Flare Radiation Study Report

REV.	DATE	PURPOSE OF ISSUE	PREPARE	CHECK	REVIEW	APPROVE
0	17.08.2017	Final Issue	Geng Yunfei	Bai Yang	Ji Ningbo	
A	16.06.2017	Issued For Comments	Geng Yunfei	Bai Yang	Ji Ningbo	

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Flare Radiation Study

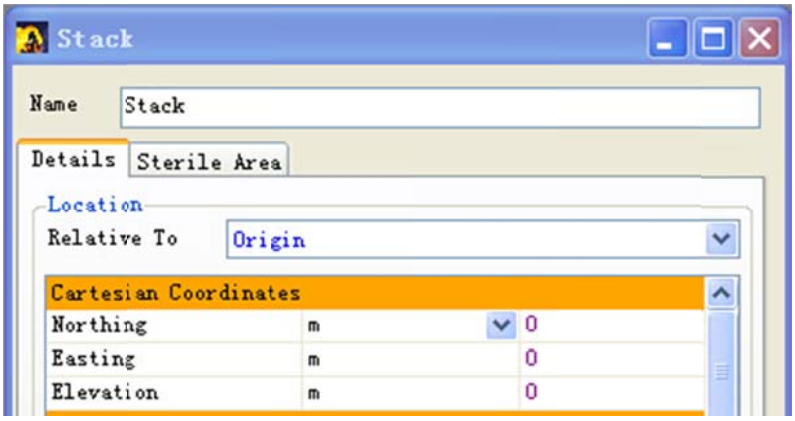
1. Case for calculation

From the "Flare header load summary" (Rev.2), the governing relieving scenario for calculation of flare radiation is a blocked outlet case for reformed gas. According to technical clarification by TCC, flare vent flow rate and temperature refer to the "summary of safety and vent valves discharging to flare". Under this case, a wind velocity of 16m/s at the elevation of flare tips blowing towards the receiver shall be used for calculations and solar radiation shall be considered.

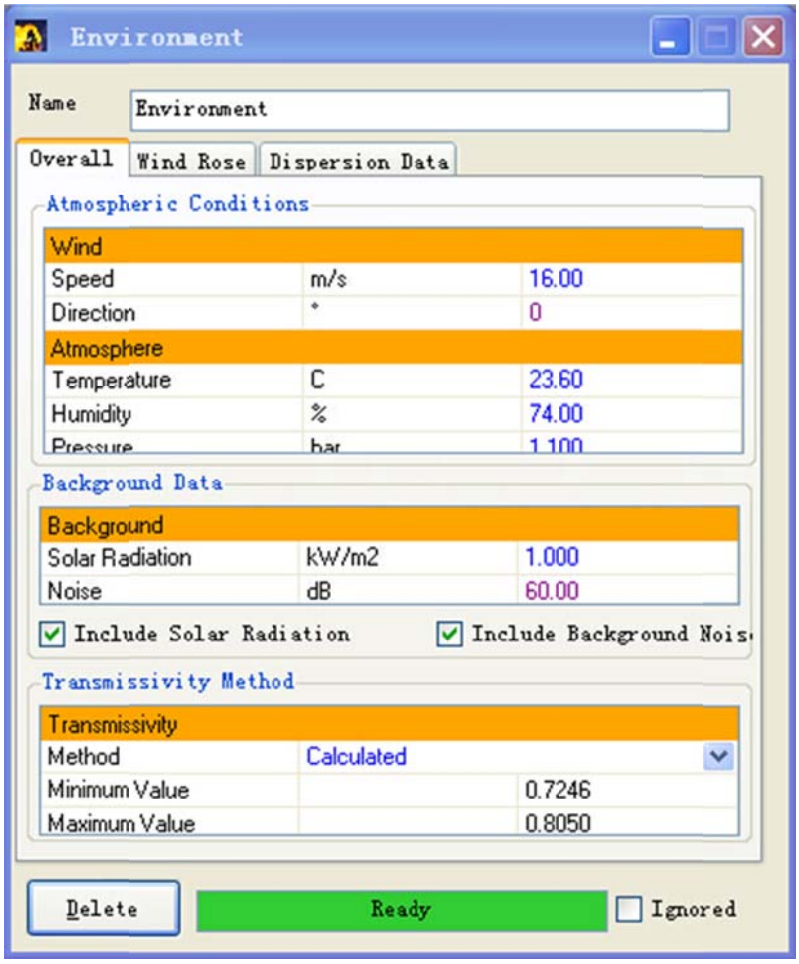
Flare Gas Datasheet for calculation

Reliving Case		Blocked Outlet Case for Reformed Gas
Composition (mol %)		Argon 0.02 Carbon Dioxide 5.17 Carbon Monoxide 15. 17 Hydrogen 48.85 Methane 0.46 Nitrogen 0.92 Water 29.42
Characteristics Molecular weight (kg/kmol) Viscosity(cP) Low heating value (kJ/Nm^3)		 13.15 0.025 7350
Flow Rate	(kg/h)	510000
	(Nm^3/h)	868745
Temperature (ºC)		360

The total flare height is fixed on 70m (ground elevation is EL+0.0m).

