MEKPCO FLARE NETWORK DESIGN

ASPEN FLARENET

Content

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.

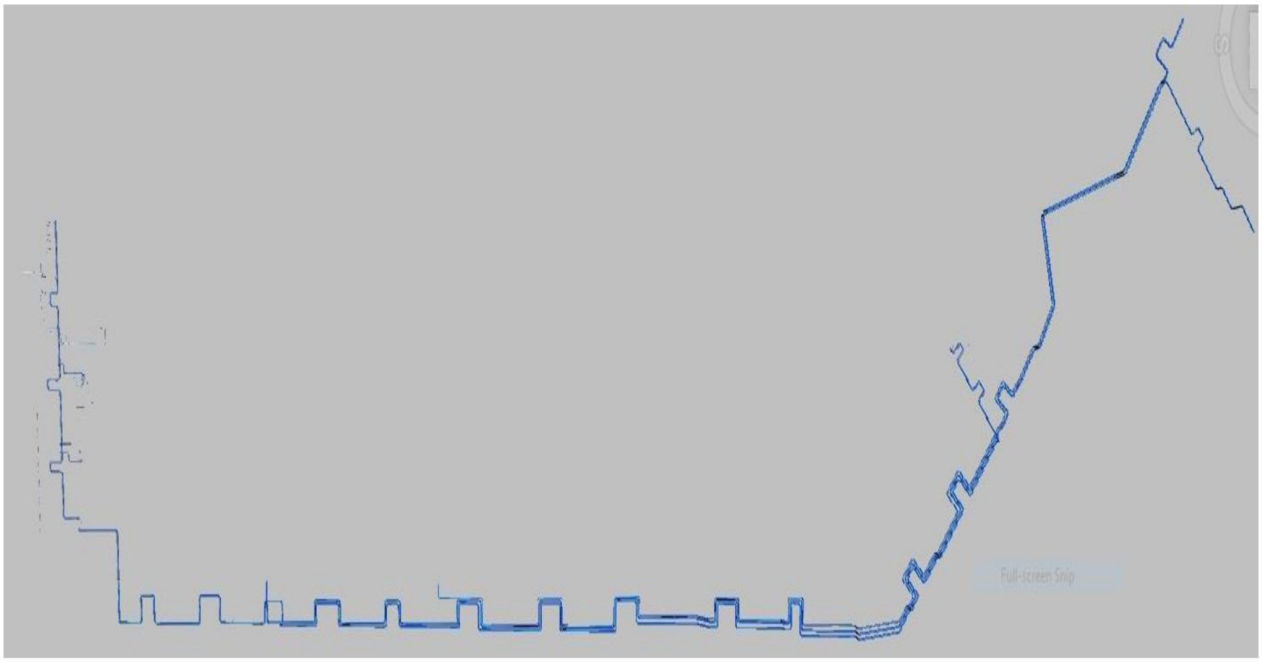
2. The flare main header approximate length is considered 2715 for hydraulic analysis implementation, including the flare piping length 305m between the starting point and the tie-in point in methanol plant and the flare piping length 2410 between the tie-in point and the actual flare site.

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.

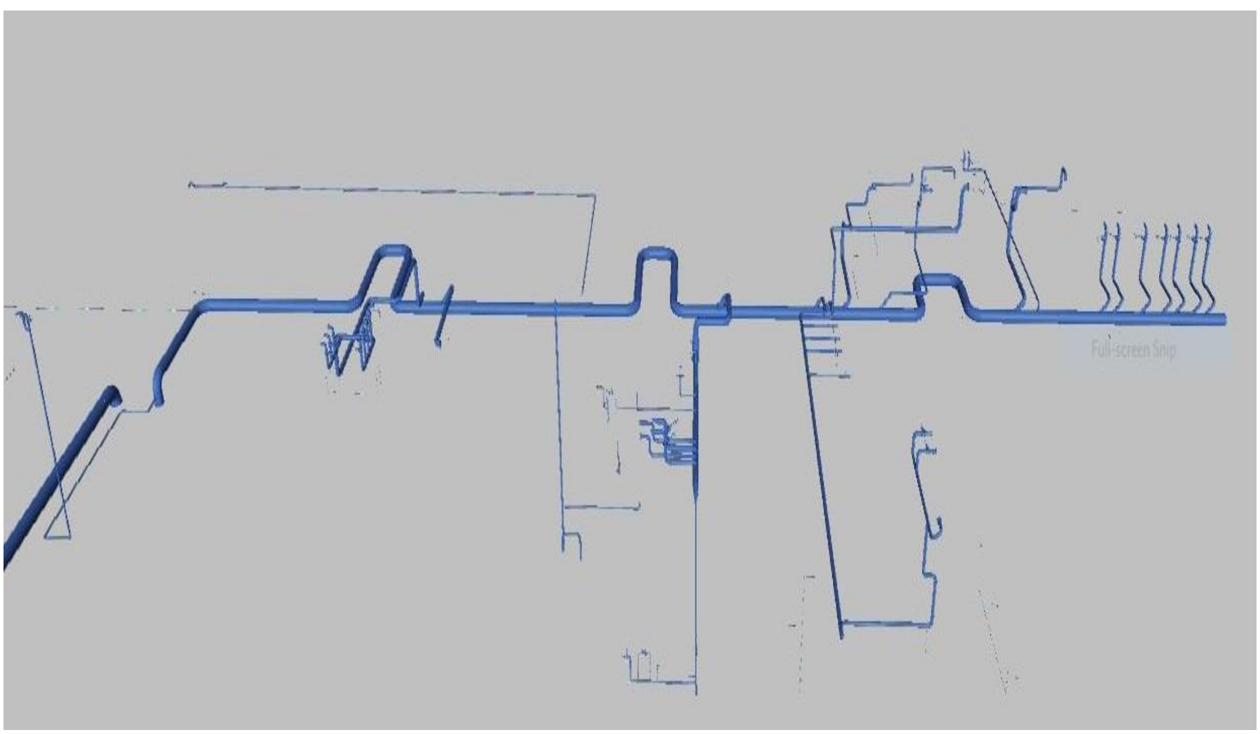
4. For the flare piping routing, the elevation changes between the tie-in location of methanol plant and the actual flare site is about 111m.

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

The Whole Plot



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 ρv2 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 (kg/hr)	MW (g/mole)	T (°C)	LHV (kJ/Nm³)	HHV (kJ/Nm³)	Reference stream no.[1]
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 (kg/hr)	MW (g/mole)	T (°C)	LHV (kJ/Nm³)	HHV (kJ/Nm³)	Reference stream no.[1]
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	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

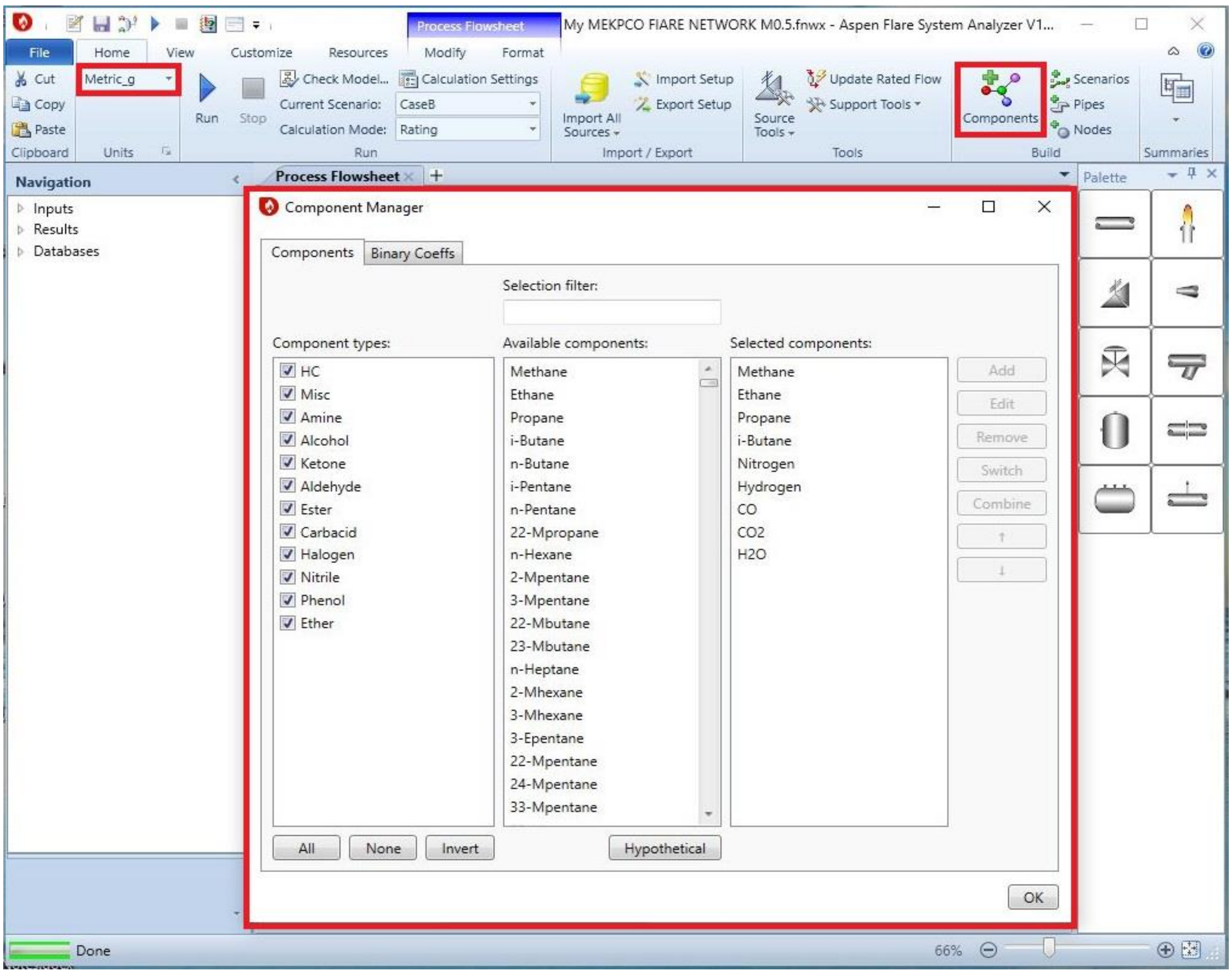
Table 2 - Summary of flaring scenarios cases.

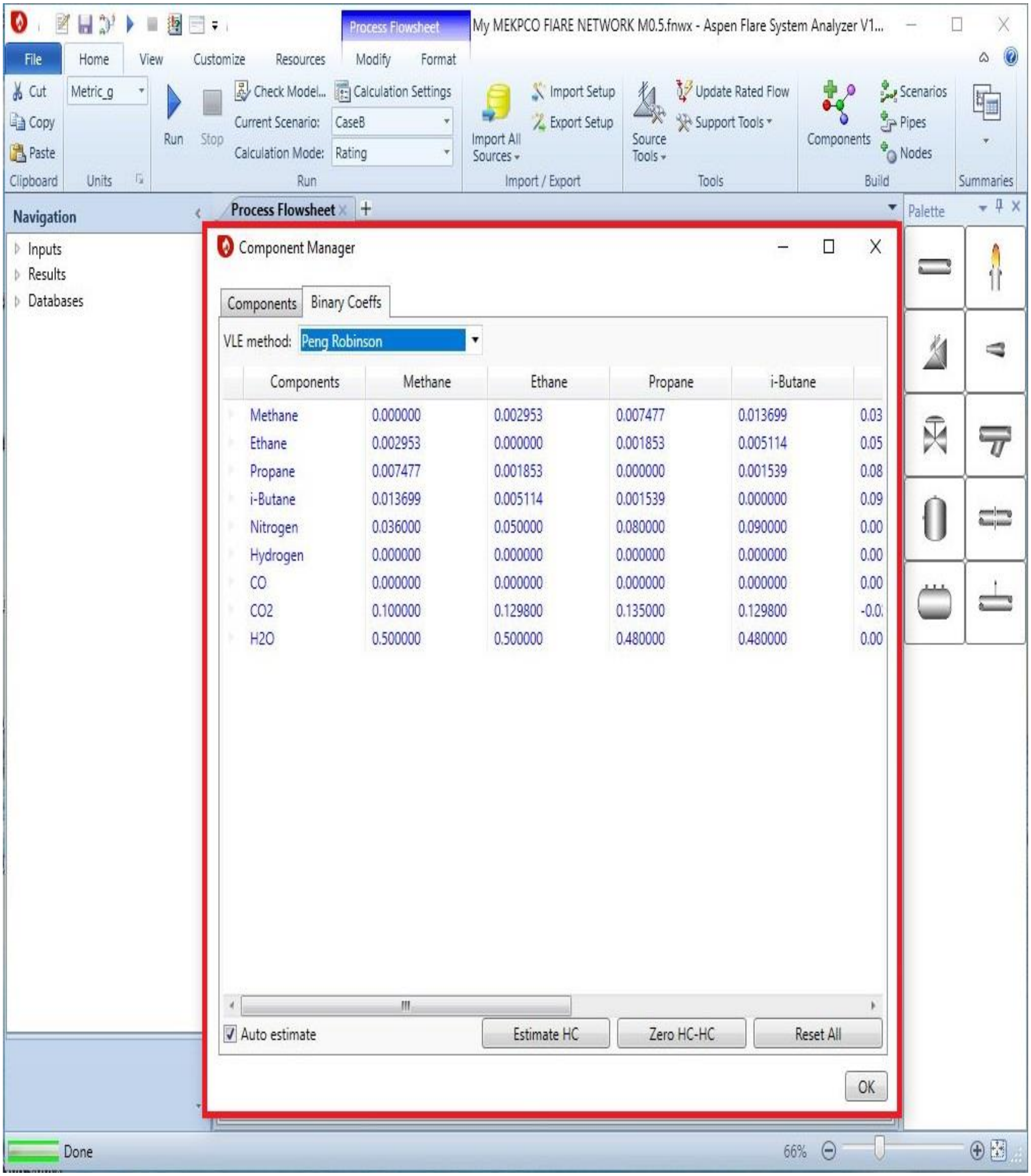
Scenario	Case A	Case B	Case C: Plant Trip
Case Explanation	Reformed gas blocked outlet and overpressure (Maximum discharge case)	Plant Start-up/Shut Down Failure	Valve failure at normal operating pressure/trip of methanol synthesis
Total Mass Flow (Kg/h)	510000	343700	282206
Release source	PSV-2354 PSV-2355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

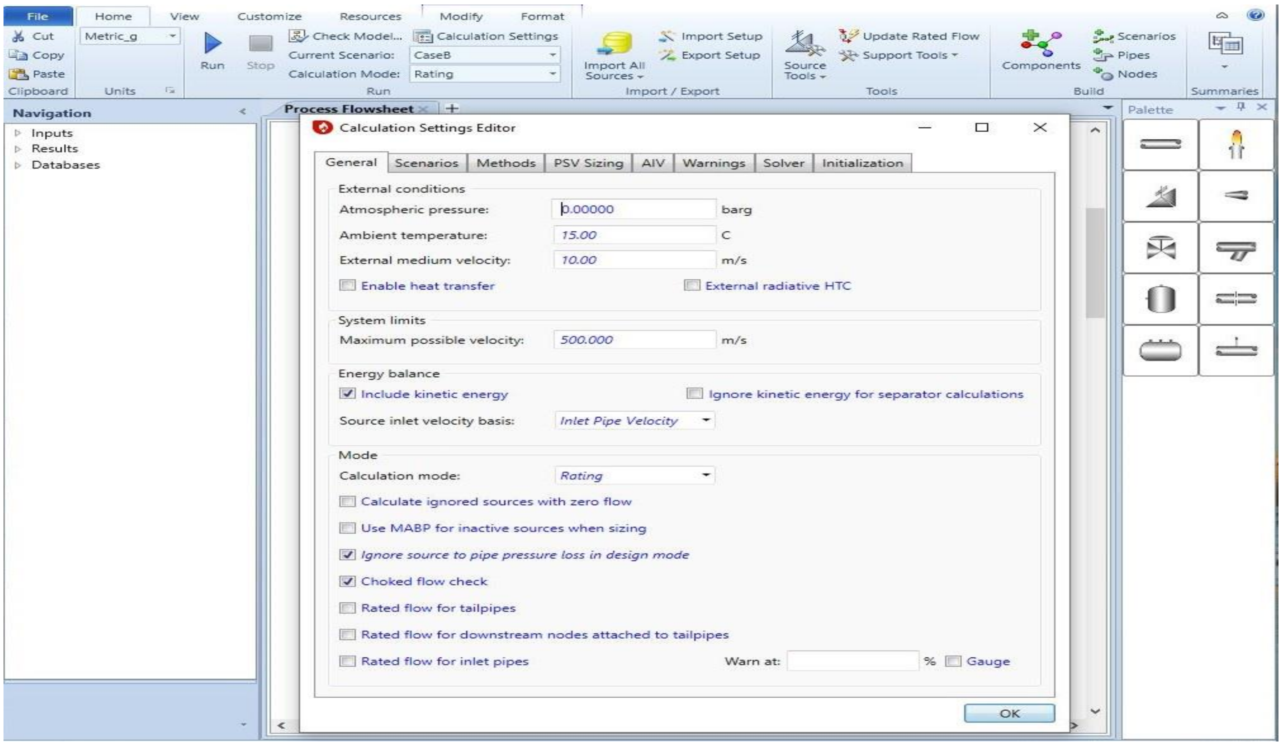
Procedure: The discharge load of each release point, the backpressure of flare stack, the diameter and length of each pipe segment is given to seek the Mach number and backpressure alongside each pipe segment.

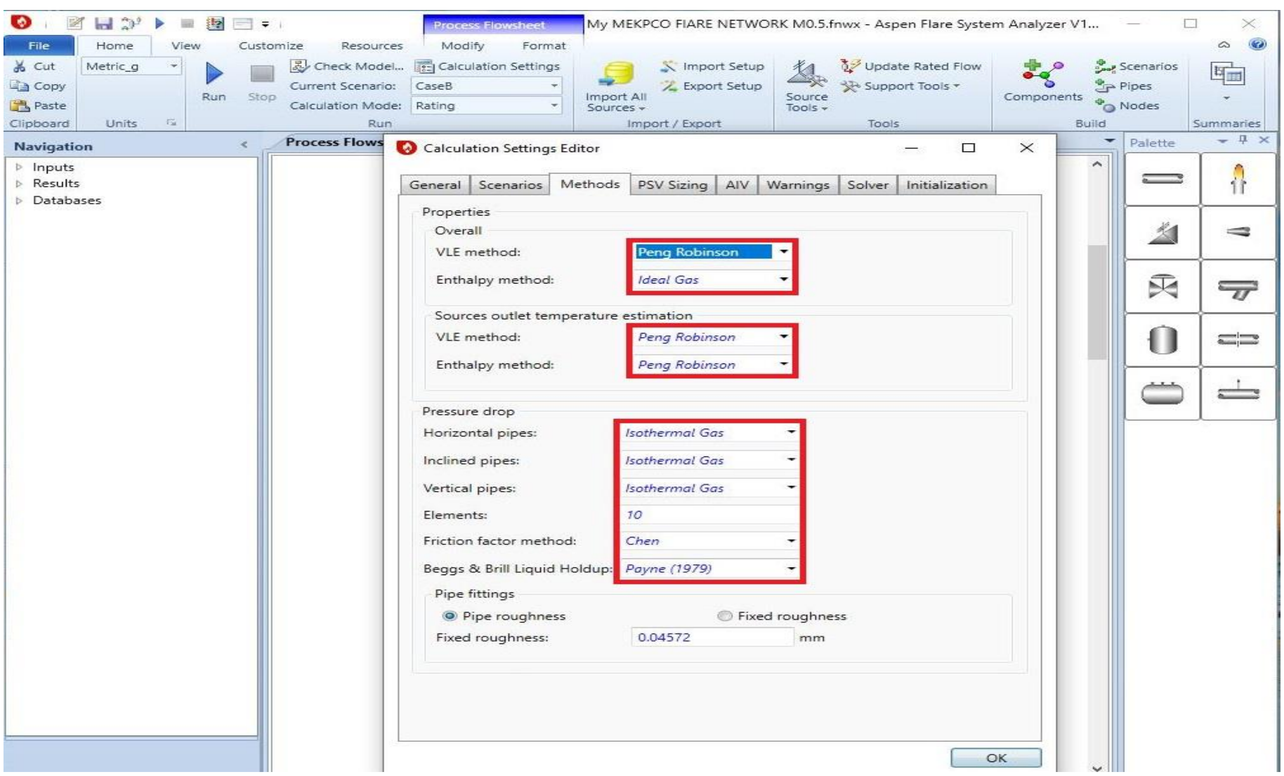
1[st] Step: Create the component and set the unit



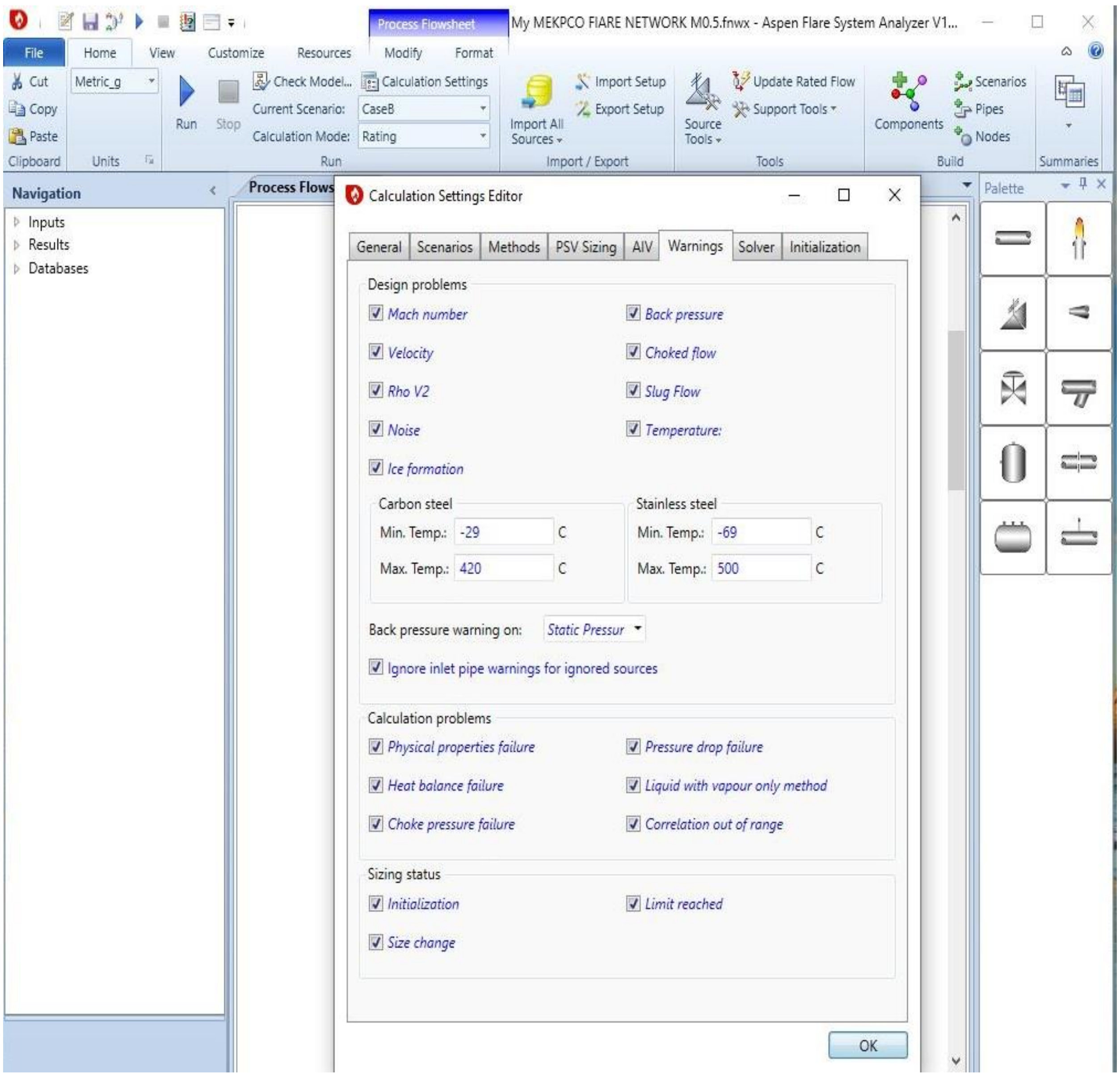

Process Flowsheet
My MEKPCO FlARE NETWORK M0.5.fnwx - Aspen Flare System Analyzer V1...
File
Home
View
Customize
Resources
Modify
Format
Cut
Copy
Paste
Clipboard
Metric_g
Units
Run
Stop
Check Model...
Calculation Settings
Current Scenario:
CaseB
Calculation Mode:
Rating
Import All Sources
Import Setup
Export Setup
Import / Export
Source Tools
Update Rated Flow
Support Tools
Tools
Components
Scenarios
Pipes
Nodes
Build
Summaries
Navigation
Inputs
Results
Databases
Process Flowsheet
Palette
Component Manager
Components
Binary Coeffs
VLE method:
Peng Robinson
Components Methane Ethane Propane i-Butane
Methane 0.000000 0.002953 0.007477 0.013699 0.03
Ethane 0.002953 0.000000 0.001853 0.005114 0.05
Propane 0.007477 0.001853 0.000000 0.001539 0.08
i-Butane 0.013699 0.005114 0.001539 0.000000 0.09
Nitrogen 0.036000 0.050000 0.080000 0.090000 0.00
Hydrogen 0.000000 0.000000 0.000000 0.000000 0.00
CO 0.000000 0.000000 0.000000 0.000000 0.00
CO2 0.100000 0.129800 0.135000 0.129800 -0.0
H2O 0.500000 0.500000 0.480000 0.480000 0.00
Auto estimate
Estimate HC
Zero HC-HC
Reset All
OK
Done
66%

