Overpressure Predictions by the MEM and the Baker-Strehlow-Tang Blast Curves for the SRI H_2 Explosion Test in the Open Space

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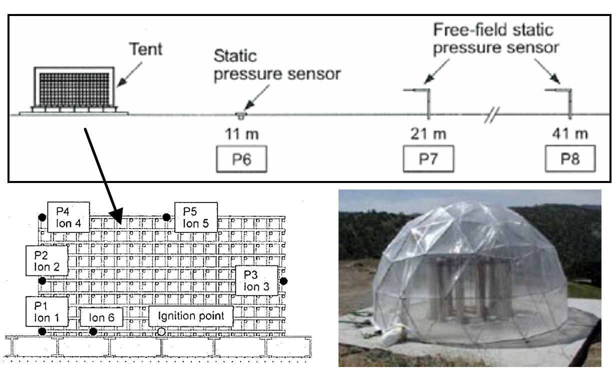
1. Introduction

A safety distance between a Very High Temperature Gas-Cooled Reactor (VHTR) and a hydrogen production facility is usually determined based on the maximum overpressure under the assumption of a H_2 explosion accident [1]. If the overpressure due to the H_2 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 Multi-Energy Method (MEM) and the Baker-Strehlow-Tang blast curves (B-S-T blast curves) are widely used because they can cover from a deflagration to a detonation [2,3]. However, they were mainly validated for a hydrocarbon gas explosion [2,3]. Thus, a validation work should be performed against the H2 explosion test data [4] to apply the MEM and B-S-T curves for the H_2 explosion accident.

2. SRI H_2 Explosion Test

The SRI performed a H_2 explosion test in an open space by varying the H_2 concentration, the H_2-Air mixture volume, the ignition energy and the existence of an 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) [4]. The selected test case is $5.2 m^3$ and $300 m^3$ of H_2–Air mixture volume (30 vol. %) with an obstacle under the spark ignition because the overpressure is greatly increased due to the obstacle configuration [1,2].



(a) 5.2 m^3 of H_2 (30%)-Air (b) 300 m^3 of H_2 (30%)-Air

Figure 1. H_2 explosion test facility [4]

3. Prediction Methods of Overpressure

3.1 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. 2) [2]. And the overpressure at a certain location is represented by the combustion energy scaled distance from the explosion of the H_2-Air mixture cloud. However, the MEM has some drawbacks in which it does not correctly predict the peak overpressure at the center region of a H_2 explosion because it can not accurately simulate the overpressure build-up process when the combustion flame passes the obstacles [1].

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

VBR : Volume Blockage Ratio
L_p : Length of the flame path
D : Typical diameter
S_L : Laminar burning velocity (30% H_2 : 2.1 m/s)

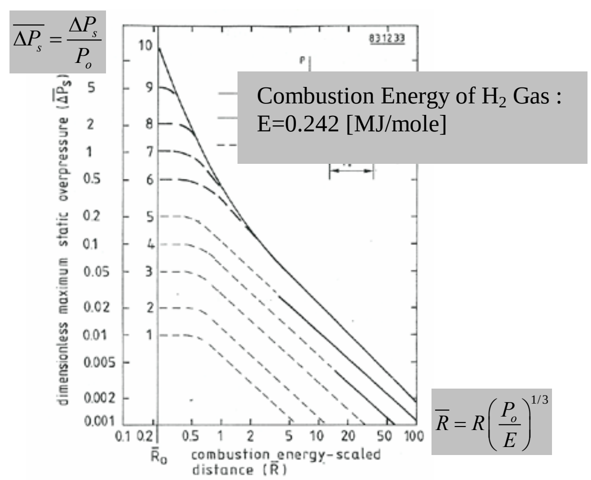


Figure 2. Blast wave overpressure dependent on the distance for a hemi-spherical fuel-air charge on the earth's surface (P_o : ambient pressure) [2]

3.2 Baker-Strehlow-Tang Blast Curves

In order to select a proper B-S-T blast curve over the whole curves (Fig. 3), a flame speed value (M_f) is calculated by using the relation (Eq. (2)) of the peak overpressure measured (P_{max}) in the test and the flame speed. And the overpressure at a certain location from the explosion cloud can be determined by using the combustion energy scaled distance along the selected blast curve by the obtained flame speed. However, the predictions by the B-S-T blast curves may not be accurate if the flame speed is changed into the combustion wave propagation [4].

$$\frac{P_{max}-P_o}{P_o}=2.4\frac{M_f^2}{1+M_f} \qquad (2)$$

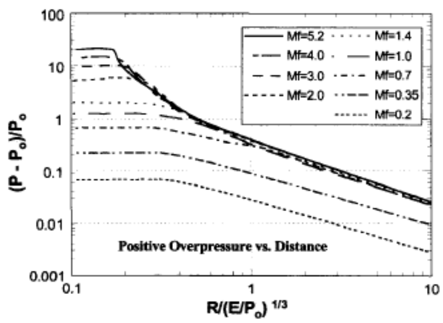


Figure 3. Positive overpressure vs. distance for various flame speed [3]

3.3 Comparison of Prediction Results with Test Result

The predicted overpressures by the MEM and B-S-T blast curves (Fig. 4) show good agreement with the test data over the whole range except the tent region. But, the predicted overpressures inside the tent region by the MEM and B-S-T blast curves are 10~20% lower than the measured overpressure in the test. The main reason may be explained that MEM and B-S-T blast curves were developed and validated based on the hydrocarbon explosion data. When comparing the H_2 and CH_4 explosion test results [4,5], the overpressure magnitude of the H_2 explosion may be increased due to higher H_2 gas temperature and flame speed than those of the CH_4 explosion.

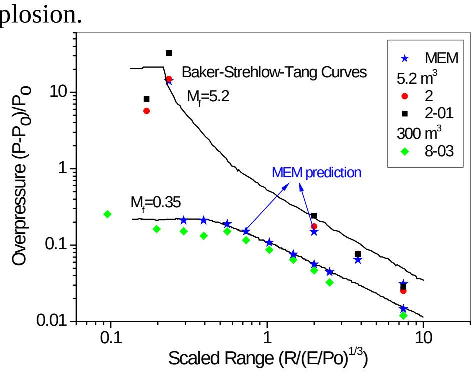


Figure 4. Comparison of Test Results with the MEM and B-S-T Blast Curves predictions

However, the calculated peak pressure by Eq. (1) in the MEM for the different obstacle configuration (Fig. 1, (a) and (b)) is reasonable because it has the term of "L_p/D" which explains the combustion flame acceleration due to a turbulence generation by the obstacle. Whereas, the B-S-T blast curves don't have the estimation method for the maximum pressure of the gas cloud explosion [3]. In this comparison work, the measured overpressure value was used to obtain the flame speed. And also, the B-S-T blast curves have a weakness point where it doesn't predict well the overpressure if the flame speed value is varied as the combustion wave propagates [4].

4. Conclusions and Further Research

As the result of a comparison of overpressures by the MEM and B-S-T blast curves with the H_2 explosion test data, it was found that the predictions by MEM are better than the ones by B-S-T blast curves because the MEM has the reasonable peak overpressure equation for the H_2-Air mixture cloud, which can be applied into a various obstacle configuration. However, the overpressure build-up process during the combustion wave propagation into the obstacle geometry is not represented in the MEM. And also, the MEM could not be applied for the explosion without the obstacle geometry because it does not have the peak overpressure equation for non-obstacle explosion. Therefore, it is judged that the peak overpressure equation for non-obstacle should be developed to prepare a various H_2 explosion accident scenario in the VHTR.

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