Overpressure Predictions by TNT and MEM for the JAEA Explosion Test in the Open Space

H. S. Kang,[a] S. B. Kim,[a] M. H. Kim,[a] W. J. Lee,[a] H. C. No [b]

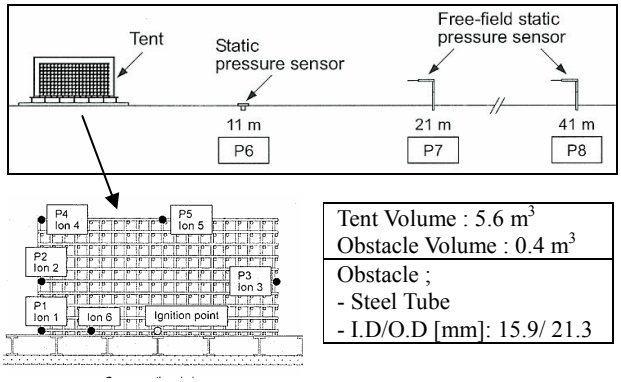
a Korea Atomic Energy Research Institute, P. O. Box 105,Yuseong,Taejon, Korea, 305-600, hskang3@kaeri.re.kr
b Korea Advanced Institute of Science and Technology, 373-1, Guseong,Yuseong,Taejon,Korea, 305-701,

1. Introduction

A safety distance between a High Temperature Gas-Cooled Reactor (HTGR) and a hydrogen production facility is usually determined based on the maximum overpressure under the assumption of a gas explosion accident [1]. If the overpressure due to the gas explosion is predicted by a correlation, the determination of the safety distance may be performed easily. As for the prediction method of the overpressure, the TNT equivalent method and the Multi-Energy Method (MEM) are widely used [2]. The TNT assumes that a detonation shock wave always occurs when a gas explosion happens [2]. Whereas the MEM classifies the peak overpressure at the center of a gas cloud into 10 classes, and the overpressure at a certain location from the gas cloud may be different depending on the class. The TNT and the MEM are applied to the JAEA explosion test [3] to establish the applicability.

2. Gas Explosion Test [3]

JAEA performed a gas explosion test in an open space by varying the gas concentration, the ignition method and the existence of a obstacle, and measured the overpressure and the flame front arrival inside the tent where the flammable gas was located and around the tent (Fig. 1). The selected test case is a mixture of methane (9.5 vol. %) and air with an obstacle under the spark ignition because the TNT and the MEM are only applied to a stoichiometry condition [4].



Tent Volume : 5.6 m^3
Obstacle Volume : 0.4 m^3

Obstacle ;
- Steel Tube
- I.D/O.D [mm]: 15.9/ 21.3

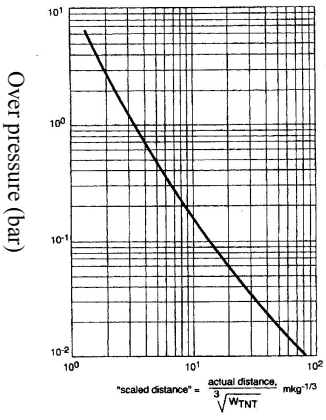
Figure 1. JAEA Gas explosion test facility

In the test, the tent was quickly removed after the start of the ignition.

3. Prediction Methods of Overpressure

3.1 TNT Equivalent Method

The TNT equivalent method was developed based on the experimental results which measured the overpressure according to the weight of TNT [2]. The relation between the overpressure, TNT weight and the distance from the explosion source was represented by a graph (Fig. 2). In order to use this graph for a gas explosion, the equivalent TNT charge (W_{TNT}) for a flammable gas and the scaled distance are calculated under the assumption that the combustion energy of a gas fuel was emitted at the stoichiometry condition [2]. The drawback of the TNT equivalent method is that it is not applicable for a weak gas explosion and the conservative assumption was used that a detonation shock wave always occurs when a gas explosion happens [2].



Equivalent TNT charge for Hydrocarbon Gas [2] :

W_{TNT} [kg] = 0.16 × V

V [m^3] : the smaller of either the total volume of the congested region or the volume of the gas cloud

Figure 2. Chart for blast overpressure according to TNT equivalent method

3.2 Multi-Energy Method

In the MEM, the overpressure around a gas cloud is predicted by an empirical correlation (Eq. 1) and classified into 10 classes based on it (Fig. 3)[2,4,5]. The first class is almost similar to the TNT curve. And the overpressure at a certain location represented by the combustion energy scaled distance from the gas cloud may be different depending on the class. However, the MEM has some drawbacks in which it does not correctly predict the

overpressure at the center of a gas explosion.

$$\Delta P_s = 0.84\left(VBR\frac{L_P}{D}\right)^{2.75} S_L^{2.7} D^{0.7} \qquad (1)$$