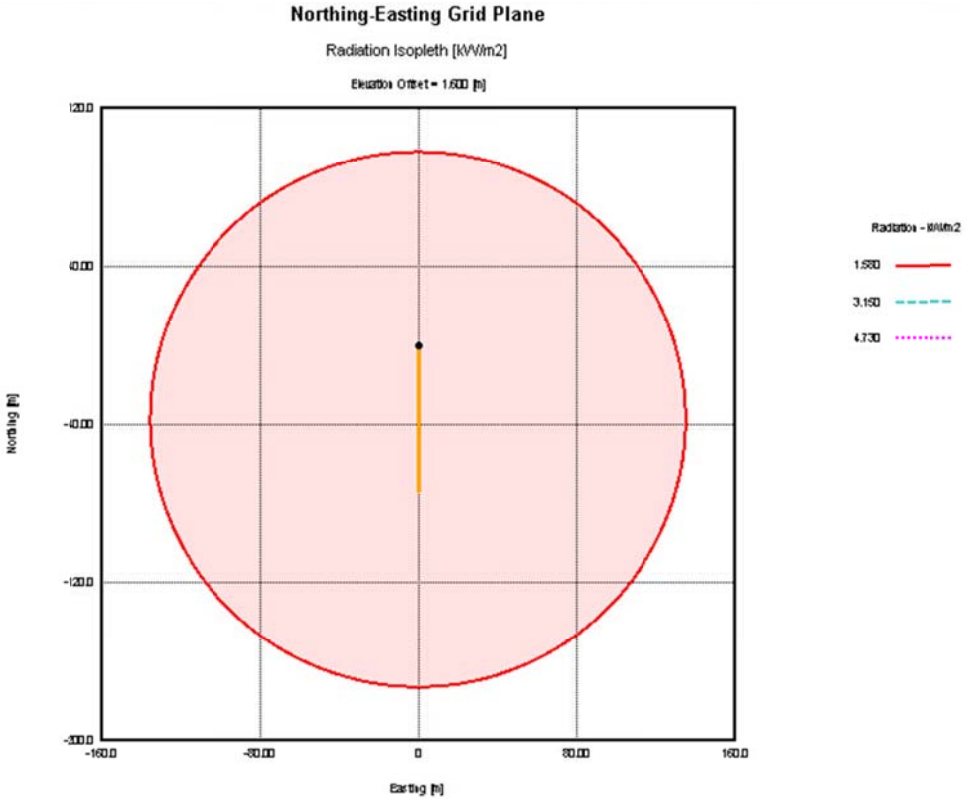


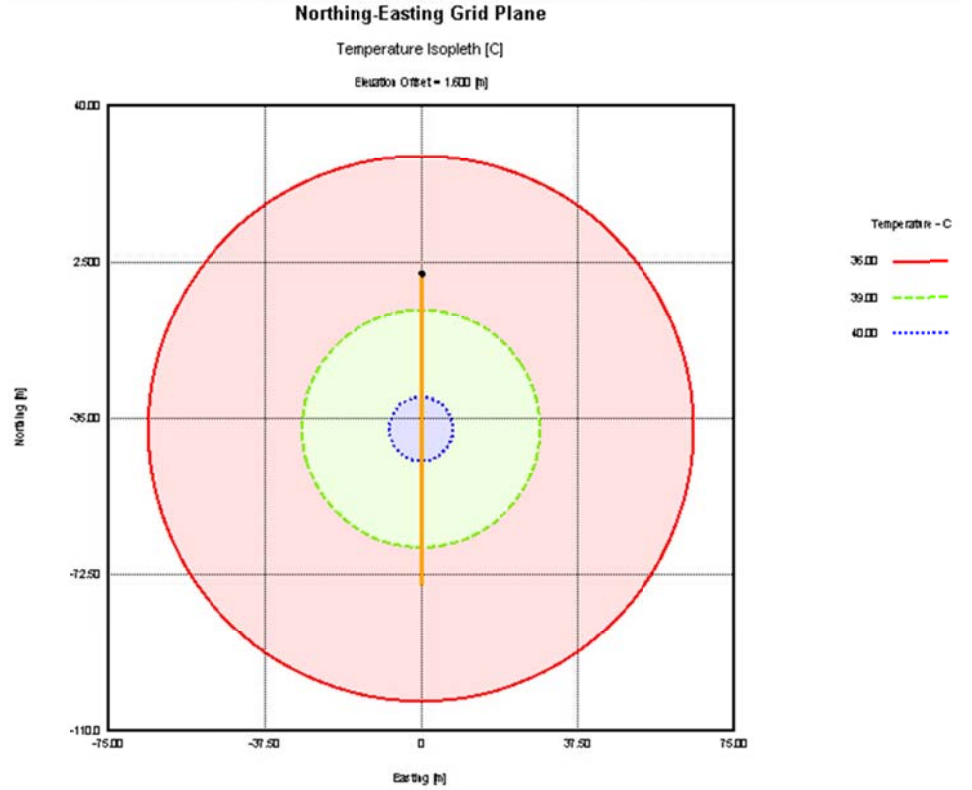
The characters of environment are shown as below:



2. Conclusions

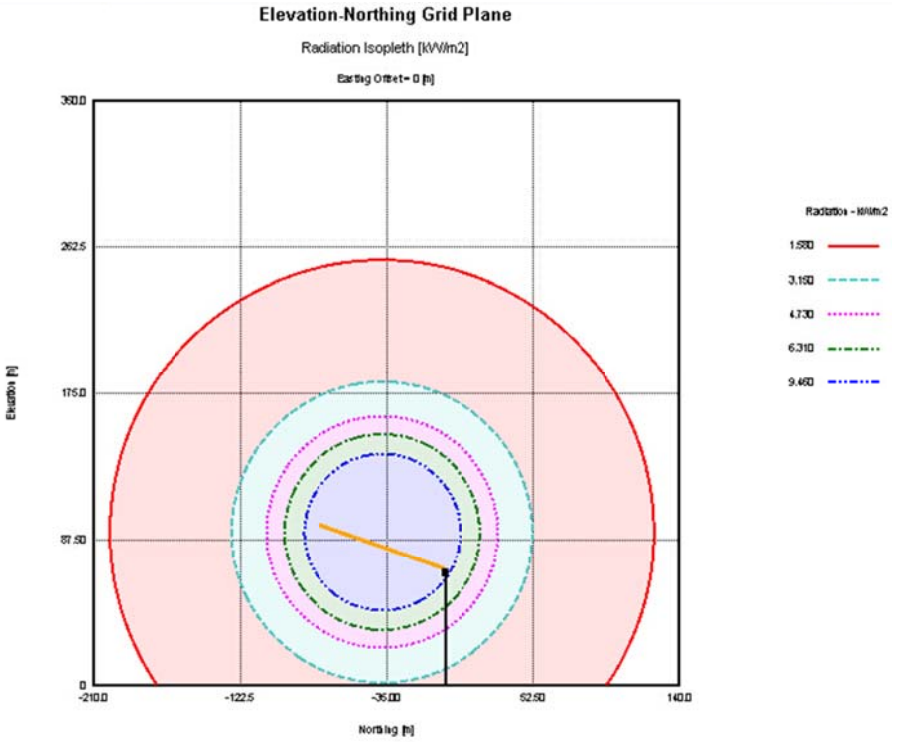
The ground radiation and temperature isopleths are shown as below:

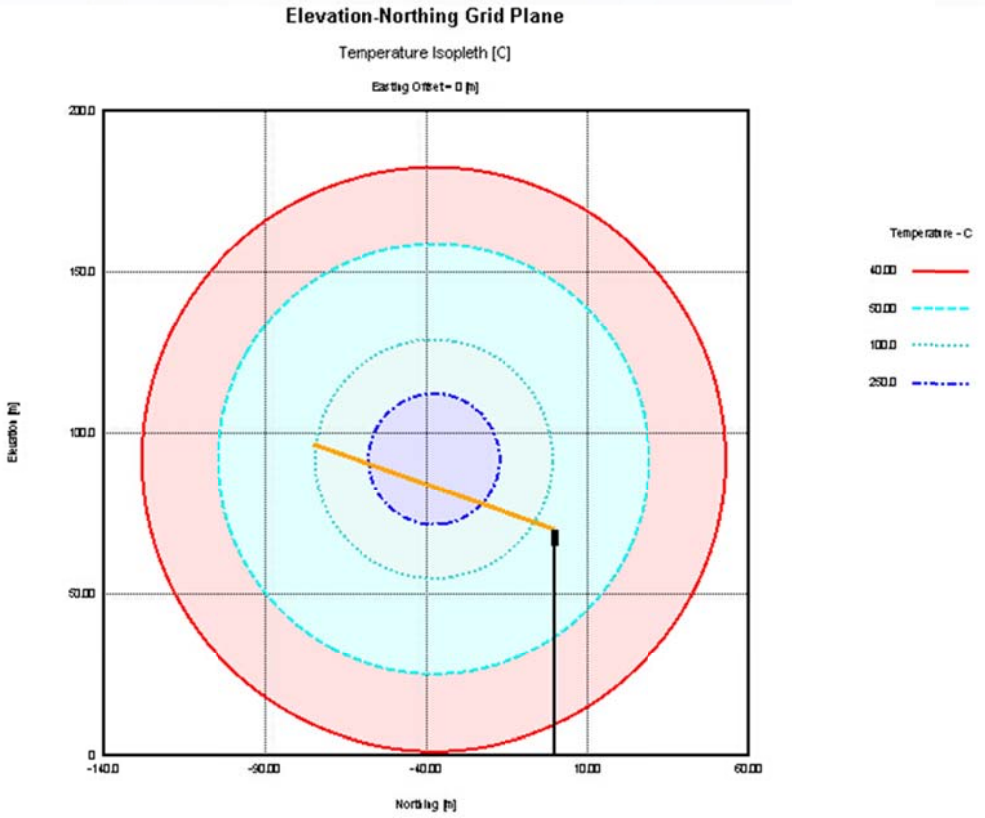




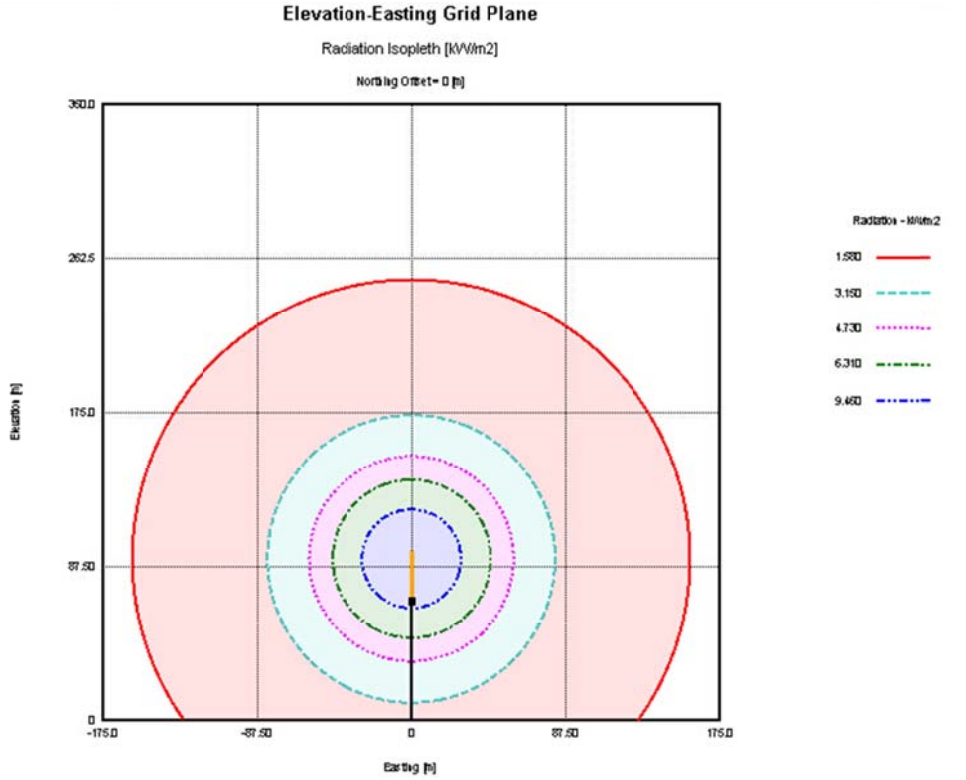
The elevation radiation and temperature isopleths are shown as below:

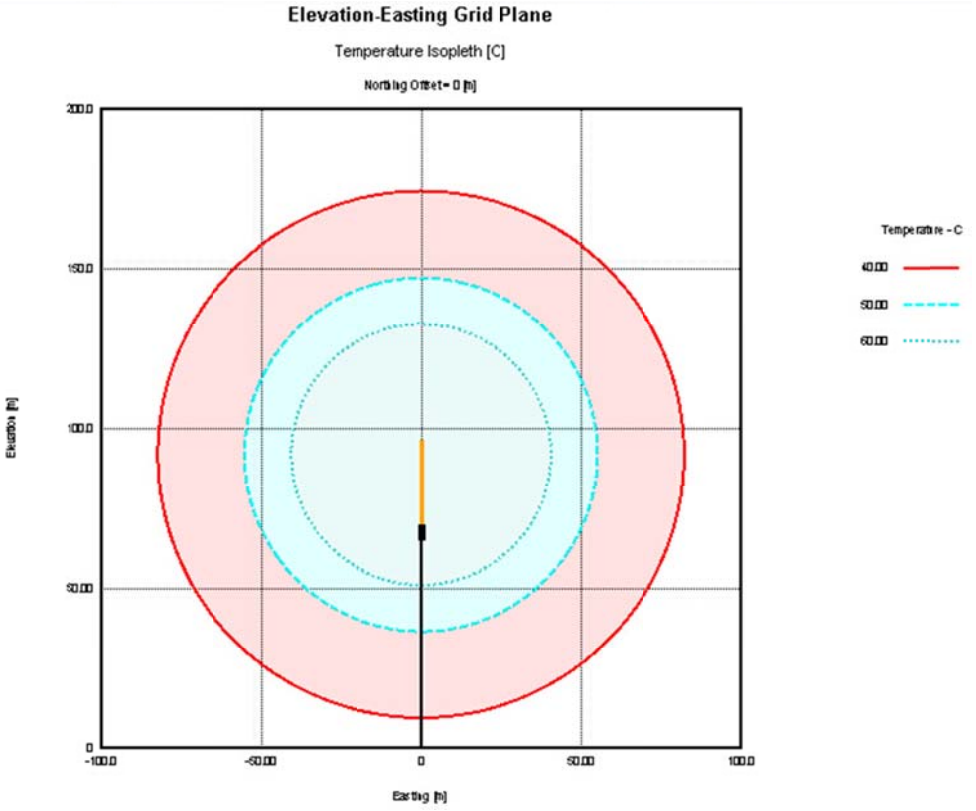
Grid Section 1: Elevation-Northing





Grid Section 2: Elevation-Easting





Based on the above results, the radius of public, continuous exposure (Radiation limit **1**.58kW/m^2) is 172 meter. The radiation value of 35m radius from flare stack is 3.054kW/m^2.The maximum radiation value on ground is 3.135kW/m^2. TCC should evaluate the radiation effect on equipment according to the results.

Recommended design thermal radiation for personnel（API521）

Permissible design level *K* kW/m^2 (Btu/h·ft^2)	Conditions
9,46（3 000）	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), then 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 6,31 kW/m^2 (2000 Btu/h·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 [a] can be continuously exposed
[a] Appropriate clothing consists of hard hat, long-sleeved shirts with cuffs buttoned, work gloves, long-legged pants and work shoes. Appropriate clothing minimizes direct skin exposure to thermal radiation.	

Attachment: Flare Calculation Report

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Job		
Run by		
Problem		
DataFile	D:\Flaresim\MKP Methanol Project_Blocked Outlet Case.fsw	
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Calculation Options

General

Method	Brzustowski	Nbr Flame Elem.	1	Calculation mode	Sizing
Element Position	50	Active Environment	Environment	Noise Method	Spectrum
Liquid Buoyancy	0.030 m/s	Pipe Buoyancy	3.048 m/s	Sonic Buoyancy	4.572 m/s

Options

Expert Mode	Ignored	Windchill	Active	Noise Attenuation	Active
Jet Dispersion	Ignored	Gaussian Dispersion	Ignored		
Run Dynamics	False	Run Case Studies	False		

Heat Transfer Coef. in W/m2/K

HTC = 1.25 * WindSpeed^ 1.00 + 4.54 Wind speed below 4.572 m/s
HTC = 3.18 * WindSpeed^ 0.75 + 0.00 For higher wind speeds

Temperature Rise Calculations

Exposure Time	900.0 s
Nbr of Steps	90

Emission Data

NOX Basis	Mass/Heat Release	CO Basis	Mass/Heat Release	HC Basis	Mass/Heat Release
NOX Rate	0.02923 kg/GJ	CO Rate	0.15900 kg/GJ	HC Rate	0.06016 kg/GJ

Fitting Data

Fitting Tip		Fitting Point	<All Active>
Fitting Result	-----	Fitting Error	-----

Sizing Information

Stack to be sized	None	Minimum Length	1.00 m	Maximum Length	200.00 m
Sizing Wind Direction	-----	Sizing Wind Speed	-----	Calculated Size	-----

Pressure Profile

Pressure Tolerance	0.000 bar	Tip Elements	4	Riser Elements	40

Dispersion Data

Jet Disp. Averaging	Short	Jet Disp. Stop Conc.	0.00001 mole/mole

Environmental data

Environment: Environment - Active

Atmosphere

Pressure	1.100 bar	Temperature	23.6 C	Humidity	74.00 %
Wind Speed	16.000 m/s	Wind Direction	0.00 °		

Background

BackGround Noise	60.0 dB	Solar Radiation	1.000 kW/m2
Inc. Background Noise	Active	Inc. Solar Radiation	Active

Transmissivity

Method	Calculated	Min Value	0.725	Max Value	0.805

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Wind Rose Calculations

Wind Speed Array	Ignored	Wind Speed vs Direction	Ignored

Dispersion Data

Stability Class	PasquillD	Terrain Class	Rural	Surface Roughness	0.20 m
Wind Reference Height	10.00 m	Correct Wind Speed	False		