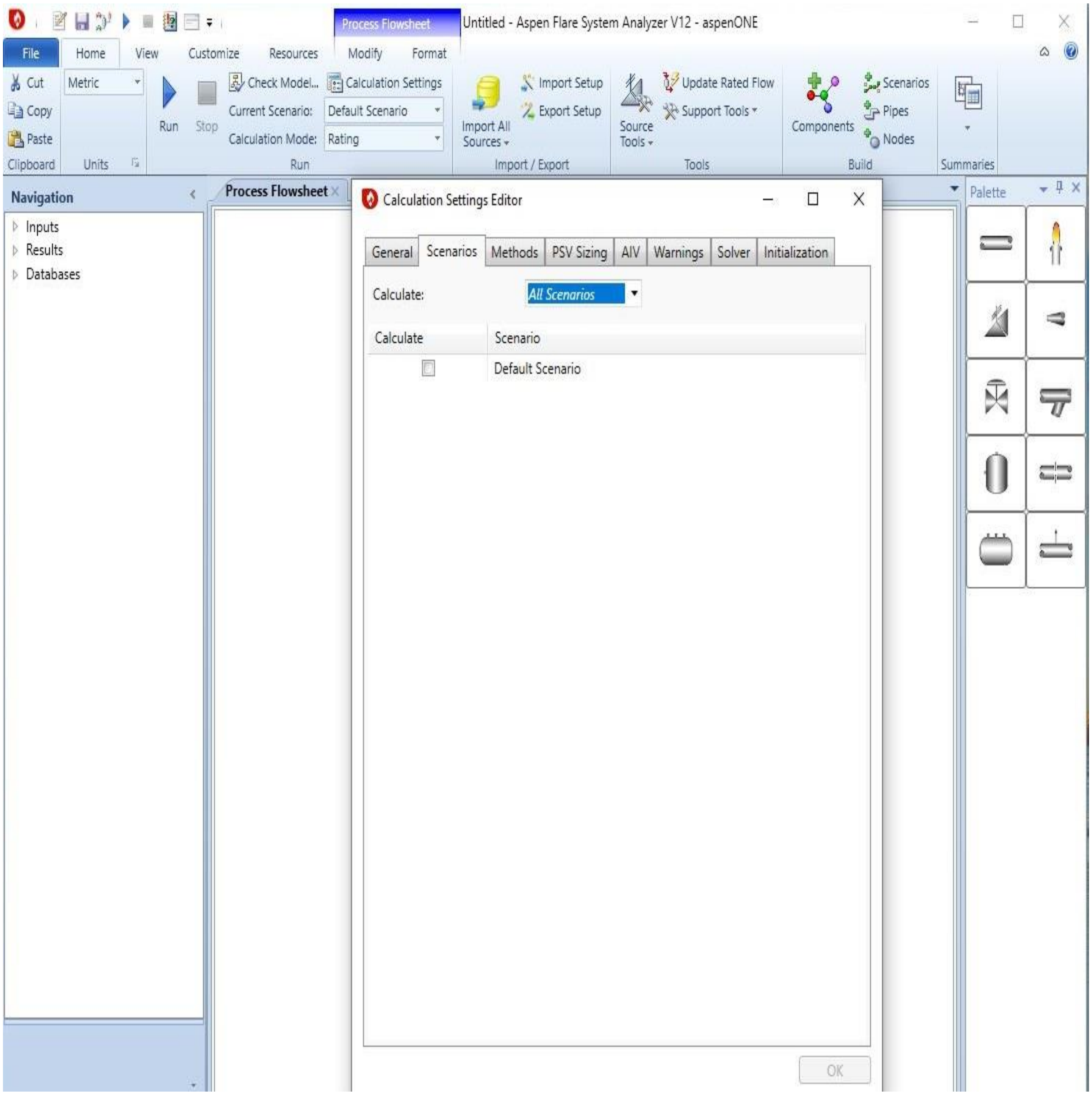
2nd Step: Checking “Calculation Setting”



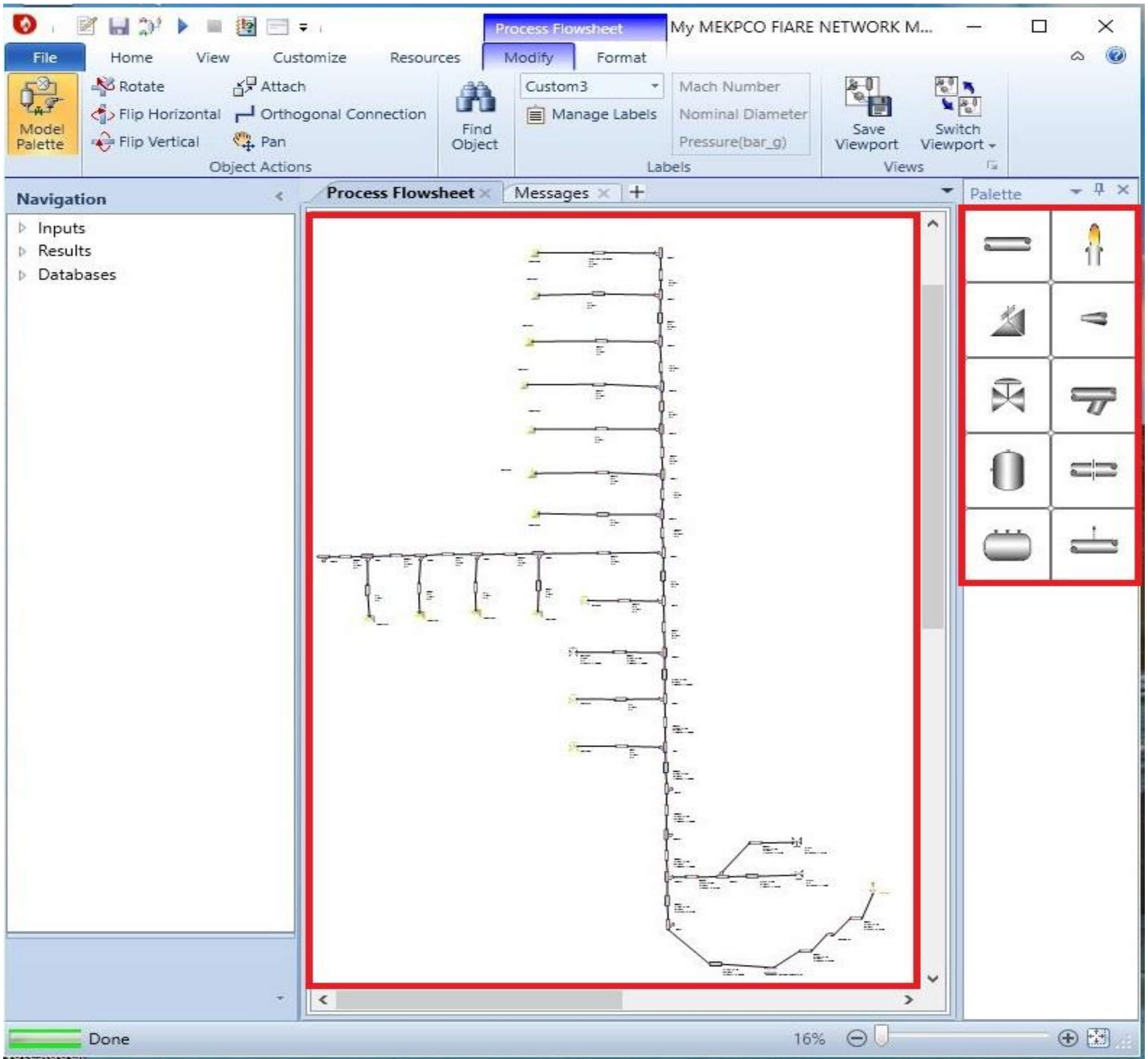


Note: There is no need to change PSV sizing, Solver, Initialization and AIV tabs in calculation setting.

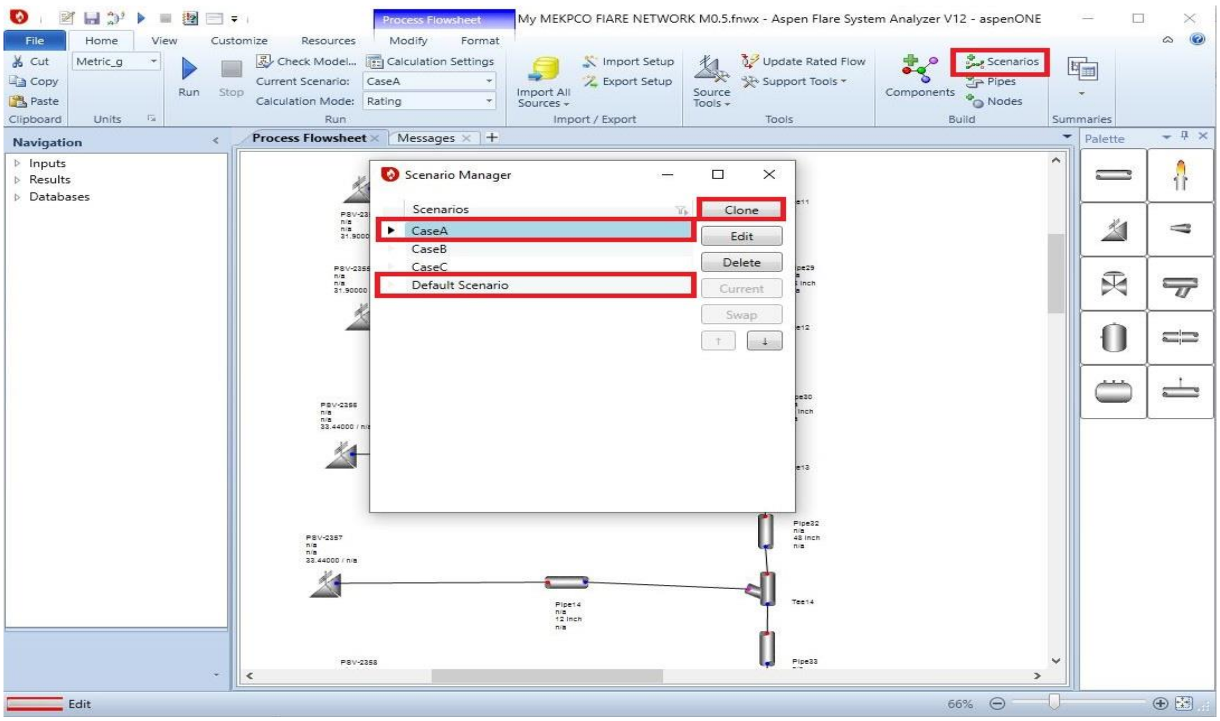


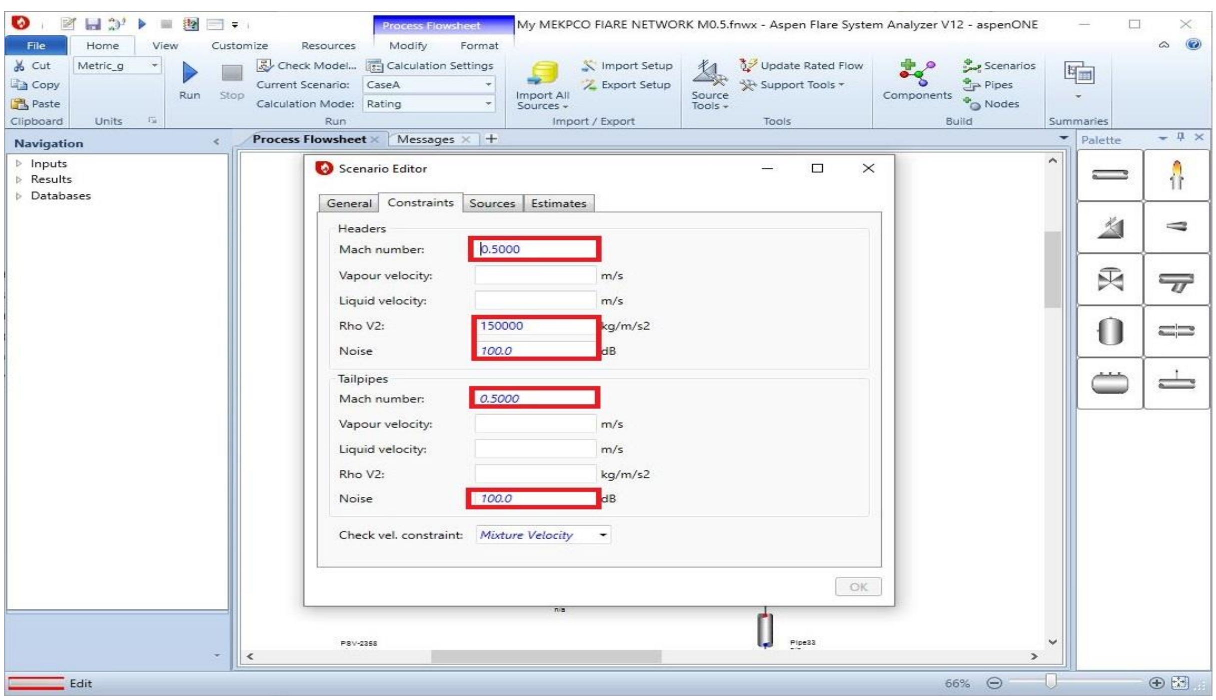

Process Flowsheet
Untitled - Aspen Flare System Analyzer V12 - aspenONE
File
Home
View
Customize
Resources
Modify
Format
Cut
Copy
Paste
Clipboard
Metric
Units
Run
Stop
Check Model...
Calculation Settings
Current Scenario:
Default Scenario
Calculation Mode:
Rating
Import All Sources
Import Setup
Export Setup
Import / Export
Source Tools
Update Rated Flow
Support Tools
Tools
Components
Scenarios
Pipes
Nodes
Build
Summaries
Navigation
Inputs
Results
Databases
Process Flowsheet
Palette
Calculation Settings Editor
General
Scenarios
Methods
PSV Sizing
AIV
Warnings
Solver
Initialization
Calculate:
All Scenarios
Calculate
Scenario
Default Scenario
OK

3rd Step: Create the layout

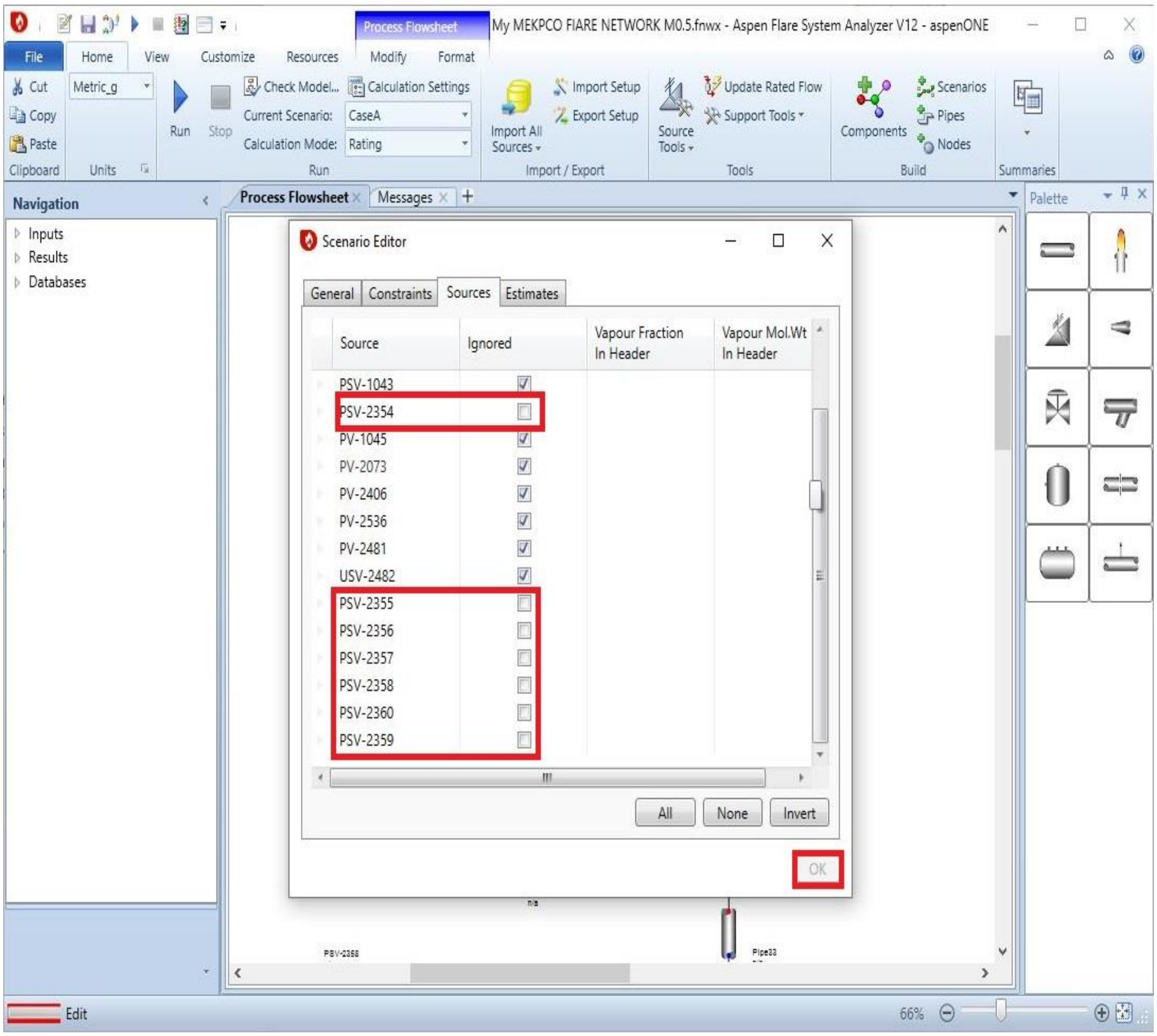


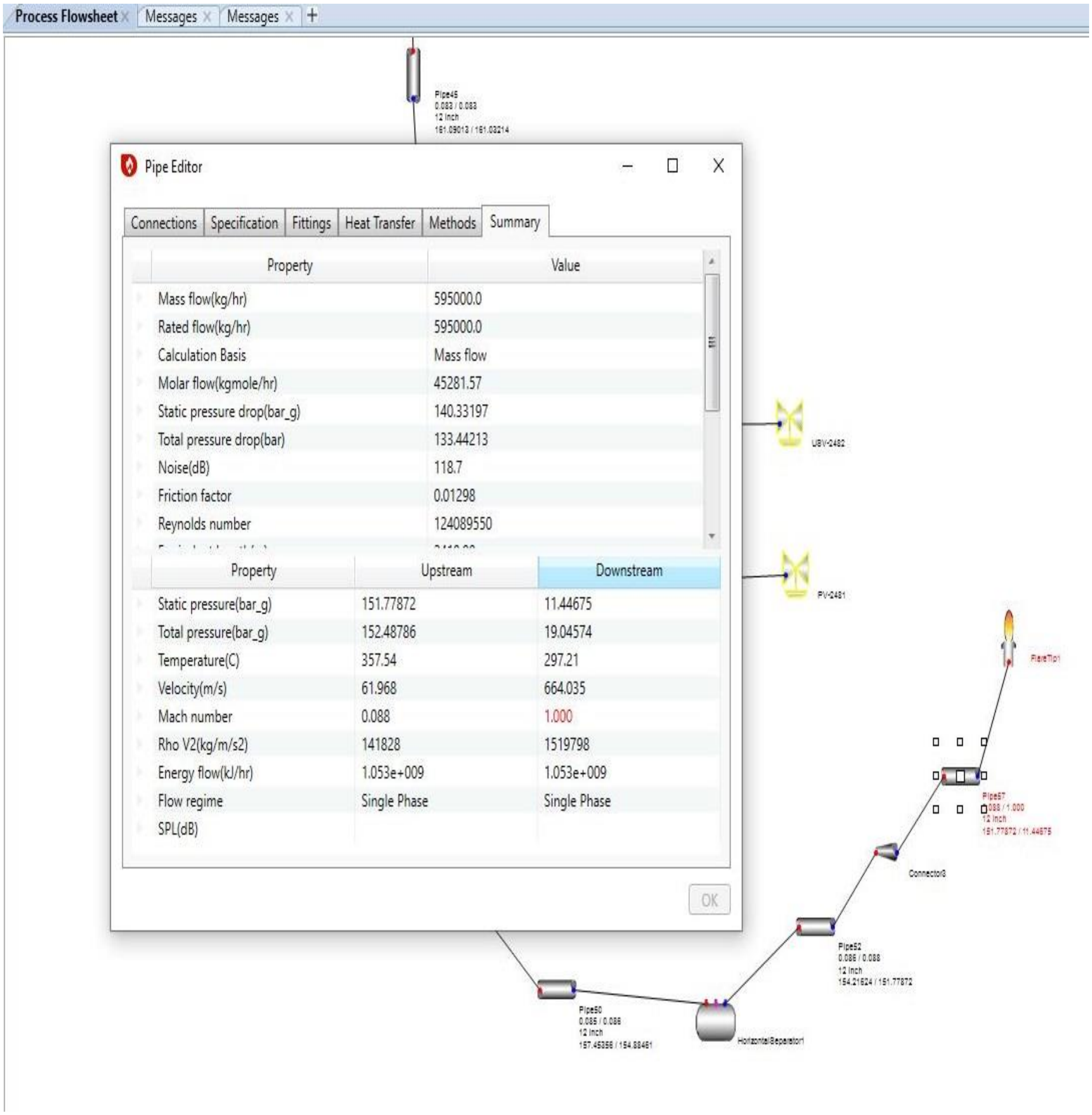
4^{th} Step: Definition of Scenarios



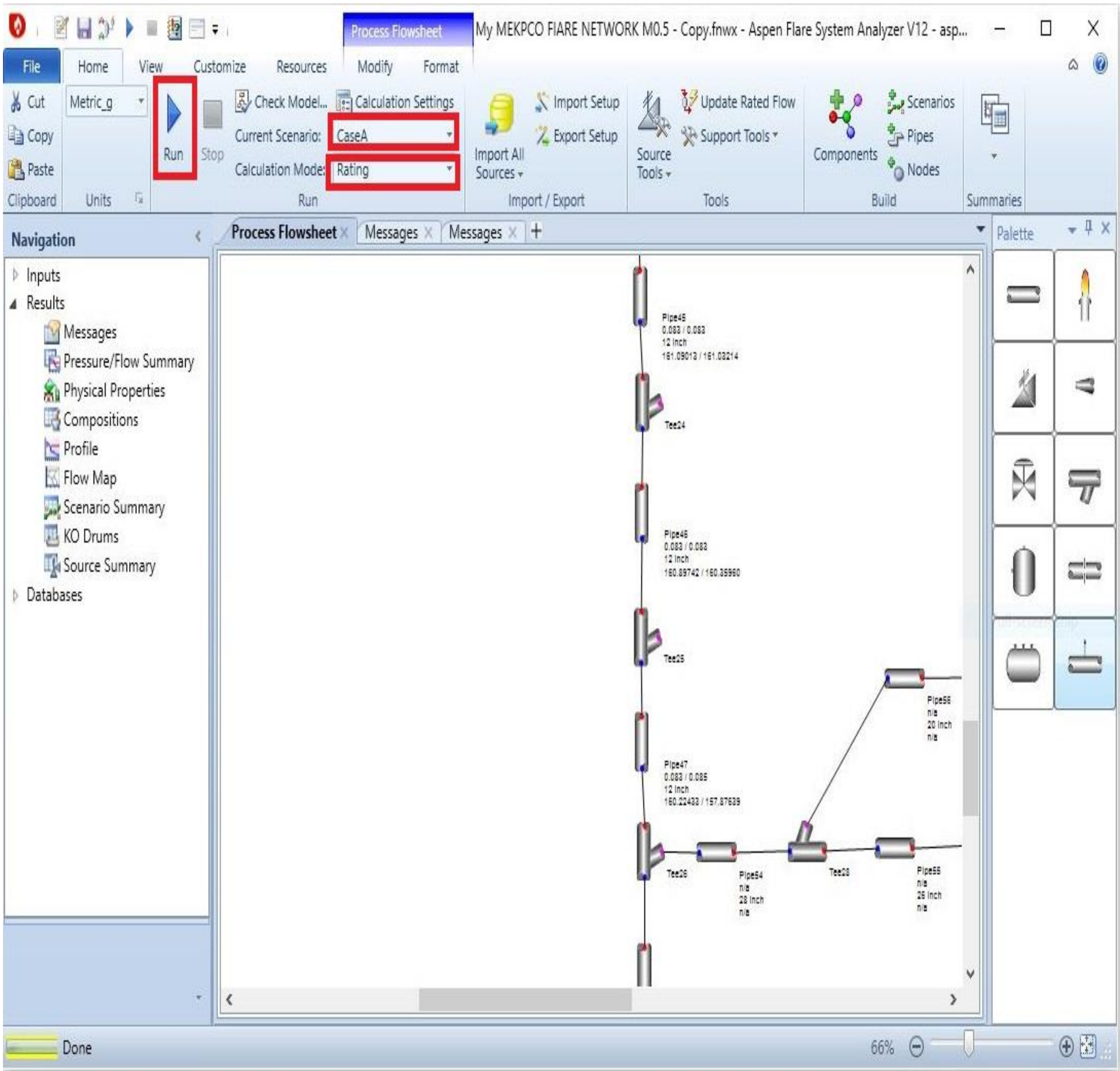


In order to define a scenario, at first "clone" a new scenario from default scenario and then complete the Scenario. Also, in "sources" tab, do not select the PSVs included in the scenario.

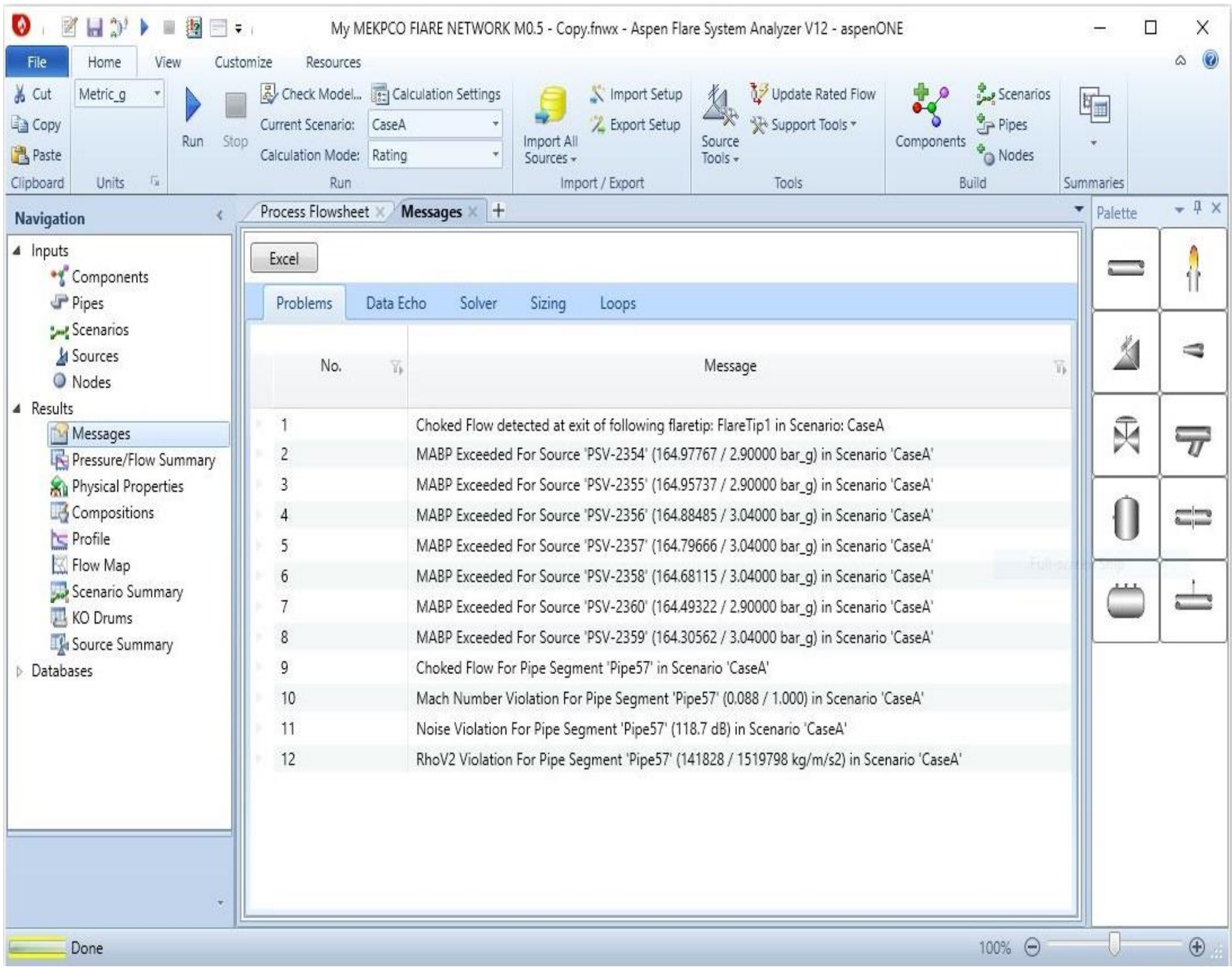



Process Flowsheet
Messages
Messages
Pipe Editor
Connections
Specification
Fittings
Heat Transfer
Methods
Summary
Property
Value
Mass flow(kg/hr) 595000.0
Rated flow(kg/hr) 595000.0
Calculation Basis Mass flow
Molar flow(kgmole/hr) 45281.57
Static pressure drop(bar_g) 140.33197
Total pressure drop(bar) 133.44213
Noise(dB) 118.7
Friction factor 0.01298
Reynolds number 124089550
Property
Upstream
Downstream
Static pressure(bar_g) 151.77872 11.44675
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
Energy flow(kJ/hr) 1.053e+009 1.053e+009
Flow regime Single Phase Single Phase
SPL(dB)
OK

5th Step: Act accordingly and Run the software



Results


My MEKPCO FlARE NETWORK M0.5 - Copy.fnwx - Aspen Flare System Analyzer V12 - aspenONE
File
Home
View
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Units
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Stop
Check Model...
Calculation Settings
Current Scenario:
CaseA
Calculation Mode:
Rating
Import All Sources
Import Setup
Export Setup
Import / Export
Source Tools
Update Rated Flow
Support Tools
Tools
Components
Scenarios
Pipes
Nodes
Build
Summaries
Navigation
Inputs
Components
Pipes
Scenarios
Sources
Nodes
Results
Messages
Pressure/Flow Summary
Physical Properties
Compositions
Profile
Flow Map
Scenario Summary
KO Drums
Source Summary
Databases
Process Flowsheet
Messages
Palette
Excel
Problems
Data Echo
Solver
Sizing
Loops
No.
Message
1 Choked Flow detected at exit of following flaretip: FlareTip1 in Scenario: CaseA
2 MABP Exceeded For Source 'PSV-2354' (164.97767 / 2.90000 bar_g) in Scenario 'CaseA'
3 MABP Exceeded For Source 'PSV-2355' (164.95737 / 2.90000 bar_g) in Scenario 'CaseA'
4 MABP Exceeded For Source 'PSV-2356' (164.88485 / 3.04000 bar_g) in Scenario 'CaseA'
5 MABP Exceeded For Source 'PSV-2357' (164.79666 / 3.04000 bar_g) in Scenario 'CaseA'
6 MABP Exceeded For Source 'PSV-2358' (164.68115 / 3.04000 bar_g) in Scenario 'CaseA'
7 MABP Exceeded For Source 'PSV-2360' (164.49322 / 2.90000 bar_g) in Scenario 'CaseA'
8 MABP Exceeded For Source 'PSV-2359' (164.30562 / 3.04000 bar_g) in Scenario 'CaseA'
9 Choked Flow For Pipe Segment 'Pipe57' in Scenario 'CaseA'
10 Mach Number Violation For Pipe Segment 'Pipe57' (0.088 / 1.000) in Scenario 'CaseA'
11 Noise Violation For Pipe Segment 'Pipe57' (118.7 dB) in Scenario 'CaseA'
12 RhoV2 Violation For Pipe Segment 'Pipe57' (141828 / 1519798 kg/m/s2) in Scenario 'CaseA'
Done
100%

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

Discussion

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.
2. 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.
3. 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

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.

