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Study of Concepts of Blast Analysis of a Building in Petrochemical Facilities

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Abstract: Process plants in petrochemical industry handle hydro carbons and other fuels that can produce accidental explosions. Here, the vapor cloud explosion is the most commonly observed. Peak side on overpressure, impulse and time period of blast wave are the basic parameters required for defining the blast load.
Technological structures is refinery are generally unmanned structures and need not to be design for resisting blast. Refinery is operated to control buildings and substations; hence these structures are occupied continuously. This makes these structures extremely important and we shall design the same for resistant blast.

Keywords: Dynamic Pressure, Blast Wind, Clearance Time, Impulse, Shock Wave Front, Transit Time.

I. INTRODUCTION

Petrochemical facilities handle various hydrocarbons which may lead to the explosions in certain cases. These days demand of the hydrocarbons has increased drastically and to meet this demand petrochemical plant has increased in size. This increases the risk of accidental explosions. Such explosions have demolished plant buildings, in some cases resulting in substantial personal casualties and business losses.This calls for the requirement to design some of the plant buildings for resisting blast. Such requirements of the building are greatly influenced by the factors of distance from blast source, criticality of the function, and the expected occupancy. This paper covers the general considerations pertaining to the design of plant building to resist the effects of accidental explosions in petrochemical plant, necessity, type of explosion, blast parameters and blast loadings on structure.

Necessity of blast resistant design

It is very uneconomical to design every plant building to resist blast whose possibility of occurrence is very less. Main intention in blast resistant design of to save the life of persons working in plant complex. Generally petrochemical plants are unmanned and most of the operations are controlled through control buildings and substations. Hence, these use to be continuously occupied by the operations personnel. Further,
during blast these buildings may fall on the persons residing inside the building. Thus these buildings itself become hazard for them.

Important Definitions:

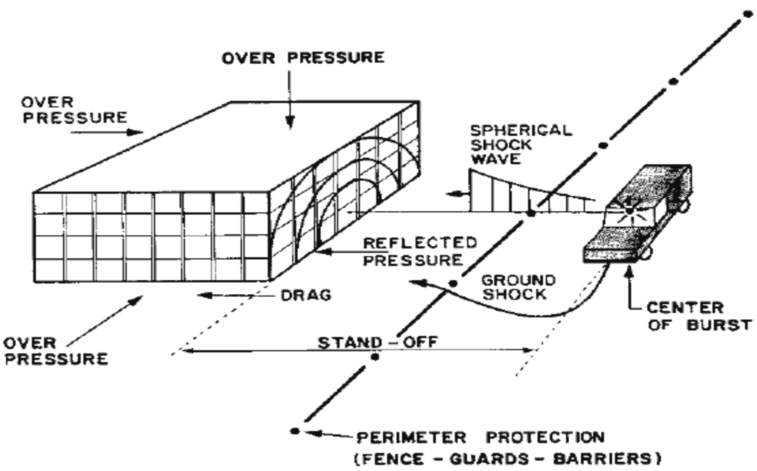

Fig no.1 Blast Loads on Buildings.

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Blast Wind - It is the moving air mass along with the over-pressures resulting from pressure difference behind the shock wave front. The blast wind movement during the positive phase of the overpressures is in the direction of shock front propagation.
Clearance Time - This is the time in which the reflected pressure decays down to the sum of the side on overpressure and the drag pressure.
Decay Parameter - It is the coefficient of the negative power of exponent governing the fall of pressure with time in the pressure-time curves.
Drag Force - It is the force on a structure or structural element due to the blast wind. On any structural element, the drag force equals dynamic pressure multiplied by the drag coefficient of the element.
Ductility Ratio - It is the ratio of the maximum deflection to the deflection corresponding to the elastic limit.
Dynamic Pressure - It is the pressure effect of air mass movement called the blast wind.
Ground Zero- It is the point on the earth surface vertically below the explosion.
Impulse - This has a sudden, almost instantaneous rise in pressure above ambient atmospheric conditions to a peak free field (side-on or incident) overpressure. The peak side-on overpressure gradually returns to ambient with some highly damped pressure oscillations. The results in a negative pressure wave following the positive phase of blast wave.

