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A Study on Optimum Pressure Vent of Experimental Booth by Gas Explosion

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Abstract – The purpose of this paper is to find optimum vent port of the booth for gas explosion experiment. Also, it is to understand the safety of the booth for explosion experiment which is installed to let the trainees for legal education which is managed by IGTT(Institute of gas technology training) know the riskiness of explosion. Since the booth for gas explosion experiment is a confined space, we used the exhaust model for indoor explosion. As the result, it was safely calculated when the amount of leaking gas was close to the maximum of explosion limit on the explosion experiment.

Key words : Gas Explosion, Safety, Explosion Venting

I. Introduction

Consumption amount of gas in industry and house has been dramatically increasing as an environmental friendly energy source. Fig. 1 shows a status of domestic energy consumption in recent 5 years. Gas energy charges 30% of total energy consumption and LPG, charges 10%, and increases steadily [1].

Also, with the development of the industry, humans' desire for safety has increased. However, gas accidents occur with various causes and types.

The potential dangerous factors always exist as well in industry and in the home, and the same types of accidents occur repeatedly.

Especially, the gas explosion accidents cause a severe loss in our society. Accidents occurred in large scale storage facilities in recent 5 years and configuration are as follows.

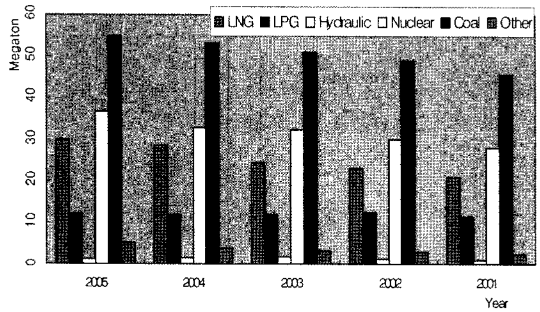

Fig. 1. Energy consumption.

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From the accidents, it is known 54 accidents (90%) happened in house and restaurants. Accidents happened in house covers half, that is 34 accidents (55%), and accidents happened in an independent house doubled than those in an apartment house.

It is considered that the reason why of many accidents happen in house and restaurants is those places are not the safety management applied targets usually.

From the types of accidents, 57 accidents (65%) of LP gas were occurred by explosion and fire. Among these accidents by explosion covers 50%, which covers more than twice than those by fire [2].

To avoid these gas accidents, safety supervisors should be keep in large-scale gas handling places [3-5], and they should be trained the legal safety training within six months from the assignment.

The booth for the explosion experiment was installed at The Institute of Gas Technology Training recently like Fig. 2 to teach the real situation of the gas explosion to the legal trainees.

Fig. 2, the number "①", "②" is 0.39 m^2 (725 mm× 535 mm), the number "③", "④" is 0.45 m^2 (775 mm× 580 mm).

The study on the damage range by the gas explosion such as flame behavior and safety of the gas fire was preceded [6-9], and the explosion experiments were carried actively to verify the rise of gas explosion, but since it is difficult to make the experiments at the real buildings, the experiments [10,11] are made with the models which are reduced with the fixed rate. Therefore, this study built a real building to teach the

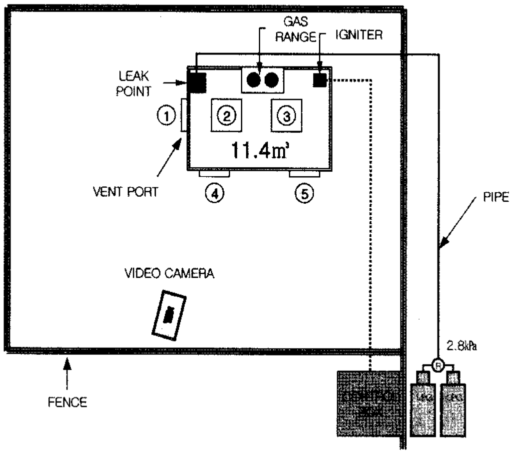

Fig. 2. Experimental apparatus.

danger of the explosion.