Stack Configuration Data

Stack: Stack - Active

Input Data

Base point name	Stack (Base)	Base refers to	Origin		
Base - Northing	0.00 m	Base - Easting	0.00 m	Base - Elevation	0.00 m
Base - Angle from North	0.00 °	Base - Angle to Horizontal	0.00 °	Base - Radius	0.00 m
Stack					
Rotation from North	0.00 °	Angle to Horizontal	90.00 °	Stack Length	65.00 m

Sterile Area

Elevation	0.00 m	Noise Basis	NoiseA	Run SA Calcs	False

Fluid Data

Fluid: Stream No.2200

Input Data

Thermo Method	Flaresim	Use Temp Corr.	False
Use RK ZFactor	True		

LHV	12474.18 kJ/kg	Tc	-28.5 C	LEL	7.40 %
Fluid Temperature	360.0 C	Pc	81.152 bar	Saturation	100.00 %
Molecular Weight	13.137	Cp/Cv	1.373	Ref. Pressure	1.100 bar

Composition in mole fraction

Methane	0.004600	Nitrogen	0.009200	Water	0.294200
Hydrogen	0.488500	Carbon dioxide	0.051700	Carbon monoxide	0.151700
Argon	0.000100				

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Results

Flue to Feed Volume Ratio	1.009	Stoichiometric O2	0.329
Enthalpy @ 25°C	675.79 kJ/kg	Enthalpy @ Fluid Temp.	1479.32 kJ/kg

Stoichiometric Flue Gas Composition

Carbon Dioxide	0.20610 mole/mole	Water	0.78468 mole/mole	Oxygen	0.00000 mole/mole
Nitrogen	0.00912 mole/mole	Sulphur Dioxide	0.00000 mole/mole		

Tip Data

Tip: Tip - Active

Input Data

General

Located on stack	Stack	Nbr of Burners	1	Tip Type	Pipe
Seal Type	Molecular 1	Angle to Horizontal	90.00 °	Angle to North	0.00 °
Tip Length	5.00 m	Tip Diameter	2900.00 mm	Tip Opening	100.00 %

Fluids

Fluid	Stream No.2200	LP Fluid		Assist Fluid	
Fluid Mass Flow	510000.000 kg/h	LP Mass Flow	0.000 kg/h	Assist Mass Flow	0.000 kg/h

Pressure Drop

Riser Diameter	1600.00 mm	Tip Outlet Pressure	1.100 bar	Contraction Coeff.	1.000
Roughness	0.02500 mm	Exit Loss	1.000		

Flame and Radiation

F Factor Method	User Specified	User F Factor	0.170	Correct User F Factor	False
Combustion Air Ratio	1.000	Flame Temperature	1714.8 C		
Flame Length Method	Brzustowski				
Radiation Method	Global	Flame Element Count	1	Element Position	50.00 %

Noise

Noise Method	Low Noise Reference
Jet Noise Method	Flaresim

Purge Gas

Purge Gas Fluid	Nitrogen	Purge Fixed Velocity	0.060 m/s	Purge Fixed Volume Flow	0.283 m3/h
Purge HUSA O2	6.00 %	Purge HUSA Height	7.62 m		

Emission Data

NOX Basis	Mass/Heat Release	CO Basis	Mass/Heat Release	HC Basis	Mass/Heat Release
NOX Rate	0.02923 kg/GJ	CO Rate	0.15900 kg/GJ	HC Rate	0.06016 kg/GJ

Tip: Tip - Results

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General

Flame Length	85.89 m	Heat Release	1767171.0 kW	Tip End - Northing	0.00 m
API Flame Length	86.36 m	Frac.Heat Radiated	0.170	Tip End - Easting	0.00 m
Exit Temperature	360.0 C	Actual Volume Flow	1857871.567 m3/h	Tip End - Elevation	70.00 m
Assist Fluid Mass Flow	-----	Assist Fluid Flow Ratio	-----	Wind Speed At Tip	16.000 m/s

Velocities and Pressure Drop

Exit Velocity	78.132 m/s	Tip Outlet pres.	1.100 bar	Total Outlet pres.	1.108 bar
Sonic Velocity	741.838 m/s	Tip Backpres.	1.100 bar	Total Backpres.	1.109 bar
Exit Mach Number	0.105	Seal Backpres.	1.146 bar	Total Backpres.	1.154 bar
Contraction Coeff.	1.000	Stack Backpres.	1.098 bar	Total Backpres.	1.189 bar
		Tip Pressure Drop	0.000 bar	Tip Total Pressure Drop	0.000 bar
		Seal Pressure Drop	0.045 bar	Seal Total Pressure Drop	0.045 bar
		Stack Pressure Drop	-0.048 bar	Stack Total Pressure Drop	0.035 bar

Noise Results

Peak sound pressure			
Distance	30.00 m	Sound pressure	95.3 dB

Noise Spectrum Results

Frequency	Total PWL	Combustion PWL	Jet PWL
Hz	dB	dB	dB
31.3	126.7	126.7	86.9
62.5	131.7	131.7	81.2
125.0	129.7	129.7	75.3
250.0	127.7	127.7	69.3
500.0	122.7	122.7	63.3
1000.0	120.7	120.7	57.3
2000.0	115.7	115.7	51.3
4000.0	111.7	111.7	45.2
8000.0	110.7	110.7	39.2
16000.0	107.7	107.7	33.2

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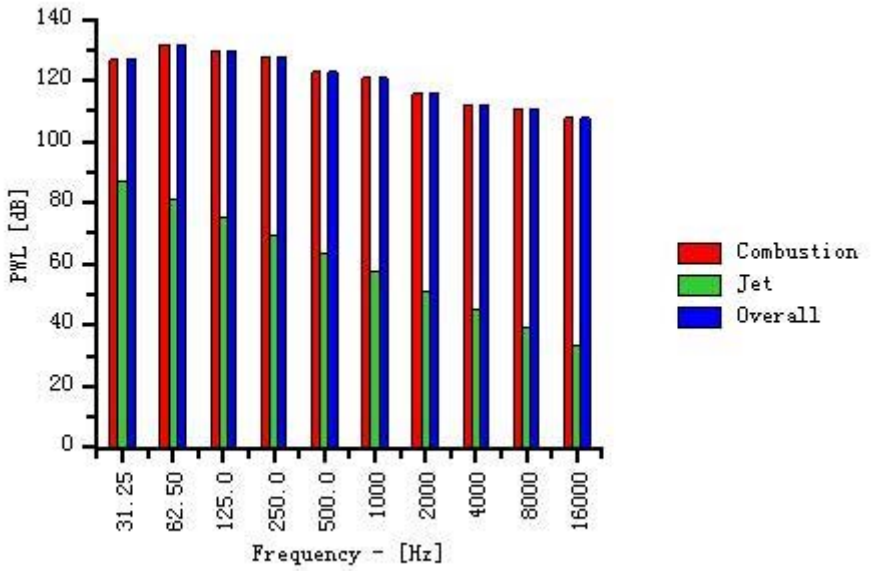
Noise Spectrum



Combustion Results General

Adiabatic Flame Temperature	1967.1 C	Calculated Flame Temperature	1714.8 C

Combustion Gas Mass Flow

Carbon dioxide	355377.577 kg/h	Water	553834.401 kg/h	Oxygen	0.000 kg/h
Nitrogen	1357212.553 kg/h	Sulphur dioxide	0.000 kg/h	Nitrogen monoxide	185.986 kg/h
Carbon monoxide	1011.509 kg/h	Methane	382.733 kg/h	Argon	155.093 kg/h

Combustion Gas Mole Flow

Carbon dioxide	2.243 kgmole/s	Water	8.540 kgmole/s	Oxygen	0.000 kgmole/s
Nitrogen	13.458 kgmole/s	Sulphur dioxide	0.000 kgmole/s	Nitrogen monoxide	0.002 kgmole/s
Carbon monoxide	0.010 kgmole/s	Methane	0.007 kgmole/s	Argon	0.001 kgmole/s