Pressure Wave

This has a gradual pressure rise to the peak side-on overpressure followed by gradual pressure decay and a negative phase similar to that for a shock wave.

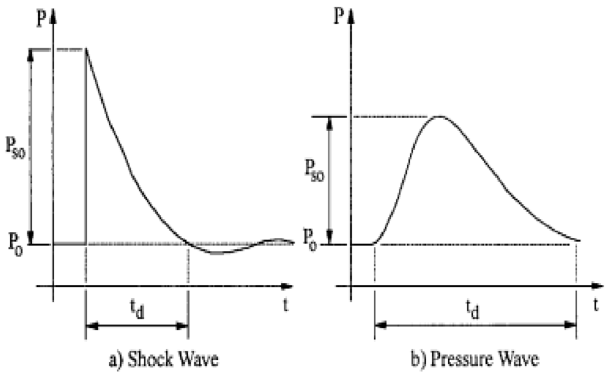

Fig No. 2 : Characteristics of Blast wave

The negative phase of a shock or pressure wave is usually much weaker and more gradual than the positive phase, and consequently is usually ignored in blast resistant design.
In figure 2, the time over which the blast wave overpressure lasts is referred to as the positive phase duration, or simply duration. The area under the pressure-time curve is the impulse of the blast wave.

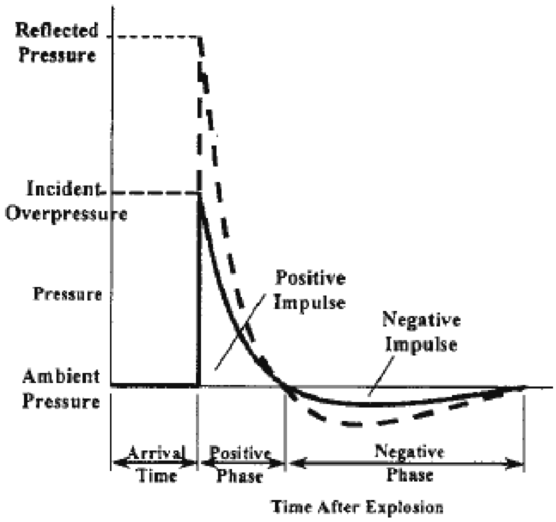

Fig No. 3 : Characteristic Shape of Blast Wave

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I_o =0.5 P_{so} t_d, for a triangular wave …………………………………
=0.64 P_{so} t_d, for a half –sine wave
=c P_{so} t_d, for an exponentially decaying shock wave
Where,
c = a value between 0.2 and 0.5 depending on P_{so}

Blast Loading on Building

To design a blast resistant building, the design engineer first has to determine loads on the buildings as a whole and on each individual structural component such as walls, roofs, frames, etc. from the free field blast overpressure usually provided by the facility owner. To establish these loads, the design engineer should understand the interaction of the propagating blast wave with the building.

When a blast wave strikes a building, the building is loaded by overpressure and drag forces of the blast wave. The interaction between the blast wave and the structure is quite complex as shown in figure 6. For the purpose of design, the resulting blast loading can be simplified based on the idealized shock wave. The blast wave in figure 5 shown travelling horizontally left to right. However, depending on the location of potential explosion hazards relative to the building site, the blast could strike the building from any direction and may, in the case of an elevated explosion source, slant downward towards the building. Depending on its distance and orientation, relative to the blast source, the building and its components will experience various combinations of blast effects (reflected overpressure, side-on overpressure, dynamic pressure and negative pressure). Based on the owner specified side-on overpressure and duration, the design engineer can determine the blast loads for the various components of the building.

