J. Korea Saf. Manag. Sci. Vol. 22 No. 2 June 2020
http://dx.doi.org/10.12812/ksms.2020.22.2.073
ISSN 1229-6783(Print)
ISSN 2288-1484(Online)

A Study on Complementary Method for Hazardous Area Extent by IEC 60079-10-1 Edition 2.0

Jae-Young Choi* · Sang-Hoon Byeon*
*Department of Health and Safety Convergence Science, Korea University

IEC 60079-10-1 edition 2.0에 의한 방폭 설계 한계점 보완 방법에 관한 연구

최 재 영* · 변 상 훈*
*고려대학교 보건안전융합과학과

Abstract

IEC 60079-10-1 edition 2.0, the global standard for hazardous area classification, was newly revised in 2015. There are many differences compared to the previous edition 1.0 version, first released in 2008, so it has caused confusion in the industry. In case of edition 1.0, the hazardous area extent can be derived through the mathematical formula, but in case of edition 2.0, there was the problem that the exact hazardous area extent was not known because of the mathematical formula of the plot for applying the hazardous area extent was not presented. In this study, we converted the plot introduced in edition 2.0 to CAD format and derived the plot as the mathematical equations. Through this, we suggest the hazardous area extent formula of three states (heavy gas, diffusive, jet). As the IEC committee did not provide the mathematical formula of the hazardous area extent according to the release characteristic, it is impossible to apply the exact hazardous area extent. In this study, a mathematical approach was derived for the plot introduced in edition 2.0, which can reduce the confusion of the applying hazardous area extent.

Keywords : Hazardous Area Classification, IEC 60079-10-1, Characteristic of Release, Process Safety, Explosive Atmosphere

1. Introduction

IEC 60079-10-1 is an engineering standard used worldwide for hazardous area classification. edition 1.0 was first published in 2008 [1]. Then in 2015, the content was fully revised to edition 2.0 [2]. The concept of the hypothetical volume (V_Z) [3] used in the previous edition was disappeared, and the new parameter called the characteristic of release was introduced to revise the way to apply the hazardous area type and extent. However, edition 2.0 does not provide an exact hazardous area extent because there is no mathematical equation for the plot that shows the hazardous area extent by the release characteristic.

In the previous edition 1.0, the hypothetical volume was obtained through quantitative parameters, and the hazardous area extent was applied by the radius of hypothetical volume as a sphere. Therefore, the hazardous area extent at the time of edition 1.0 was clear.

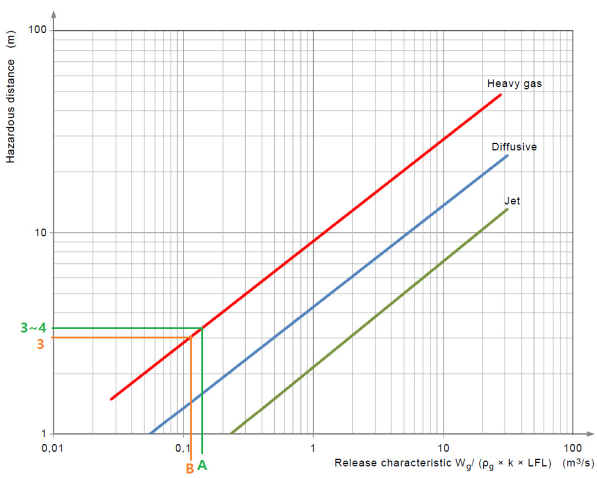
Edition 2.0 also quantitatively derives the new parameter called characteristic of release. And in edition 2.0, plot with release characteristic as X-axis

†Corresponding Author : Sang-Hoon Byeon, Health and Safety Convergence Science, Korea University, 145 Anam-ro, Seongbuk-gu, Seoul, E-mail: shbyeon@korea.ac.kr
Received: May 11, 2020; Revision Received: June 2, 2020; Accepted: June 25, 2020

and hazardous area extent as Y-axis is presented. It was changed in such a way as to derive the hazardous extent, which is the value of the Y axis corresponding X axis [4]. However, the formula for this plot is not disclosed, and the interval between the X-axis and the Y-axis is set to log scale, which makes it difficult to find an accurate coordinate value. In the study of Jung and Lee in 2020, the same problem was pointed out [5]. Therefore, it is not possible to derive the exact hazardous area extent using only the plot presented in edition 2.0, and there is a drawback that the engineers show a difference in the analysis of the explosion radius [6].

For example, assume a heavy gas type release and a release characteristic of 0.15 m^3/s. First, we need to find out where 0.15 is located on the X axis, but it is difficult to determine exactly where 0.15 is located because it is in log scale.