Purge Gas Results

Fixed velocity rate	542.079 kg/h	Fixed volume velocity	0.000 m/s	Fixed volume rate	0.353 kg/h
HUSA velocity	0.040 m/s	Reduced HUSA velocity	0.040 m/s	API velocity	-----
HUSA rate	357.812 kg/h	Reduced HUSA rate	357.780 kg/h	API flow	-----

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Receptor Points

Receptor Point Summary

Name	Status	Northing m	Easting m	Elevation m	Radiation kW/m2	Avg. Noise dB	Noise dB	NoiseA dB	Temp. C
Base	Active	-35.00	0.00	0.00	3.054	77.1	87.1	77.4	39.7

Receptor Point: Base - Active

Input Data

Location		**Properties**		**Sizing**	
Northing	-35.00 m	Emissivity	0.700	Max. Radiation	-----
Easting	0.00 m	Absorbtivity	0.700	Observed Radiation	-----
Elevation	0.00 m	Mass per Area	24.0 kg/m2	Max. Noise	-----
Location rel. to	Origin	Area Ratio	2.000	Max. Average Noise	-----
Angle From North	180.00 °	Mass Cp	450.000 J/kg/C	Max.A Noise	-----
Angle To Horizontal	0.00 °	Initial Temp.	15.6 C	Max.Temp.	-----
Radius	35.00 m	Orientation	None		
		Local Environment	Global		

Results

Radiation		**Temperature**		**Noise**	
Radiation	3.054 kW/m2	Temperature	39.7 C	Average Noise	77.1 dB
Concentration		**Local Wind Speed**		Noise	87.1 dB
Concentration	-----	Local Wind Speed	16.000 m/s	Noise A (*)	77.4 dB

Noise Spectrum Results

Frequency	Noise	Noise A (*)
31.3 Hz	77.9 dB	38.5 dB
62.5 Hz	82.9 dB	56.7 dB
125.0 Hz	80.9 dB	64.8 dB
250.0 Hz	78.9 dB	70.3 dB
500.0 Hz	74.0 dB	70.8 dB
1000.0 Hz	72.1 dB	72.1 dB
2000.0 Hz	67.4 dB	68.6 dB
4000.0 Hz	63.8 dB	64.8 dB
8000.0 Hz	62.2 dB	61.1 dB
16000.0 Hz	60.3 dB	53.7 dB

(*) Noise A = Noise weighted for human ear sensitivity

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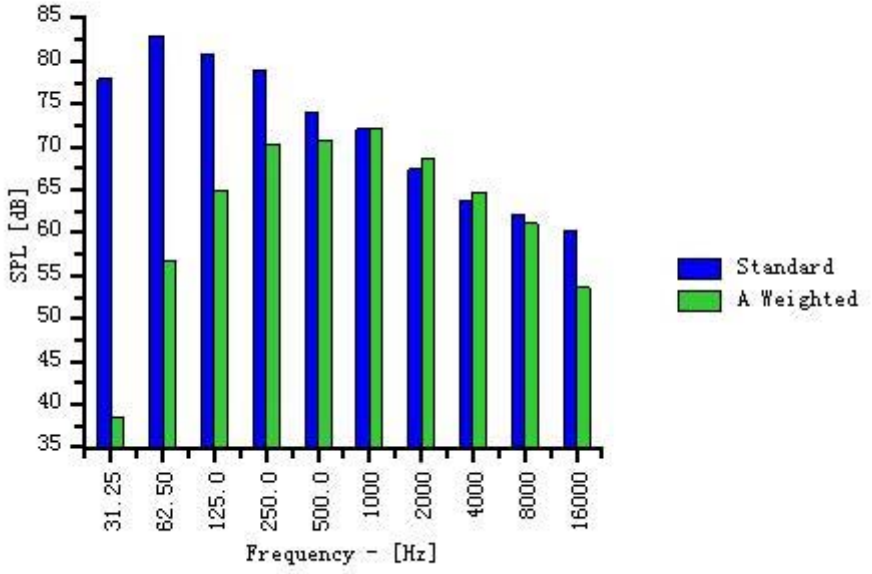
Noise Chart



Time Dependent Curves

Time s	Temp. C	TDU (kW/m2)4/3.s	Time s	Temp. C	TDU (kW/m2)4/3.s
0.0	15.6	0.0	10.0	18.3	44.3
20.0	20.8	88.6	30.0	23.0	132.9
40.0	24.9	177.3	50.0	26.7	221.6
60.0	28.2	265.9	70.0	29.5	310.2
80.0	30.7	354.5	90.0	31.7	398.8
100.0	32.7	443.1	110.0	33.5	487.5
120.0	34.2	531.8	130.0	34.8	576.1
140.0	35.4	620.4	150.0	35.9	664.7
160.0	36.3	709.0	170.0	36.7	753.3
180.0	37.1	797.7	190.0	37.4	842.0
200.0	37.6	886.3	210.0	37.9	930.6
220.0	38.1	974.9	230.0	38.3	1019.2
240.0	38.4	1063.5	250.0	38.6	1107.9
260.0	38.7	1152.2	270.0	38.8	1196.5
280.0	38.9	1240.8	290.0	39.0	1285.1
300.0	39.1	1329.4	310.0	39.2	1373.7
320.0	39.2	1418.1	330.0	39.3	1462.4
340.0	39.3	1506.7	350.0	39.4	1551.0
360.0	39.4	1595.3	370.0	39.4	1639.6
380.0	39.5	1683.9	390.0	39.5	1728.3
400.0	39.5	1772.6	410.0	39.5	1816.9
420.0	39.5	1861.2	430.0	39.6	1905.5
440.0	39.6	1949.8	450.0	39.6	1994.1
460.0	39.6	2038.4	470.0	39.6	2082.8

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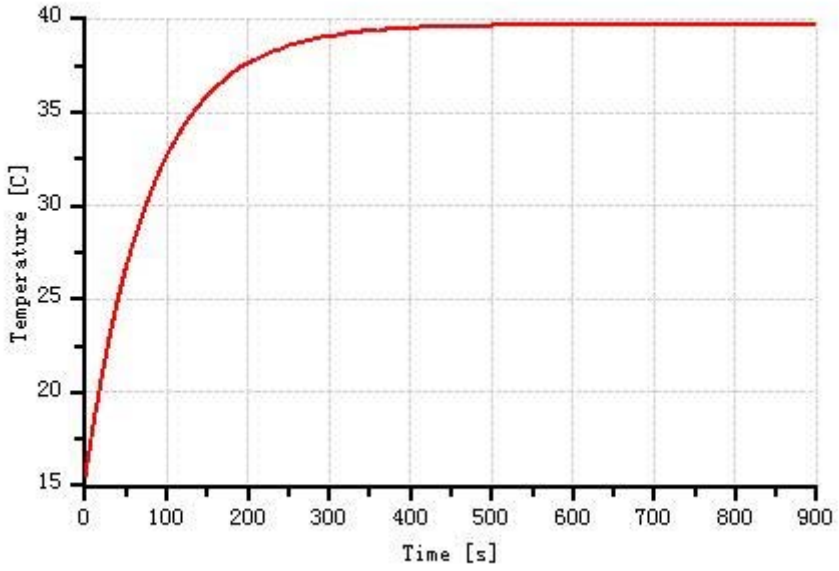
Time s	Temp. C	TDU (kW/m2)4/3.s	Time s	Temp. C	TDU (kW/m2)4/3.s
480.0	39.6	2127.1	490.0	39.6	2171.4
500.0	39.6	2215.7	510.0	39.6	2260.0
520.0	39.6	2304.3	530.0	39.6	2348.6
540.0	39.6	2393.0	550.0	39.6	2437.3
560.0	39.7	2481.6	570.0	39.7	2525.9
580.0	39.7	2570.2	590.0	39.7	2614.5
600.0	39.7	2658.8	610.0	39.7	2703.2
620.0	39.7	2747.5	630.0	39.7	2791.8
640.0	39.7	2836.1	650.0	39.7	2880.4
660.0	39.7	2924.7	670.0	39.7	2969.0
680.0	39.7	3013.4	690.0	39.7	3057.7
700.0	39.7	3102.0	710.0	39.7	3146.3
720.0	39.7	3190.6	730.0	39.7	3234.9
740.0	39.7	3279.2	750.0	39.7	3323.6
760.0	39.7	3367.9	770.0	39.7	3412.2
780.0	39.7	3456.5	790.0	39.7	3500.8
800.0	39.7	3545.1	810.0	39.7	3589.4
820.0	39.7	3633.8	830.0	39.7	3678.1
840.0	39.7	3722.4	850.0	39.7	3766.7
860.0	39.7	3811.0	870.0	39.7	3855.3
880.0	39.7	3899.6	890.0	39.7	3944.0
900.0	39.7	3988.3			

