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Thermal Radiation and Noise Safety Assessment of an Offshore Platform Vent Pipe

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Abstract: The purpose of the offshore platform vent pipe is to release the excess associated gas produced by the oilfield production process in a safe place. Based on the characteristics of the vent pipe of offshore oil platform and the potential hazards of the vent pipe to some working points on the platform caused by sudden emergency discharge, this paper focuses on the analysis of the thermal radiation and noise of each working point on the offshore platform, the thermal radiation and noise of the calculation point were simulated by Flaresim 6.0. The evaluation method is based on the guidelines for pressure relief and decompression systems recommended by the American Petroleum Institute (API RP 521). The simulation results of Flaresim software show that the thermal radiation and noise values of the main working points on the offshore platform meet the requirements of the limits. However, in order to avoid high temperature phenomenon on the surface of the equipment in the working area, low absorptivity coating or protective layer should be used on the surface of the equipment. When vent pipe is empty, the staff should return to the room as far as possible or must wear sound insulation earplug for protection to meet the noise safety assessment. Through the detailed analysis of thermal radiation and noise safety design of offshore platform vent pipe, this study provides an effective reference for similar vent pipe or flare system design projects in the future.

Keywords: Offshore Platform Vent Pipe, Thermal Radiation, Noise, Safety Assessment, Flaresim

1. Introduction

The vent pipe is to directly and safely discharge the gas which cannot be economically utilized, discharged from normal production and discharged in fault state into the atmosphere. However, direct emission to the atmosphere is conditional, and it is allowed by laws and regulations. If one of the following conditions is met, vent pipe can be selected instead of flare system. The suitable conditions for vent pipe are as follows: the venting only occurs under accident conditions, the venting gas is lighter than air, the concentration of harmful components in the venting gas meets the safety requirements, and the risk of accidental ignition is controllable [1, 2]. Vent pipe emergency assessment method is based on the pressure-relieving and de-pressuring systems guidelines (API RP 521 [3]) recommended United States Petroleum Association. Using Flaresim Ver. 6.0 calculates the thermal radiation and noise values of vent pipe. As the sudden emergency relief takes place, thermal radiation and noise safety assessment of an offshore platform vent pipe is necessary. The thermal radiation and the noise are released when the vent pipe discharges. According to the platform general layout, a few key points are selected. As long as the point of thermal radiation and noise value is lower than the allowed values, all other positions on the platform of the thermal radiation and noise will also be lower than the allowed value. So personnel on the platform are safety.

2. Calculating Model

2.1. Cold Vent Diffusion Simulation and Analysis

2.1.1. Structural Model

The dimension of the upper deck is 52m×33m×0.9m. The physical model is shown in Figure 1. The deck of the offshore platform is composed of steel plates, and the support of the platform is also welded by steel. The density of steel is 7.85 g/cm^3.

2.1.2. Model Meshes Division

The model calculation space is divided by tetrahedron whose length of side is 0.4 m, and the total grids are about 581,953 grid cells. The dimension of the calculation regions is 150m×150m×150m. The origin coordinate locates in the center of the upper deck bottom and the coordinate of the vent pipe inlet is (x,y,z)=(-25.3, -16.01, 13.05).

