOS versions of Flaresim and Flaresim for Windows versions prior to version 2.0 was the Flaresim API method. Either API method may be generally applied to most flare systems.
- The Point source method is a multiple point extension of the API method in which the flame is assumed to be completely transparent such that radiation from one point does not either interfere with or occlude another. The flame is divided into a series of smaller point source elements whose contributions are summed to derive the total radiation from the flame. In practice this method generally gives more realistic and less conservative values than the API method. It does however tend to over predict thermal radiation in the near field.
- ✓ The <u>Diffuse source</u> method assumes that the flame is completely opaque such that radiation is emitted entirely from the surface of the flame envelope. This method tends to under predict the thermal radiation in the near field.
- The <u>Mixed source</u> method is an empirical combination of both the Point and Diffuse source methods. This has been found to give more realistic results in both the near and far fields.
- ✓ The <u>Brzustowski method</u> is a single point method in which the flame center is determined from jet dispersion theory. The method as described in API RP-521 is subject to a number of limitations in its implementation in Flaresim: -



- Only vertical tips may be modelled.
- Air assisted flares may not be modelled.
- Liquid burners may not be modelled.
- ✓ The <u>M.Point Brz method</u> is a Flaresim extension to the standard Brzustowski method to allow the number of flame elements and the element position to be specified by the user. In versions of Flaresim prior to 1.2 these options could be set for the Brzustowski method. In Flaresim 1.2 the Brzustowski method is forced to be a single flame element with fixed element position. Old cases that specify the Brzustowski method will be updated automatically to M.Point Brz if they have more than one flame element or the element position is not 50%.
- The Chamberlain method, also known in the industry as the Shell Thornton method is based on a modelling the flame as a conical frustum radiating from its surface with a uniform emissive power. The method was developed to provide more accurate predictions of flame shape and radiation in the near field.

Number of flame element

The number of elements that the flame is divided into for calculation of flame shape and the sources for the Point, Diffuse and Mixed methods. Larger values will generally give more realistic values for the thermal radiation at the expense of calculation time. 1 Element is set for this case.

Element Position

The element position indicates the source point within a flame element that is used for calculations. Typically this is 50% i.e. the middle of the flame element is taken to be the point source. 0% indicates the source is the start of the element, 100% is the end. 50% is set in this project.



Noise Method

Selects the method to be used for the <u>noise calculations</u>. The API method taken from RP521 is a simple single value method and considers jet noise only. The Spectrum method uses multiple frequency values and includes combustion noise. Generally, the Spectrum method is recommended.

Spectrum is selected.

Windchill

When set an empirical <u>Windchill correlation</u> is used to correct the incident thermal radiation at any receptor point by taking into account the heat losses due to passage of wind over the point. Use of this option will generally be a matter of individual judgement or your company standards. It is recommended that you do not use this option if you are interested in the surface temperature calculations. Note that effective of wind on convective heat transfer in the surface temperature calculations is independent of the setting of this option.

Atm. Noise Attenuation

When set a correction will be applied to the noise calculations to allow for the attenuation in noise due to <u>atmospheric absorption</u>. This option should normally be set

Jet Dispersion

Selecting this enables the jet dispersion calculations and will calculate concentrations of flare fluid at receptor points and for receptor grids under flame out conditions

Gaussian Dispersion

Selecting this enables the calculations for all Gaussian Dispersion objects defined in the model



Run Dynamics

Selecting this enables dynamics calculations to be run to evaluate the change in radiation and other results with time as the flare flow varies with time. The variation in flare flow with time must be defined on the Tip Dynamics View and the results variation with time can be viewed on the Receptor.

Point Dynamics View

The dynamics calculations are run in addition to the defined base case. Receptor Grid objects and Dispersion objects are not included int the dynamic calculations

Buoyancy

For all methods except the Brzustowski and Chamberlain methods, the flame shape is calculated by resolving the velocity vectors in three dimensions. The main components are the tip exit velocity and the wind velocity. There is however an additional velocity component which is due to the density differences between the hot combustion gases and the surrounding air. This is referred to as the flame buoyancy term.