Based on the point A, which is assumed to be exactly 0.15 between 0.1 and 0.2 on the X-axis, the hazardous area extent is between 3 m and 4 m according to the heavy gas plot. However, because the Y axis is also a log scale, it is difficult to know exactly what the hazardous area extent is between 3 m and 4 m [Figure 1. Normally, no matter what value the hazardous area extent is, it does not exceed 4 m. Therefore, the hazardous area extent of 4 m is conservatively selected.



[Figure 1] Hazardous area extent by the release characteristic in IEC edition 2.0

From another point of view, considering that the scale interval between 0.1 and 0.2 on the X axis is a log scale, one could argue that 0.15 is B, which is visually close to 0.1. In this case, it can be interpreted as having the hazardous area extent of 3 m according to the heavy gas release plot ([Figure 1]).

As described above, in case of edition 2.0, the hazardous area extent may be interpreted differently according to the engineer, and it is impossible to accurately verify that any value is wrong. Therefore, this study aims to present the mathematical equation that applies heavy gas, diffusive, jet release plot as mathematical solution by making full use of plot given in edition 2.0. Equation provides a scientific basis for engineers by applying the hazardous area extent.

2. Background

This section briefly introduces hazardous area classification methodology of edition 1.0 and 2.0 of IEC 60079-10-1. Among them, we introduce the section on deriving the hazardous area extent, not the classification of hazardous area zones.

2.1 Edition 1.0 methodology

In the case of edition 1.0, the concept of hypothetical volume (V_Z)is an important keyword[7]. This is because the hypothetical volume calculated by this methodology is assumed as a sphere, and the radius length at this time is derived as the hazardous area extent. The formula for calculating this hypothetical volume is Equation 1.

$$V_Z = \frac{f \times \left(\frac{dV}{dt}\right)_{\min}}{0.03} \tag{1}$$

The hypothetical volume is denoted V_Z and the unit is m^3/s. To derive this value, f value and $(dV/dt)_{min}$ value is required. The f value is applied to one of integer values from 1 to 5 as the quality factor. The closer to 1, the less well ventilated around the hazardous source, and the closer to 5, it is in the well-ventilated environment. In industry practice, the median value of 3 is applied by default. The value of $(dV/dt)_{min}$ means minimum volumetric

http://dx.doi.org/10.12812/ksms.2020.22.2.073
ISSN 1229-6783(Print)
ISSN 2288-1484(Online)

flow of fresh air and can be obtained through the following formula (Equation 2). To derive this value, $(dG/dt)_{max}$ and T, k, LEL_m values are required.

$$\left(\frac{dV}{dt}\right)_{min} = \frac{\left(\frac{dG}{dt}\right)_{max}}{k \times LFL_m} \times \frac{T}{293} \quad (2)$$

In the case of T, it represents the atmospheric temperature and the unit is K. The ambient temperature at which the hazardous source is placed can be applied. The value of k is a safety factor. The value of 0.25 is applied in case of continuous or primary grade of release and 0.5 in case of secondary grade of release. In general, the hazardous source leaks to the secondary grade of release, so the value of 0.5 is applied by default. The value of LEL_m(kg/m^3) is obtained by converting the value of LEL_v(vol%) through the following equation (Equation 3).

$$LEL_m = 0.416 \times 10^{-3} \times M \times LEL_V \quad (3)$$

This equation was introduced in IEC edition 1.0. Since LEL value is expressed as vol % in MSDS, it should be converted to kg/m^3. M is the molecular weight of the hazardous source material. In case of $(dG/dt)_{max}$, it means the amount of release rate t from hazardous source. First, it is divided according to whether it is a liquid phase or a gas phase. In the case of a gas phase, it is divided into chocked state or non-choked state. The parameters applied to the equations for each phase are shown in <Table 1>, and the equations are as follows (Equation 4, Equation 5, Equation 6).

<Table 1> Parameters of release rate in IEC edition 1.0

Parameter	Description
$\frac{dG}{dt}$	Release rate of liquid, gas [kg/s]
S	Cross section of the opening, through which liquid is released [m^2]
ρ	Liquid density [kg/m^3]
$\triangle p$	Pressure difference across the opening that leaks [Pa]
M	Molecular mass of gas [kg/kmol]
γ	Polytropic index of adiabatic expansion
R	Universal gas constant [8314 J/kmol K]
p	Pressure inside the container [Pa]
p_0	Pressure outside the gas container [Pa]

$$\frac{dG}{dt} = S\sqrt{2\rho \triangle p} \quad (4)$$

$$\frac{dG}{dt} = Sp\sqrt{\gamma\frac{M}{RT}\left(\frac{2}{\gamma+1}\right)^{\frac{(\gamma+1)}{2(\gamma-1)}}} \quad (5)$$

$$\frac{dG}{dt} = Sp\sqrt{\frac{M}{RT}\frac{2\gamma}{\gamma-1}\left[1-\left(\frac{p_0}{p}\right)^{\frac{(\gamma-1)}{\gamma}}\right]}\left(\frac{p_0}{p}\right)^{\frac{1}{\gamma}} \quad (6)$$

In sum, the applying hazardous area extent methodology of edition 1.0 is calculated through quantitative input values, so there is no need for qualitative judgment by the engineer.