Temperature Chart



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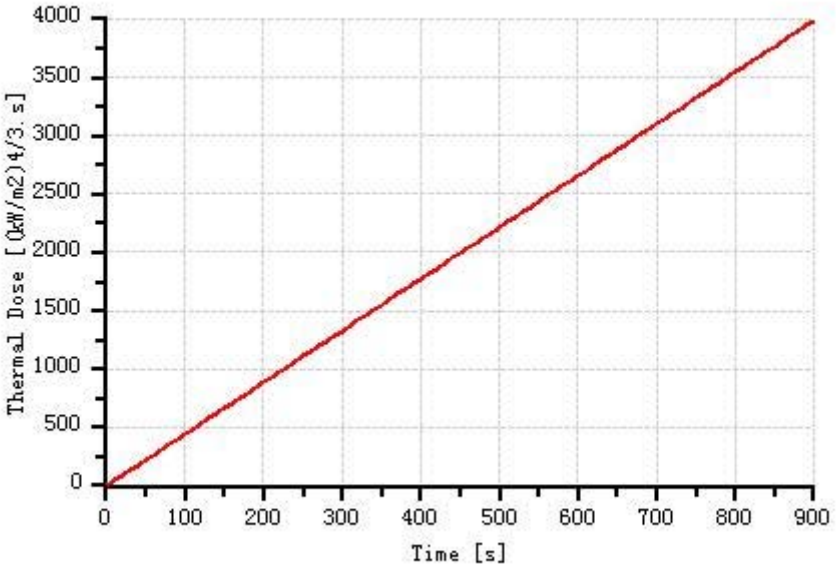
TDU Chart



Receptor Grids

Receptor Grid: Northing-Easting Grid Plane - Active

Input Data

Location		**Properties**		**Noise**	
Orientation	Northing-Easting	Emissivity	0.700	Noise Basis	Noise
Offset	1.60 m	Point Absorbtivity	0.700		
Axis 1	Northing	Area Ratio	2.000		
Axis 2	Easting	Point Orientation	None		

Axis information

Northing	Minimum	-200.00 m	Maximum	120.00 m	Nbr. of Points	100
Easting	Minimum	-160.00 m	Maximum	160.00 m	Nbr. of Points	100

Results

Maximum Radiation

Sizing Limit	-----	Find Max. Rad.	True	Initial Grid Points	100
Radiation	3.135 kW/m2	Northing	-37.56 m	Easting	0.00 m

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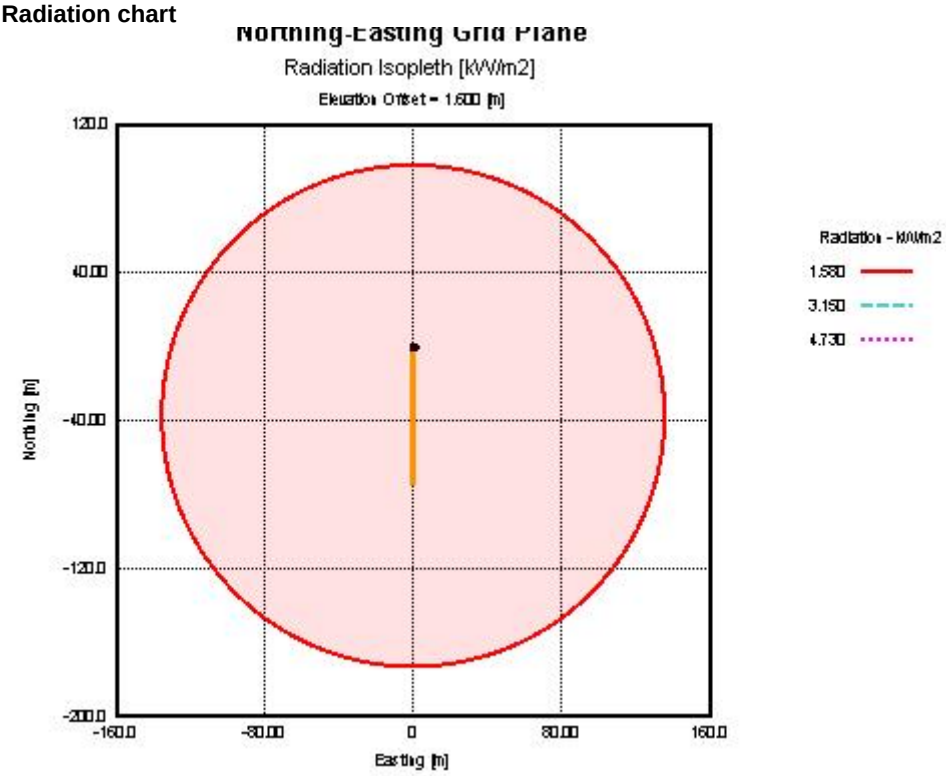
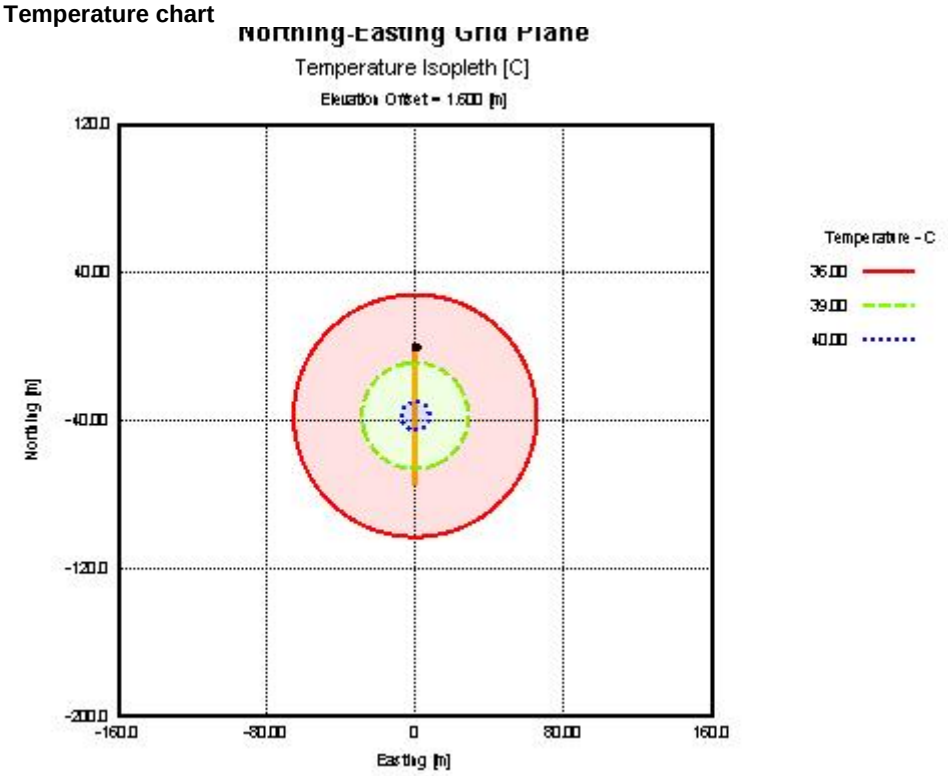
Radiation chart