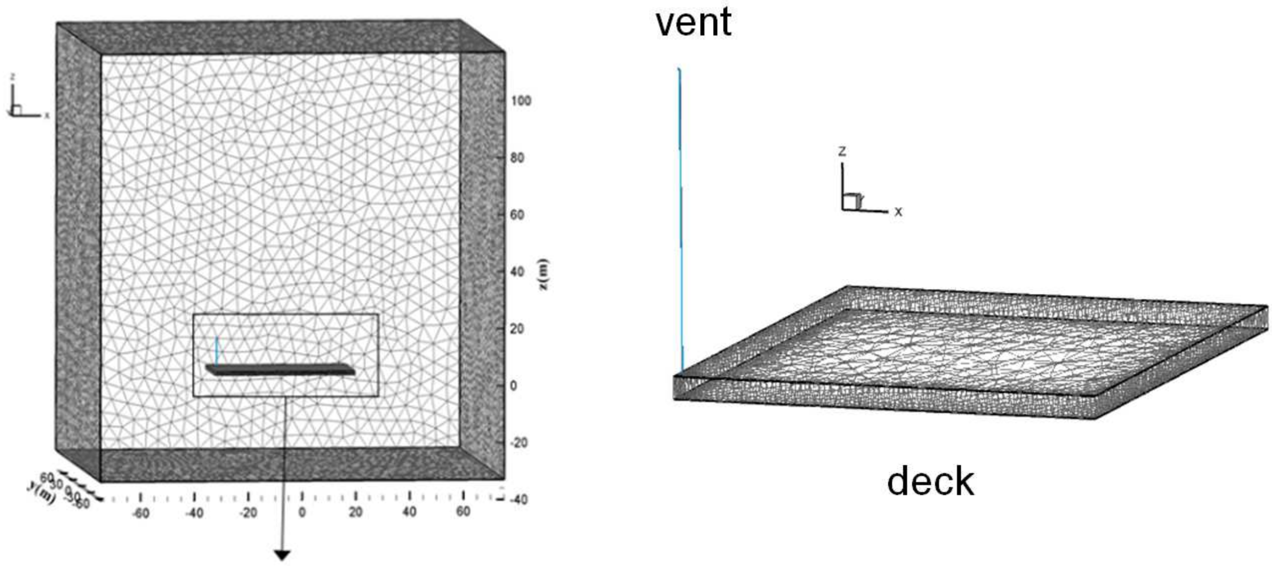

Figure 1. *The model calculation space is divided by tetrahedron.*

Calculation Model:

a. The flow model is k-epsilon turbulent model.
b. The diffusion model is species transport model.
c. The effect of gravity is considered.

According to API RP 521, vent pipe calculation includes thermal radiation, surface temperature and noise models. Permissible design levels for personnel are showed in table 1.

Solar thermal radiation intensity is 0.4~1.04 KW/m^2. Thermal radiation intensity is 4.73 KW/m^2 as the emergency relief takes place. The solar thermal radiation intensity of south sea is 0.4~0.8 KW/m^2. Choose 0.7 KW/m^2 as solar Radiation value.

2.2. Surface Temperature [4-8]

The equilibrium surface temperature of metal surfaces exposed to the thermal radiation is calculated from a heat balance between the thermal radiation from the flame incident at the specified point and the heat losses from the same point. Equation (1) may be used for the surface temperature.

$$\alpha K = (h_c + h_f) \cdot (T_m - T_\infty) \quad (1)$$

where:

K is thermal radiation at receptor, (W/m^2); α is metal surface absorbtivity, α=0.7;

Table 1. *Recommended design thermal radiation for personnel [1].*

Permissible design level K (KW/m^2)	Conditions
1.58	Maximum radiant heat intensity at any location where personnel with appropriate clothing*can be continuously exposed
4.73	Maximum radiant heat intensity in areas where emergency actions lasting 2 to 3 min can be required by personnel without shielding but with appropriate clothing *.
6.31	Maximum radiant heat intensity in areas where emergency actions lasting up to 30s can be required by personnel without shielding but with appropriate clothing*.
9.46	Maximum radiant heat intensity at any location where urgent emergency action the personnel is required reach to. When personnel enter or work in an area with the potential radiant heat intensity is greater than 6.31 KW/m^2, then radiation shielding and/or special protective apparel (e.g. a fire approach suit) should be considered. SAFETY PRECAUTIO---It is important to recognize that personnel with appropriate cloth*cannot tolerate thermal radiation at 6.31 KW/m^2 for more than a few seconds.

* Appropriate cloth consists of hard hat, long-sleeved shirts with cuffs, work gloves, long-legged pants and work shoes. Appropriate cloth can minimizes personnel' s body skin direct exposure to thermal radiation.

h_c is the convective heat transfer coefficient which is calculated from a series of empirical correlations that are a function of air velocity.

$$h_c = \begin{cases} 0.8 + 0.22u_\infty & 0 \le u_\infty \le 15m/s \\ 0.56u_\infty^{0.75} & u_\infty \rangle 15m/s \end{cases} \tag{2}$$

This heat balance equation assumes that heat losses by convection and radiation occur only from the surface exposed to the radiation. The overall heat loss from the point is the sum of the radiation from the point and the forced/free convection from the point. The radiative heat transfer coefficient is given by:

$$h_f = \sigma E \frac{(T_m^4 - T_\infty^4)}{(T_m - T_\infty)} \tag{3}$$

E is the metal surface emissivity, E=0.7;
σ is Stephan Boltzman constant, 5.67×10^{-8} W/m^2·K^4;
u_∞ is the wind velocity, m/s;
T_m is the metal surface temperature, K;
T_∞ is the atmospheric temperature, K;