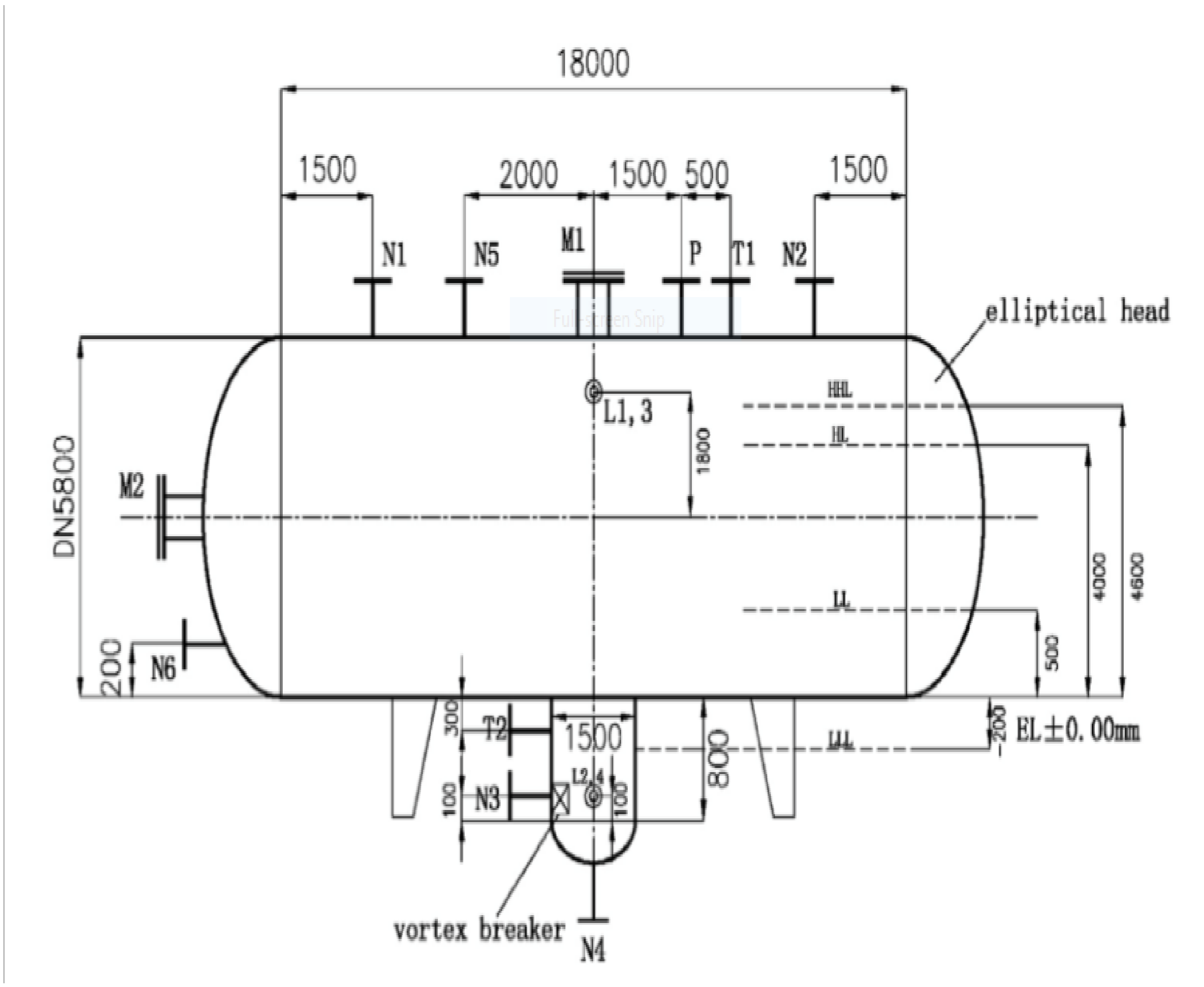
6. Liquid droplets 300 um and larger may drop out of the gas stream at less than 2 m/s. If liquids are not drained from the system, flare flows with gas velocities exceeding about 3 m/s or 4 m/s can entrain liquid droplets up to 1000 μm in size. Liquid droplets exceeding 1000 μm can readily lead to burning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

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.

2^{nd} 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 = Π(D^2)/4   t = Hold-up time

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

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

4. Calculate hV = D. (1 – hL/D)

Parameters	Values
Vapor mass kg/h	510000
Liquid mass kg/h	30000
ρv 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:

$$u_c = 1.15\sqrt{\frac{g \times D(\rho_l - \rho_v)}{\rho_v \times C}}$$

where

g is the acceleration due to gravity [= 9.8 m/s^2 (32 ft/s^2)];

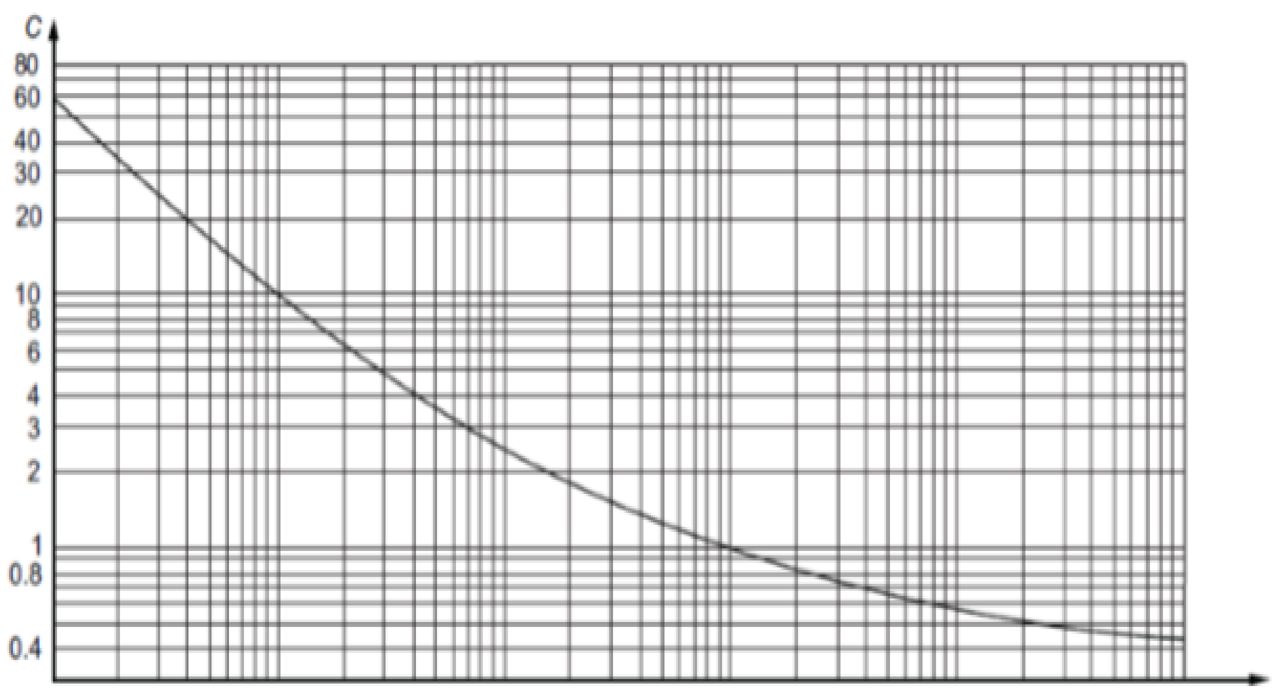
D is the particle diameter, expressed in m (ft);

ρ_l is the density of the liquid at operating conditions, expressed in kg/m^3 (lb/ft^3);

ρ_v is the density of the vapor at operating conditions, expressed in kg/m^3 (lb/ft^3);

Full-screen Snip

C is the drag coefficient (see Figure 5).



6. Calculate φ = 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

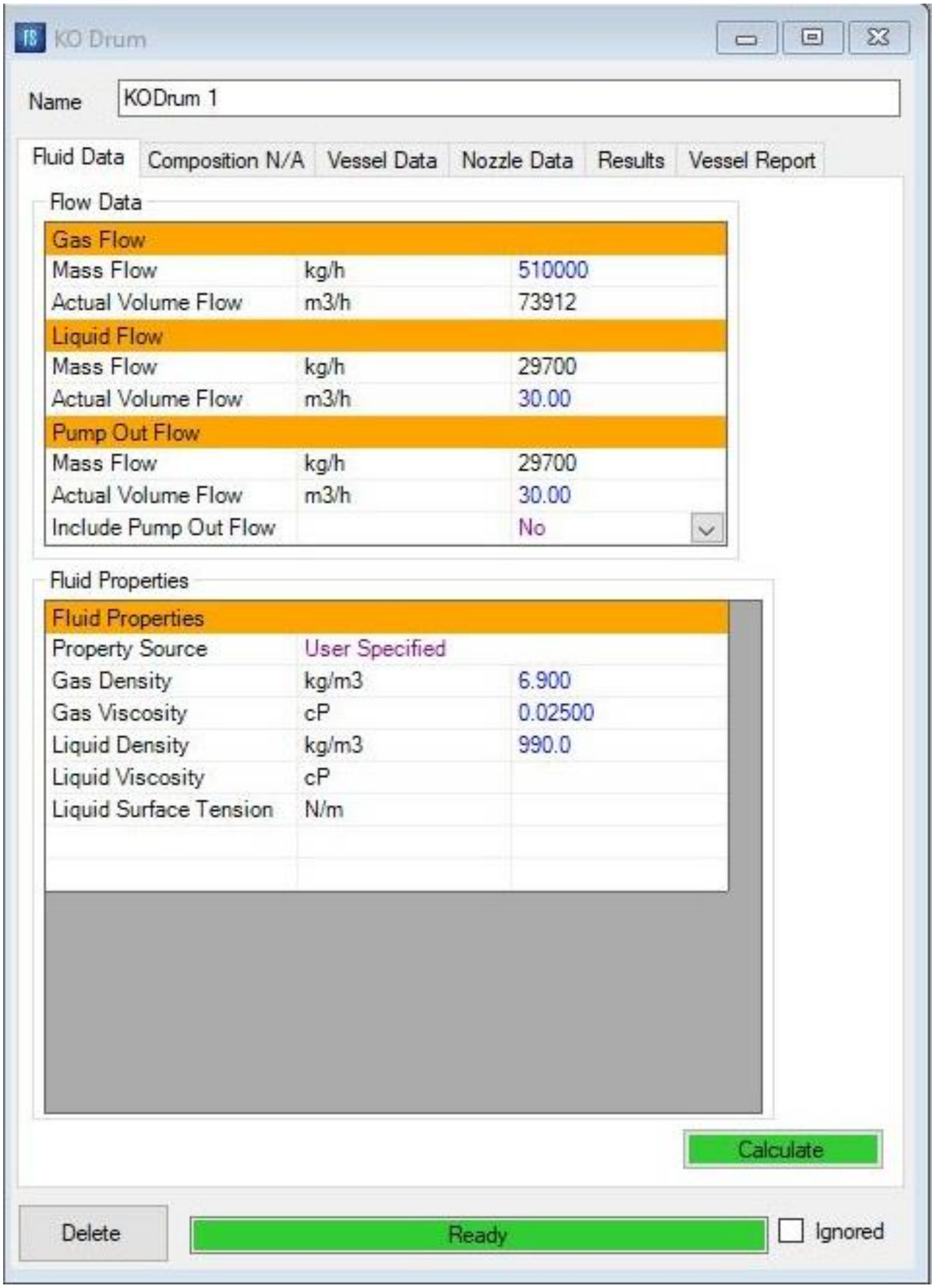
Parameters	Value
AL	5.43
AT	12.57
AL/AT	0.43
hL/D	0.44
ERROR	Goal Seek Function
hV/D	0.55
hV	2.21

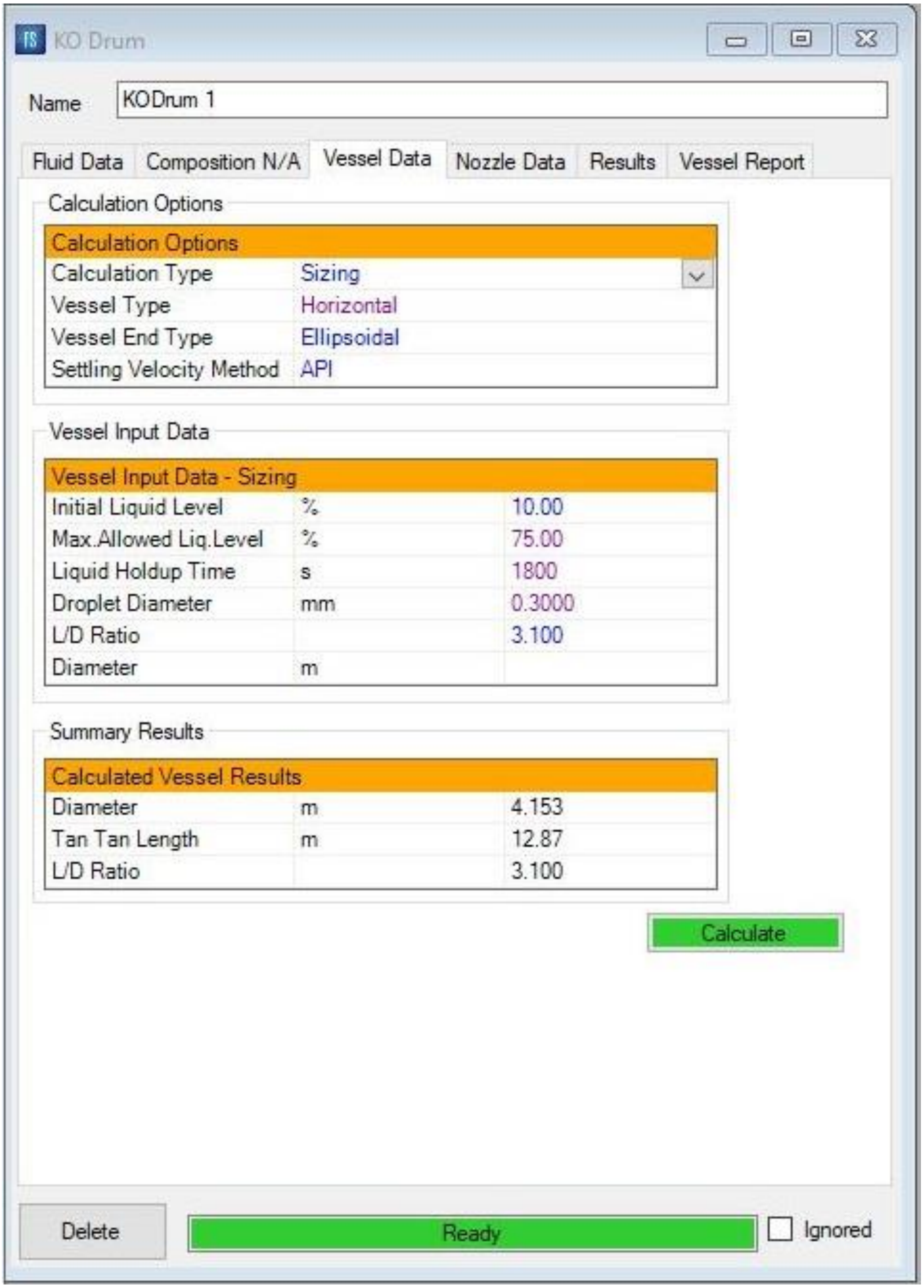
Parameters	Value
φ	2.95
AV	7.14
Uv	2.92
Lmin m	8.62
Inlet ID inch	64
Outlet ID inch	72

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




KO Drum
Name
KODrum 1
Fluid Data
Composition N/A
Vessel Data
Nozzle Data
Results
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
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 Results
Diameter
m
4.153
Tan Tan Length
m
12.87
L/D Ratio
3.100
Calculate
Delete
Ready
Ignored

Flare Thermal Radiation Assessment

Based on

API-521 and Schlumberger Flaresim

Calculation of Flare Stack Diameter

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

In SI units:

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

In USC units:

$$Ma_2 = 1.702 \times 10^{-5} \left(\frac{q_m}{p_2 \times d^2} \right) \left(\frac{Z \times T}{M} \right)^{0.5}$$

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
T	273.15 K
Z	1.33
M	13.44
P2	141 kpa
Mach	0.1
DD	2.46

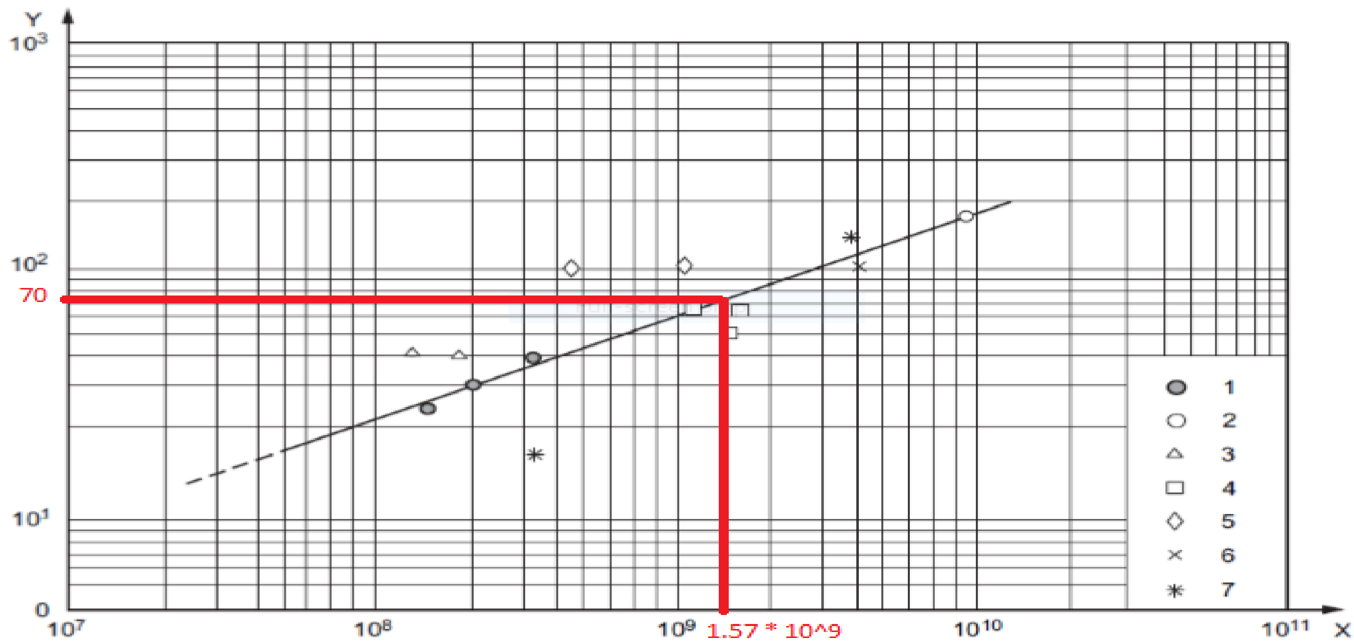
Calculation of Flame Length

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

Q = Mass (kg/h) . LHV (kJ/kg) . (1h/3600s)

Q = 712342 Nm3/h . 7964 / 3600 = 1.57 × 10^6 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)

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 ∆X and ∆Y.
4. Use distance equation and plot to estimate flare stack height.

1st Step

T = 273K

qv = (51000/3600) × $\left(\frac{22.4}{13.4}\right)$ × (273/273) = 236.8 m3/s

T = 633K

qv = (51000/3600) × $\left(\frac{22.4}{13.4}\right)$ × (633/273) = 549 m3/s

2nd Step

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

$$u_j = \frac{q}{\pi d^2 / 4}$$

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

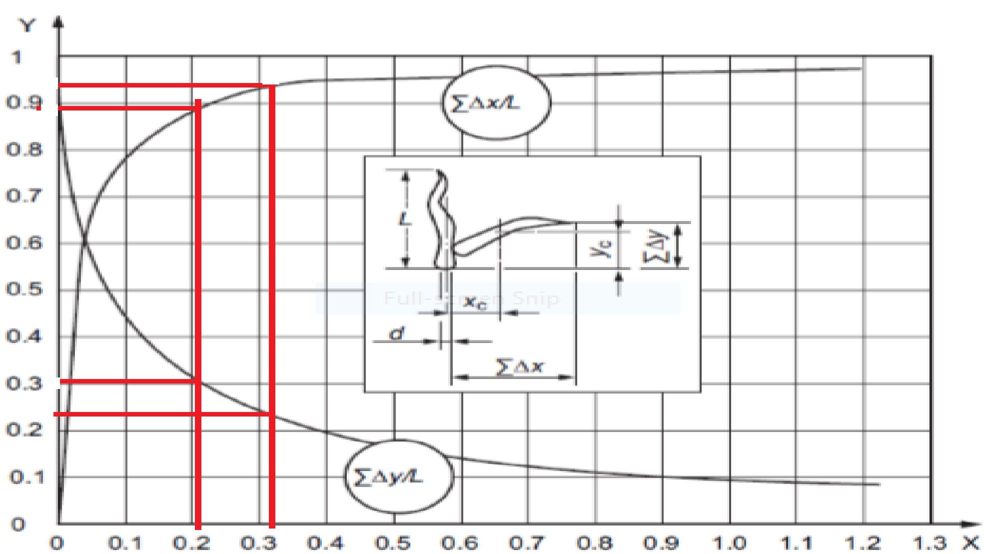
According to next-page diagram, ∆Y/L = 0.3 therefore ∆Y = 21m

According to next-page diagram, ∆X/L = 0.9 therefore ∆X = 63m

T=273K

According to next-page diagram, ∆Y/L = 0.23 therefore ∆Y = 16m

According to next-page diagram, ∆X/L = 0.93 therefore ∆X = 65m



Key

X $\sum(u_\infty/u_j)$

Y $\sum \Delta y/L$ or $\sum \Delta x/L$

u_∞ is the lateral wind speed

u_j is the jet exit velocity

NOTE Insert shows the flame geometry in still air and lateral wind.

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

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.