2.2 Edition 2.0 Methodology

In edition 2.0, the concept of hypothetical volume used to calculate the hazardous area extent in 1.0 has been removed. In addition, the new factor called characteristic of release was introduced, and this value was changed to a way to derive the hazardous area extent through the plot suggested in IEC code. The formula for obtaining the characteristic of release is as follows and the unit is m^3/s (Equation 7).

$$\frac{W_g}{\rho_g k LFL} \quad (7)$$

The density of the gas, which is the parameter constituting the characteristic of release, can be obtained through the Equation 8, and the unit is kg/m^3.

$$\rho_g = \frac{p_a M}{RT_a} \quad (8)$$

Pa is the atmospheric pressure, M is the molecular weight of the hazardous source material, R is the gas constant, Ta is the atmospheric temperature near the hazardous source. In the other parameter constituting the characteristic of release, K is the safety factor and has a value of 0.5 to 1 depending on the accuracy of the LFL. This is different from k in edition 1.0, which applied the given value depending on the release type. In case of LFL, unlike edition 1.0, there is no need to convert to LFL_m, and the LFL_v value from the MSDS of the hazardous source material can be applied. Wg is the same concept as the release rate $(dG/dt)_{max}$ of edition1.0. Release rate is not much different from edition1.0, but only a few detailed parameters have been added. Edition2.0 is also divided into liquid phase (Equation 9) and gas phase, as in1.0, and gas phase is divided into chocked (Equation 10) or non-choked (Equation 11).

$$W = C_d S \sqrt{2\rho \triangle p} \qquad (9)$$

$$W = C_d S p \sqrt{\gamma \frac{M}{ZRT}} \left(\frac{2}{\gamma+1}\right)^{\frac{(\gamma+1)}{2(\gamma-1)}} \qquad (10)$$

$$W = C_d S p \sqrt{\frac{M}{ZRT} \frac{2\gamma}{\gamma-1} \left[1-\left(\frac{p_0}{p}\right)^{\frac{(\gamma-1)}{\gamma}}\right]} \left(\frac{p_0}{p}\right)^{\frac{1}{\gamma}} \qquad (11)$$

There is nothing unusual about the addition of parameters C_d and Z to the release rate of edition1.0. C_d has a discharge coefficient of 0.5 to 0.75. This is a value that changes depending on the characteristics of the release hole. It is a concept added to obtain more accurate data on leaks compared to edition 1.0. Z means the coefficient of expansion of the material that is the source of leakage, and in the case of an ideal gas has a value of 1. This is also the concept added to obtain more accurate data on leakage.

In other words, the characteristic of release introduced in edition 2.0 are calculated through quantitative input values, so there is no need for qualitative judgment by the engineer. However, there is a problem in the method of applying the hazardous area extent through this characteristic of release. In the code, three types of plots are presented, depending on the type of release, heavy gas, diffusive, and jet, but the formula for this plot is not provided. In addition, the values of the X-axis and Y-axis are also set to the log scale so that the value between the sub-scales cannot be known accurately. Therefore, the most conservative method is to apply the explosion radius to the higher value that can know the coordinate value of the Y axis against the hazardous area extent of the Y axis that

<Table 2> Assumption of hazardous area extent by considering safety margin

Heavy gas		Diffusive		Jet	
Charatertistic of release	Hazardous area extent	Charatertistic of release	Hazardous area extent	Charatertistic of release	Hazardous area extent
≤ 0.05	2	≤ 0.2	2	≤ 0.8	2
≤ 0.1	3	Somewhere between 0.2 and 0.3 in characteristic of release is a value of 2 in hazardous area extent.		Somewhere between 0.8 and 0.9 in characteristic of release is a value of 2 in hazardous area extent.	
Somewhere between 0.1 and 0.2 in characteristic of release is a value of 3 in hazardous area extent.		≤ 0.5	3	≤ 1	3
Somewhere between 0.2 and 0.3 in characteristic of release is a value of 4 in hazardous area extent.		≤ 0.9	4	Somewhere between 1 and 2 in characteristic of release is 3 in hazardous area extent.	
≤ 0.3	5	Somewhere between 1 and 2 in characteristic of release is 5, 6 in hazardous area extent.		≤ 3	4
Somewhere between 0.3 and 0.4 in characteristic of release is a value of 5 in hazardous area extent.		≤ 2	7	Somewhere between 3 and 4 in characteristic of release is a value of 4 in hazardous area extent.	
≤ 0.4	6	Somewhere between 2 and 3 in characteristic of release is a value of 7 in hazardous area extent.		≤ 5	5
Somewhere between 0.4 and 0.5 in characteristic of release is 6 in hazardous area extent.		≤ 3	8	≤ 7	6

http://dx.doi.org/10.12812/ksms.2020.22.2.073 ISSN 2288-1484(Online)