2.3. Vent Pipe Noise [9]

Vent pipe noise is mainly composed of the combustion noise and the nozzle noise. Although the noise can be represented in average value, it was constituted by different frequencies of noise, each frequency noise contributing to the average value depends on the noise which is caused by the flare combustion noise in a duct or which is caused by the noise of Sonic flare nozzle. The noise spectrum is usually caused by 63 Hz~8000 Hz, usually indicated by a sound power level and sound pressure level:

$$PWL = 10\log\left(\frac{W}{W_0}\right) \tag{4}$$

$$SPL = 10\log\left(\frac{P}{P_0}\right)^2 \tag{5}$$

where:
PWL is sound power level, dB; SPL is sound pressure level, dB; W_0 is the reference value, $W_0=10^{-12}$ W;
P_0 is the reference value, $P_0=2\times10^{-6}$ Pa;
When the flare device is positioned in the surrounding empty environment, sound pressure level and sound power levels of noise are as follows:

$$SPL = PWL - 20\log D - 0.49 - SPL_A \tag{6}$$

where:
D is the minimum distance from the flare midpoint to receptor, m;
SPL_A is the attenuation of the sound pressure level of noise in the atmosphere, dB. The attenuation is a function of the noise frequency, with higher frequencies being more readily attenuated than lower ones.
PWL is associated with the noise of the vent pipe nozzle. SPL is associated with the combustion noise.

3. Calculation Parameter

The above-mentioned models are calculated by using Flaresim 6.0 software. Calculated parameters include platform environment and vent pipe data, vent gas compositions data and the location of the assessment point information. Platform environment and vent pipe data are showed in table 2. Vent gas compositions data are showed in table 3. The data in table 2 and table 3 come from the site of the designed platform, the venting amount and the composition of venting gas. Location of the assessment point information is showed in table 4.

Calculation conditions include: SSW wind direction is always towards the check point; Max wind speed is 38 m/s. The higher the wind speed, the more conducive to the diffusion of emissions, and the smaller the impact on each point on the platform. But when the wind speed is lower, it is not good for gas diffusion, the radiation to each calculation point is higher. Tables 5 and 6 calculated parameters: the ambient temperature is 35.4°C, Humidity is 97%, Solar Radiation is 0.700 kW/m^2, Back Ground Noise is 50.0 dB.

Table 2. *Environment and VENT PIPE data.*

Air average temperature	22.9°C
Vent gas temperature	62°C
Maximal vent gas flow rate	4.85×10^4 Sm^3/d
Height of vent pipe	12 m
Diameter of vent pipe	3" (76.2 mm)
Humidity (%)	81
Low wind speed	1 m/s
Maximal wind speed	38 m/s
The most dangerous direction of wind	SSW
Maximum ambient temperature	35.4°C

Table 3. *Vent Gas Compositions Tata.*

Compositions	Chem. formula	Mole fraction
Nitrogen	N_2	0.0145
Carbon-dioxide	CO_2	0.0388
Water-vapor	H_2O	0.0034
Methane	CH_4	0.8639
Ethane	C_2H_6	0.0388
Propane	C_3H_8	0.0295
i-Butane	C_4H_{10}	0.0033
n-Butane	C_4H_{10}	0.0061
i-Pentane	C_5H_{12}	0.001

Table 4. *Assessment point information.*

Assessment point	Description	Coordinate (m)		
		x	y	z
1	Vent pipe outlet	-25.3	-16.01	13.05
2	CO_2 snuffing system	8	-14.94	0.9
3	Helideck	28	0	4.2
4	Living quarter (up)	15	-14.94	-3.3
5	Material room	6.37	-14.94	0.9
6	Central air conditioning sets	22.8	-14.94	0.9
7	Foam bladder vessel	26	-14.94	0.9

4. Safety Assessment Criteria

4.1. Radiation Criteria

Radiation limit shall be as per API RP 521 recommendation. Since emergency relief is typically infrequent and short duration, meanwhile, the CO_2 snuffing system can work and the worker can escape within several seconds, so we chose 4.73 KW/m^2 as radiation level.

The radiation intensities at the assessment points with wind velocity v=1 m/s and v=38 m/s are showed in table 5 and table 6. According to calculating results, the radiation intensities meet the requirements when emergency fire condition occurs.