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

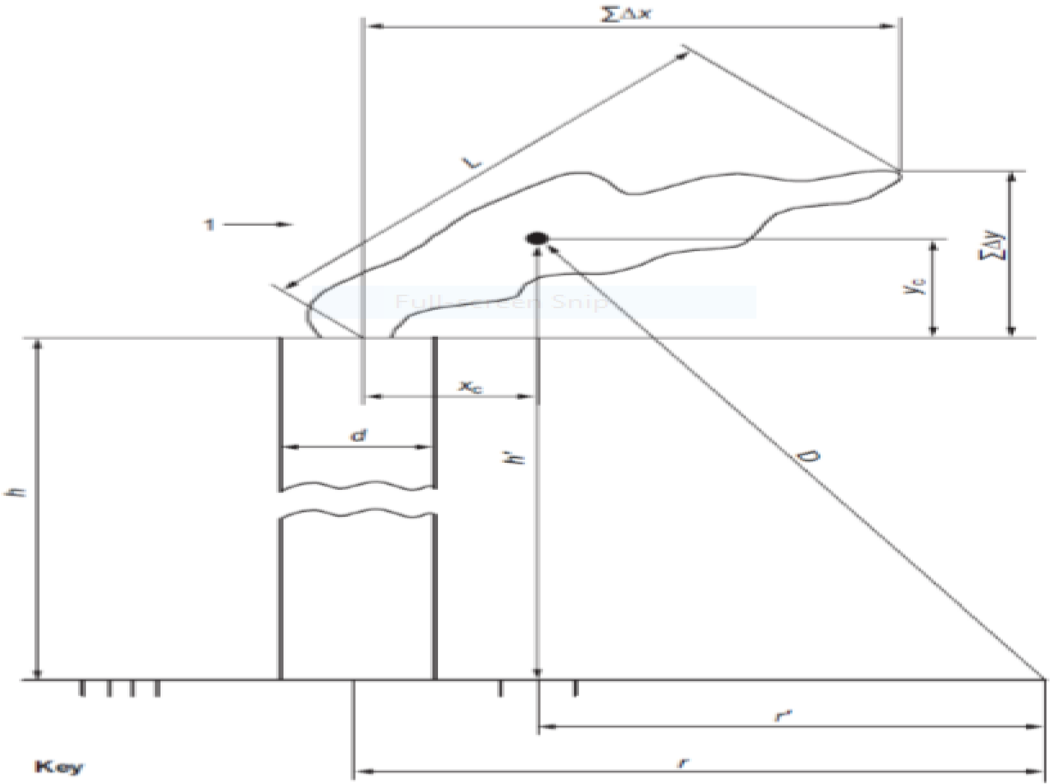
Parameters	Values
τ	0.8
F	0.15
Q	1.57 × 10^6
K	3.13
D	70 m

Parameters	Values
τ	1
F	0.2
Q	1.57 × 10^6
K	3.13
D	89.5 m

F-factor

Table F.1—Radiation from Gaseous Diffusion Flames

Gas	Burner Diameter cm	Fraction of Heat Radiated
Hydrogen	0.51	0.095
	0.91	0.091
	1.90	0.097
	4.10	0.111
	8.40	0.156
	20.30	0.154
	40.60	0.169
Butane	0.51	0.215
	0.91	0.253
	1.90	0.286
	4.10	0.285
	8.40	0.291
	20.30	0.280
	40.60	0.299
Methane	0.51	0.103
	0.91	0.116
	1.90	0.160
	4.10	0.161
	8.40	0.147
Natural gas (95 % CH_4)	20.30	0.192
	40.60	0.232



Key

1 wind direction

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
ΔX	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**
∆Y	**16**	**16**
h	**81.4 m**	**62 m**

T=633K

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

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

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

Parameters	Values
r	**35**
∆X	**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
∆Y	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)


FS
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FLARE SYSTEMS DESIGN AND ANALYSIS SOFTWARE
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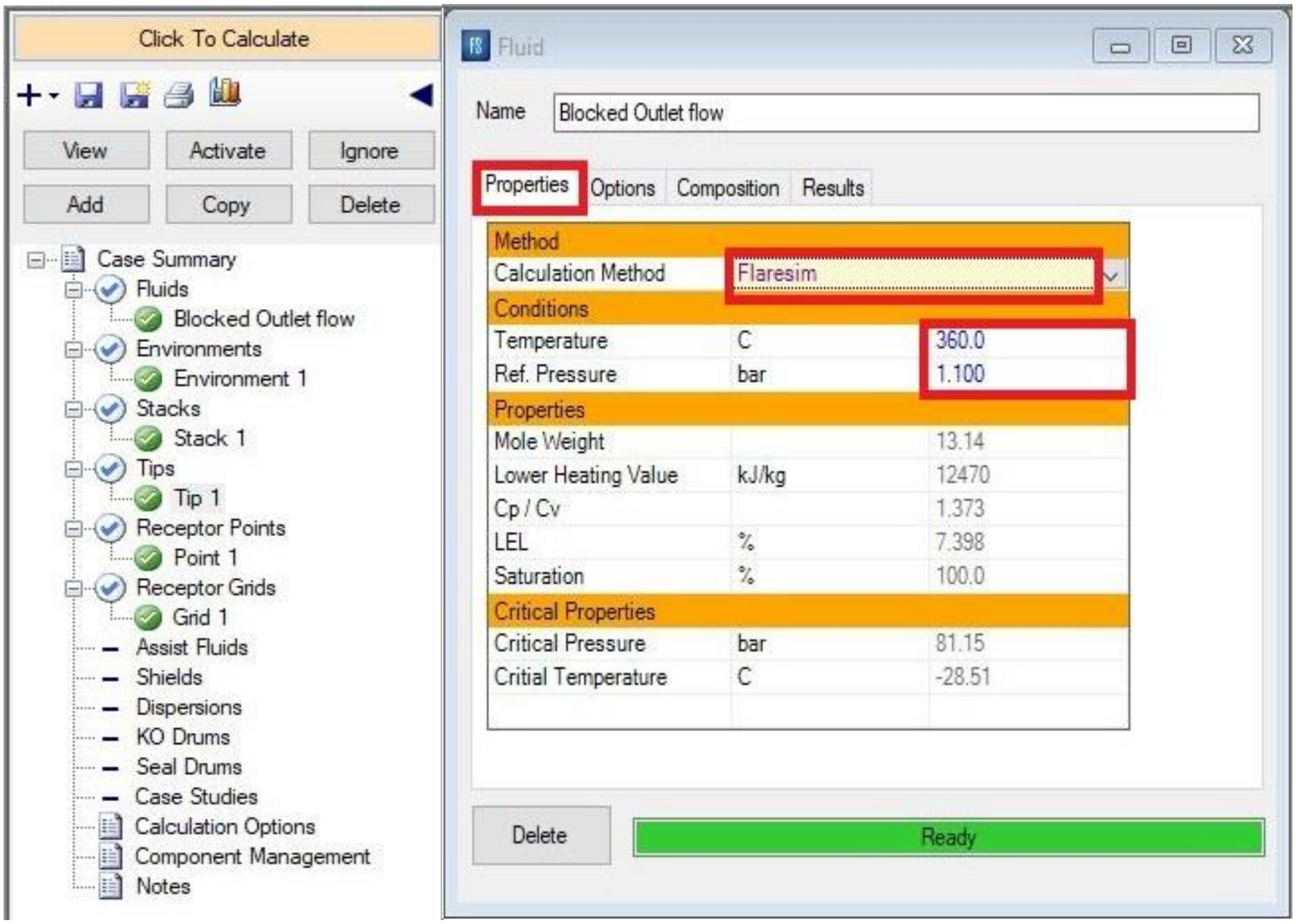
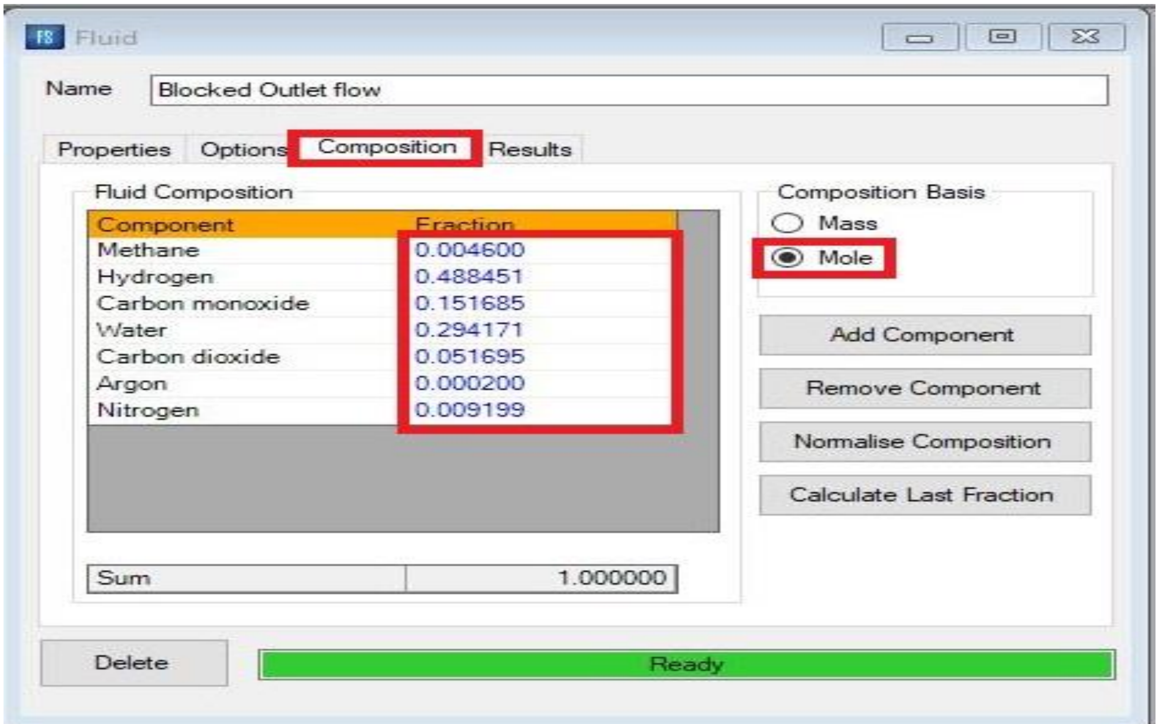
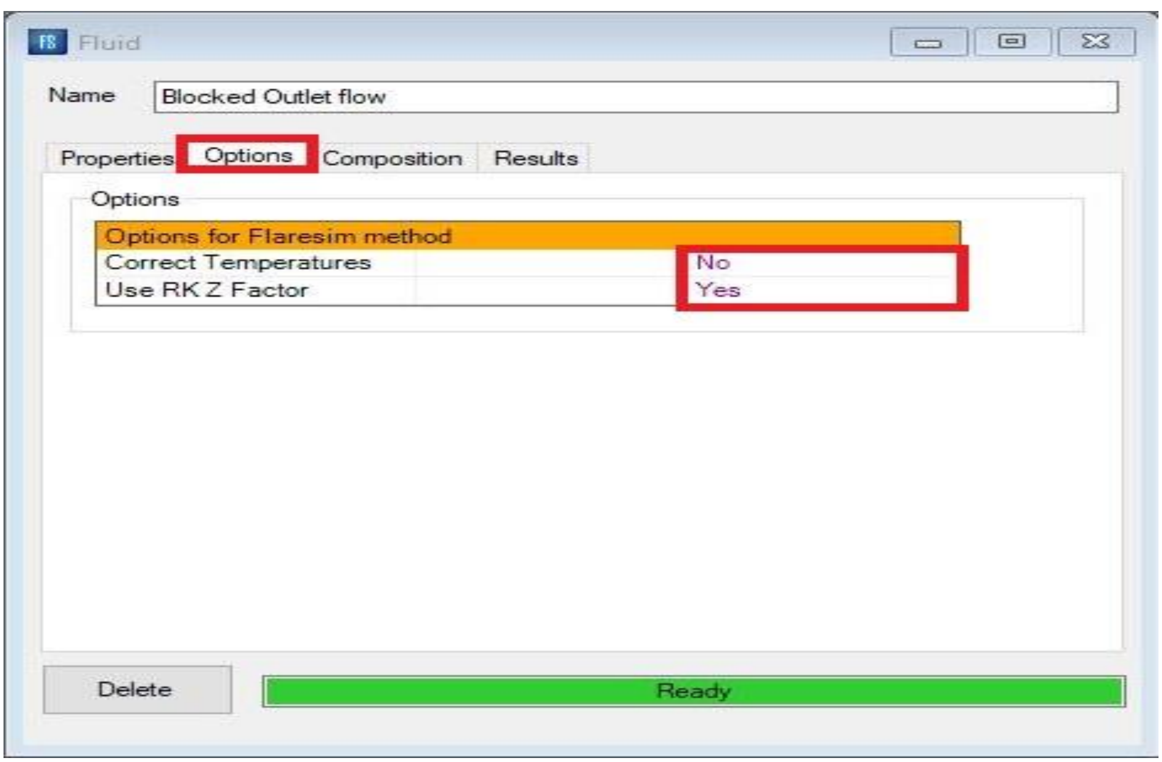
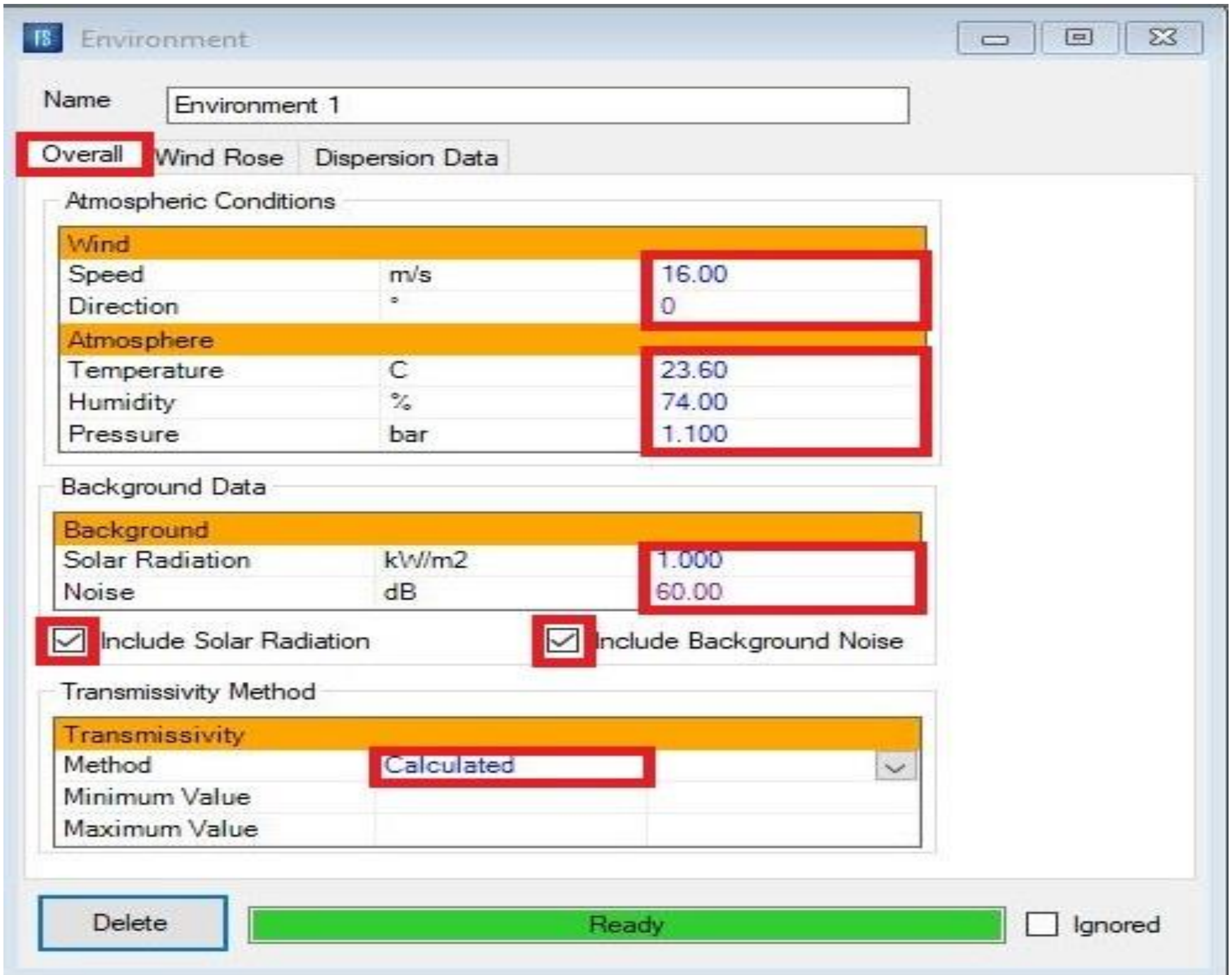
1st Step: Click on “Fluid TAB” and “Add” a Fluid Table




Fluid
Name
Blocked Outlet flow
Properties
Options
Composition
Results
Fluid Composition
Component
Fraction
Methane
0.004600
Hydrogen
0.488451
Carbon monoxide
0.151685
Water
0.294171
Carbon dioxide
0.051695
Argon
0.000200
Nitrogen
0.009199
Sum
1.000000
Composition Basis
Mass
Mole
Add Component
Remove Component
Normalise Composition
Calculate Last Fraction
Delete
Ready


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

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



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.

Permissible Design Level K kW/m^2 ($Btu/h \cdot ft^2$)	Conditions
9.46 (3000)	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 $Btu/h \cdot ft^2$), 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 $Btu/h \cdot ft^2$) for more than a few seconds.**
6.31 (2000)	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]
4.73 (1500)	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]
1.58 (500)	Maximum radiant heat intensity at any location where personnel with appropriate clothing can be continuously exposed.

[a] Appropriate clothing consists of a hard hat, a long-sleeved shirt with cuffs buttoned, work gloves, long-legged pants, and work shoes. Appropriate clothing minimizes direct skin exposure to thermal radiation.

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
UK Land	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.

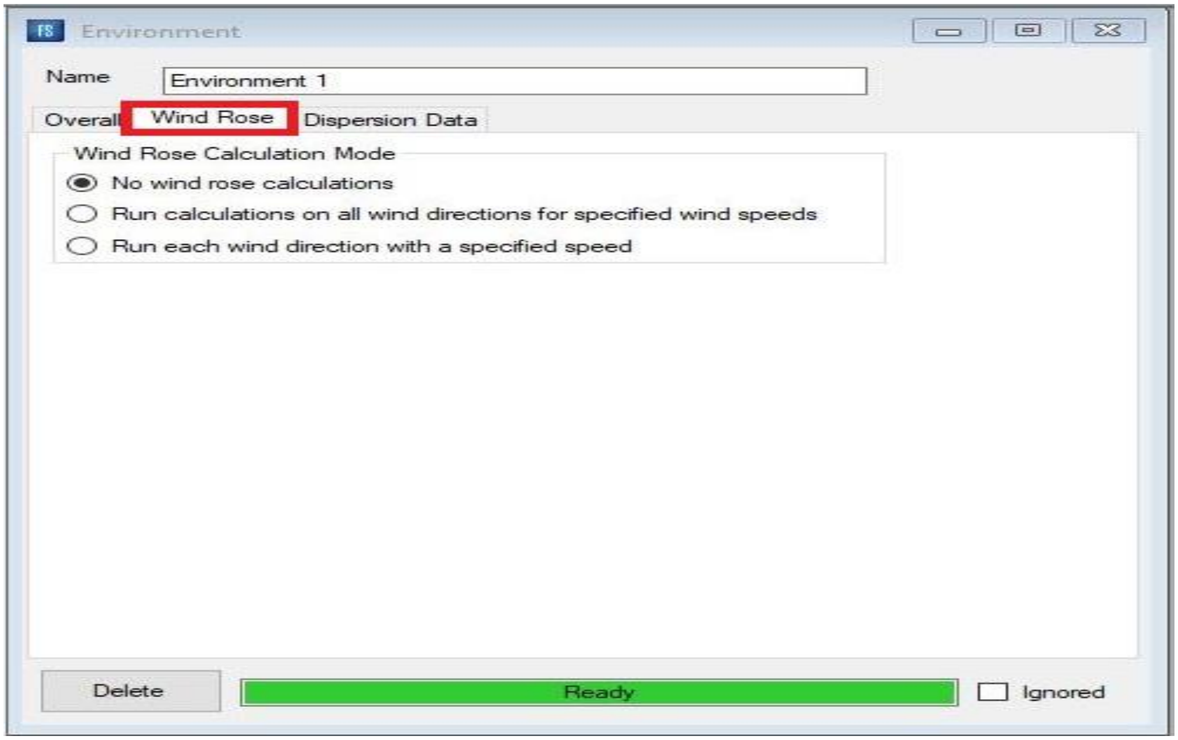
In MEKPCO Project, solar radiation has been included.

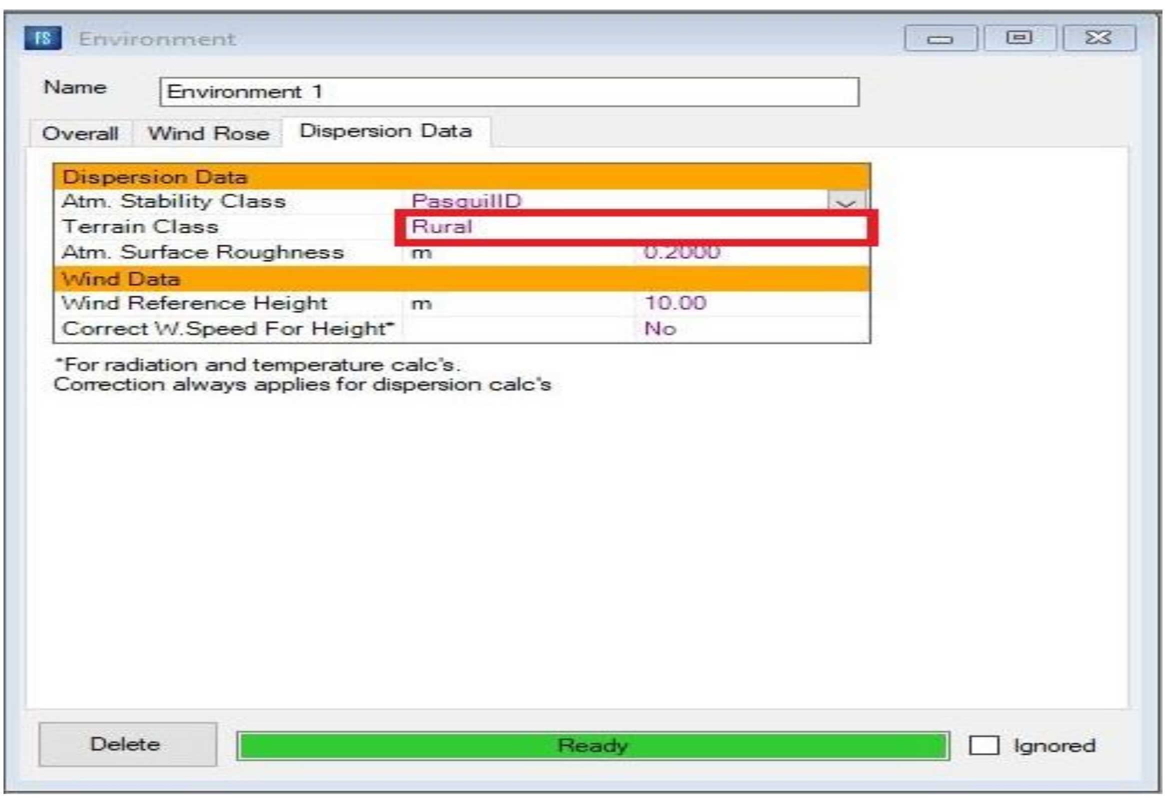
Noise

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
Run calculations on all wind directions for specified wind speeds
Run each wind direction with a specified speed
Delete
Ready
Ignored


Environment
Name
Environment 1
Overall
Wind Rose
Dispersion 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*
No
*For radiation and temperature calc's.
Correction always applies for dispersion calc's
Delete
Ready
Ignored

Stability Class

PasquillA through PasquillF

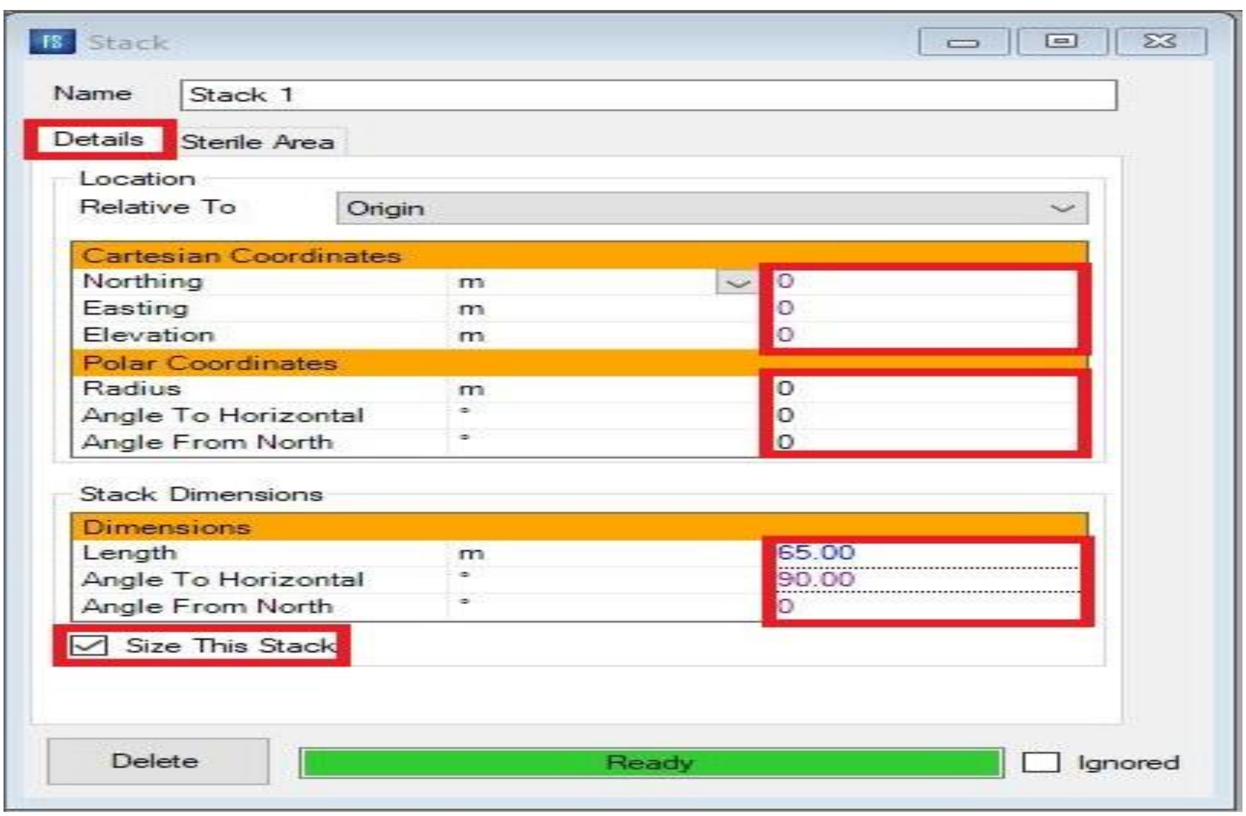
This defines the atmospheric stability class to be used to characterize the atmospheric turbulence for both Gaussian and jet dispersion calculations.

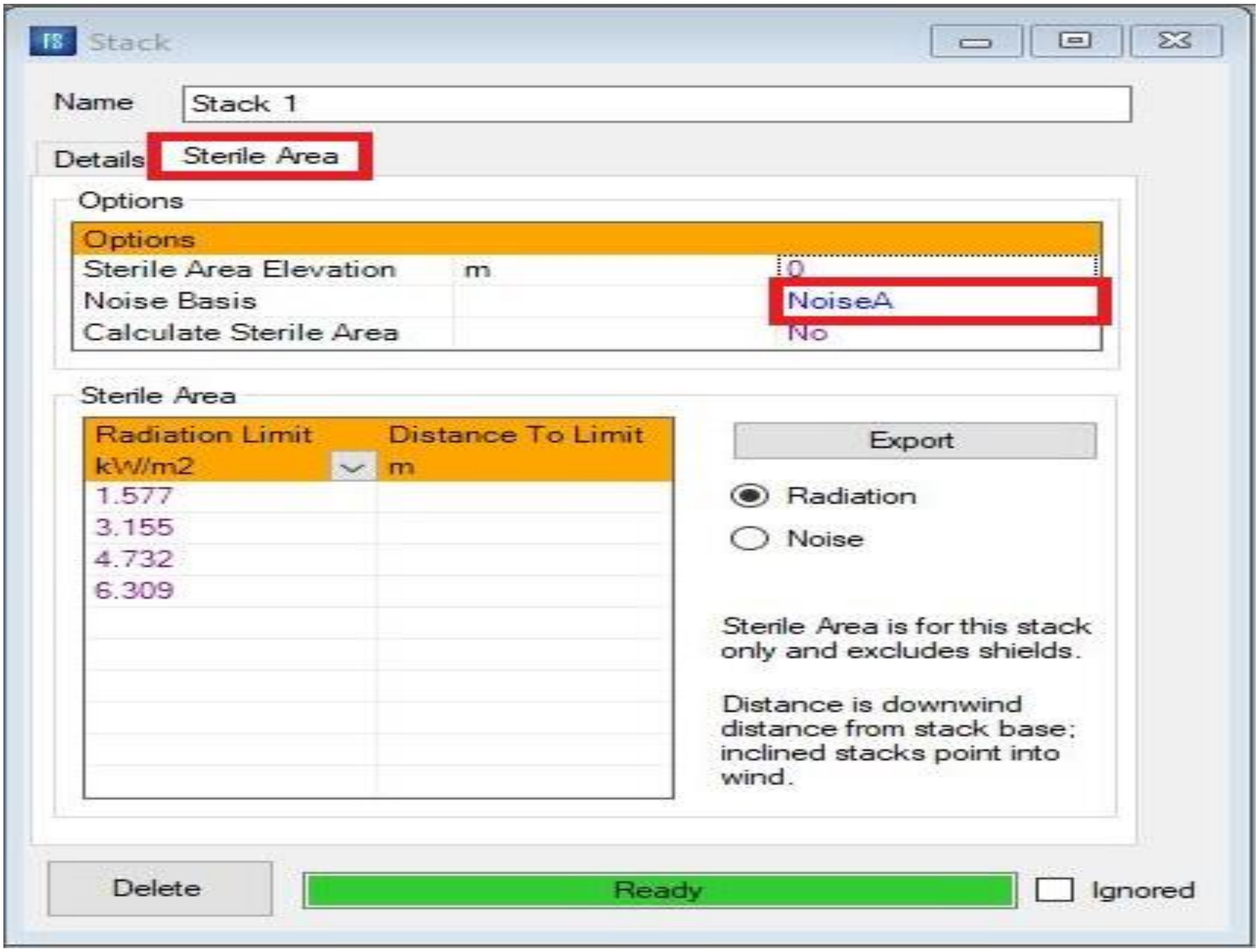
Flaresim uses the widely used Pasquil stability class designation from A to F where A is the most turbulent or most unstable atmosphere and F the least turbulent or most stable.