Buoyancy - Pipe

The flame buoyancy which should be used for Pipe flares. A value of 3.0 m/s is recommended unless specific vendor information suggests otherwise.

Buoyancy - Sonic

The flame buoyancy to be used for Sonic flare tips. A value of 4.6 m/s is suggested unless specific vendor information suggests otherwise.

Buoyancy - Welltest

The flame buoyancy to be used for Liquid flare tips. A value of 0.03 m/s is suggested unless specific vendor information suggests otherwise.



The recommended buoyancy values are based on empirical information supplied by a flare vendor. The wide range of allowed values is intended to provide flexibility for users with specific information and the validity of any values entered is the responsibility of the user.

Minimum Length Maximum Length Maximum Length Mizing Result Calculated Length	m m	1.000 200.0
Animum Length Aaximum Length Sizing Result Calculated Length	m	200.0
Sizing Result Calculated Length	U.S.	200.0
Calculated Length		
sandaratea congin	m	
Wind Speed Used	m/s	
Vind Direction Used	•	
ressure Profile Options		
Pressure Profile Options		
Pressure Tolerance	bar	0.00000
Tip Elements		4
Riser Elements		40
liser Elements		40



Wind Speed Units	ft/s	
Transition Wind Speed	m/s	4.572
Windspeed Below Trans	aition	1.040
Equation Parameter A	W/m2/K	1.249
Equation Parameter B	1.11.011	1.000
Equation Parameter C	W/m2/K	4.543
Windspeed Above Trans	sition	0.100
Equation Parameter A	W/m2/K	3.180
Equation Parameter B	1.0.000	0.7500
Equation Parameter C	W/m2/K	U
Dynamic Calculations		
Dynamics Parameters		
Exposure Time	S	900.0
No. Of Steps		90

missio	ns	1997.	
Combu	stion Gas Calcula	ations	
Calcul	ation Method	Emissions-V5.2	
missi	ons Data		
IOx E	mission Basis	Mass/Heat Release	
IOx R	late	kg/GJ	0.02923
O En	nission Basis	Mass/Heat Release	
O Ra	ite	kg/GJ	0.1590
nbur	t HC Basis	Mass/Heat Release	
Inburr	nt HC Rate	ka/G.	0.06016
Unbu	mt hydrocarbons re	ported as methane	Reset Defaults
Unbu	nt hydrocarbons re	ported as methane	Reset Defaults
Unbu)ispers let Dis	nt hydrocarbons re ion Options	ported as methane	Reset Defaults
Unbu ispers et Dis verag	mt hydrocarbons re ion Options persion Options jing Time	ported as methane	Reset Defaults



General S	izing & Pressure	e Profile	Heat Transfer	Emissions Fitting
F Factor F	itting			
Fitting Pa	rameters			
Target Ti	p			
Target Re	ceptor Point	<all a<="" td=""><td>ctive></td><td></td></all>	ctive>	
Result				
Error				
				Bun Fitting
				i han i i hun ing
)



6th Step: Click on "Receptor point TAB" and "Add" a Point

Location Relative To Origi	n	~
Castanian Canadiantes		
Northing	m	-35.00
Fasting	m	0
Elevation	m	0
Polar Coordinates		
Radius	m	35.00
Angle To Horizontal	•	0
Angle From North	•	180.0
Sizing Constraints		
Max Radiation	kW/m2	3.054
Max Noise	dB	
Max Noise A	dB	
Max Average Noise	dB	80.00
Max Temperature	С	
Observed Values		
Radiation	kW/m2	


ame Point 1		8
finition Properties Re	sults Noise Results	WindRose
Point Properties		
Point Properties		
Emissivity		0.7000
Absorbtivity		0.7000
Area Ratio Basis	User Defined	
Area Ratio		2.000
Mass / Unit Area	kg/m2	24.00
Mass CP	J/kg/C	450.0
Thermal Conductivity	W/m/K	50.00
Conduction Area Ratio		0
Conduction Distance	m	1.000
Initial Temperature	С	15.56
Local Environment	Global	
On Plane None		~
Threshold Limit Values Threshold TDU Limit	(kW/m2)4/3.s	290.0
Threshold Temp. Limit	C	100.0