Table 5. *The distribution of radiation intensity in assessment point with v=1 m/s, ambient temperature =35.4°C. SSW WIND.*

Name	Northing m	Easting m	Elevation m	Radiation kW/m^2	Noise (A) dB	Final Temp. °C Emissivity=0.9 Absorptivity =0.1	Final Temp. °C Emissivity=0.7 Absorptivity=0.3	Final Temp. °C Emissivity=0.6 Absorptivity =0.1
Vent pipe outlet	-16.01	-25.3	13.05	12.896	131.9	56.5	1 100	59.93
CO_2 snuffing system	-14.94	8	0.9	0.911	89.8	41.5	55.23	42.52
Helideck	0	28	4.2	0.79	85.7	38.08	44.17	38.51
Living quarter (up)	-14.94	15	-3.3	0.841	88	38.26	44.73	38.71
Material room	-14.94	6.37	0.9	0.928	90.2	38.55	45.68	39.05
Central air conditioning sets	-14.94	22.8	0.9	0.813	86.8	38.16	44.42	38.6
Foam bladder vessel	-14.94	26	0.9	0.8	86.3	38.12	44.28	38.55

Receptor Point Summary (Solar Radiation: 0.700 kW/m^2; Back Ground Noise 50.0 dB; tip length=0.1 m).

Table 6. *The distribution of radiation intensity in assessment point with v=38 m/s, ambient temperature=35.4°C. SSW WIND.*

Name	Northing m	Easting m	Elevation m	Radiation kW/m^2	Noise (A) dB	Final Temp. °C Emissivity=0.9 Absorptivity =0.1	Final Temp. °C Emissivity=0.7 Absorptivity =0.3	Final Temp. °C Emissivity=0.6 Absorptivity =0.1
Vent pipe outlet	-16.01	-25.3	13.05	12.97	131.9	38.00	43.28	38.04
CO_2 snuffing system	-14.94	8	0.9	0.9435	89.8	36.16	37.69	36.17
Helideck	0	28	4.2	0.7998	85.7	35.72	36.37	35.73
Living quarter (up)	-14.94	15	-3.3	0.8598	88	35.74	36.45	35.75
Material room	-14.94	6.37	0.9	0.9659	90.2	35.79	36.57	35.79
Central air conditioning sets	-14.94	22.8	0.9	0.8236	86.8	35.73	36.40	35.74
Foam bladder vessel	-14.94	26	0.9	0.8093	86.3	35.72	36.38	35.73

Receptor Point Summary (Solar Radiation: 0.700 kW/m^2; Back Ground Noise 50.0 dB; tip length=0.1 m).

By analyzing table 5 and table 6, the following conclusions can be got.

1) When the vent pipe empties, the radiation at the vent pipe outlet exceeds only the limit value, another points are ok..
2) The change of ambient wind speed has little effect on the radiation of each calculation point, but has a greater impact on the final temperature of the calculation point. When ambient wind speed is 1 m/s, the air flow is small, the heat from the vent pipe is trapped around the platform, the final temperature of the calculation point is higher than ambient wind speed is 38 m/s.
3) The decrease of the absorptivity of the equipment at the calculation point can reduce the end temperature of the surface final temperature of the equipment greatly. Try to use coatings or materials with low absorption rate as thermal insulation protective layer.
4) The change of emissivity of the equipment at the calculation point has little effect on the final temperature of the equipment surface.

4.2. Noise Analysis

Noise and vibration requirements shall be limited to those noted in this specification, except that where the governing laws of the People's Republic of China are more stringent they shall apply. The follow codes and standard regulations (latest edition if existing) are part of this specification and shall be complied.

4.2.1. Industry Standards and Codes for Noise

1) API 615 Sound control of mechanical equipment for refinery service.
2) 29 CFR 1910 Occupational Safety & Health Standard.

4.2.2. Industry Standards and Codes for Vibration

1) API 670 Vibration, axial position and bearing temperature monitoring system.
2) API 678 Accelerometer-based vibration monitoring system.

4.2.3. Results and Analysis

Since emergency relief is typically infrequent and short duration, the noise might not be subject to regulation. According to “Safety Rules for Offshore Fixed Platforms”, open machinery spaces mean that the equipment is located in open spaces not enclosed around them. The noise value for such spaces shall not exceed 115 dB(A). Permissible worker noise level is showed in table 7. By calculating, the noises at the assessment points with wind velocity v=1 m/s and v=38 m/s are showed in table 5 and table 6. According to the results, wind velocity is not effect on assessment point noise. Vent pipe outlet’s noise is 131.9 dB(A), exceed 115 dB(A). So, the vent pipe outlet should be designed into a noise reducing tip.