Temperature chart



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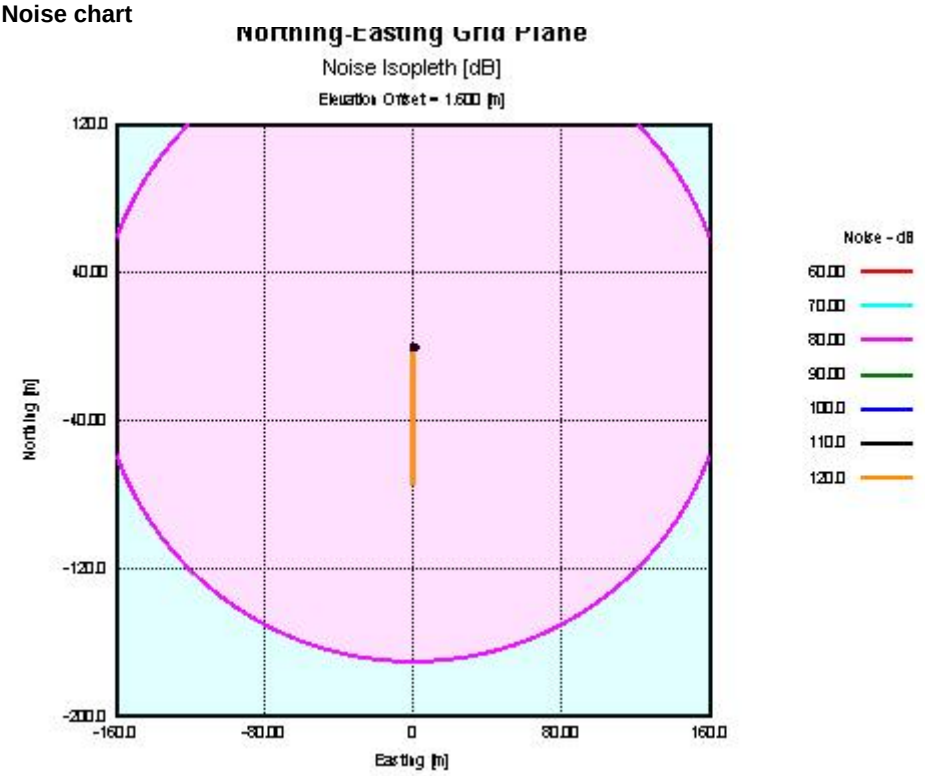
Noise chart



Receptor Grid: Elevation-Northing Grid Plane - Active

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Input Data

Location		**Properties**		**Noise**	
Orientation	Elevation-Northing	Emissivity	0.700	Noise Basis	Noise
Offset	0.00 m	Point Absorbtivity	0.700		
Axis 1	Elevation	Area Ratio	2.000		
Axis 2	Northing	Point Orientation	None		

Axis information

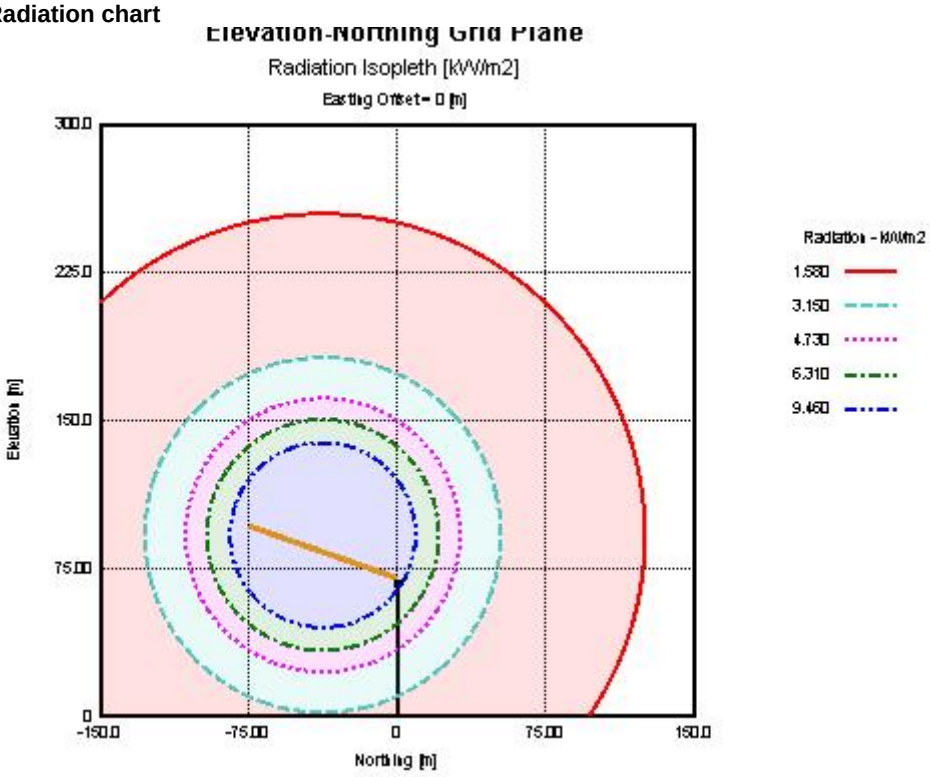
Elevation	Minimum	0.00 m	Maximum	300.00 m	Nbr. of Points	100
Northing	Minimum	-150.00 m	Maximum	150.00 m	Nbr. of Points	100

Results

Maximum Radiation

Sizing Limit	-----	Find Max. Rad.	True	Initial Grid Points	100
Radiation	3292611252.095 kW/m2	Elevation	91.83 m	Northing	-37.56 m

Radiation chart



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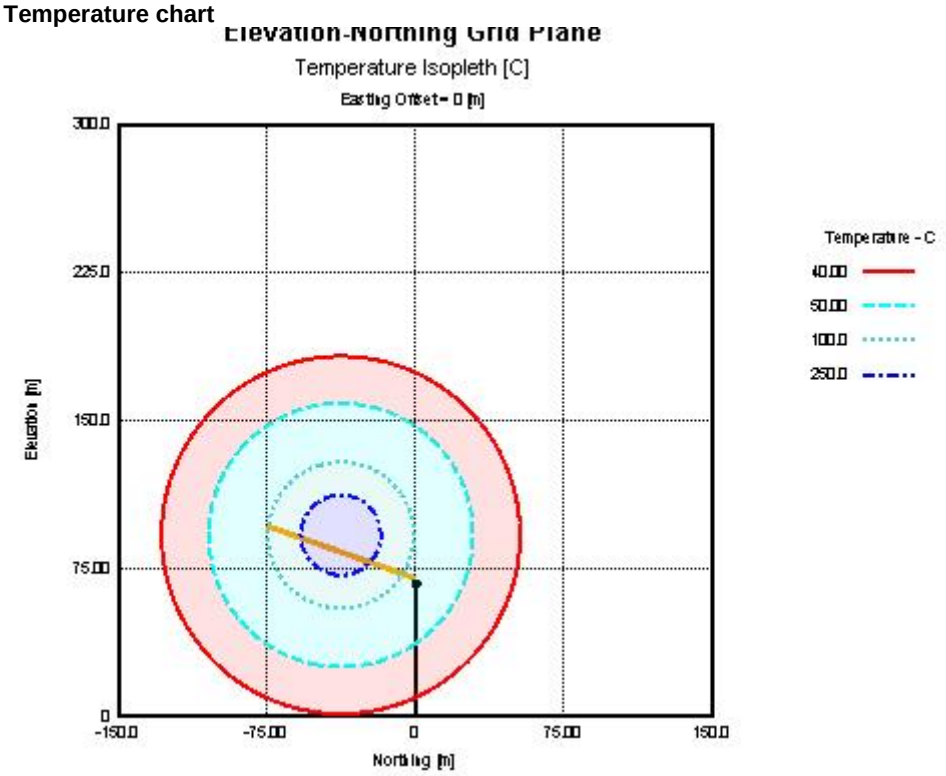
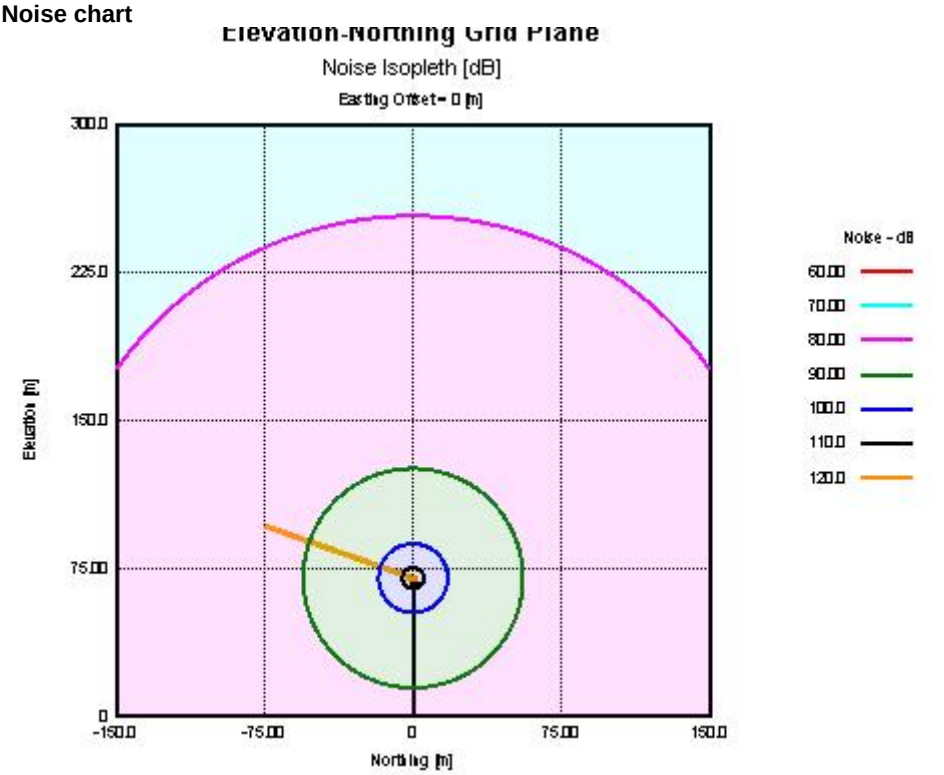
Temperature chart