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.

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

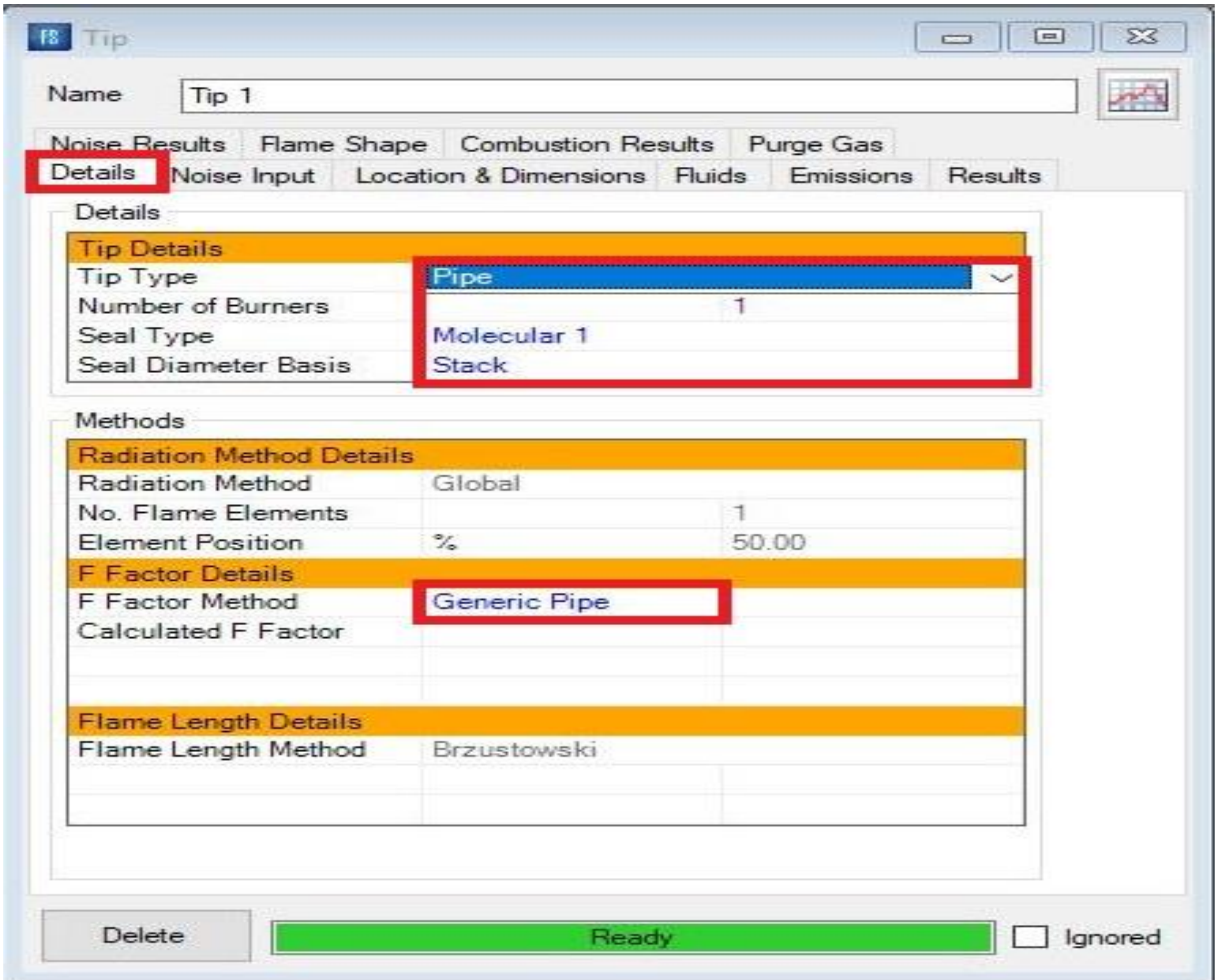




At first estimation, a stack length of 65 m is selected. Since the stack is vertical 90 degrees for Horizontal angle is selected.

Notice that Noise A means Noise weighted for human ear sensitivity

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



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.

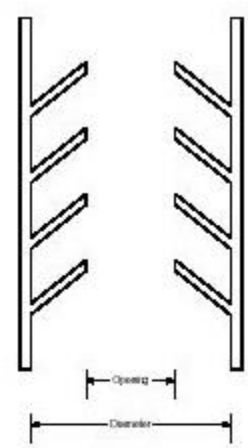
Where a combined HP/LP tips is selected the HP tip is assumed to be a sonic tip and the LP a sub-sonic one. The flow ratio of HP to LP fluids should be 3 or greater.

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

In MEKPCO Project, Pipe is selected.

Seal Type

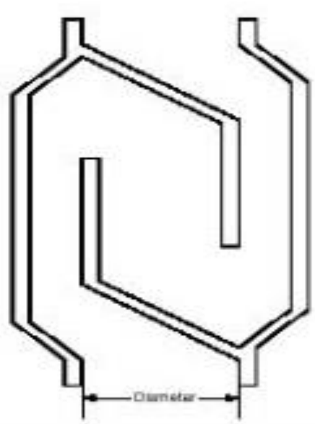
There are two basic types of seal, Fluidic or Molecular. Seals are only appropriate for pipe and sonic flare tips. If the tip type is set to *Welltest* the seal type will be set to None automatically. The figure below shows the general design concept for the fluidic seal.



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.
3. 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

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

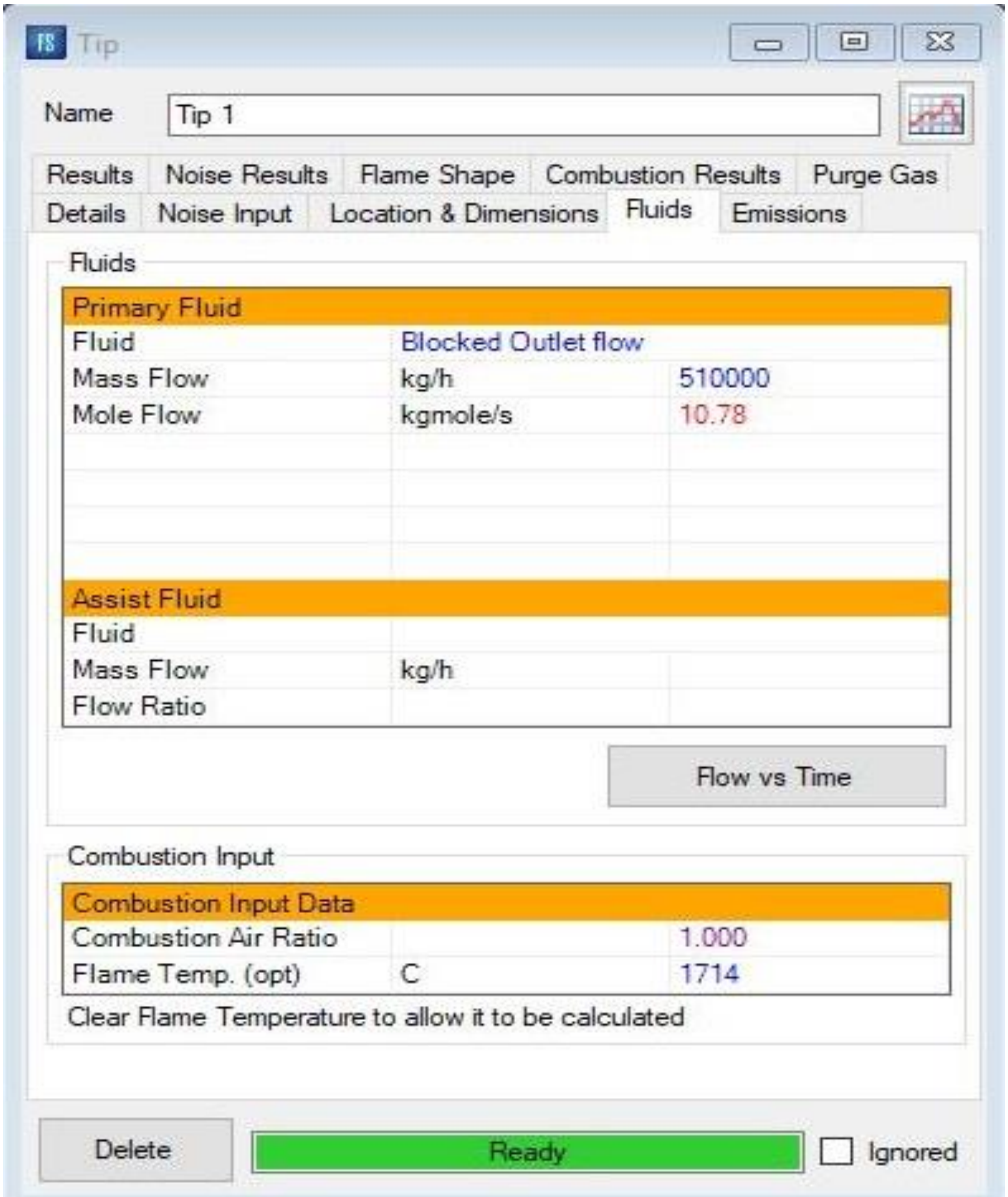
Tip Type	I1	I2
Pipeflare	0.00331	0.4776
Single Burner Sonic	0.00241	0.4600
Multiple Burner Sonic	0.00129	0.5000

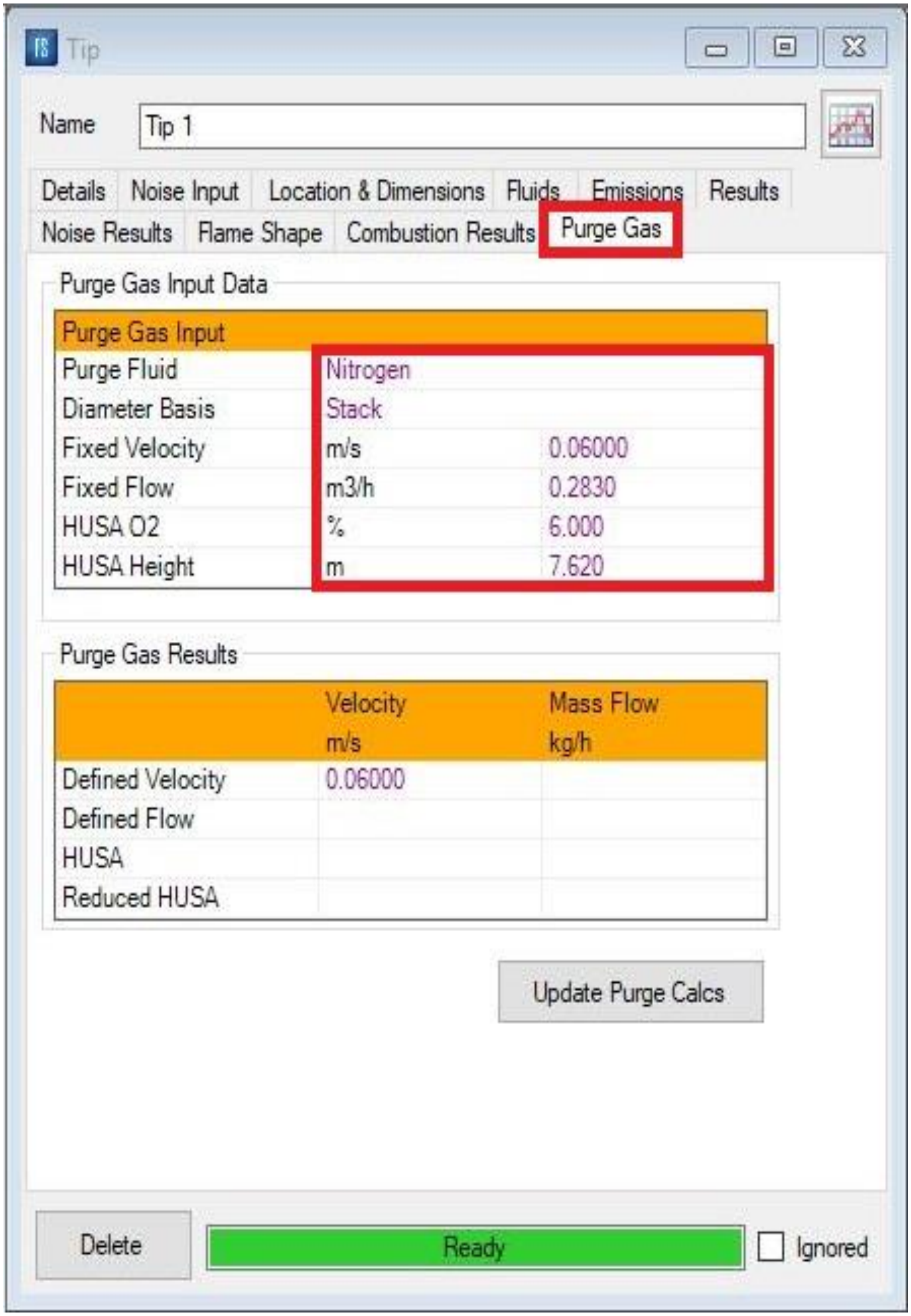
L is flame length in m

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.

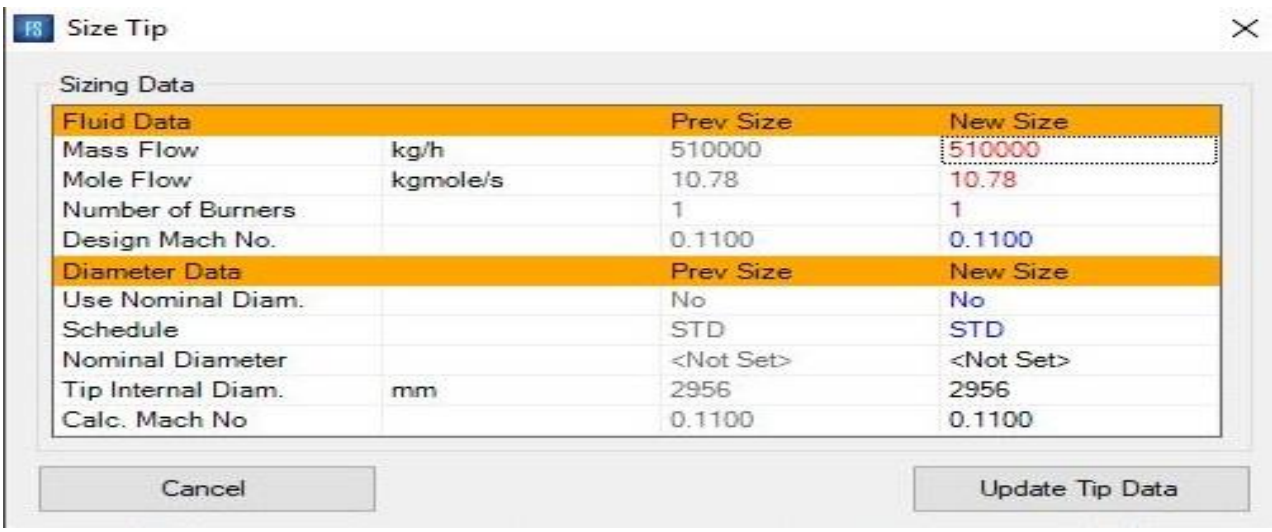

Tip
Name
Tip 1
Results
Noise Results
Flame Shape
Combustion Results
Purge Gas
Details
Noise Input
Location & Dimensions
Fluids
Emissions
Fluids
Primary Fluid
Fluid
Blocked Outlet flow
Mass Flow
kg/h
510000
Mole Flow
kgmole/s
10.78
Assist Fluid
Fluid
Mass Flow
kg/h
Flow Ratio
Flow vs Time
Combustion Input
Combustion Input Data
Combustion Air Ratio
1.000
Flame Temp. (opt)
C
1714
Clear Flame Temperature to allow it to be calculated
Delete
Ready
Ignored

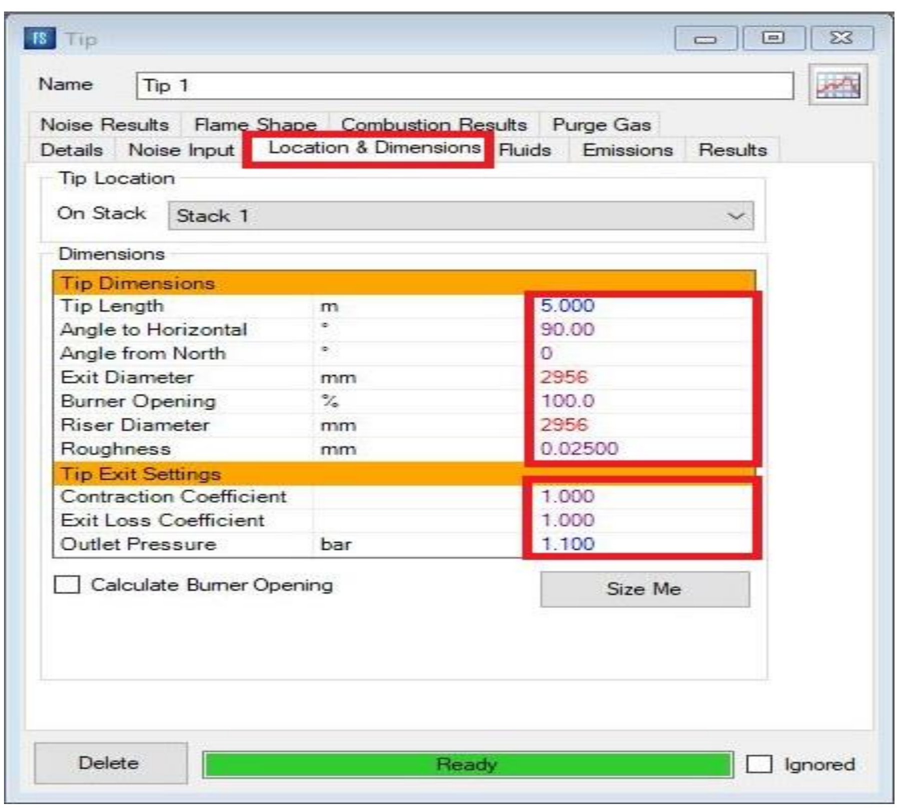


Tip
Name
Tip 1
Details
Noise Input
Location & Dimensions
Fluids
Emissions
Results
Noise Results
Flame Shape
Combustion Results
Purge Gas
Purge Gas Input Data
Purge Gas Input
Purge Fluid
Nitrogen
Diameter Basis
Stack
Fixed Velocity
m/s
0.06000
Fixed Flow
m3/h
0.2830
HUSA O2
%
6.000
HUSA Height
m
7.620
Purge Gas Results
Velocity
m/s
Mass Flow
kg/h
Defined Velocity
0.06000
Defined Flow
HUSA
Reduced HUSA
Update Purge Calcs
Delete
Ready
Ignored

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.





Noise input

Selects the noise calculation method to be used.

1. Acoustic Efficiency method

2. Reference Curve method

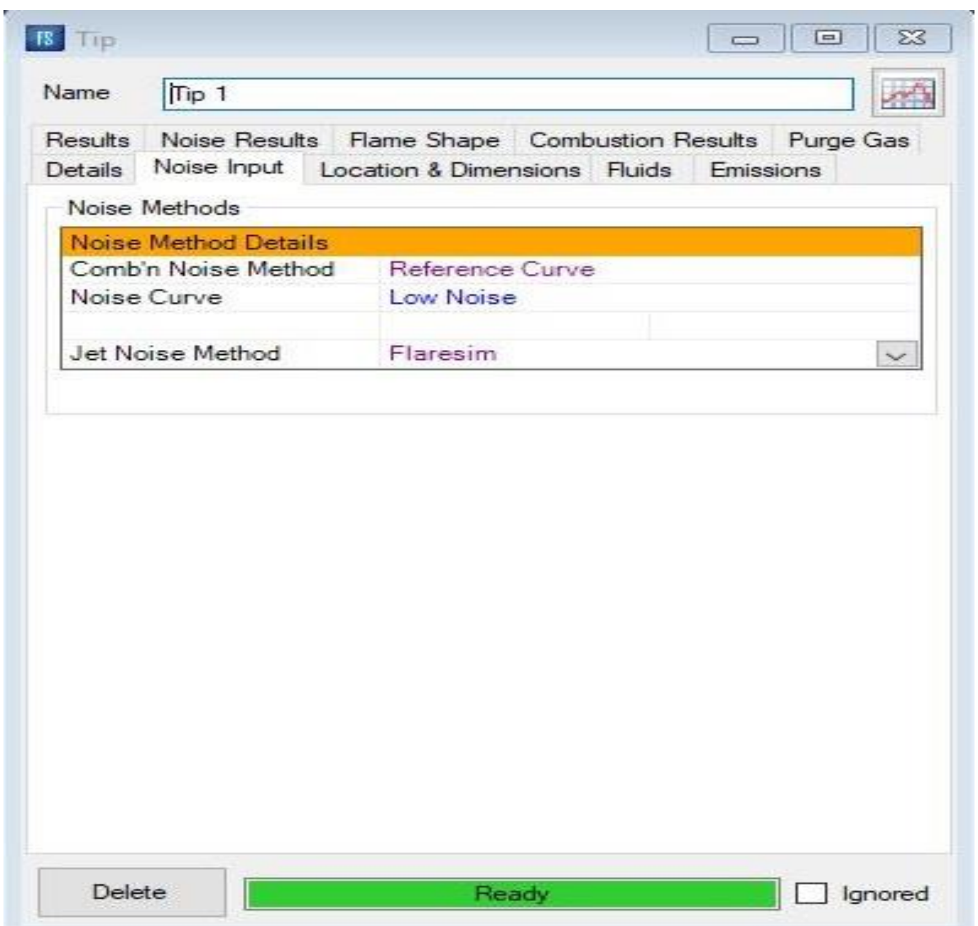
The Reference Curve method is based on a reference spectrum of noise at a known heat release.

Select Noise Curve

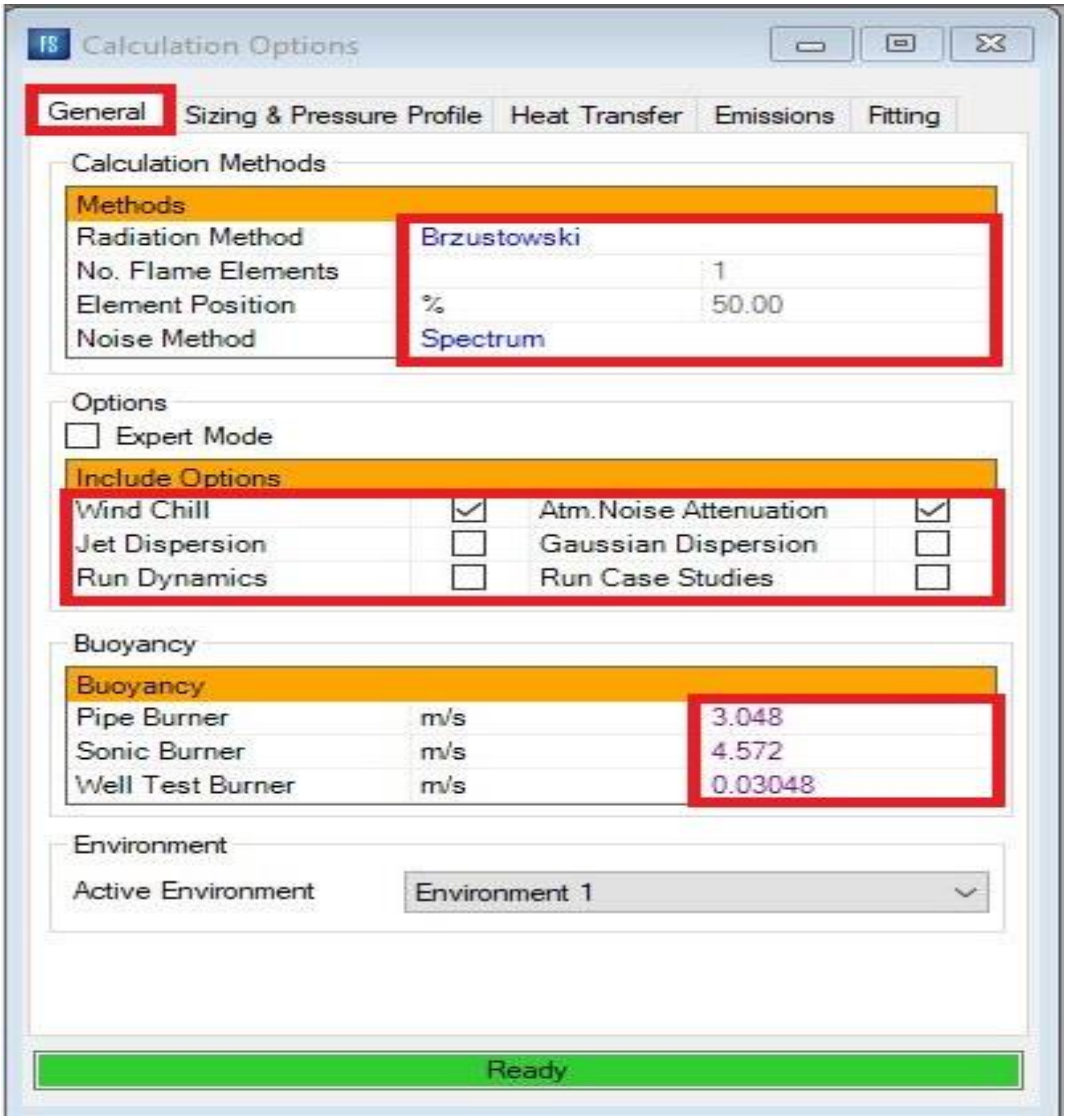
1.Standard

2.Low Noise

The Standard and Low Noise reference data options are proprietary data supplied by a flare system vendor.



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



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 Diffuse source 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 Mixed source 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 Brzustowski method 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 M.Point Brz method 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 noise calculations. 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 Windchill correlation 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 atmospheric absorption. 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.

