Study on safe distance and strength check of natural gas flaring

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Abstract. In this paper, the PHAST software was used to determine the safe distance considering different factors and check strength in flare. The results show that neither in the direction of downwind or on the ground, the wind velocity and outlet pressure show little influence on distribution of thermal intensity, while the diameter of riser greatly affects the distribution of thermal intensity in the direction of downwind. The results of strength check meet the requirements of flare.

1. Introduction
Nowadays, considering the environmental pollution due to venting natural gas, the flare has got more attention[1-4]. When the natural gas is jetted into atmosphere and ignited, the combustion reaction speed will be faster and the flame temperature will be higher with enough oxygen. However, under this circumstance, affected by thermal radiation, the temperature of the upper part of the torch will rise, which will require the strength and performance of the equipment and pipeline. The throttling and decompression of the plug valve will lead to the lower temperature of the valve and the bottom of the torch, and "frosting" may occur. For another hand, the thermal radiation can harm operators. The related studies shows that the thermal intensity reaching 12.5kW/m², 25.0kW/m² and 37.5kW/m² can result in burn, major harm and even death to people respectively. Therefore, in this paper, the PHAST software was used to determine the safe distance considering different factors and check strength in flare.

2. Mathematical model of the problem
Flare of jetting natural gas is a kind of diffusive combustion. The combustion flame of natural gas and air is almost in the outer layer of jet diffusion zone, which can be regarded as a kind of surface flame. Assuming that the flame region is spherical, the heat radiation flux can be described as follows[5].

\[ Q_{\text{jet}} = \eta_j H_c Q_0 \]  

In Eq.(1), \( Q_{\text{jet}} \) is the radiant heat flux released by a gas injection during steady combustion with W; \( \eta_j \) is efficient factor and in this paper, \( \eta_j=0.35 \); \( Q_0 \) is flow of jetting natural gas with kg/s.

For a point outside the steady-state combustion zone, its thermal radiation intensity can be calculated as follows.

\[ I(x) = \frac{Q_{\text{jet}} T_{\text{jet}}}{4 \pi x^2} \]
In Eq. (2), $I(x)$ is the thermal radiation intensity at a distance of $x$ from the combustion center with W/m²; $T_{jet}$ is emissivity coefficient, and in this paper, $T_{jet}=0.2$.

Considering the complexity of modeling and its adaptability to engineering practice, the thermal radiation simulation of flare is mainly carried out by "Jet Fire" module of PHAST. There are two main flame models to choose from, the Shell model and the API model, as shown in Fig. 1. In this paper, the API model is applied to calculate the thermal radiation[6].

![Flare model calculated for numerical simulation](image)

Fig. 1 Flare model calculated for numerical simulation

3. Results and analysis

According to the field testing value, the temperature of atmosphere is 20°C, relative humidity is 0.85, the ground roughness is 0.1 m, the atmospheric stability is D degree, the height of riser is 20 m, and the volume of venting natural gas is $8 \times 10^5$ m³.

3.1 Analysis of the influence area of thermal radiation

(1) Wind velocity

Fig. 2 shows the thermal radiation range of different directions in different wind velocity while the diameter of riser outlet is 0.3 m. In the direction of downwind, the distribution of thermal intensity has no obvious differences under different conditions of wind velocity. When the thermal intensity reaches 12.5 kW/m², 25.0 kW/m² and 37.5 kW/m², the distance away from the flare torch is 88.4 m, 56.4 m and 42.6 m, which does not show a linear relationship with thermal intensity. However, the maximal thermal intensity on ground all show the exponential increase with wind velocity, even though a little. Therefore, it can be seen that neither in the direction of downwind or on the ground, the wind velocity shows little influence on distribution of thermal intensity. The effect of outlet pressure on distribution of thermal intensity presents the same law.

![Wind velocity vs. thermal intensity](image)

(1) In the direction of downwind
Fig. 2 Thermal radiation range of different directions in different wind velocity while the diameter of riser outlet is 0.3m

(2) Diameter of riser

Fig. 3 shows thermal radiation range of different directions in different diameter of riser while wind velocity is 5m/s. The distance of different thermal intensity shows a linear relationship with the diameter of riser, which shows a severe effect on the distribution of low thermal intensity, as shown by the slop of linear relationship. And the maximal thermal intensity on ground all also show the linear increase with diameter of riser, even though a little. Therefore, it can be seen that neither in the direction of downwind or on the ground, the diameter of riser shows a linear influence on distribution of thermal intensity, and more great in the direction of downwind.
Fig. 3 Thermal radiation range of different directions in different diameter of riser while wind velocity is 5 m/s

3.2 Strength check

Fig. 4 shows the model for strength check while flare, the results shown in Tab. 1. It can be seen that the range of temperature resulted by flare in pipe is 20–50°C \(^{[7]}\), which strength is shown in Fig. (1). Combined with the results in Tab. 1, at different temperatures, the SUS\(_{\text{max}}\) and EXP\(_{\text{max}}\) all lie in the positive range. This shows that the station yard, valve chamber pipe and equipment can fully adapt to the whole process of flare.

![Graph](image)

(a) Maximal thermal intensity
(b) Location of maximal thermal intensity

(2) On ground

| Temperature (°C) | SUS\(_{\text{max}}\) (MPa) | EXP\(_{\text{max}}\) (MPa) |
|------------------|--------------------------|--------------------------|
| 20               | 48.56                    | 37.32                    |
| 22               | 55.31                    | 40.92                    |
| 24               | 62.06                    | 44.69                    |
| 26               | 68.83                    | 48.51                    |
| 28               | 75.60                    | 52.36                    |
| 30               | 82.38                    | 56.24                    |
| 40               | 116.47                   | 75.82                    |
| 50               | 150.76                   | 95.59                    |

![Graph](image)

(1) Trend of yield strength
(2) Model for numerical simulation
4. Conclusions
In this paper, the conclusions and suggestions were put forward as follows.

(1) Neither in the direction of downwind or on the ground, the wind velocity shows little influence on
distribution of thermal intensity. The effect of outlet pressure on distribution of thermal intensity
presents the same law.

(2) Neither in the direction of downwind or on the ground, the diameter of riser shows a linear
influence on distribution of thermal intensity, and more great in the direction of downwind.

(3) At different temperatures, the SUS\textsubscript{max} and EXP\textsubscript{max} all meet the requirement of flare, which
means, in this paper, the station yard, valve chamber pipe and equipment can fully adapt to the whole
process of flare.

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