Heavy gas		Diffusive		Jet	
≤ 0.6	7	Somewhere between 3 and 4 in characteristic of release is 8 in hazardous area extent.		≤ 9	7
≤ 0.7	8	≤ 4	9	Somewhere between 9 and 10 in characteristic of release is a value of 7 in hazardous area extent.	
Somewhere between 0.7 and 0.8 in characteristic of release is 8 in hazardous area extent.		Somewhere between 4 and 5 in characteristic of release is 9 in hazardous area extent.		≤ 10	8
≤ 0.9	9	≤ 5	10	Somewhere between 10 and 20 in characteristic of release is 8, 9, 10 in hazardous area extent.	
Somewhere between 0.9 and 1 in characteristic of release is a value of 9 in hazardous area extent.		Somewhere between 5 and 6 in characteristic of release is 10 in hazardous area extent.		≤ 20	20
≤ 1	10	≤ 20	20		
Somewhere between 1 and 2 in characteristic of release is a value of 10 in hazardous area extent.					
≤ 4	20				
Somewhere between 4 and 5 in characteristic of release is 20 in hazardous area extent.					
≤ 10	30				
Somewhere between 10 and 20 in characteristic of release is a value of 30, 40 in hazardous area extent.					
≤ 20	50				

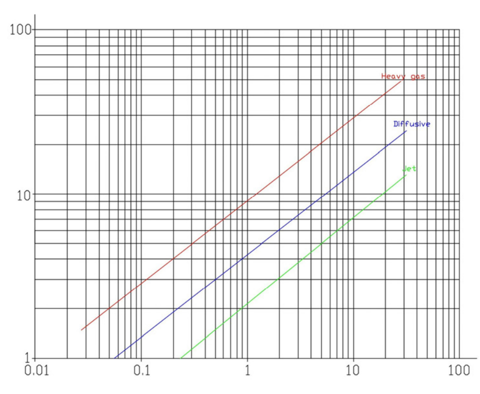
has substituted the characteristic of release of the X axis on the plot [6]. According to such a criterion it is possible to derive the hazardous area extent according to the characteristic of release according to the following <Table 2>.

At the present time without plot equation provided by IEC edition 2.0, if the hazardous area extent is applied based on the values in the <Table 2>, there is no problem from a conservative perspective. However, considering the excessive safety margin, the hazardous area extent can be unnecessarily widened.

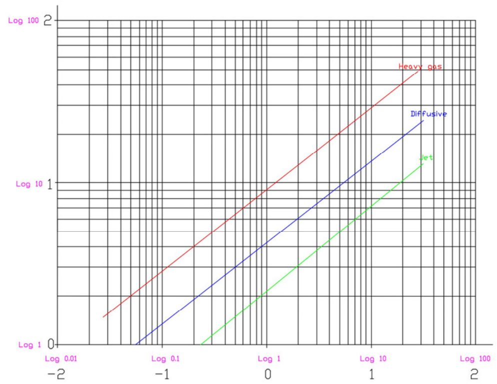
3. Methodology

This section introduces the method of deriving the plot of characteristic of release and hazardous area extent introduced in edition 2.0 by mathematical equation. Only the plot for the plot is presented in the code, and there is no detailed explanation anywhere. So the plot was converted to CAD and analyzed.

When the plot is converted to CAD, it is as [Figure 2]. At this time, if the values indicated on the X-axis and the Y-axis are converted into a log, they are as follows as [Figure 3].



[Figure 2] IEC edition 2.0 plot converted by CAD

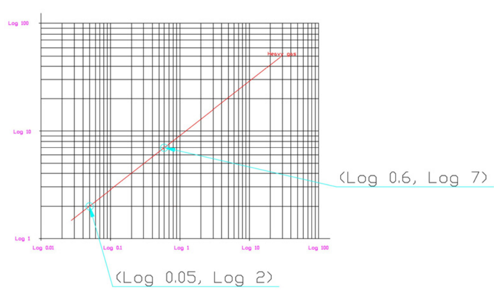


[Figure 3] IEC edition 2.0 plot's axis substituted by log scale

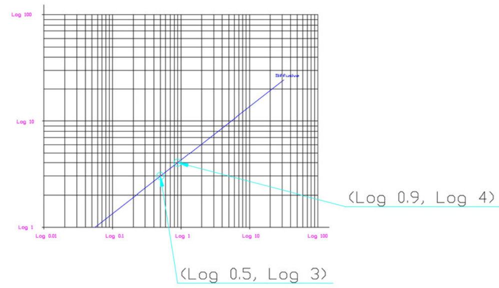
In other words, the X and Y axis of the plots introduced in the code can be seen to have the same spacing if they are converted to log scale rather than the introduced values themselves. Therefore, in this study, the actual X coordinate is applied as the log value to the characteristic of release, and the Y axis is also interpreted as the log value is derived from the hazardous area extent.