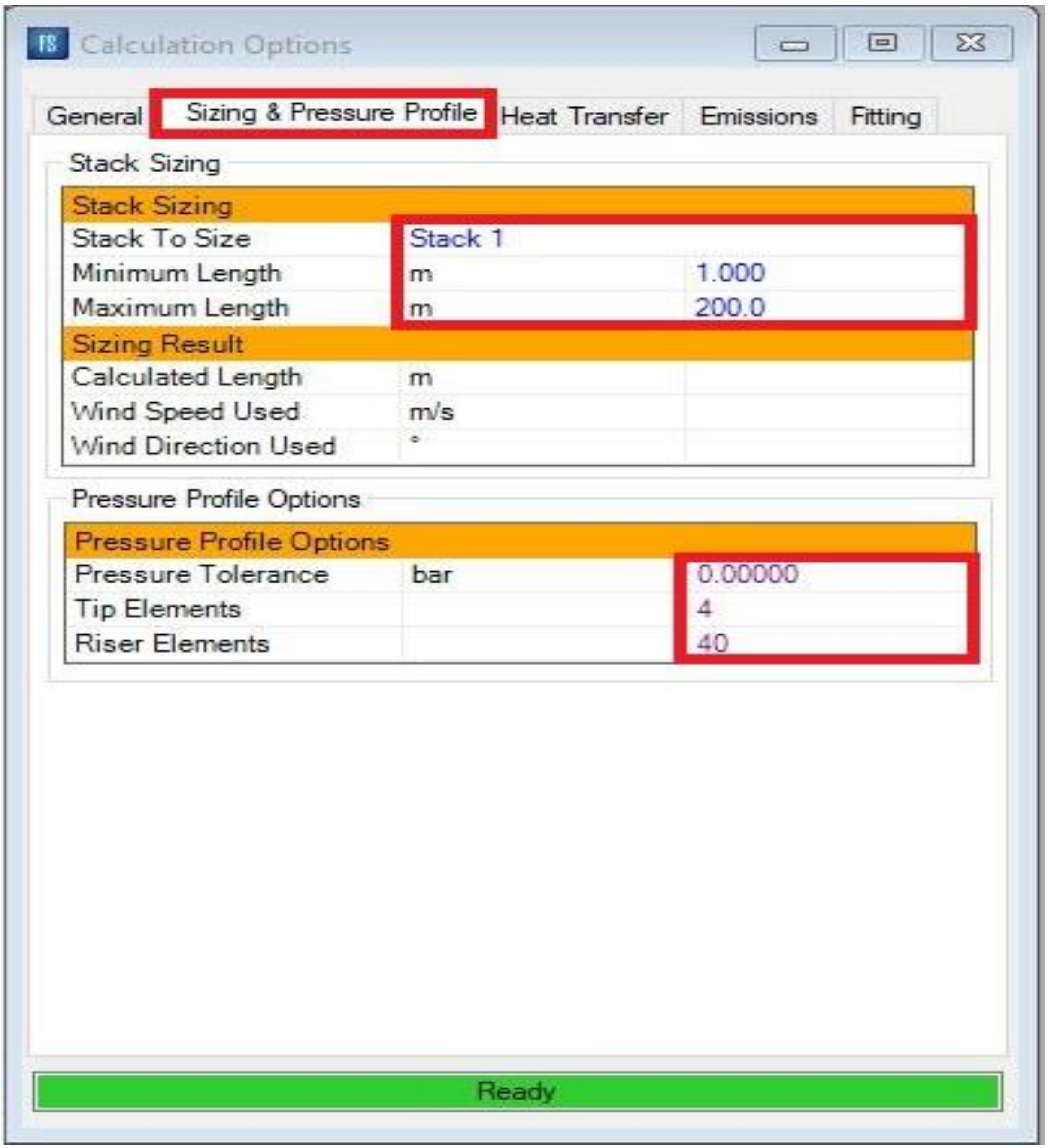
Buoyancy - Sonic

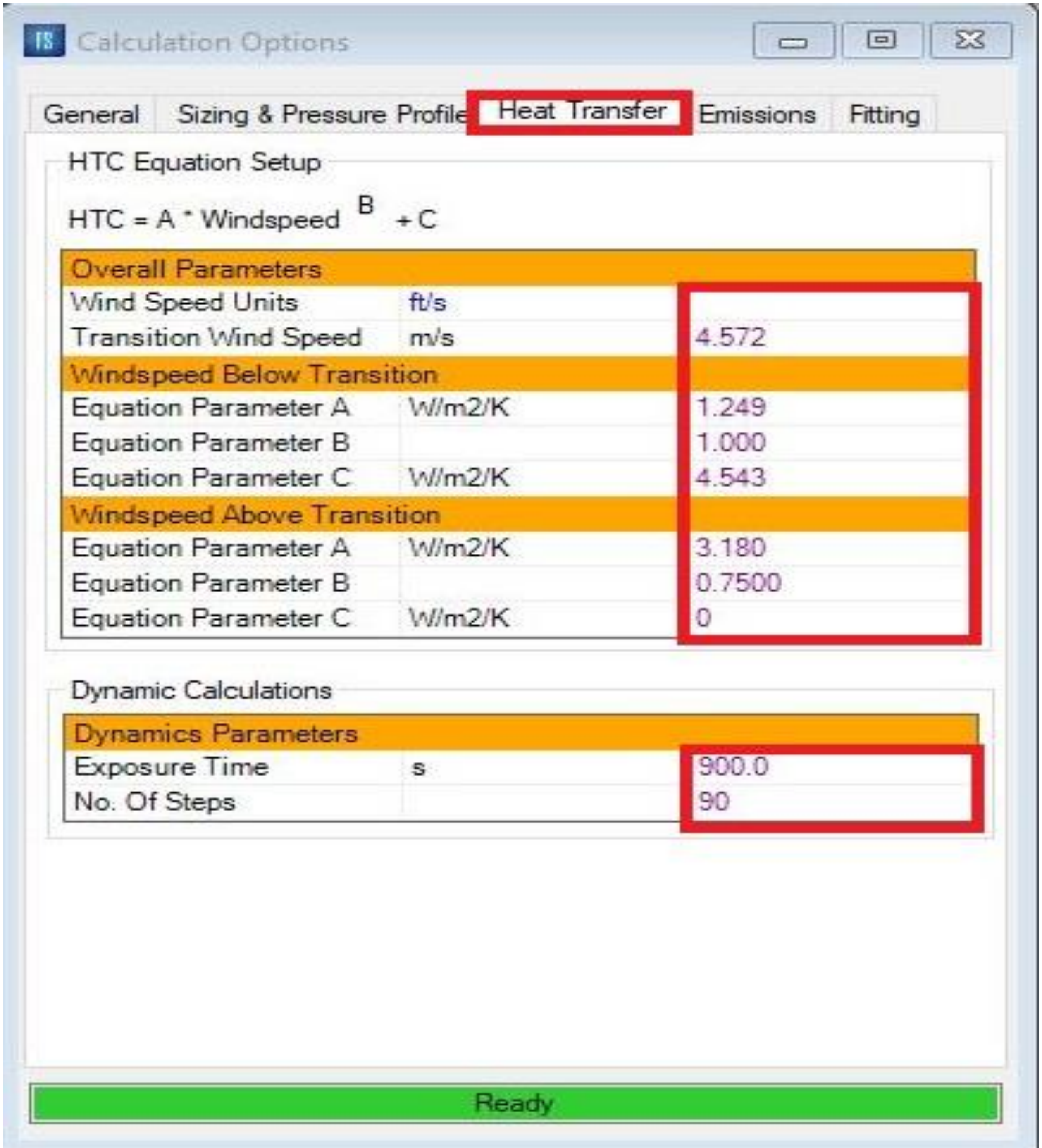
The flame buoyancy to be used for Sonic flare tips. A value of 4.6 m/s is suggested unless specific vendor information suggests otherwise.

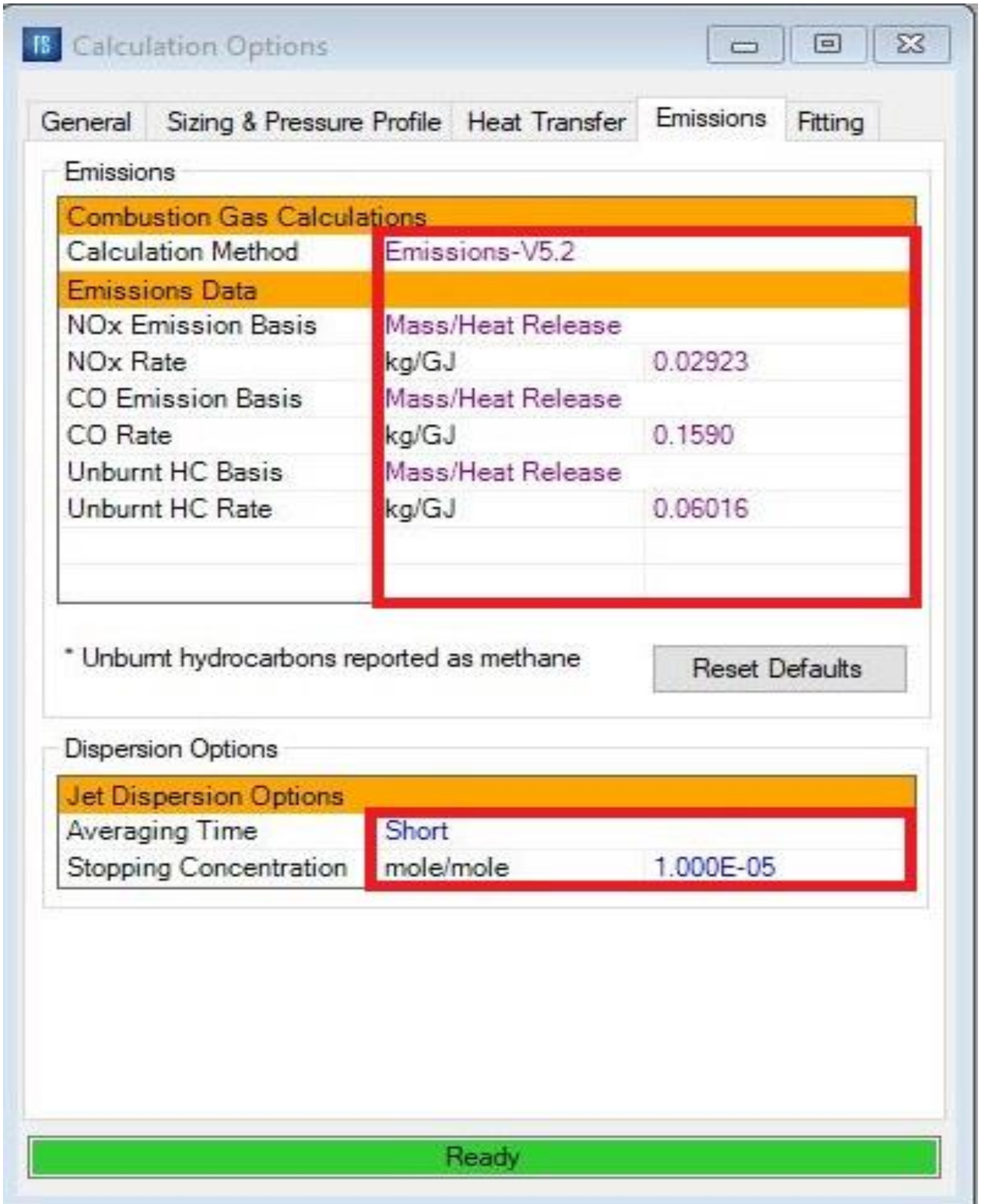
Buoyancy - Welltest

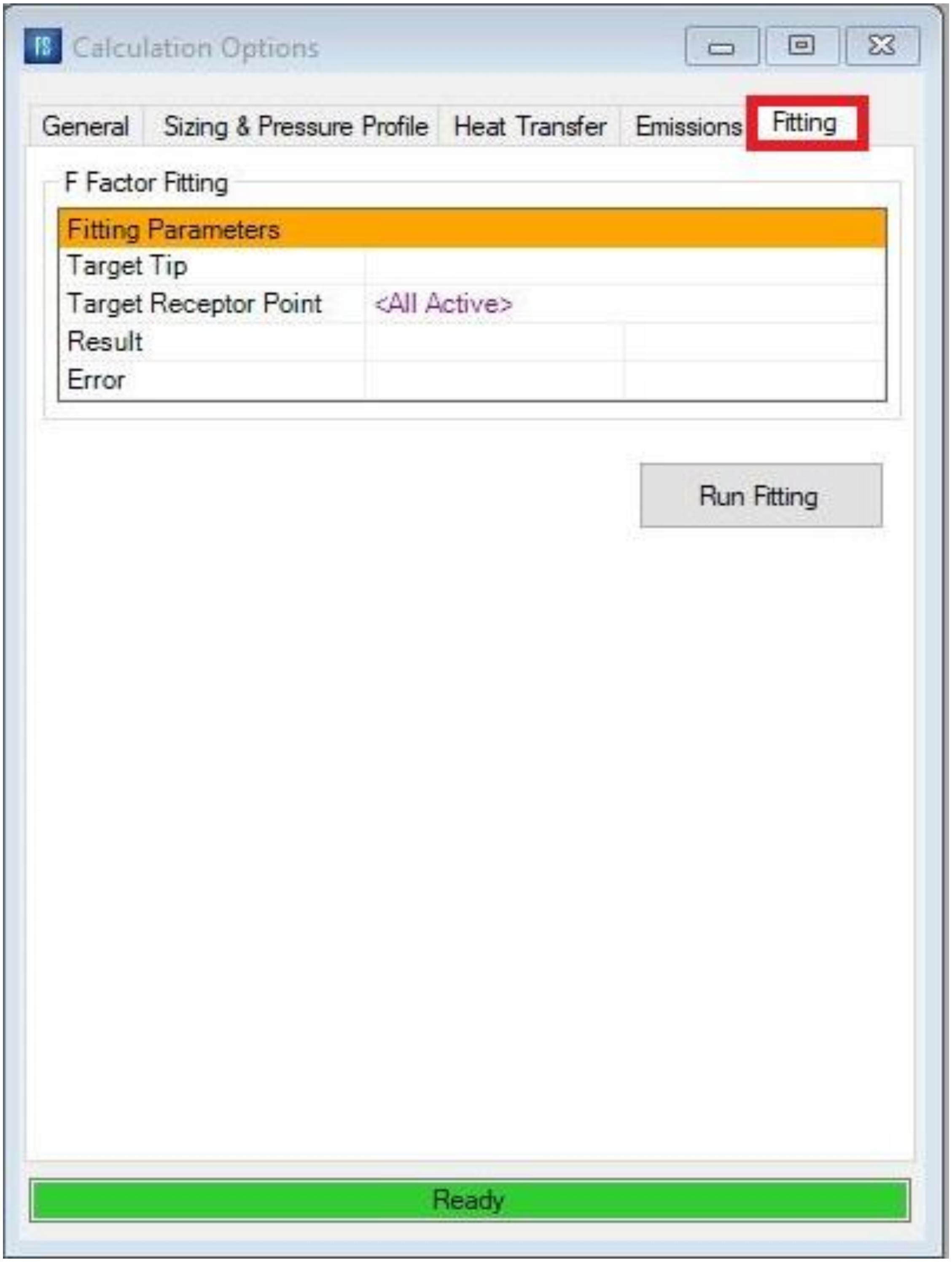
The flame buoyancy to be used for Liquid flare tips. A value of 0.03 m/s is suggested unless specific vendor information suggests otherwise.

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.

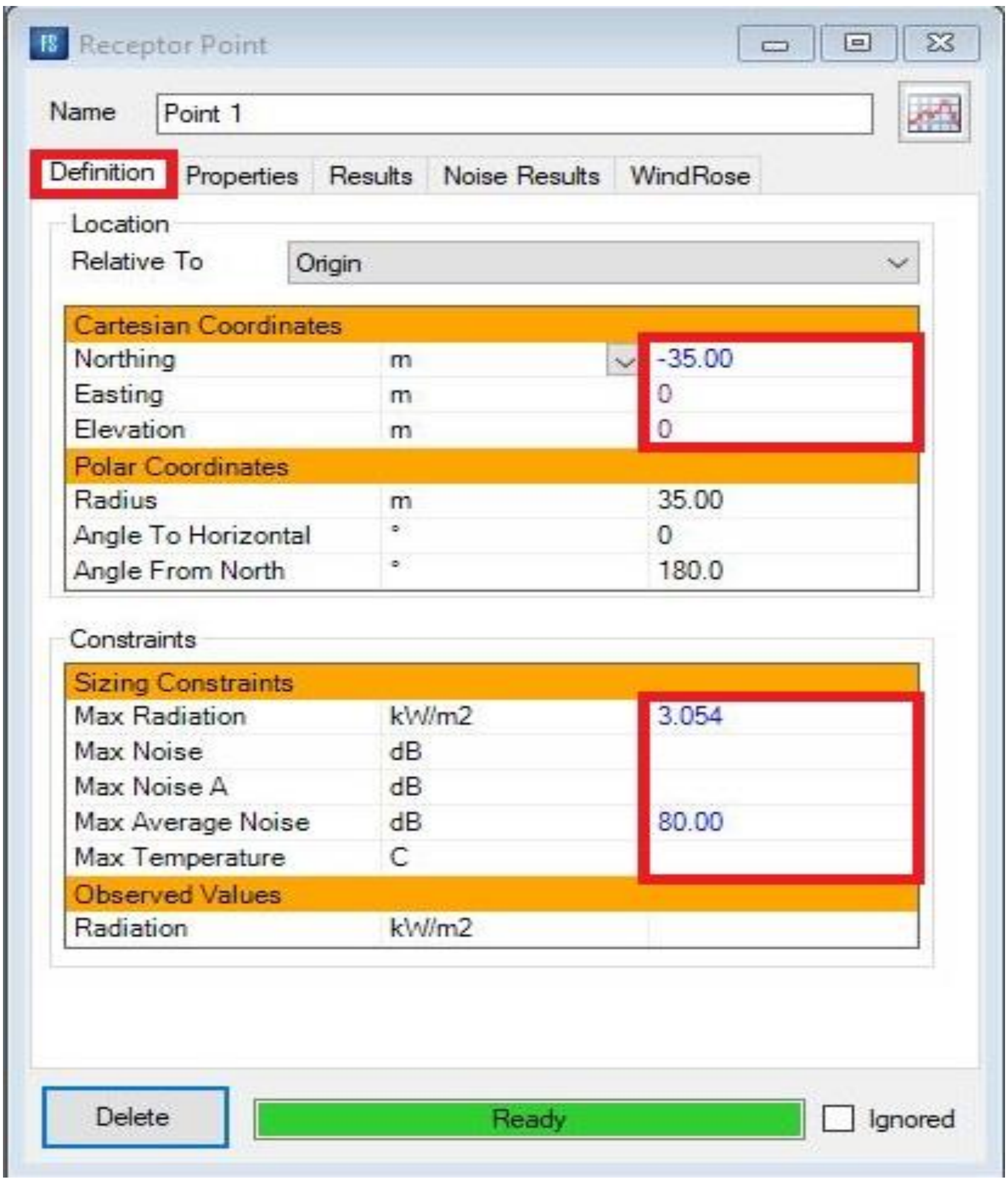


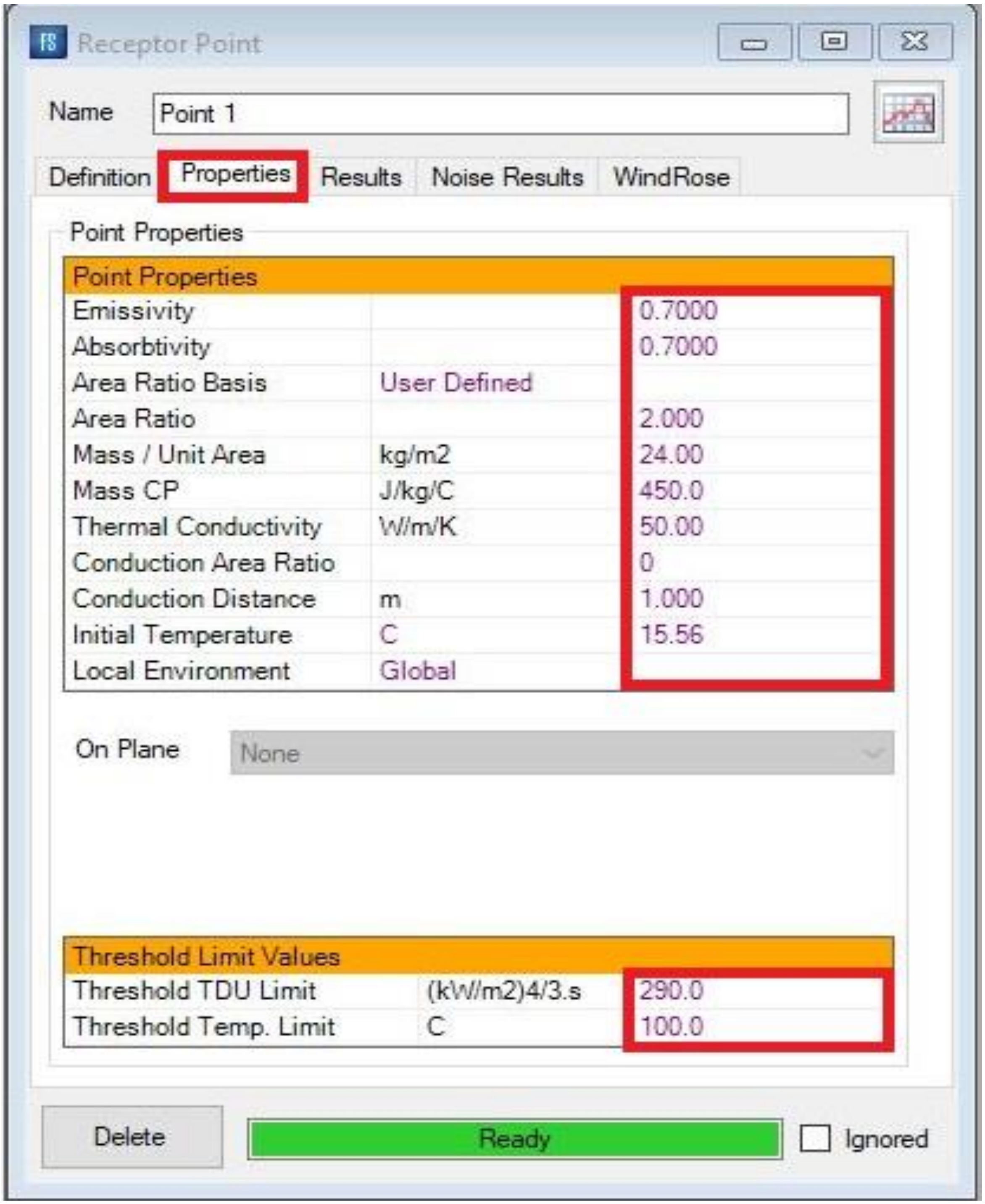

Calculation Options
General
Sizing & Pressure Profile
Heat Transfer
Emissions
Fitting
HTC Equation Setup
HTC = A * Windspeed B + C
Overall Parameters
Wind Speed Units ft/s
Transition Wind Speed m/s 4.572
Windspeed Below Transition
Equation Parameter A W/m2/K 1.249
Equation Parameter B 1.000
Equation Parameter C W/m2/K 4.543
Windspeed Above Transition
Equation Parameter A W/m2/K 3.180
Equation Parameter B 0.7500
Equation Parameter C W/m2/K 0
Dynamic Calculations
Dynamics Parameters
Exposure Time s 900.0
No. Of Steps 90
Ready


Calculation Options
General
Sizing & Pressure Profile
Heat Transfer
Emissions
Fitting
Emissions
Combustion Gas Calculations
Calculation Method
Emissions-V5.2
Emissions Data
NOx Emission Basis
Mass/Heat Release
NOx Rate
kg/GJ
0.02923
CO Emission Basis
Mass/Heat Release
CO Rate
kg/GJ
0.1590
Unburnt HC Basis
Mass/Heat Release
Unburnt HC Rate
kg/GJ
0.06016
* Unburnt hydrocarbons reported as methane
Reset Defaults
Dispersion Options
Jet Dispersion Options
Averaging Time
Short
Stopping Concentration
mole/mole
1.000E-05
Ready


Calculation Options
General
Sizing & Pressure Profile
Heat Transfer
Emissions
Fitting
F Factor Fitting
Fitting Parameters
Target Tip
Target Receptor Point
<All Active>
Result
Error
Run Fitting
Ready

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

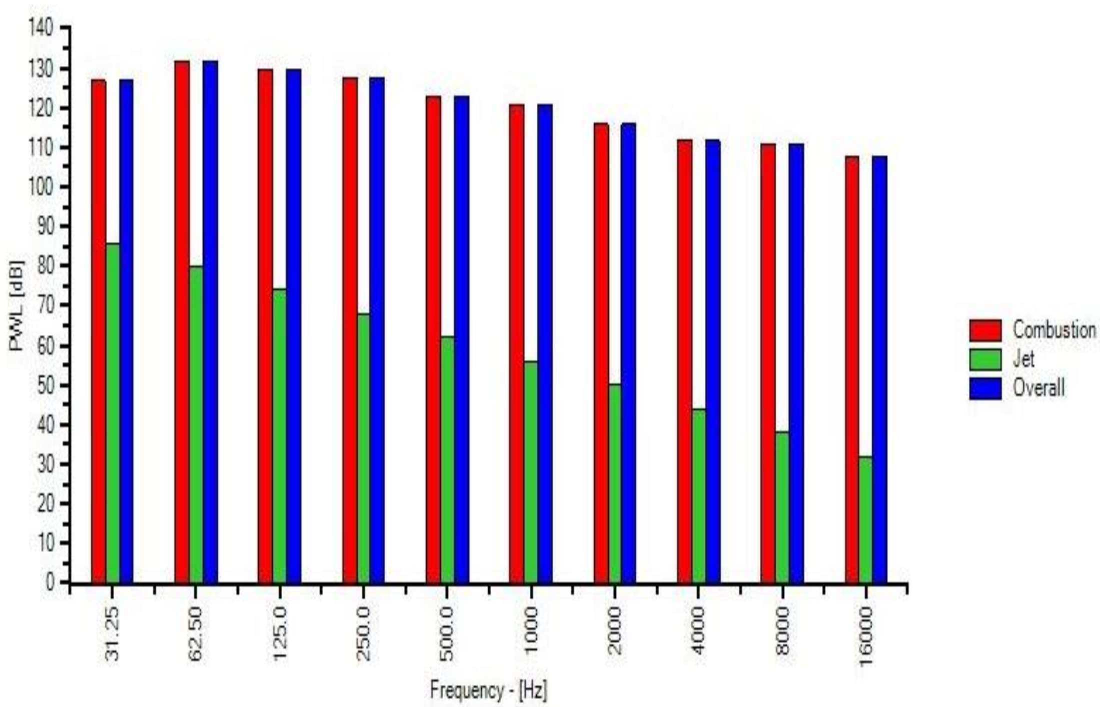



Receptor Point
Name
Point 1
Definition
Properties
Results
Noise Results
WindRose
Point Properties
Point Properties
Emissivity 0.7000
Absorbtivity 0.7000
Area Ratio Basis User Defined
Area Ratio 2.000
Mass / Unit Area kg/m2 24.00
Mass CP J/kg/C 450.0
Thermal Conductivity W/m/K 50.00
Conduction Area Ratio 0
Conduction Distance m 1.000
Initial Temperature C 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
Delete
Ready
Ignored

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	C	360.0
Flame Results		
Heat Release	kW	1.767E+06
Flame Length	m	87.64
API Length	m	86.35