However, there was no real experiment, so this study evaluate the collapse level of the booth by using the exhaust model for the indoor explosion.

II. Explosion Theory

Explosion is to mean the condition which has discontinuous change in the density, the pressure and the speed of the surrounding air by giving off the energy in an instant. Explosion is divided into physical explosion and chemical explosion, and the gas explosion is defined as the combustion process of the combustible gas cloud which is mixed with an oxidizer. The gas explosion is again divided into the explosion in the sealed space and in the open space. The pressure which is made by the gas explosion can also cause damage to humans and structures, and the explosion can be developed to fire and to the accident such as BLEVE [12-16].

The gas explosion in the sealed space becomes the worst when the gas concentration of the inside is near the equivalent of oxygen, and it is opened from the weaker part by the increase of pressure as the combustion is progressed. The damage of the gas explosion is seriously influenced by the explosion pressure, and the variables are fuel, kinds of oxidizer, the concentration and size of the gas cloud, the ignition spot, the strength of ignition source, the size, place, and type of vent, the surrounding obstacles, the method to make the smallest damage and so on [17,18].

The gas explosion is sensitively changed by the above variables, so it is difficult to predict the damage degree. It is not sufficient to control the formation of the gas cloud and the ignition source to decrease the gas explosion accidents. We should reduce leakage frequency of gas which is the basic cause of the accidents. However, the gas accidents occurred frequently, and the recent explosion accidents made huge damage, so it is enough to give rise to public criticism. Therefore, we should install the equipment to make the damage minimum in the explosion accidents with the danger analysis of the gas explosion and real experience. That is to say, the danger of the gas explosion can be reduced by installing the optimum safety equipment using the knowledge about the past explosion accidents and the methods to prevent damages. In building general plants, it is concerned about bent by acknowledging the danger of the gas explosion as the initial step of the project for the building plants. In a general house, there is always potential danger of the gas explosion accidents because most of houses use liquefied petroleum gas or city gas as fuel gas. If the gas explosion occurs, the weaker parts such as windows are opened at first by the increase of pressure, and if the speed of gas leakage is slower than the speed of combustion in the open parts, the pressure of the room may be continuously increased and can be developed to the secondary accident as giving severe damage to the whole building. To prevent the secondary accident, bent should be considered for the case of the explosion accident.

As you can see above, it is the way for the building treating combustibles to prevent the explosion damage by the leakage of combustibles that it should be designed to have sufficient exhaust pipes which can give off the explosion pressure on the explosion [19].

Rasbash method and Runes method are used for the exhaust model on the gas explosion in buildings. Both methods concerns about the situation of the gas leakage in buildings in an instant. There is Harris method as well, which is the way to approach theoretically about the increasing speed of incipient pressure and the incipient pressure on the gas explosion in buildings [20].

The formula of Rasbash method and Runes method are used the most to calculate the maximum reaching pressure by indoor gas explosion. This formula is generally applied when the ratio of length and dimension is under 3. The flame spreading speed of 3.35 m/s is applied in the mixed gas of propane and air. Also, The harris method was developed in 1983. The formulas are just applied to the case that there is no obstacle in the room, so they should be applied with

Table 1. Related number of explosion pressure.

Fuel \ Constant	a	b	c	d
CH_4	0.105	0.770	1.230	-0.823
C_3H_8	0.148	0.703	0.942	-0.671

care in the case that the spreading speed of the flame is accelerated by any obstacle and the explosion pressure is increased.

According to NFPA 68, it was settled that a building should have large size of opening by using Rasbash method and Runes method in 1974, and the revised one of 1978 ordered to use only Runes method. However, the revised formula of 1994 is as follows.

$$A_v = C\frac{A_s}{P_{red}^{1/2}}, \qquad P_{red} \leq 0.1 \tag{1}$$

$$A_v = a(V)^b e^{c(P_{stat})}(P_{red})^d, \quad P_{red} \geq 0.1 \tag{2}$$

The constant of the exhaust for the above formula is applied 0.045 for propane and 0.037 $bar^{1/2}$ for methane. The constants applied to the realm of which the maximum explosion pressure is over 0.1 is shown in Table 1.