Results/Tip

Tip Results		
Exit Properties		
Exit Velocity	m/s	75.16
Mach Number		0.1013
Actual Volume Flow	m3/h	1.857E+06
Calculated F Factor		0.1905
Contraction Coefficient		1.000
Exit Temperature	С	360.0
Flame Results		
Heat Release	k₩	1.767E+06
Flame Length	m	87.64
API Length	m	86.35





Pressure Profile			
Pressure Profile			
bar	V	Static	Total
Tip Outlet	il.es	1.100	1.108
Tip Inlet		1.100	1.108
Tip DP		1.234E-04	1.227E-04
Seal Inlet		1.101	1.109
Seal DP		0.001253	0.001243
Stack Inlet		1.103	1.111
Stack DP		0.001734	0.001722

Noise Results			
Total Noise		a secondaria de la compañía de la co	j
Noise - SPL	dB	95.33	
Reference Distance	m	30.00	

	-	
Combustion	Gases -	Mass

Combustion gas flows	- mass basis	
Carbon dioxide	kg/h	352631
Water	kg/h	552807
Oxygen	kg/h	2005
Nitrogen	kg/h	1.341E+06
Sulphur dioxide	kg/h	0
Nitrogen monoxide	kg/h	185.9





Dimensions			
Length	m	70.31	
Angle To Horizontal	0	90.00	
Angle From North	٥	0	



Results/Point1

Calculated Results		
Radiation	kW/m2	3.054
Final Temperature	С	39.67
Concentration	mole/mole	
Local Wind Speed	m/s	16.00
Time To TDU Limit	S	65.44
Time To Temp. Limit	S	Limit Not Reached





dB	86.56	
dB	76.88	
dB	76.56	
	dB dB dB	dB 86.56 dB 76.88 dB 76.56

Frequency	Noise	NoiseA
Hz	dB	dB
31.25	77.42	38.02
62.50	82.36	56.16
125.0	80.38	64.28
250.0	78.40	69.80
500.0	73.53	70.33
1000	71.65	71.65
2000	66.91	68.11
4000	63.44	64.44
8000	61.91	60.81
16000	60.22	53.62





7th Step: Click on "Receptor Grid TAB" and "Add" a Grid1

t Overlay Graphic Rep	ort	
tent Radiation Noise	Temperature Conc	entrations Max Radiation
arid Extent		
Grid Extent		
Grid Plane	Elevation-Northing	
Easting Offset	m	0
Elevation		
Minimum	m	0
Maximum	m	300.0
Number of Points		100
Vorthing		
Minimum	m	-150.0
Maximum	m	150.0
Number of Points		100
Properties		
Grid Point Properties		
Point Orientation	None	~
Emissivity		0.7000
Absorbtivity		0.7000
Area Ratio		2.000
Options		
Noise Basis	Noise	
Report Dispersion As	Concentration	

Equipment & Process Design



Results/Grids



Max Radiation Input		
Initial Grid Points		11
Sizing Constraint	kW/m2	
Calculate Max Radiat	ion	Yes
Max Radiation Result	5	
Max Radiation	kW/m2	3.008E+09
Elevation Offset	m	97.01
Northing Offset	m	-38.54