Front Wall Loading

The walls facing the explosion source will experience a reflected overpressure; the reflected overpressure amplification of the blast wave depends on the angle of incidence α, and on the rise-time t_r, of the side on overpressure pulse. For design purpose, the normal shock reflection conditions (α=0, t_r =0) should be assumed unless the specified design explosion scenario dictates otherwise. However, in some cases oblique reflection (about 30 to 60 deg) may be critical to the overall building because the full reflected overpressure could load 2 adjacent sides of the building. The reflected overpressure decays to the stagnation pressure Ps, in the clearing time t_c, as defined below and illustrated in figure 7.

$P_s = P_{so}+C_d Q_o$ ……………………………………………

$t_c = 3S/U < t_d$ ……………………………………………

Where,

S- Clearing distance, the smaller H, or B/2
H-building height
B-building width

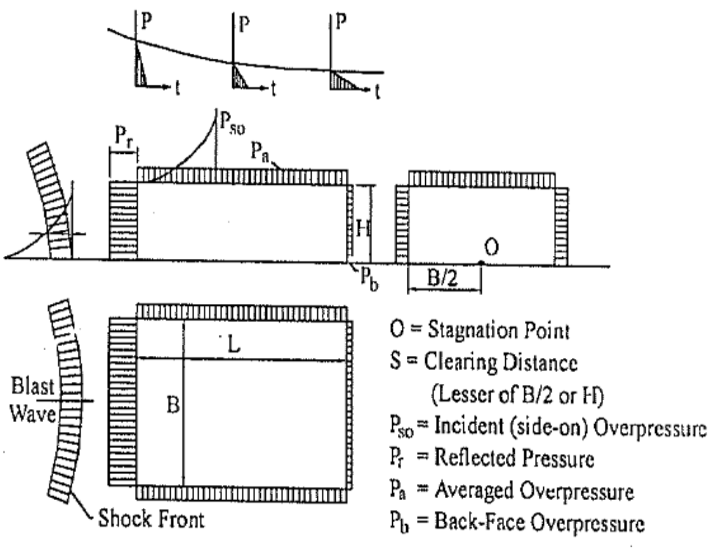

Fig No. 6 : Blast Loading General Arrangement for a Rectangular Building

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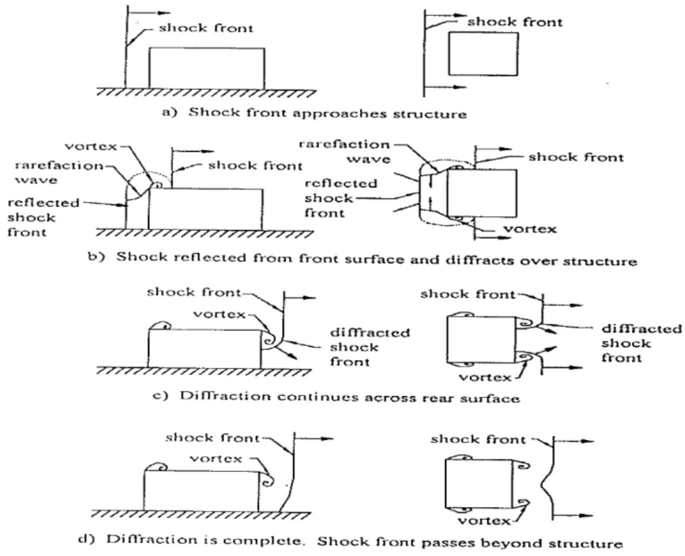

Fig No. 7 : Schematic of Blast Wave Interaction with a Rectangular Building

In order to use the dynamic response charts based on a triangular shaped load, the bilinear pressure-time curve as shown, can be simplified to an equivalent triangle.

$I_w = 0.5\,(P_r - P_s)\,t_c + 0.5\,P_s\,t_d$ …………………………….

The duration, Tc, of the equivalent triangle is determined from the following equation

$t_c = (2\,Iw) / Pr = [(t_d - t_c) / Pr] + t_c$ ……………………………………………

Conclusion

- This study have helped in understanding the basics of blast, which proved useful in all considerations made in design of blast resistant building.
- Getting basic knowledge of blast loading and their respective forces.
- Understanding the detail concept of blast loading and load mechnism with respect to structure.

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