Table 2. Explosion pressure effect on structur.

Pressure (kpa)	Damage
0.2068	glass window part damage
0.2758	big noise
1.0342	glass explosion pressure
2.0684	serious damage occurrence probability 95%
3.4474	big and small window fracture
4.8263	house small breakage
6.8948	house portion breakage
8.9632	building steel frame flexure
13.7895	weak concrete wall fracture
15.8579	serious structural damage lowlevel
20.6843	steel frame building collapse
27.5790	oil storage tank explosion
34.4738	wood pillar is crash and explosion of tympanum
41.3685	house whole breakage
48.2633	overthrow of carry burden freight car
62.0528	whole destruction of carry burden freight car
68.9476	whole destruction of building

III. Results and Analysis of the Experiment

The size of the booth for the gas explosion experiment is 1.83 m wide, 2.82 m long and 2.21 m high, which means the volume of the booth is 11.4 m^3. Also, we used LPG which was the main cause of the explosion accidents. A paper sheet was attached to the opening for protect the booth from destruction by the explosion pressure.

The explosion pressure which affected to the damage of the structures and the buildings is shown in Table 2.

3.1. Calculation Results

The explosion venting area of the booth from the explosion was calculated with the exhaust model of NFPA 68, revised in 1994, and the result is as follows.

3.1.1. In Case of Propane

In case of propane, exhaust model to the calculation applied is as follows.

$$A_v = 0.148(11.4)^{0.703} \times (2.718)^{0.942\times0.002068} \times (0.206843)^{-0.671} = 2.3622\ m^2$$

3.1.2. In Case of Natural Gases

In case of natural gases, exhaust model to the calculation applied is as follows.

$$A_v = 0.148(11.4)^{0.77} \times (2.718)^{1.23\times0.002068} \times (0.206843)^{-0.823} = 2.5081\ m^2$$

3.2. The study of the Development of the Explosion Flame

As a result of the explosion experiment on venting the combustion gas, the explosion flame and the moving direction of the pressure wave was like Fig. 3(a)~(f).

As you see Fig. 3(a), the explosion pressure come out from the left-top at first. And then, the top is opened and the left window starts to be opened like Fig. 3(b). It is judged because the escape of the gas was made at the right-top and the place of the ignition source was worked at the left-bottom.

The pressure wave worked to the opposite direction, so the front door started to be opened like Fig. 3(c). Besides, with Fig. 3(d), we came to know the pressure wave was given off to the right-top.