Now we want to derive the respective equation for heavy gas, diffusive and jet release. The derivation method selects two points closest to the coordinates that can know the exact value in the CAD plot. Since this plot is a linear function, it is based on the simple principle that knowing the values of two coordinates yields an equation.

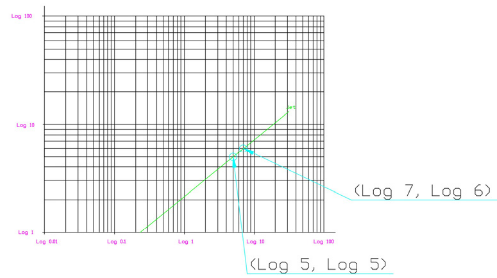
Of course, since the plot introduced in code is converted to CAD as it is, it can be difficult to see the exact same coordinates. However, assuming a value closest to the true coordinates is the only way to derive an equation based on the data given in the code. The two coordinate values close to the positive coordinates for each release type are as follows [Figure 4], [Figure 5], [Figure 6].



[Figure 4] IEC edition 2.0 heavy gas plot



[Figure 5] IEC edition 2.0 diffusive plot



[Figure 6] IEC edition 2.0 jet release gas plot

Two coordinates closest to the most given axis coordinate in the heavy gas [Figure 4], diffusive [Figure 5], and jet release plots [Figure 6].

$$[Hazardous\ area\ extent] = 10^{\left[\left\{\frac{\log 7-\log 2}{\log 0.6-\log 0.05}\times([Characteristic\ of\ release]-\log 0.6)\right\}+\log 7\right]} \quad (12)$$

$$[Hazardous\ area\ extent] = 10^{\left[\left\{\frac{\log 4-\log 3}{\log 0.9-\log 0.5}\times([Characteristic\ of\ release]-\log 0.9)\right\}+\log 4\right]} \quad (13)$$

$$[Hazardous\ area\ extent] = 10^{\left[\left\{\frac{\log 6-\log 5}{\log 7-\log 5}\times([Characteristic\ of\ release]-\log 7)\right\}+\log 6\right]} \quad (14)$$

Based on this, hazardous area extent is derived from Equation 12 in heavy gas release, Equation 13 in diffusive release, and Equation 14 in jet release.

Since the characteristic of release is a value that can be derived from quantitative data, the hazardous area extent can also be obtained by applying the above equations for each release case.

4. Case Study

This section compares the hazardous area extent obtained by directly reading the plot with by applying equation suggested in this study applied through the case study on the release characteristics of heavy gas, diffusive, and jet and the method proposed in this study. The characteristics of materials applied for each type of release are shown in the <Table 3>.

<Table 3> Case study: characteristic of material by the release type

	Heavy gas	Diffusive	Jet
Applied fluid	n-Hexane	Methane	Hydrogen
Molecular weight [kg/kmol]	86.18	16.04	2
LFLv [vol/vol]	1.1	5	4
Polytrophic index of adiabatic expansion	N/A	1.3	1.4

In addition, the parameters for IEC calculation to be applied to the case study are shown in <Table 4>. In addition, the hazardous area extent is affected by the release rate, and the release rate tends to increase with the pressure [8]. Therefore, a case study was performed while varying the pressure value with an increased interval of 5 barg from 5 barg to 100 barg.

<Table 4> Case study: parameters for IEC calculation

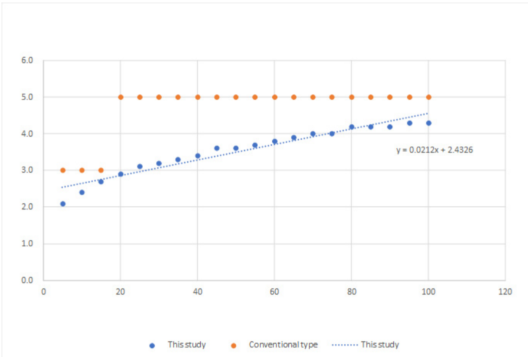
Parameter		Description
C_d	Discharge coefficient	0.75
k	Safety factor	1
S	Cross section of the opening	5.0 x 10^{-6} [m^2]
Z	Compressibility factor	1
R	Universal gas constant	8314 [J/mol K]
T_a	Absolute ambient temperature	313.15 [K]
T	Absolute temperature of the fluid, gas or liquid	293.15 [K]
p_a	Atmospheric pressure	101325 [Pa]
Evaporation rate		2%
Facilities' pressure condition		Application at 5 barg Interval from 5 barg to 100 barg

Hazardous area extent calculation results for each representative case according to the above conditions are <Table 5>.