Pressure Profile

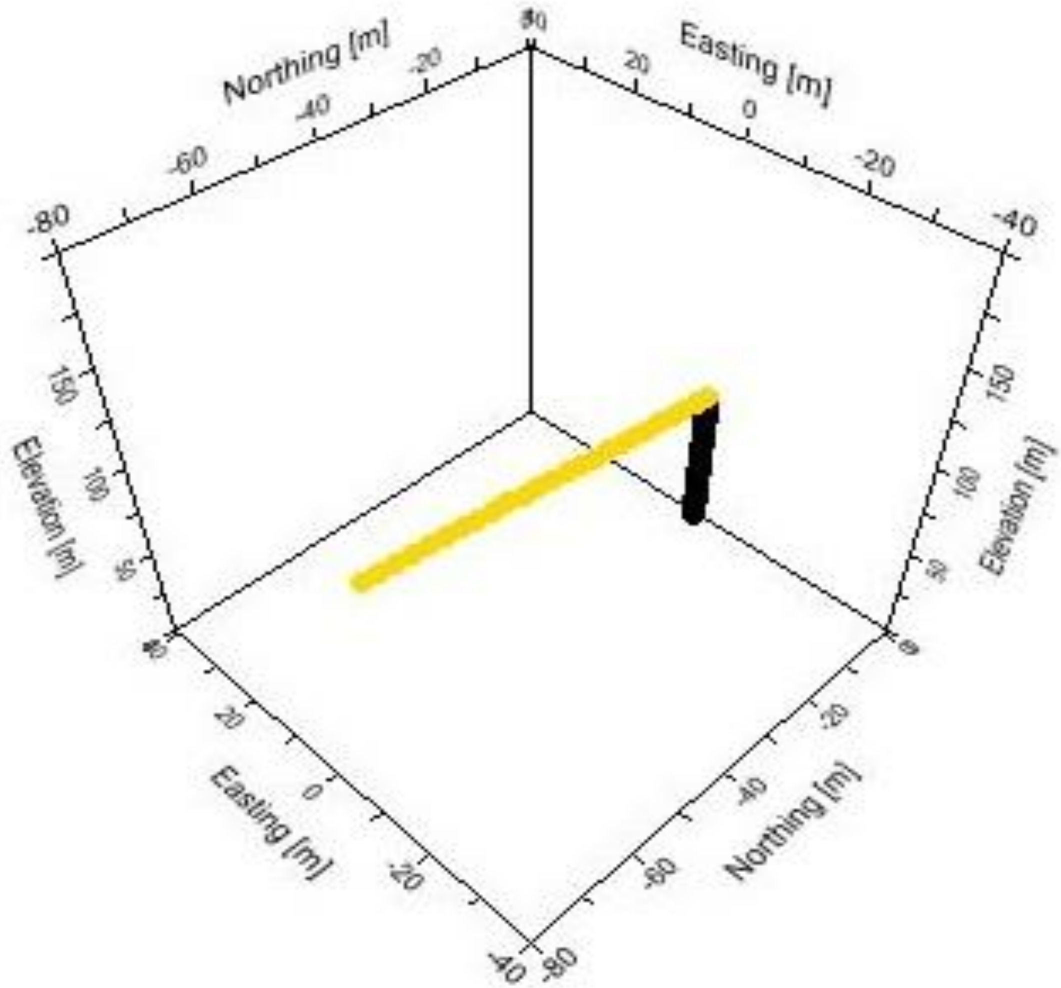
Pressure Profile		
bar	Static	Total
Tip Outlet	1.100	1.108
Tip Inlet	1.100	1.108
Tip DP	1.234E-04	1.227E-04
Seal Inlet	1.101	1.109
Seal DP	0.001253	0.001243
Stack Inlet	1.103	1.111
Stack DP	0.001734	0.001722

Noise Results

Total Noise		
Noise - SPL	dB	95.33
Reference Distance	m	30.00

Combustion Gases - Mass

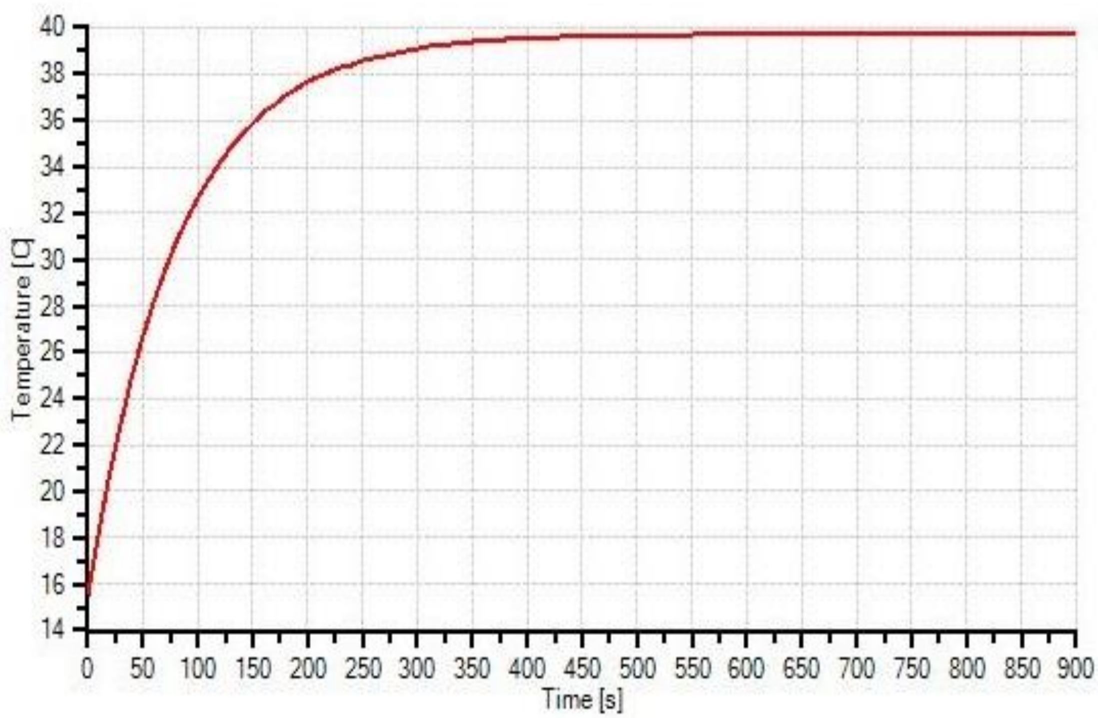
Combustion gas flows - mass basis		
Carbon dioxide	kg/h	352631
Water	kg/h	552807
Oxygen	kg/h	2005
Nitrogen	kg/h	1.341E+06
Sulphur dioxide	kg/h	0
Nitrogen monoxide	kg/h	185.9



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

Results/Point1

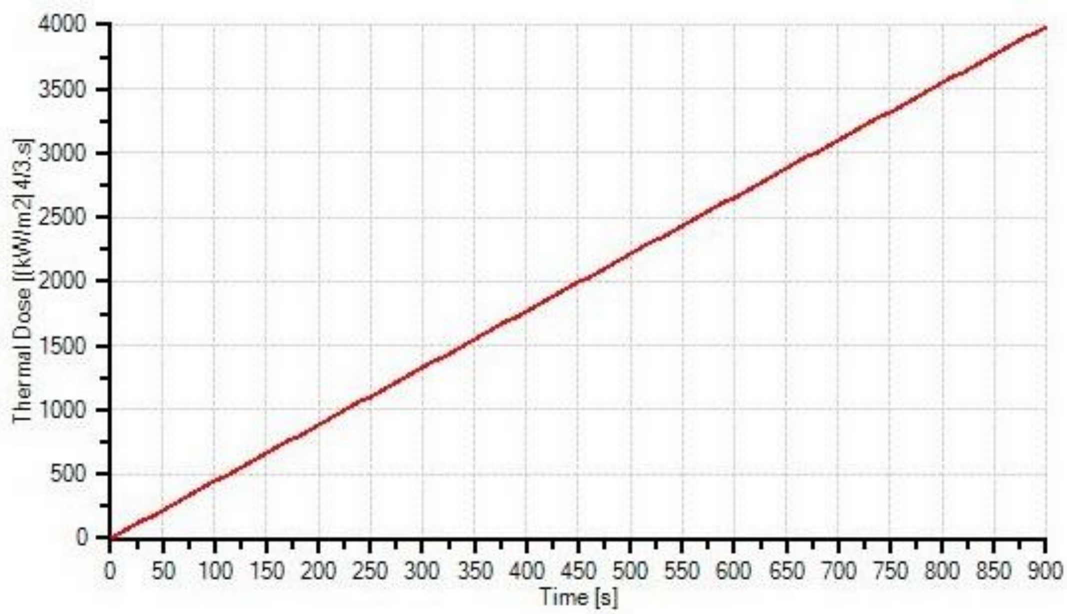
Calculated Results		
Radiation	kW/m2	3.054
Final Temperature	C	39.67
Concentration	mole/mole	
Local Wind Speed	m/s	16.00
Time To TDU Limit	s	65.44
Time To Temp. Limit	s	Limit Not Reached



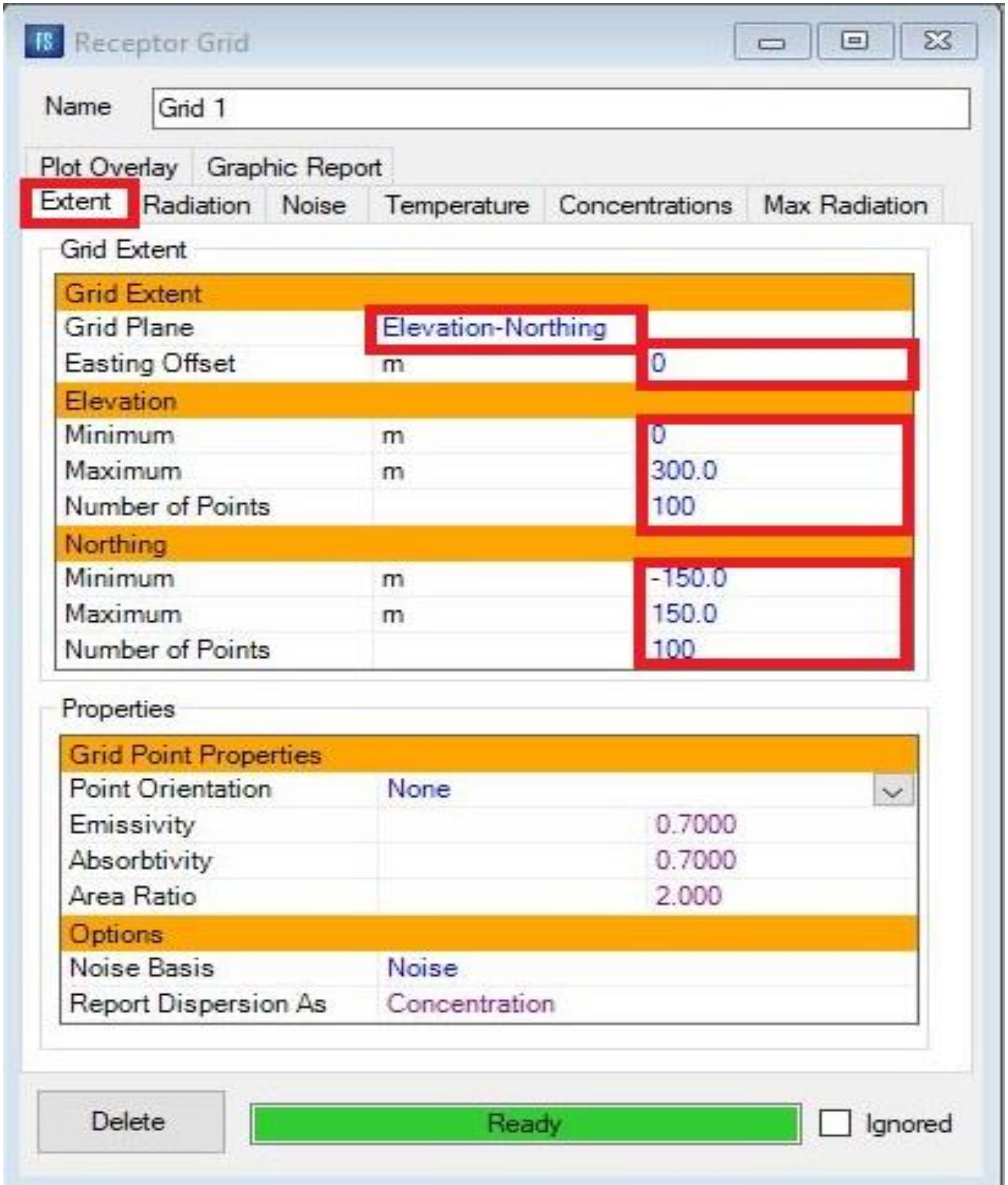
Noise Results

Noise Results		
Noise	dB	86.56
NoiseA	dB	76.88
Average Noise	dB	76.56

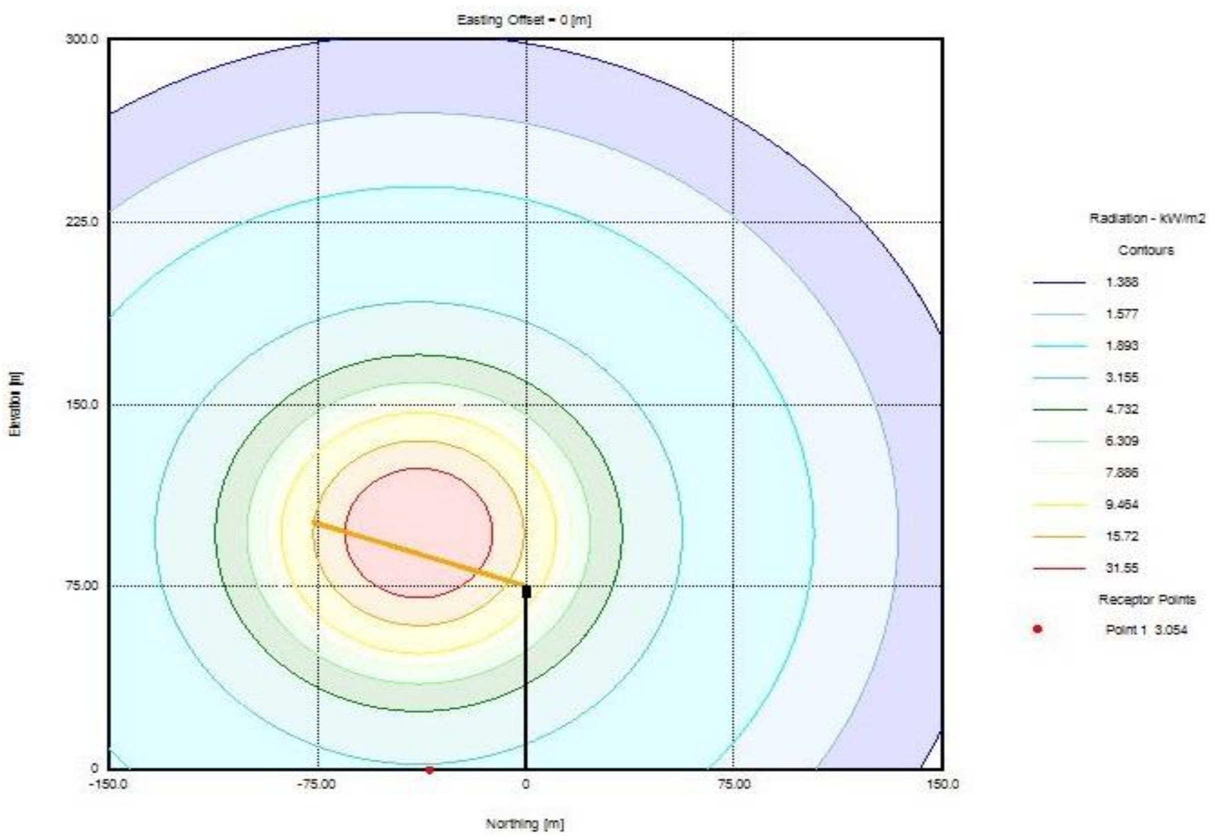
Frequency Hz	Noise dB	NoiseA dB
31.25	77.42	38.02
62.50	82.36	56.16
125.0	80.38	64.28
250.0	78.40	69.80
500.0	73.53	70.33
1000	71.65	71.65
2000	66.91	68.11
4000	63.44	64.44
8000	61.91	60.81
16000	60.22	53.62



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

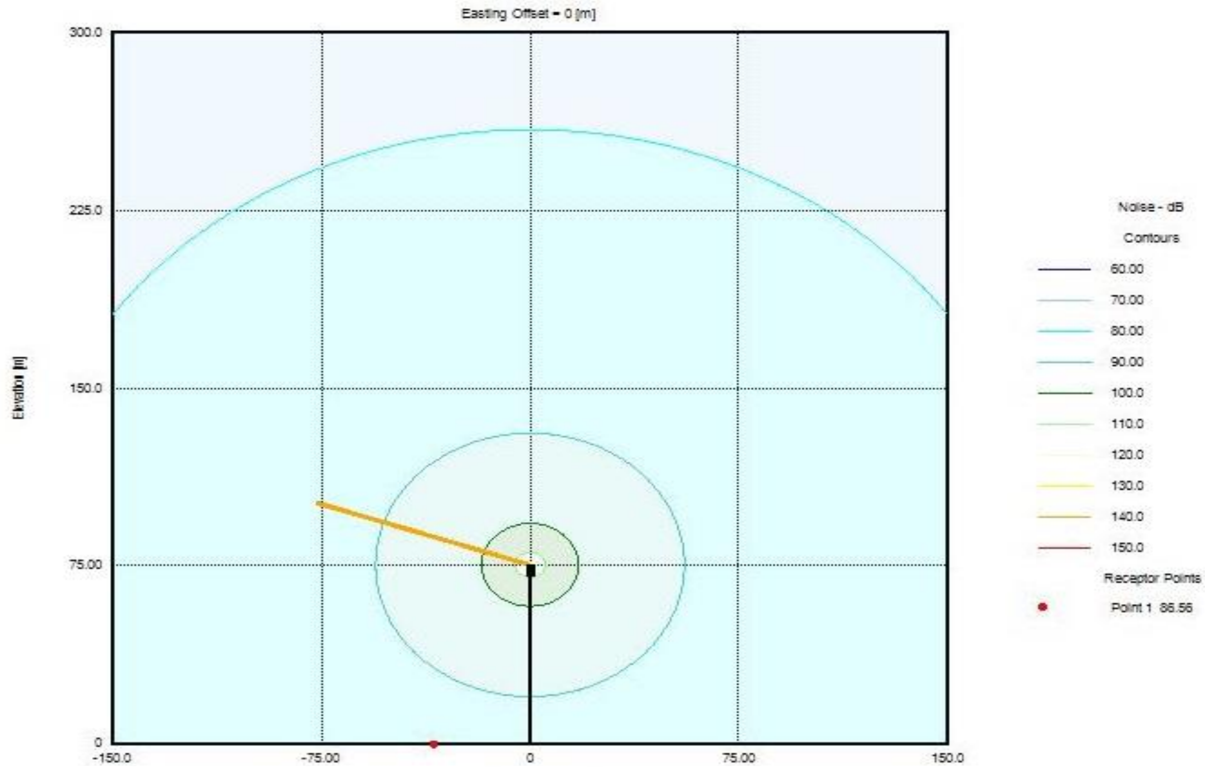


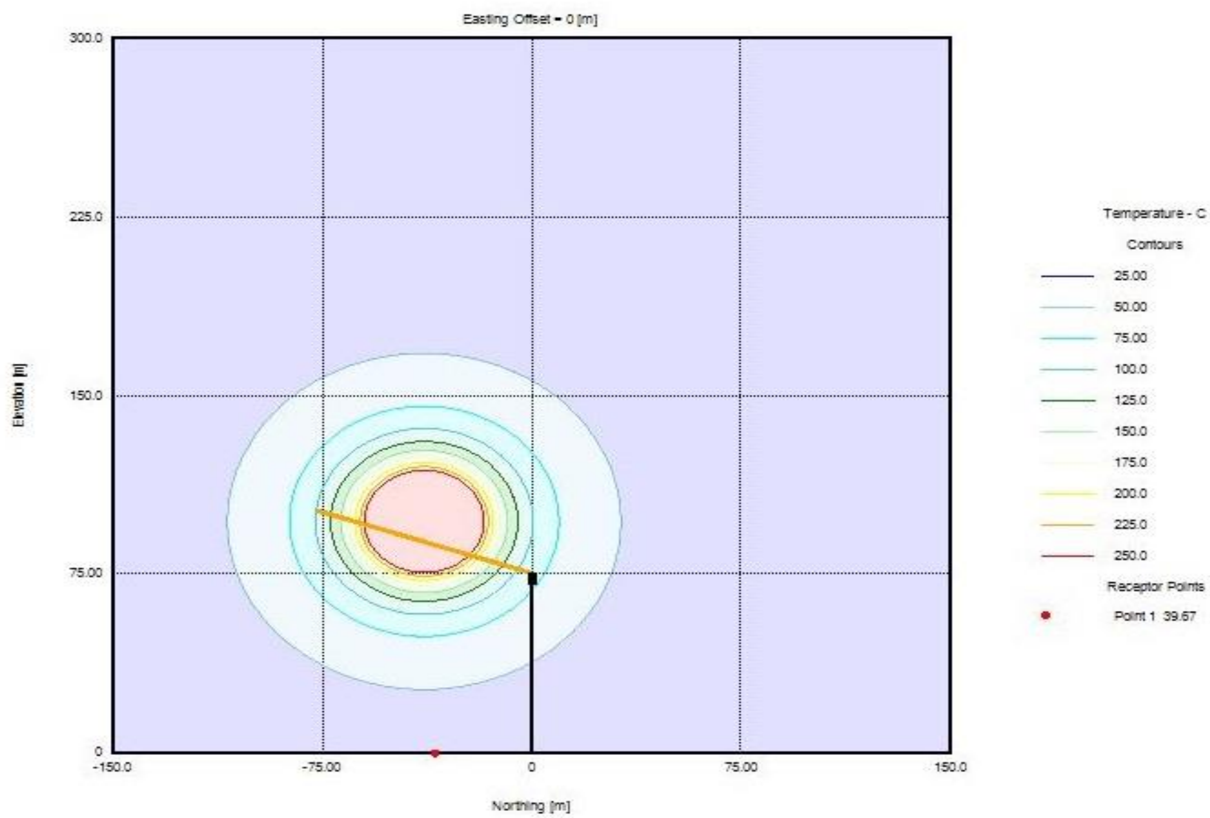
Results/Grids



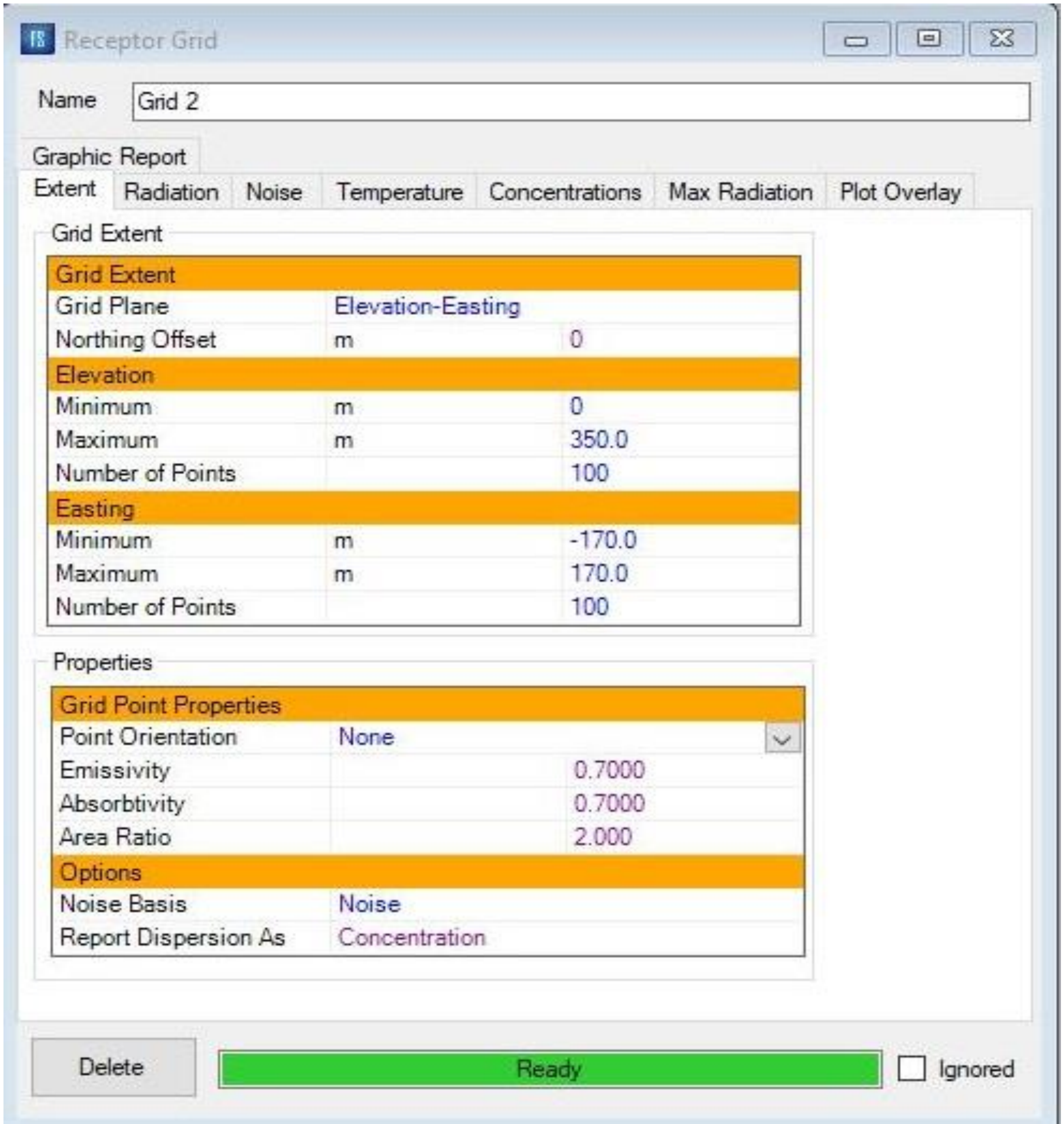
Maximum Radiation

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

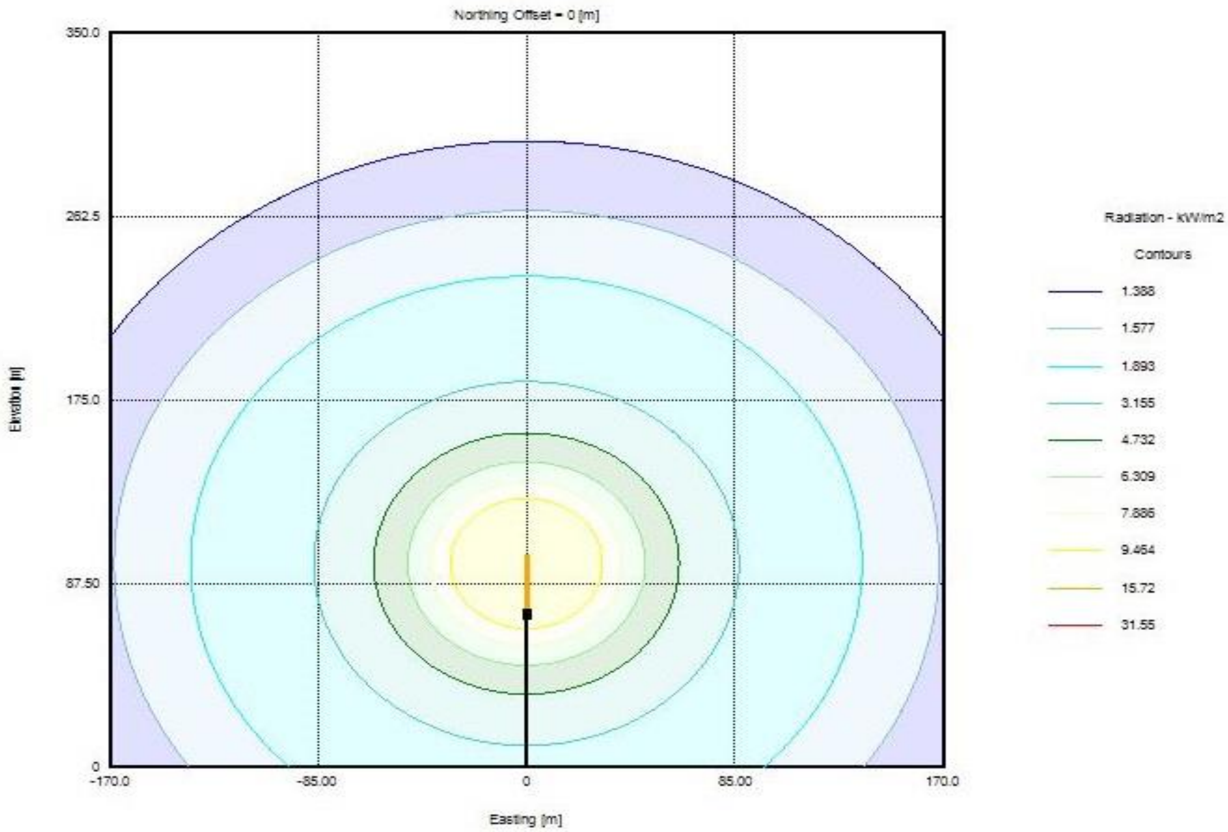

Easting Offset = 0 [m]
300.0
225.0
150.0
75.00
0
-150.0
-75.00
0
75.00
150.0
Elevation [m]
Noise - dB
Contours
60.00
70.00
80.00
90.00
100.0
110.0
120.0
130.0
140.0
150.0
Receptor Points
Point 1 86.56


