Study on diffusion range and safe distance of natural gas venting

Q M Lu and L Shu
Chongqing Energy College, Chongqing, 402260, China

Abstract. Due to the possible risk of flashover and explosion caused by the venting natural gas, in this paper, the PHAST software was used to determine the safe distance considering different factors. The results shows that the range of flashover is mainly depended on the venting pressure and venting, and once venting velocity within 20×10^4 m^3/h, the fire emptying is suggested. The range of flashover of natural gas in different directions were determined.

1. Introduction
At present, the emptying natural gas is mainly carried out by torch or riser, including venting and fire. Compared with the fire [1], venting is a method of discharging the high-pressure natural gas into atmosphere directly by the emptying riser. However, this method may cause fire even explosion once the concentration of natural gas is in one range encountering the fire source, the harm named as flashover and deflagration [2]. Therefore, it is necessary to describe the diffusion range and concentration distribution of venting to prevent serious accidents. In this paper, the PHAST software was used to determine the safe distance considering different factors in venting natural gas.

2. Mathematical model of the problem
In this paper, the UDM (Unified Dispersion Model) in PHAST software can be used to described continuous diffusion process of venting natural gas. Based on the assumptions of(1) All the variables are steady; (2) The ground has no entrainment of the gas; (3) The effects of gravity and buoyancy are not considered; (4) No chemical reactions of air and natural gas; (5) The wind velocity is no less than 1 m/s; (6) No barriers; the mass concentration distribution of natural gas over time can be described by the following equation [3,4]:

\[
C(x, y, z, t) = \frac{Q}{(2\pi)^{3/2}\sigma_x\sigma_y\sigma_z} e^{-\frac{(x-u)^2}{2\sigma_x^2}} e^{-\frac{(y-v)^2}{2\sigma_y^2}} \left[ e^{-\frac{(z-h-w)^2}{2\sigma_z^2}} + e^{-\frac{(z+H+h-w)^2}{2\sigma_z^2}} \right] \quad (1)
\]

In Eq.(1), \( C \) is mass concentration with kg/m^3; \( t \) is time with s; \( Q \) is flow of natural gas with kg/s; \( u, v \) and \( w \) is wind velocity in \( x, y \) and \( z \) directions with m/s, respectively; \( \sigma_x, \sigma_y \) and \( \sigma_z \) is diffusion coefficient in \( x, y \) and \( z \) directions with m/s, respectively; \( h \) is the height of riser with m; \( H \) is the height of natural gas over time with m.

3. Results and analysis
According to the field testing value, the temperature of atmosphere is 15℃, relative humidity is 0.85, the ground roughness is 0.1m, the atmospheric stability is D degree [5], the diameter of riser outlet is 0.3m while the height is 20m, and the volume of venting natural gas is 8×10^5 m^3.
3.1 Influencing factors

To our best knowledge, the concentration range of flashover of natural gas is 2.5%~5% [6], therefore, in this paper, the distance of range of flashover were obtained under different influencing factors.

(1) Venting pressure

Figure 1 shows the distance of flashover under the different conditions of venting pressure while wind velocity is 2m/s. It can be that the distance of different concentration of 2.5% and 5% are increasing as the venting pressure goes up. However, it is interesting to find that the distance of 2.5% runs faster than that of 5%, which means the range of flashover enlarges as the venting pressure increases.

(2) Wind velocity

Figure 2 shows the distance of flashover under the different conditions of wind velocity while venting pressure is 6MPa. The two curves all consists of two stages. The first of 5% is divided into the first stage of 1~4m/s and the second stage of 4~15m/s, while the second curve of 2.5% is composed by the first stage of 1~4m/s and the second stage of 4~15m/s. These two curves also behave the same characteristics that the distance increases sharply in first stage, and then slowly even keeps flat in the second stage. The distance of 2.5% runs faster than that of 5%, which means the range of flashover enlarges as the wind velocity increases.

(3) Venting velocity

Figure 3 shows the distance of flashover under the different conditions of venting velocity while wind velocity is 2m/s. The two curves all contains a flat that means the distance keeps the same in 50×10^4~100×10^4 m^3/h in curve of 2.5% and 100×10^4~150×10^4 m^3/h in curve of 5%. However, it is interesting to find that the distance of 2.5% runs faster than that of 5%, which means the range of flashover enlarges as the venting velocity increases.

It can be seen from above analysis that the range of flashover is mainly depended on the venting pressure and velocity, as well on the environmental factor such as wind velocity. The increasing venting pressure and velocity makes enlarge the range of flashover.

![Figure 1](image.png)

Figure 1 This is a figure that shows the range of flashover in venting under the different conditions of venting pressure while wind velocity is 2m/s.
Figure 2 This is a figure that shows the distance of flashover in venting under the different conditions of wind velocity while venting pressure is 6MPa.