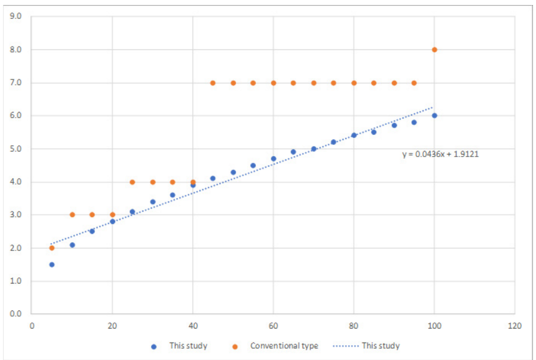
<Table 5> Case study: conclusion of the hazardous area extent from the suggested method to the conventional previous method

	Heavy gas (n-Hexane Case)				Diffusive (MethaneCase)				Jet (HydrogenCase)			
Pressure [barg]	Characteristic of release [m^3/s]	This study	Conventional type	Error rate	Characteristic of release [m^3/s]	This study	Conventional type	Error rate	Characteristic of release [m^3/s]	This study	Conventional type	Error rate
5	0.051	2.1	3	30.0%	0.120	1.5	2	25.0%	0.436	1.4	2	30.0%
10	0.072	2.4	3	20.0%	0.220	2.1	3	30.0%	0.798	1.9	2	5.0%
15	0.088	2.7	3	10.0%	0.319	2.5	3	16.7%	1.161	2.3	4	42.5%
20	0.101	2.9	5	42.0%	0.419	2.8	3	6.7%	1.523	2.7	4	32.5%
25	0.113	3.1	5	38.0%	0.519	3.1	4	22.5%	1.886	3.0	4	25.0%
30	0.124	3.2	5	36.0%	0.618	3.4	4	15.0%	2.248	3.3	4	17.5%
35	0.134	3.3	5	34.0%	0.718	3.6	4	10.0%	2.610	3.6	4	10.0%
40	0.143	3.4	5	32.0%	0.818	3.9	4	2.5%	2.973	3.8	4	5.0%
45	0.152	3.6	5	28.0%	0.917	4.1	7	41.4%	3.335	4.1	5	18.0%
50	0.160	3.6	5	28.0%	1.017	4.3	7	38.6%	3.698	4.3	5	14.0%
55	0.168	3.7	5	26.0%	1.117	4.5	7	35.7%	4.060	4.5	5	10.0%
60	0.175	3.8	5	24.0%	1.216	4.7	7	32.9%	4.422	4.7	5	6.0%
65	0.182	3.9	5	22.0%	1.316	4.9	7	30.0%	4.785	4.9	5	2.0%
70	0.189	4.0	5	20.0%	1.416	5.0	7	28.6%	5.147	5.1	6	15.0%
75	0.196	4.0	5	20.0%	1.515	5.2	7	25.7%	5.510	5.3	6	11.7%
80	0.202	4.2	5	16.0%	1.615	5.4	7	22.9%	5.872	5.5	6	8.3%
85	0.209	4.2	5	16.0%	1.715	5.5	7	21.4%	6.235	5.7	6	5.0%
90	0.215	4.2	5	16.0%	1.814	5.7	7	18.6%	6.597	5.9	6	1.7%
95	0.220	4.3	5	14.0%	1.914	5.8	7	17.1%	6.959	6.0	6	0.0%
100	0.226	4.3	5	14.0%	2.014	6.0	8	25.0%	7.322	6.2	7	11.4%

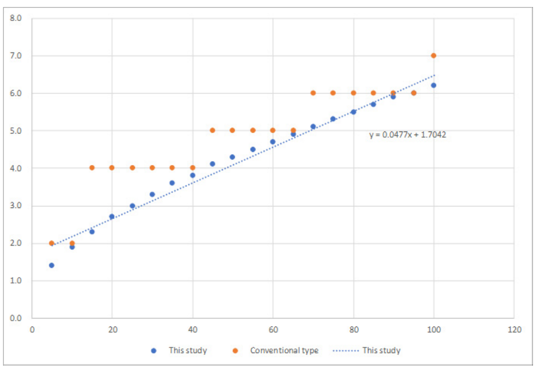
The plots for each release types are as [Figure 7], [Figure 8], [Figure 9].