7th Step: Click on "Receptor Grid TAB" and "Add" a Grid2

aphic Report	-		
ent Radiation Noise	Temperature	Concentrations Max Radiation	Plot Overlay
arid Extent Srid Plane	Elevation-East	sting	
Jorthing Offset	m	0	
-levation			
Minimum	m	0	
Maximum	m	350.0	
lumber of Points		100	
Easting			
Ainimum	m	-170.0	
Maximum	m 170.0		
Number of Points		100	
Properties			
Grid Point Properties			
Point Orientation	None	>	
Emissivity		0.7000	
Absorbtivity		0.7000	
Area Ratio		2.000	
Options			
Noise Basis	Noise	Noise	
Report Dispersion As	Concentratio	n	

Equipment & Process Design



Results/Grids



Max Radiation Input		
Initial Grid Points		11
Sizing Constraint	k₩/m2	
Calculate Max Radiat	ion	Yes
Max Radiation Result	5	
Max Radiation	kW/m2	15.23
Elevation Offset	m	97.02
Easting Offset	m	-5.994E-04







A Comparison Study

1.In Calculation Option TAB, Brzustowski method was changed to Flaresim API.

2.In "Options" just Atm. Noise Attenuation is enabled.

Results

Parameter	Flaresim API	Brzustowski
Stack Height	68.4	70.3



Tip Result Comparison

Exit Properties		
Exit Velocity	m/s	75.16
Mach Number		0.1013
Actual Volume Flow	m3/h	1.857E+06
Calculated F Factor		0.1905
Contraction Coefficient		1.000
Exit Temperature	С	360.0
Flame Results		
Heat Release	k₩	1.767E+06
Flame Length	m	87.64
API Length	m	86.35

Pressure Profile			and the second
bar	~	Static	Total
Tip Outlet		1.100	1.108
Tip Inlet		1.100	1.108
Tip DP		1.234E-04	1.227E-04
Seal Inlet		1.101	1.109
Seal DP		0.001253	0.001243
Stack Inlet		1.103	1.111
Stack DP		0.001734	0.001722



Flaresim API

Exit Properties		
Exit Velocity	m/s	75.16
Mach Number		0.1013
Actual Volume Flow	m3/h	1.857E+06
Calculated F Factor		0.1905
Contraction Coefficient		1.000
Exit Temperature	С	360.0
Flame Results		
Heat Release	kW	1.767E+06
Flame Length	m	86.35
API Length	m	86.35

Pressure Profile				
bar	~	Static	Total	
Tip Outlet		1.100	1.108	
Tip Inlet		1.100	1.108	
Tip DP		1.234E-04	1.227E-04	
Seal Inlet		1.101	1.109	
Seal DP		0.001253	0.001243	
Stack Inlet		1.103	1.111	
Stack DP		0.001687	0.001676	



Point Result Comparison

Frequency	Noise	NoiseA
Hz	dB	dB
31.25	77.42	38.02
62.50	82.36	56.16
125.0	80.38	64.28
250.0	78.40	69.80
500.0	73.53	70.33
1000	71.65	71.65
2000	66.91	68.11
4000	63.44	64.44
8000	61.91	60.81
16000	60.22	53.62





Flaresim API

Frequency	Noise	NoiseA
Hz	dB	dB
31.25	77.60	38.20
62.50	82.54	56.34
125.0	80.56	64.46
250.0	78.58	69.98
500.0	73.71	70.51
1000	71.82	71.82
2000	67.07	68.27
4000	63.56	64.56
8000	62.00	60.90
16000	60.24	53.64





Max Radiation Input		
Initial Grid Points		11
Sizing Constraint	kW/m2	
Calculate Max Radiation	i	Yes
Max Radiation Results		
Max Radiation	kW/m2	15.23
Elevation Offset	m	97.02
Easting Offset	m	-5.994E-04

Maximum Radiation

Max Radiation Input		
Initial Grid Points		11
Sizing Constraint	k₩/m2	
Calculate Max Radiation		Yes
Max Radiation Result	ts	
Max Radiation	kW/m2	27.27
Elevation Offset	m	98.55
Easting Offset	m	0.001715



Notes and Discussion

- 1. The radius of public , exposure limit (1.58 kW/m2) is 172m in Easting Direction.
- 2. The maximum radiation value on ground is 3.135 kW/m2.
- If exposure limit for all direction is set to be 1.58 kW/m2 then the flare stack height should be 152m!
- 4. Vendor has selected a fixed height and no constraint in Point Tab but here we allowed the software to size the stack height by setting 3.13 kW/m2 as sizing constraint in Point Tab.