Fig. 3(e) shows that the left-top and the left window

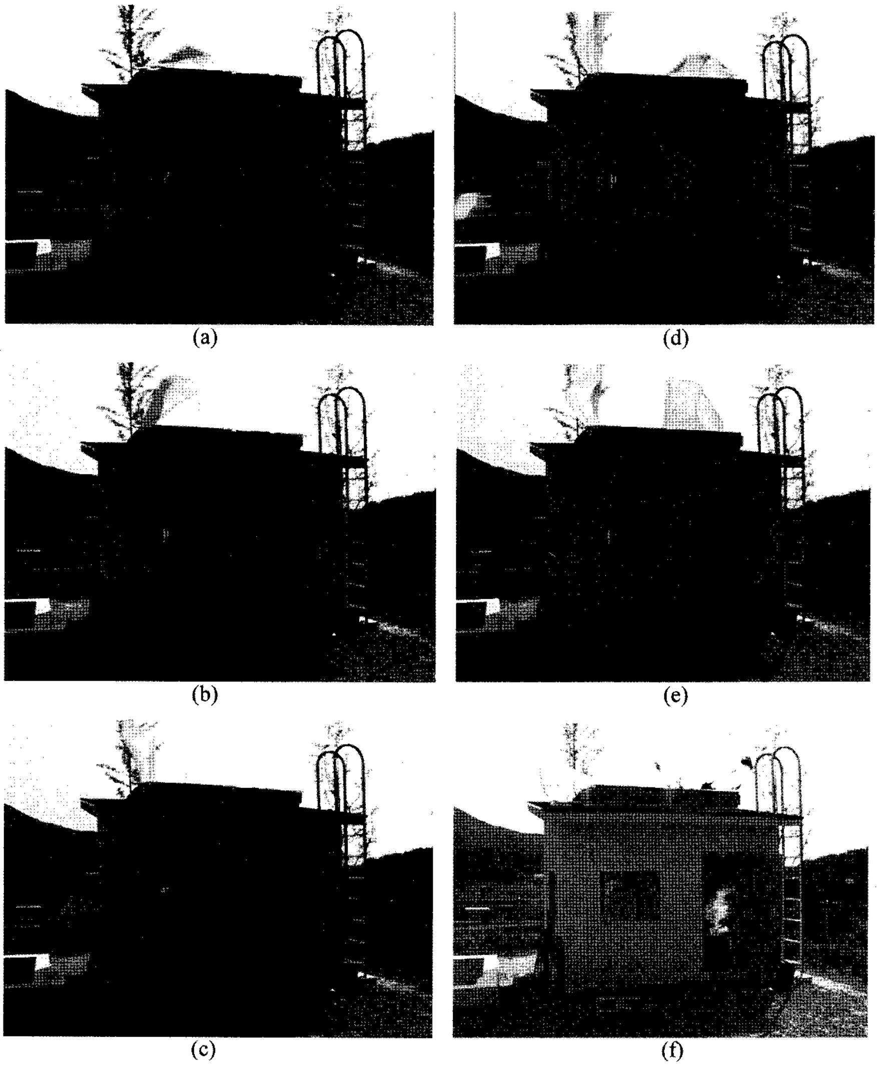

Fig. 3. Propagation of explosion pressure in the Booth.

was perfectly broken as the pressure wave was reached to the maximum point, and the right-top and the front door was opened.

Fig. 3(f) tells that the pressure wave was disappeared, and the flame moved from the right-top to the front door.

We think that it is need to study on the decision of the opening location by the route of the explosion flame as changing the location of the leakage and the ignition source.

IV. Conclusions and Discussion

This paper evaluated the safety of the booth that used for the gas explosion experiment at the Institute of Gas Technology Training by applying the exhaust model.

We got the following conclusions through this study.

1) The total opening area of the booth for the experiment is 2.66 m^2, and the calculated area from the model is 2.3622 m^2 in case of LPG. The actual opening area is larger than the calculation result, therefore it is consider that the booth is safe for explosion experiment.

2) In case of NG, the calculated area from the model is 2.5081 m^2 and we consider that the booth is safe for explosion experiment of NG also.

3) Since a shock wave progresses rapidly to the

upper part, we installed ventilation equipment whose size is 115% of those to the direction of the progress to secure safety.

The result of this study is calculated with the bursting pressure which is applicable to the glass, but bursting pressure of the paper is much lower than the glass which is used for the experiment in safety.

Therefore, we conclude that the experiment system may be safe enough compare with the calculation result of this study.

We plan to figure out the damage range by the flame and the explosion fragments according to the gas concentration in experiment. Also, we want to study on the ability of the protective wall by using the extensometer for the safety of the protective wall.

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Nomenclature

A_s : Gross area of the wall of the room (m^2)
A_v : Gross area of the outlet (m^2)
C : Constant of the exhaust ($kPa^{1/2}$)
P_{red} : Maximum explosion pressure (kPa)
P_{stat} : Open pressure of vent (kPa)
V : Capacity of the sealed space (m^3)