When the vent pipe empties, the noise value of each point is more than 80 dB(A), so the influence of background noise value on the combined noise value is very small.

Other assessment point noise is below to remark value. But the outdoor noise exceeds the indoor noise request, so if people want to take rest, he will stay at room.

Table 7. *Permissible worker noise level.*

Permissible Exposure	Level dB(A)
12 hours per day	88
8 hours per day	90
Less than 8 hours per day	94 (max.)
* 45 minutes per day	100
Control room, office, and lab.	60
Service area	65
Public area	55
Communication room, bedroom, clinic etc.	45
*Only in special condition, 45 minutes per day criteria shall be applied.	

Table 8. *The radiation and noise value at the vent pipe outlet with v=1 m/s, ambient temperature=35.4°C. SSW WIND.*

the tip length (m)	Radiation kW/m^2	Noise (A) dB	Final Temp. °C
0.1	12.896	131.9	56.5
1	9.423	121.3	50.99
3	5.525	111.5	44.66
4	4.488	108.9	42.95
6	3.212	105.4	40.83
12	1.734	99.31	38.34

Solar Radiation: 0.700 kW/m^2; Back Ground Noise 50.0 dB).

4.2.4. Increase the Tip Length to Reduce the Noise and Radiation at the Vent Pipe Outlet

It can be seen from table 5 and table 6 that the noise and radiation at the vent pipe outlet exceed the limits, so the tip length of the vent pipe outlet must be adjusted. See Table 8 for the radiation and noise value at the vent pipe outlet after the tip length adjustment. Although the longer the tip length is, the lower the radiation and noise will be, the more difficult the installation and maintenance will be, and the higher the investment cost will be. Because the frequency of the vent pipe empties the largest amount is not high, the tip length is 12 m. Table 9 shows the radiation and noise values of each calculation point when the tip length is 12 m, and there is no point beyond the limit. However, the noise caused by the venting of the vent pipe is still very high, so it is suggested to install a sound barrier at the vent pipe outlet. Table 10 shows the radiation and noise values of each calculation point with NNE wind and v=2.5 m/s. Radiation values of each calculation point are lower than each calculation point with SSW wind and v=1 m/s.

Table 9. *The distribution of radiation intensity in assessment point with v=1 m/s, ambient temperature =35.4°C. SSW WIND.*

Name	Radiation kW/m^2	Noise (A) dB	Final Temp. °C Emiss.=0.9 Absor. =0.1
Vent pipe outlet	1.734	99.31	38.34
CO_2 snuffing system	0.8507	88.49	41.15
Helideck	0.7784	85.20	36.86
Living quarter (up)	0.8075	86.89	38.42
Material room	0.8594	88.77	41.79
Central air conditioning sets	0.7929	86.10	41.30
Foam bladder vessel	0.7843	85.63	41.24

Solar Radiation: 0.700 kW/m^2; Back Ground Noise 50.0 dB; tip length=12 m).

Table 10. *The distribution of radiation intensity in assessment point with v=2.5 m/s, ambient temperature =35.4°C. nne WIND.*

Name	Radiation kW/m^2	Noise (A) dB	Final Temp. °C Emiss.=0.9 Absor. =0.1
Vent pipe outlet	1.783	99.31	37.54
CO_2 snuffing system	0.8467	88.49	39.45
Helideck	0.7748	85.20	36.70
Living quarter (up)	0.8050	86.89	37.46
Material room	0.8552	88.77	39.77
Central air conditioning sets	0.7904	86.10	39.44
Foam bladder vessel	0.7821	85.63	39.40

Solar Radiation: 0.700 kW/m^2; Back Ground Noise 50.0 dB; tip length=12 m).

5. Conclusion

According Flaresim software simulation results, the thermal radiation and noise meet the requirement. In order to avoid high temperature on the surface of the equipment in the working area, the coating or protective layer with low absorptivity should be used on the surface of the equipment. When the vent pipe is empty, the personnel shall return to the room as far as possible or must wear sound insulation earplug for protection. To ensure platform security, CO_2 extinguishing system should be installed beside cold vent pipe [10-14].

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