[Figure 7] Case study: heavy gas release



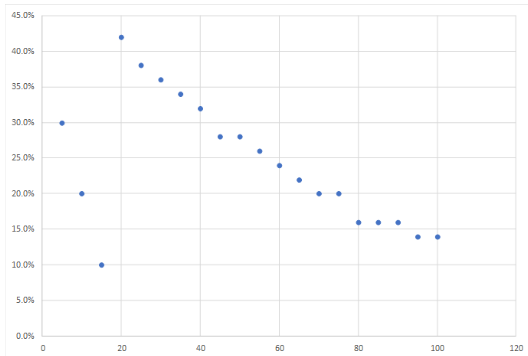
[Figure 8] Case study: diffusive release



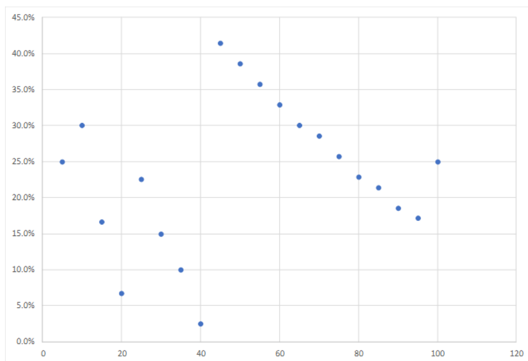
[Figure 9] Case study: jet release

The release of heavy gas, diffusive and jet can be seen in the trend of increasing the explosion radius according to the pressure according to the equation presented in this study. Also, the increase is high in order of jet, diffusive, heavy gas release.

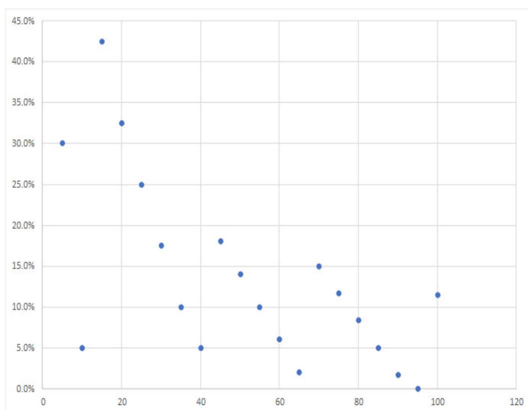
In addition, when comparing the conventional method with the consideration of excessive safety margin, it was found that the maximum error rate was 42.5% for jet release, 42.0% for heavy gas release, and 41.4% for diffusive release. The error rate could not find a constant tendency regardless of the pressure value. This means that there is almost no safety margin under certain pressure conditions and almost no safety margin under certain pressure conditions, irrespective of leakage characteristics. It can be concluded that conventional methods without the certain trend in the safety margin are not scientific. The distribution of error rate for each release type is shown in the [Figure 10], [Figure 11], [Figure 12].



[Figure 10] Error rate: heavy gas release



[Figure 11] Error rate: diffusive release

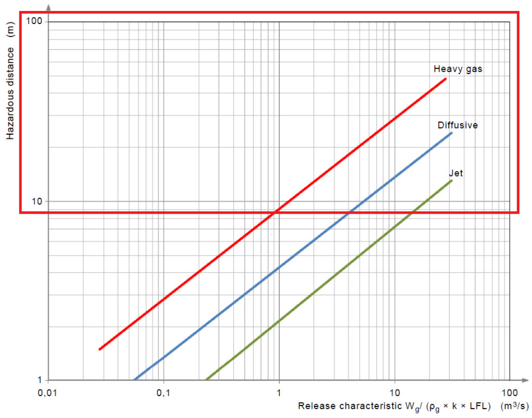


[Figure 12] Error rate: jet release

Although it is not covered by this case study, the

http://dx.doi.org/10.12812/ksms.2020.22.2.073
ISSN 1229-6783(Print)
ISSN 2288-1484(Online)

error rate is a big problem in the section of 10 m or more where the value of the Y-axis of the plot shown in the IEC code is greatly increased ([Figure 13]). This is because the hazardous area extent is increased in 10 m units such as 10 m, 20 m, and 30 m. In particular, the explosion rate of 10-20 m is expected to show a greater error rate.



[Figure 13] Big error rate about the hazardous area extent over 10 m

5. Discussion & Conclusion

The conventional method for applying hazardous area extent considering the safety margin of IEC 60079-10-1 edition 2.0 is not scientific because it considers the irregular margin irrelevant to the pressure value. On the other hand, the suggested method of hazardous area extent through the equation inference presented in this study shows the tendency of the hazardous area extent increase with the pressure increase.