Easting Offset = 0 [m]
300.0
225.0
150.0
75.00
0
-150.0
-75.00
0
75.00
150.0
Elevation [m]
Northing [m]
Temperature - C
Contours
25.00
50.00
75.00
100.0
125.0
150.0
175.0
200.0
225.0
250.0
Receptor Points
Point 1 39.67

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

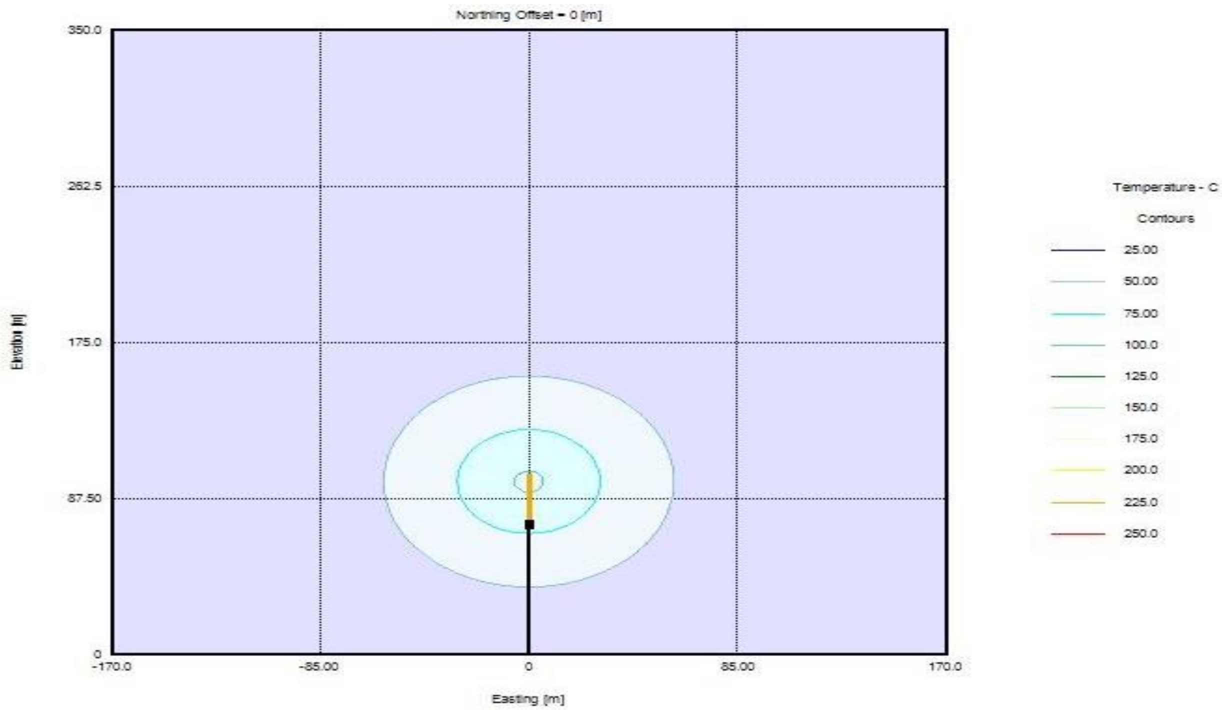


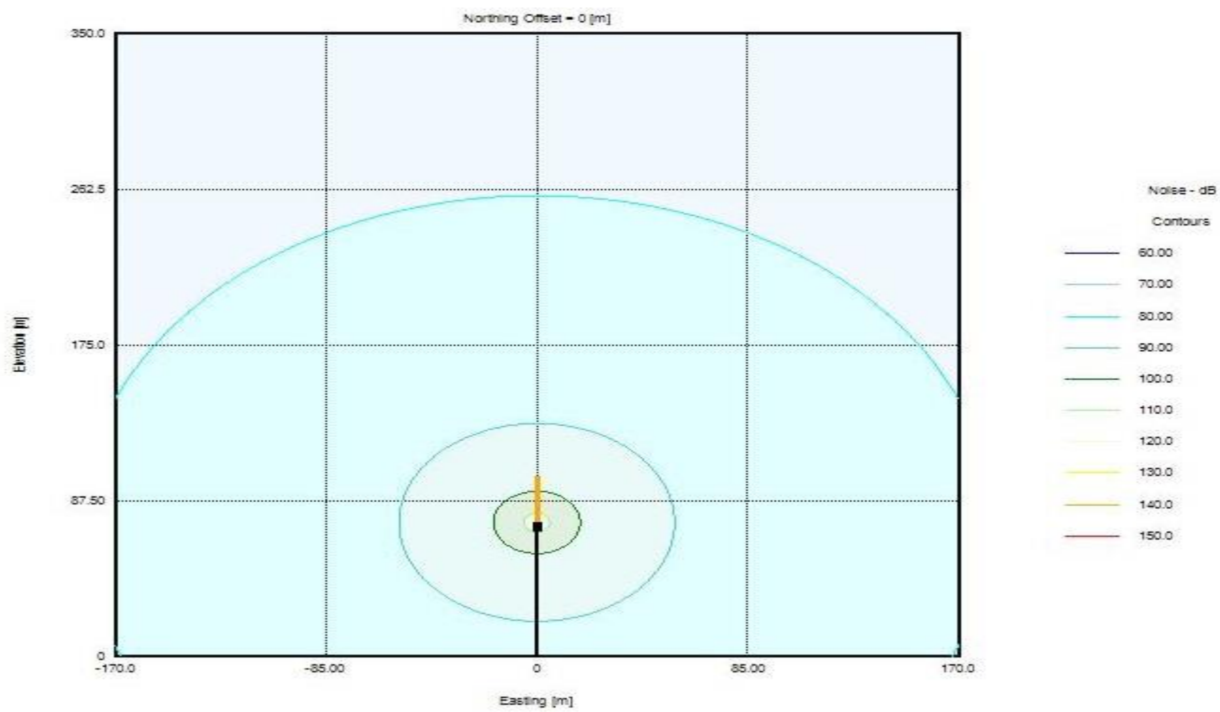
Results/Grids



Maximum Radiation

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


Northing Offset = 0 [m]
350.0
262.5
175.0
87.50
0
-170.0
-85.00
0
85.00
170.0
Easting [m]
Elevation [m]
Temperature - C
Contours
25.00
50.00
75.00
100.0
125.0
150.0
175.0
200.0
225.0
250.0


Northing Offset = 0 [m]
350.0
262.5
175.0
87.50
0
-170.0
-85.00
0
85.00
170.0
Easting [m]
Elevation [m]
Noise - dB
Contours
60.00
70.00
80.00
90.00
100.0
110.0
120.0
130.0
140.0
150.0

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	C	360.0
Flame Results		
Heat Release	kW	1.767E+06
Flame Length	m	87.64
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	0.001734	0.001722

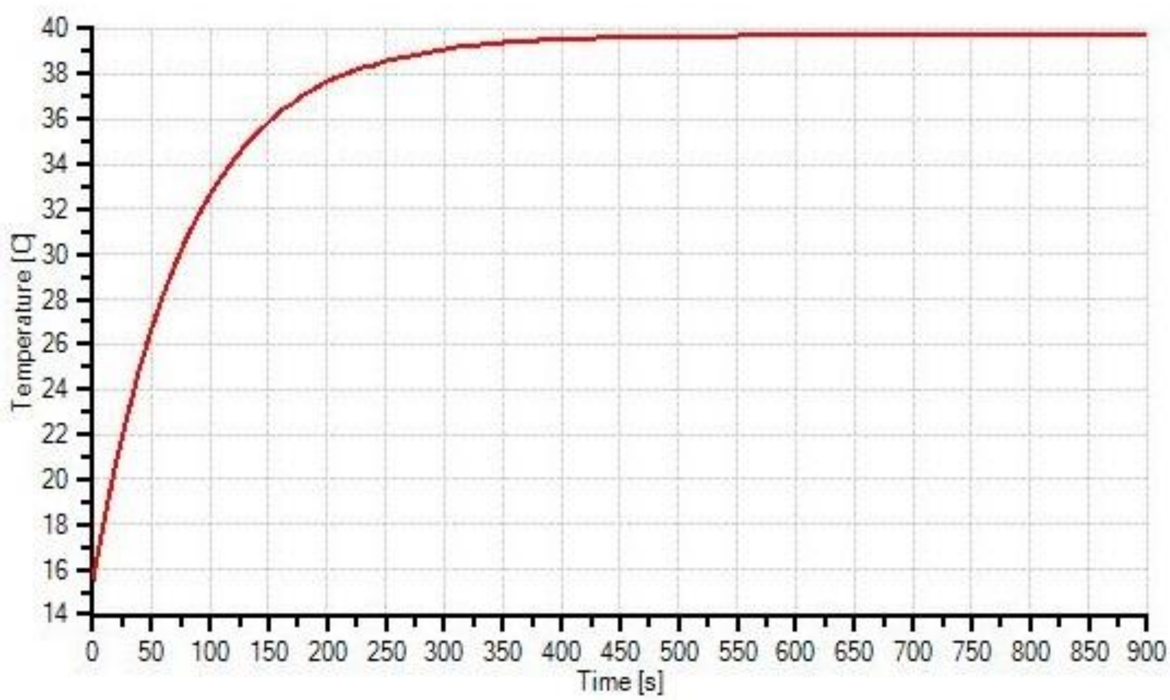
Flaresim API

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	C	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

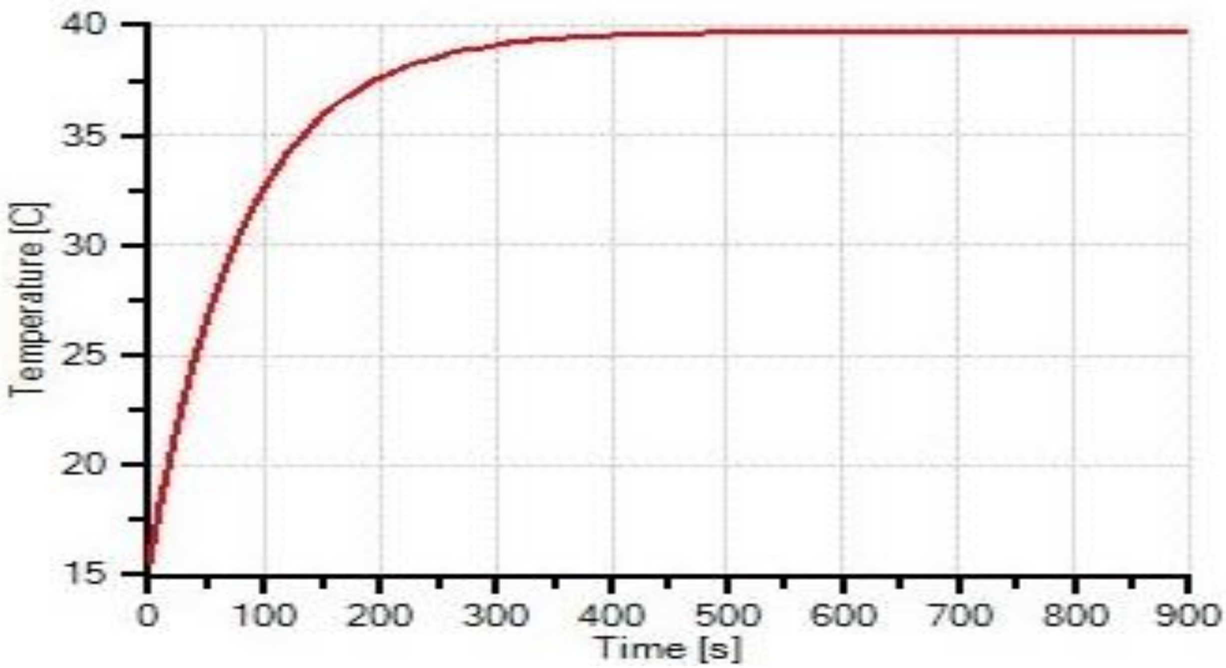
Point Result Comparison

Frequency Hz	Noise dB	NoiseA 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 Hz	Noise dB	NoiseA 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



Maximum Radiation

Max Radiation Input		
Initial Grid Points		11
Sizing Constraint	kW/m2	
Calculate Max Radiation		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	kW/m2	
Calculate Max Radiation		Yes
Max Radiation Results		
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.
3. 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.

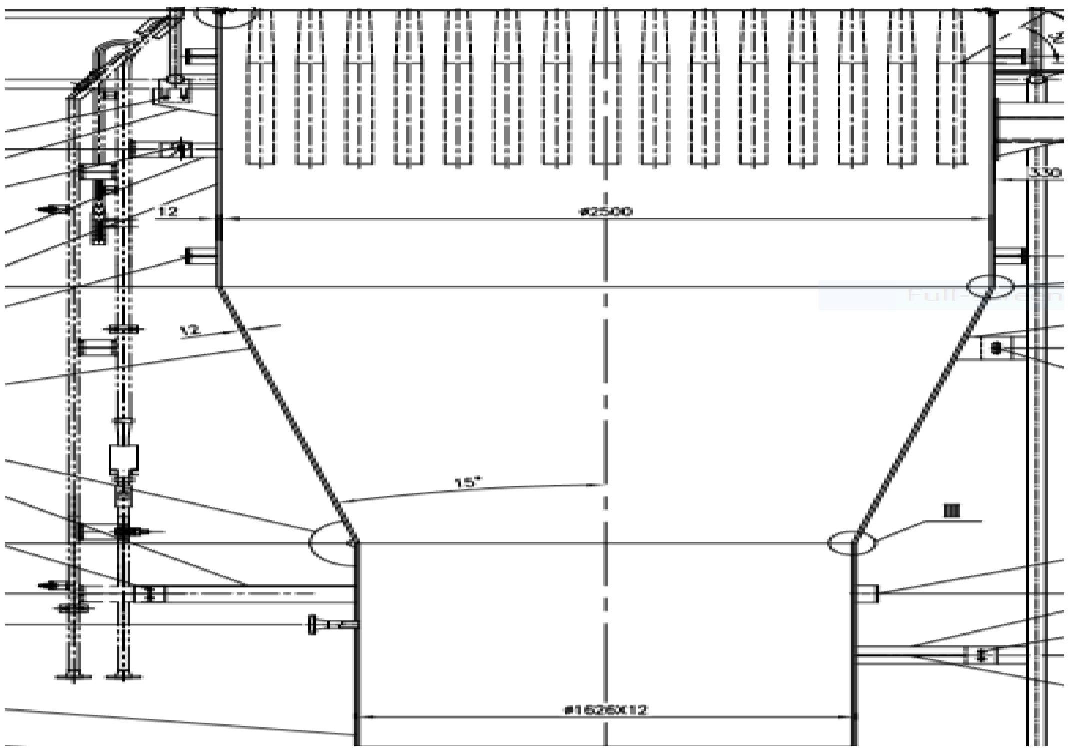
Steam is often injected into the relief gas discharge at the top of a flare burner. Typically, a steam ring that has a number of injection nozzles or slots is employed. The design and location of injector nozzles varies as different flare manufacturers each have their own proprietary design.

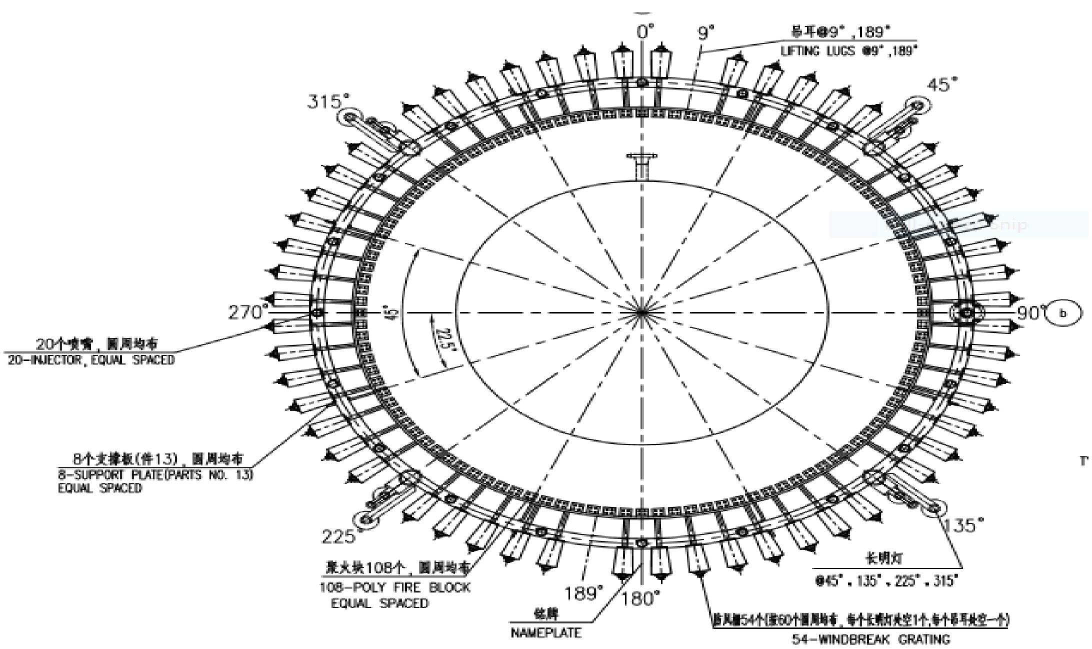
The upper steam injection functions to inspirate air and to force the air mixture into the relief gas discharging from the flare burner. The steam-injection pattern is intended to enhance fuel-air mixing and can add to the momentum of the relief gas discharge. The steam and air acts to dilute the hydrocarbon 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.

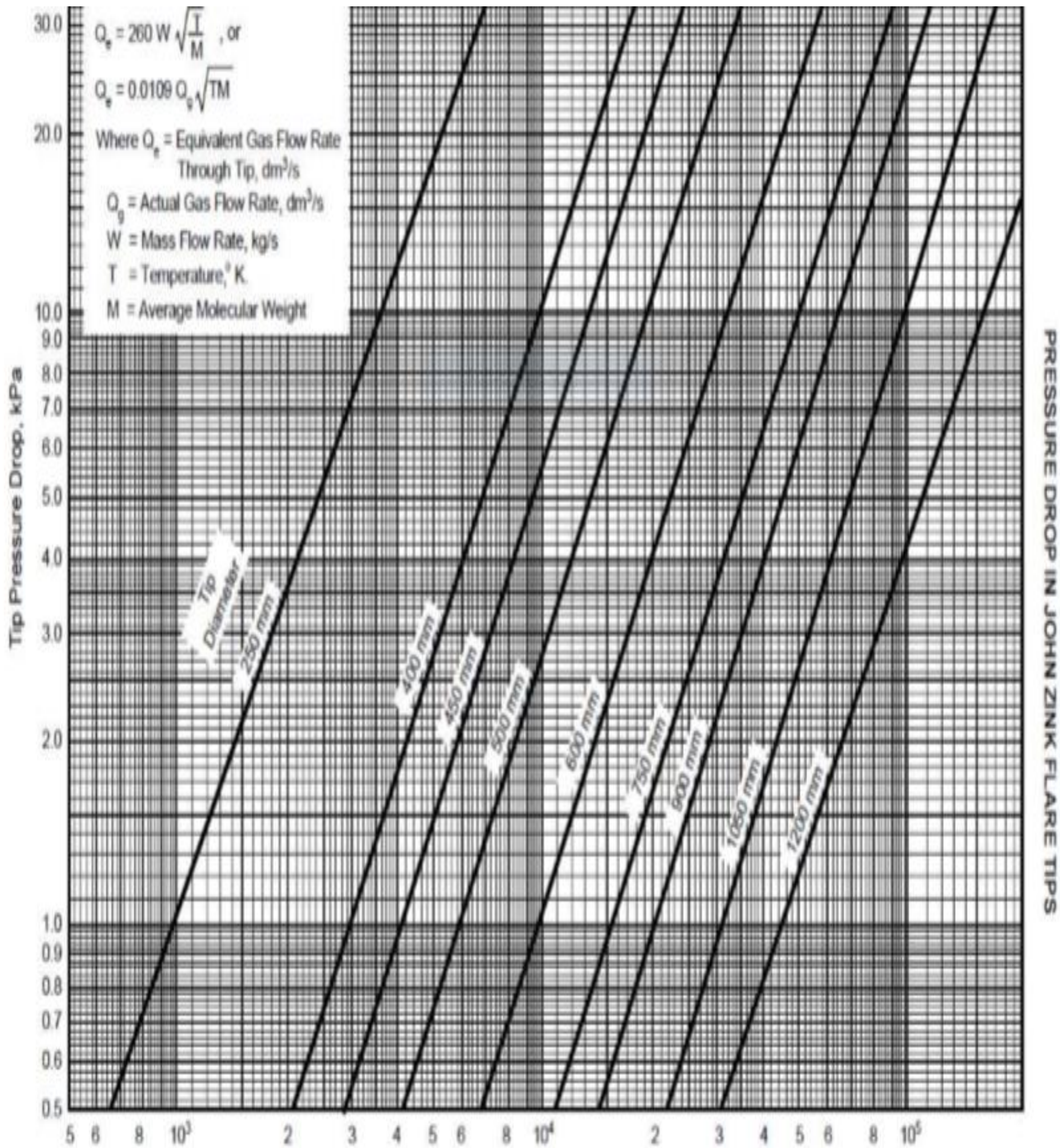
The effective addition of steam from an upper steam ring increases the turbulence of combustion. The overall noise level of the flare burner increases due to both the additional combustion noise and jet noise from the steam nozzles. Steam-assisted, smokeless flares can have significantly increased overall 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.


12
ø2500
330
12
15°
III
ø1626X12


0°
9°
吊耳@9°,189°
LIFTING LUGS @9°,189°
45°
315°
270°
90°
b
20个喷嘴，圆周均布
20-INJECTOR, EQUAL SPACED
45°
22.5°
8个支撑板(件13)，圆周均布
8-SUPPORT PLATE(PARTS NO. 13)
EQUAL SPACED
225°
135°
长明灯
@45°, 135°, 225°, 315°
聚火块108个，圆周均布
108-POLY FIRE BLOCK
EQUAL SPACED
189°
180°
铭牌
NAMEPLATE
54-WINDBREAK GRATING



$Q_e = 260\,W\sqrt{\frac{T}{M}}$, or
$Q_e = 0.0109\,Q_g\sqrt{TM}$
Where Q_e = Equivalent Gas Flow Rate Through Tip, dm³/s
Q_g = Actual Gas Flow Rate, dm³/s
W = Mass Flow Rate, kg/s
T = Temperature, °K
M = Average Molecular Weight
Tip Pressure Drop, kPa
PRESSURE DROP IN JOHN ZINK FLARE TIPS
Tip Diameter
250 mm
400 mm
450 mm
500 mm
600 mm
750 mm
900 mm
1050 mm
1200 mm

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.

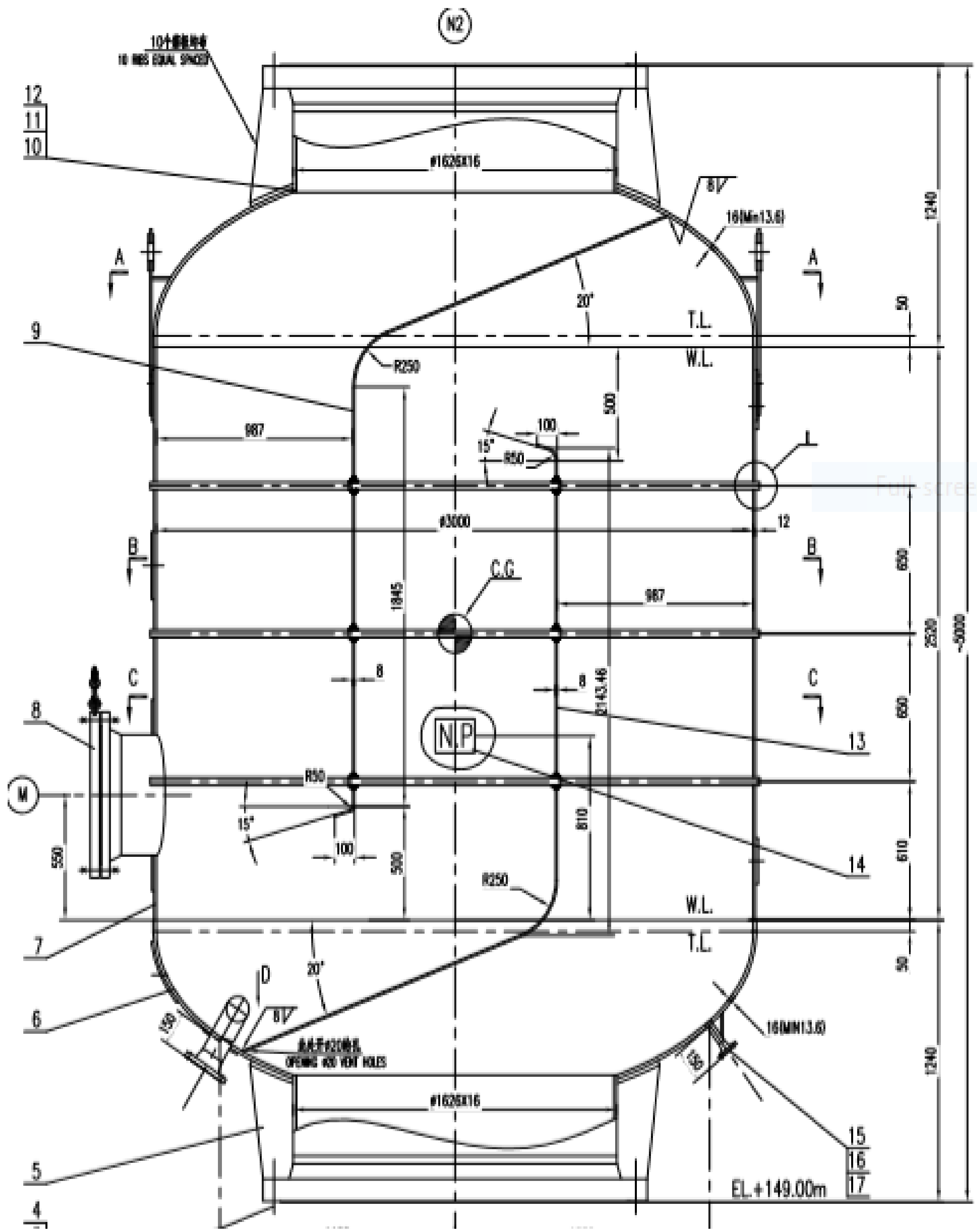
- ✓ Purge-reduction seals are not flame arrestors; that is, they will not stop a flashback. They are designed as energy-conservation devices to reduce purge-gas flows required to mitigate air infiltration into the stack.

- ✓ 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).


N2
10 RIBS EQUAL SPACED
ø1626X16
16(Min13.6)
A
20°
T.L.
W.L.
R250
987
100
15°
R50
500
L
ø3000
12
B
C.G
987
1845
8
C
2143.46
N.P
13
M
R50
810
14
550
100
500
R250
W.L.
T.L.
7
6
D
20°
OPENING ø20 VENT HOLES
ø1626X16
5
4
15
16
17
EL.+149.00m
1240
50
650
2520
~5000
650
610
610
50
1240
12
11
10
9
8