Figure 3 This is a figure that shows the distance of flashover in venting under the different conditions of venting velocity while wind velocity is 2m/s.

3.2 Safe distance
A fire or even an explosion may occur once the released natural gas encounters the source of fire. Table 1 shows the degree of injury caused by explosion overpressure. In this section, 0.2bar was taken as minor injury, 0.5bar as serious injury and 1bar as death [7].

| Explosion overpotential (bar) | Degree of injury   |
|------------------------------|--------------------|
| 0.2–0.3                      | Minor injury       |
| 0.3–0.5                      | Mid injury         |
| 0.5–1.0                      | Major injury       |
| >1.0                         | Death              |

According to the field parameters of venting velocity, the safe distance was calculated in the range of $1.2 \times 10^4 \text{m}^3/\text{h}$~$200 \times 10^4 \text{m}^3/\text{h}$ while wind velocity is 2m/s and 10m/s respectively, as shown in Figure 4 and Figure 5.

It can be seen that there is a little influence on explosion scope of wind velocity. The explosion is no injury on people if the venting velocity is less than $20 \times 10^4 \text{m}^3/\text{h}$. Therefore, the atmospheric valve is need to control the venting velocity within $20 \times 10^4 \text{m}^3/\text{h}$, once exceeds, the fire emptying is suggested [8,9].
Figure 4 This is a figure that shows the minimal safe distance of different degree under the different conditions of venting velocity while wind velocity is 2m/s.

Figure 5 This is a figure that shows the minimal safe distance of different degree under the different conditions of venting velocity while wind velocity is 10m/s.

By the above analysis method, the range of flashover range of natural gas in different directions, consisting of upwind, downwind and height, under different venting pressures were determined when the venting volume is 8×10^5m^3, as shown in Table 2. Therefore, the other safe distance of more influencing factors can be determined.

**Table 2 Safe distance in different direction is under the different conditions of venting pressure.**

| Venting pressure | 5% (m) Upwind | 5% (m) Downwind | 5% (m) Height | 2.5% (m) Upwind | 2.5% (m) Downwind | 2.5% (m) Height |
|------------------|---------------|----------------|--------------|----------------|-----------------|--------------|
| 10Mpa            | [-8,-4]       | [15,27]        | [76,205]     | [-14,-6]       | [37,66]         | [98,325]      |
| 8Mpa             | [-7,-3.5]     | [13,23]        | [70,190]     | [-12.5,-5]     | [32,57]         | [88,290]      |
| 6Mpa             | [-6,-3]       | [11.5,18.5]    | [62,165]     | [-10,-4]       | [28,48]         | [78,255]      |
| 4Mpa             | [-2.5,-5]     | [11,15]        | [55,135]     | [-8,-4]        | [19,41]         | [68,230]      |
| 2Mpa             | [-3.5,-2]     | [5.5,11]       | [45,100]     | [-6,-2.5]      | [17.5,27.5]     | [55,160]      |
| 1Mpa             | [-2.5,-1.5]   | [4.5,7.5]      | [38,83]      | [-2,-4]        | [11,20]         | [45,120]      |

4. Conclusions
In this paper, the conclusions and suggestions were put forward as follows.

1) The range of flashover is mainly depended on the venting pressure, venting velocity and wind velocity, especially the venting pressure and velocity.

2) The explosion scope is seriously affected by venting velocity instead of wind velocity. Once venting velocity within 20×10^4m^3/h, the fire emptying is suggested.
(3) The range of flashover range of natural gas in different directions, consisting of upwind, downwind and height, under different venting pressures were determined when the venting volume is \(8 \times 10^5\) m\(^3\). Therefore, the other safe distance of more influencing factors can be determined.

References
[1] Anomohanran O, 2012 Energ. Policy 45 215-25
[2] Snow N, 2010 Oil Gas J. 10 46-57
[3] Davoudi M, Rahimpour M R and Jokar S M, 2013 J. Nat. Gas Sci. Eng. 13 12-20
[4] Kerry R and Ahmed M, 2012 Eng. Geo. 151 87-95
[5] Duo F C, Lawrence M C and Harry H R, 2004 Mar. Petrol. Geol. 213 15-22
[6] Rahimpour M R, Ghorbani A and Asiaee A, 2011 J. Nat. Gas Sci. Eng. 33 27-35
[7] Stefan B, Sergey P and Sunil V, 2012 Mar. Geo. 27 332-4
[8] Young J D and Ahn B J, 2002 J. Loss Prevent. Proc.15 179-98
[9] Ghorbani A, Jafari M and Rahimpour M R, 2012 J. Nat. Gas Sci. Eng. 65 37-45