Flare Burner / Tip

In MEKPCO project, a steam-assisted flare tip is used to not only help the combustion be flameless but also cool down the equipment.

The quantity of steam required for smokeless burning is a function of the gas composition, the flare burner size and design, the steam-injector design and operating pressure, and the environmental conditions. While steam assist enhances the combustion of relief gases that smoke, it adversely affects the combustion of relief gases with a high level of inerts. Relief gases with a high level of inerts, when flared from a steam-assisted flare, can require a greater calorific value to sustain the required flame stability and hydrocarbon-destruction efficiency.

Flare tip length is normally between 3-5 meter. In MEKPCO project, pipe flare type is used due to low Mach number.

Steam is often injected into the relief gas discharge at the top of a flare burner. Typically, a steam ring that has a number of injection nozzles or slots is employed. The design and location of injector nozzles varies as different flare manufacturers each have their own proprietary design.

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The upper steam injection functions to inspirate air and to force the air mixture into the relief gas discharging from the flare burner. The steam-injection pattern is intended to enhance fuel-air mixing and can add to the momentum of the relief gas discharge. The steam and air acts to dilute the hydrocarbon fuel content, which also reduces the smoking tendency. The steam vapor can also participate in the combustion kinetics, assisting in the conversion of carbon to carbon monoxide.

The effective addition of steam from an upper steam ring increases the turbulence of combustion. The overall noise level of the flare burner increases due to both the additional combustion noise and jet noise from the steam nozzles. Steam-assisted, smokeless flares can have significantly increased overall noise levels in comparison to flares with no steam assist.

The allowable flare burner exit velocity is a function of relief gas composition, flare burner design, and the gas pressure available. These parameters are interrelated. Some flare tips incorporate a flame-retention device or other means that provides a stable burning flame either attached or detached relative to the flare tip. There is evidence that flame stability can be maintained at relatively high velocities depending on the discharge properties and the type of tip used.

Experience has shown that a properly designed and applied flare burner can have an exit velocity of more than Mach 0.5, if pressure drop, noise, and other factors permit. Many pipe flares, assisted or unassisted, and air-assisted flares have been in service for many years with maximum Mach numbers of Mach 0.8 and higher.











Molecular Seal

- ✓ Air seals (also called purge reduction or gas seals) prevent air from entering the stack, and are often recommended to prevent flashbacks and explosions in a flare system.
- Purge-reduction seals are not flame arrestors; that is, they will not stop a flashback.
 They are designed as energy-conservation devices to reduce purge-gas flows required to mitigate air infiltration into the stack.
- Air present in the stack can create a potentially explosive mixture with incoming flare gas during low-fare gas flow rate conditions.
- There are two common types of mechanical seals, usually located at/or below the flare tip that are used to reduce the amount of continuous purge gas required to prevent air infiltration into the flare stack : molecular seals (sometimes called diffusion, buoyancy or labyrinth seals), and velocity (fluidic) types.
- ✓ In the event of loss of purge-gas flow (and assuming that there is no other waste-gas flow) the oxygen level below the velocity type seal will almost immediately begin to increase. In the case of the buoyancy seal there is a time delay between the moment the purge gas flow stops and the time the oxygen level below the seal begins to increase.
- ✓ The molecular seal consists of a baffled concentric cylinder arrangement, which uses the difference in molecular weight of the flare gas and the ambient air to prevent air from entering the flare stack. This seal normally reduces the purge-gas velocity required through the tip to 0,003 m/s (0,01 ft/s).