Noise chart



Receptor Grid: Elevation-Easting Grid Plane - Active

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DataFile	D:\Flaresim\MKP Methanol Project_Blocked Outlet Case.fsw	
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Input Data

Location		**Properties**		**Noise**	
Orientation	Elevation-Easting	Emissivity	0.700	Noise Basis	Noise
Offset	0.00 m	Point Absorbtivity	0.700		
Axis 1	Elevation	Area Ratio	2.000		
Axis 2	Easting	Point Orientation	None		

Axis information

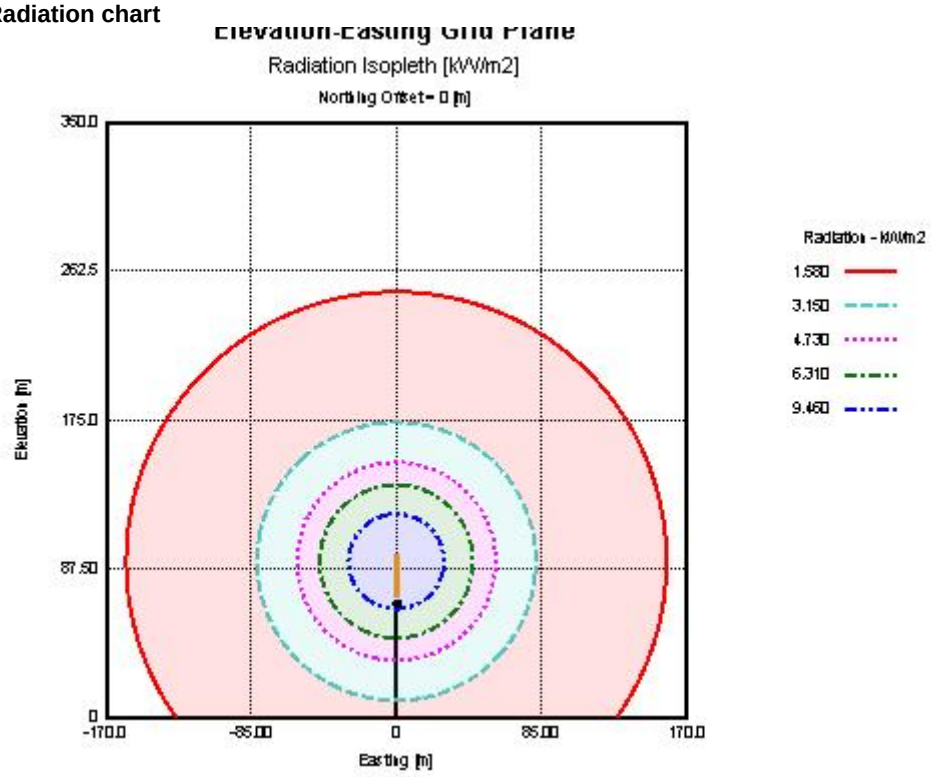
Elevation	Minimum	0.00 m	Maximum	350.00 m	Nbr. of Points	100
Easting	Minimum	-170.00 m	Maximum	170.00 m	Nbr. of Points	100

Results

Maximum Radiation

Sizing Limit	-----	Find Max. Rad.	True	Initial Grid Points	100
Radiation	14.391 kW/m2	Elevation	91.84 m	Easting	0.00 m

Radiation chart



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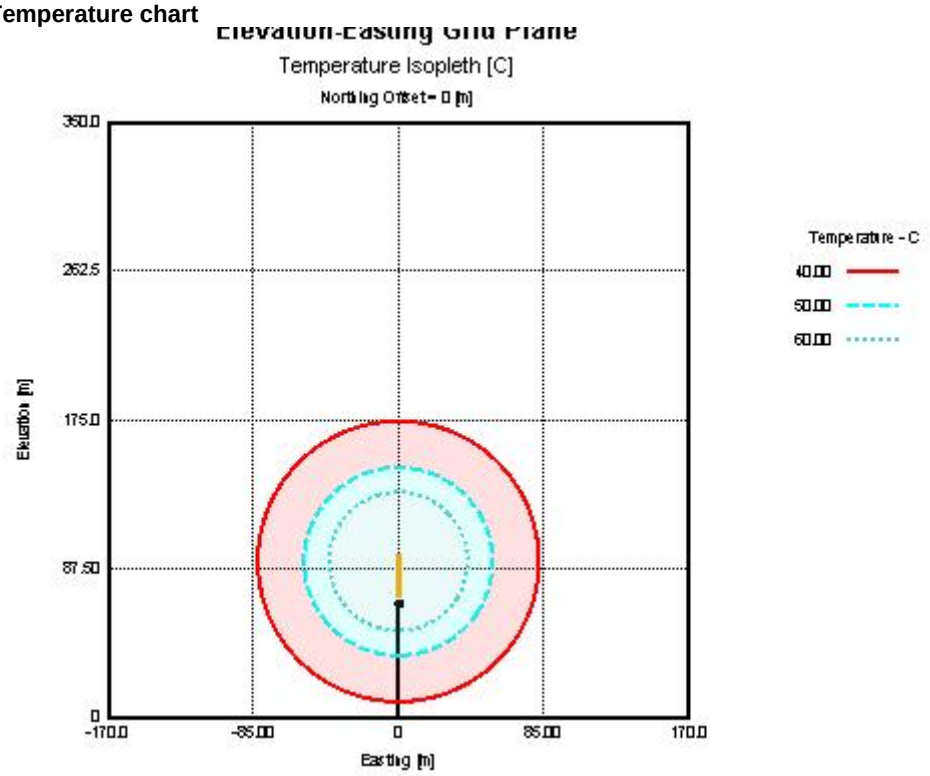
Temperature chart



Noise chart