Unconditionally wide hazardous area extent is not good for safety [9]. Excessive safety margins lead to an increase in expenditure on the establishment of a plant due to unnecessary explosion-proof equipment [10]. Therefore, the owner will try to reduce the hazardous area extent as much as possible, and the government will try to regulate it, but there is no reasonable scientific regulatory basis. In countries such as Korea, where the hazardous area extent is applied as a fire proofing extent, an inaccurate explosion radius may cause unnecessary refractory increase.

In this study, equation was calculated based on two points close to the exact coordinates of the plot by converting the plot presented by IEC Code into CAD. Even if the safety margin is added in consideration of the incompleteness of the plot, it is considered that considering the margin of a certain %, for example 10%, in the hazardous area extent calculated in this way will contribute to a more reasonable calculation of the explosion radius.

Although there are research papers on IEC Code edition 2.0, no studies have pointed out problems with the methodology of applying the hazardous area extent. Just verification of the hazardous area extent has been studied through CFD modeling [11]. However, in countries adopting the IEC Code, the IEC methodology has the same effect as the law, so applying CFD modeling to the practical hazardous area classification is not a realistic solution. In addition, hazardous area classification by CFD modeling for all facilities is not a realistic alternative because it takes a lot of time and money. Therefore, further research based on the IEC edition 2.0 Code itself will be conducted in the future.

6. Conflict of Interest

The author confirms that this article content has no conflict of interest

7. References

[1] International Electrotechnical Commission(IEC) (2008), "IEC 60079-10-1 : Classification of areas - Explosive gas atmospheres (1.0 Ed.)." IEC International, Geneva.

[2] International Electrotechnical Commission (IEC) (2015), "IEC 60079-10-1 : Classification of areas - Explosive gas atmospheres (2.0 Ed.)." IEC International, Geneva.

[3] R. Tommasini(2013), "The classification of hazardous areas where explosive gas atmospheres may be present." Safety Science, 58:53-58.

[4] A. Bozek(2017), "Application of IEC 60079-10-1

edition 2.0 for hazardous area classification." 2017 Petroleum and Chemical Industry Technical Conference (PCIC), September 18-20, Calgary, AB, Canada.

[5] Y. J. Jung, C. J. Lee(2020), "A Study on Predictive Models based on the Machine Learning for Evaluating the Extent of Hazardous Zone of Explosive Gases." Korean hemical Engineering Research, 58:248-256.

[6] J. Y. Choi(2018), "An Analysis on the Main Amendment of Hazardous Area Classification in Korea and a Study on Its Limitation." Korean Journal of Hazardous Materials, 6:8-17.

[7] M. J. Ivings, S. Clarke, S. E. Gant, B. Fletcher, A. Heather, J. Pocock, D. K. Pritchard, R. Santon, C. J. Saunders(2008), "RR630 : Area classification for secondary releases from low pressure natural gas systems Area classification for secondary releases from low pressure natural gas systems." Health and Safety Laboratory, Derbyshire.

[8] S. Givehchi, H. Zohdirad, T. Ebadi(2016), "Utilization of regression technique to develop a predictive model for hazard radius from release of typical methane-rich natural gas." Journal of Loss Prevention in the Process Industries, 44:24-30.

[9] R. Tommasini, E. Pons, F. Palamara(2014), "Area classification for explosive atmospheres: Comparison between European and North American approaches." IEEE Transaction on Industry Applications, 50: 3128-3134.

[10] H. Zohdirad, T. Ebadi, S. Givehchi, H. Meysami (2016), "Grid-based individual risk calculation in the classification of hazardous area with a risk-based approach." Journal of Loss Prevention in the Process Industries, 43:98-105.

[11] D. M. Webber, M. J. Ivings, R. C. Santon(2011), "Ventilation theory and dispersion modelling applied to hazardous area classification." Journal of Loss Prevention in the Process Industries, 24:612-621.

저자 소개

최 재 영

서강대 화공생명공학과 (공학사), 고려대 환경생태공학과 (이학석사), 위험물기능장, 현대엔지니어링 플랜트안전소방설계팀 공정안전 엔지니어로 근무 중. 현재 고려대학교 대학원 보건안전융합과학과 박사과정 중

관심분야 : Technical Safety 분야 (방폭, 내화, 이격거리, 등)

변 상 훈

고려대 화학과 (이학사), 연세대 화학공학 (공학박사), KOSHA 선임연구원, 산업위생기술사. 현재 고려대학교 보건안전융합과학과 교수 재직 중.

관심분야 : 공중보건위험성평가, 화학물질 위험성평가, 작업장노출평가, 유해물질 우선순위 관리기법, 수동식 시료채취방법, 호흡보호구 평가 등