VBR : Volume blockage method
L_p : Length of the flame path
D : Typical diameter
S_L : Laminar burning velocity

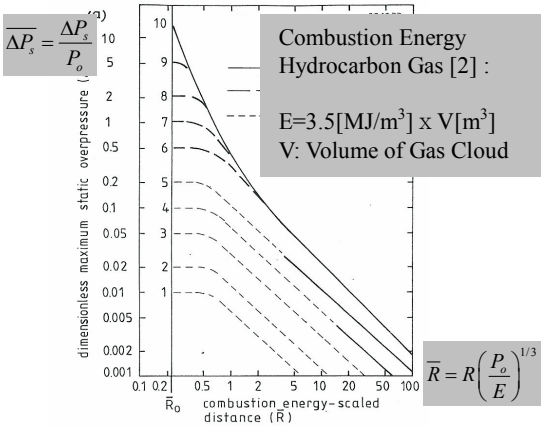


Figure 3. Blast wave overpressure dependent on the distance for a hemi-spherical fuel-air charge on the earth's surface (P_o : ambient pressure)

3.3 Comparison of Prediction Results with Test Result

The predicted overpressure by TNT and MEM are shown in Table 1 and Fig. 4. The overpressures by TNT are predicted higher than those of the test over the whole range. It may be that TNT was developed under the assumption of a detonation shock wave whereas the gas explosion test was a deflagration phenomenon [3,4]. And also, the overpressure can not be obtained at around the physical distance of 1m (Fig. 2). The predicted overpressure values by MEM show good agreement with the test results in the range from 10m to 40m, but the overpressure is lower than that of the test at 1m of which the location is inside the tent (Fig. 1).

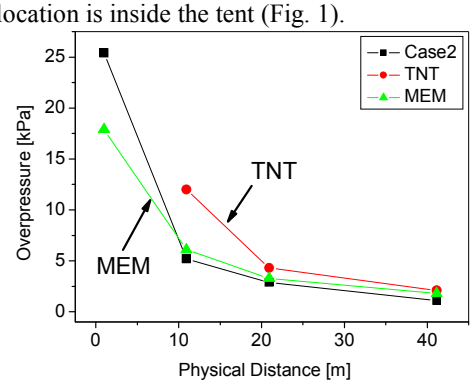


Figure 4. Comparison of Test Results with TNT and MEM Results

Table 1 Calculated Overpressure by TNT and MEM

4. Conclusion and Further Research

TNT Equivalent Method				
TNT Charge ($W_{TNT}^{1/3}$)	0.832 [m $kg^{-1/3}$] (Volume = 5.2 m^3)			
Physical Distance (R) [m]	1	11	21	41
Scaled Distance	N/A	11.69	22.32	43.59
Overpressure [bar]	N/A	0.120	0.043	0.021
Multi-Energy Method (5 Class)				
Combustion Energy	18.2 [MJ] (Volume = 5.2 m^3)			
Physical Distance (R) [m]	1	11	21	41
Comb. E.-scaled distance	0.176	1.941	3.706	7.235
Overpressure [bar]	0.179	0.061	0.033	0.018

As the result of a comparison of overpressures by TNT and MEM with test data, it was found that the predictions by MEM are better than the ones by TNT because the gas explosion phenomenon of the JAEA test did not produce a detonation shock wave. Therefore, the development of a detonation should be checked in advance when the overpressure prediction method is applied to the determination of the safety pressure between the HTGR and the hydrogen production facility. And also, a careful consideration in determining the overpressure around the gas cloud should be performed because an obstacle around a gas cloud may increase it.

ACKNOWLEDGEMENTS

This work was financially supported for the nuclear R&D program from the Ministry of Science and Technology of Korea.

REFERENCES

1. H. S. Kang, et al, "Regulatory Issues on the Safety Distance between HTGR and Hydrogen Production System", Proc. of KNS Autumn Meeting, Chuncheon, Koera, 2006.
2. Dag Bjerketvedt, et al, Gas Explosion Handbook, J. Of Hazardous Materials, **52**, pp.1-150, 1997.
3. Yoshitomo Inabal, Tetsuo Nishihara, Mark A. Groethe and Yoshikazu Nitta, "Study on explosion characteristics of natural gas and methane in semi-open space for the HTTR hydrogen production system", *NED* 232, (2004), pp. 111-119.
4. H. S. Kang, "Evaluation for the overpressure of JAEA Explosion Test by TNT and MEM", Design Calculation Document, NHDD-KA06-RD-20, 2007.
5. A. C. van den Berg, "The Multi-Energy Method: basic concepts and guidence for use for Course on Explosion Prediction and Mitigation", TNO Prins Maurits Laboratory, (2004).