Blast Resistant Doors Monograph

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Overview

Ever since the invention of gunpowder we've had to worry about adequate protection against devastating blasts. No matter whether the blasts were accidental-from contact of the tiniest spark with some volatile material-or part of a controlled series of research-associated or production-associated operations, the tragic loss of lives and facilities simply had to be reduced.

Except for its staggering results, very little was known about the nature of explosions until the mid 1950's. Now we know a great deal, and we learn more every day it seems. There's a growing mountain of knowledge about the reaction of various materials under various situations; an entire generation of engineers has specialized in developing means for securing adequate protection; today it is possible to drastically reduce loss of life and damage to facilities under blast conditions.

But sadly, the new knowledge and ability has grown more rapidly than the awareness that it exists. So we see hazardous facilities being designed even today without safety provisions which could have been incorporated easily and at relatively little expense.

Now a discussion of blast resistant doors becomes unavoidably technical, and there are a few items and concepts one doesn't encounter everyday. But when explosions can be expected to occur in a facility there is no way to secure adequate protection without incorporating state-of-the-art equipment, so it is important for designers to understand the basics of today's protection.

For instance, the first and most important criterion of blast resistant door design is to determine whether one really has a blast resistant door application. Lets talk about that for a moment.

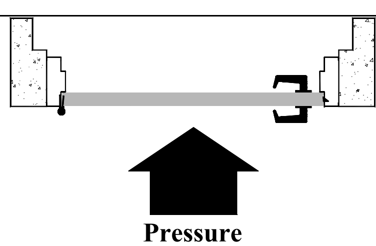
The terms "blast resistant door" and "pressure resistant door" are used sometimes as though they were synonymous, which they are not. Each is a separate design task and warrants being treated as such. To specify a blast resistant door where a pressure resistance door is required, or vice versa, can be extremely hazardous.

Pressure Resistant Doors

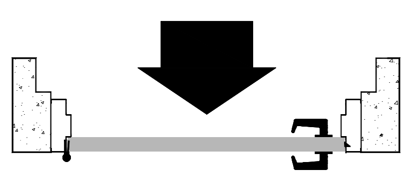
A typical example of a pressure resistant door application is found in an air lock where negative or positive air pressure exists for control purposes such as in a clean room. A pressure resistant door is normally defined as: "A door where a positive or negative pressure load (above or below atmospheric pressure) is applied over a long duration (expressed in seconds, minutes, or longer), and where the pressure loading decay (is removed from the door) over a long duration."

With durations of such length the loads can be considered static, and the doors can be designed accordingly. The dynamic response of the door is not considered for this type of loading.

If the door is positioned so that the pressure loading acts to seat the door into the frame against the stops, no consideration need be given to the hardware other than it be sufficient to support the weight and size of the door.



Seating Load



Unseating Load

However, if the pressure acts to unseat the door away from the stops, then the hardware must be capable of resisting all loads imposed by the pressure as well as radial and thrust loads. This is an important consideration in the design of both pressure resistant and blast resistant doors, and it has lead to the design of special hinges and locking devices. [NB]

Blast resistant doors, on the other hand, are normally designed to resist a high pressure shock front of very short durations (expressed in milliseconds) which expands outward from the center of the detonation, with intensity of the pressures decaying with distance and as a function of time: The exception to this is for nuclear blasts where long durations (in seconds) are common.

When a detonation occurs, there is a violent release of energy in a gaseous medium. This gives rise to a sudden pressure increase in that medium . The pressure disturbance is termed a "blast wave", and it is characterized by an almost instantaneous rise from the normal or "ambient" pressure to what we call a "peak incident over-pressure".
This pressure increase - or "shock front" - travels rapidly from the burst point with a velocity which will be diminishing but which will remain in excess of sonic velocity of the gaseous medium.

The nature of the shock wave varies according to several factors, not the least of which derive from the type of "burst" experienced. We can classify the bursts into "free air bursts", "air bursts", "surface bursts", "partially confined", and "confined". In all types of bursts the door will be engulfed by the shock pressures as the wave front impinges on the structure. The magnitude and distribution of the blast loads on the door, rising from these pressures, are a function of the explosive properties.

These consist of:
- ❖ Type of explosive material;
- ❖ Its energy output;
- ❖ Weight of the explosive;
- ❖ Location of the explosive relative to the door.

The blast wave pressure is also increased due to reflection and reinforcement by its interaction with the ground area or the structure in which the door is installed.

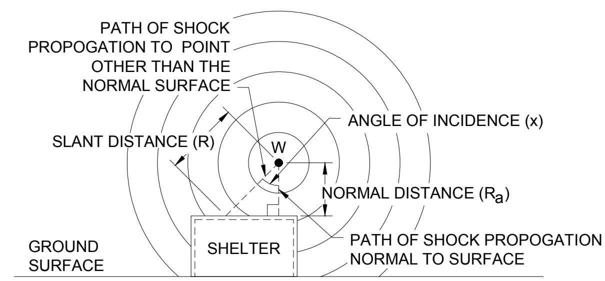
[NB] See separate monograph on Pressure Resistant Doors which covers this subject in greater depth.

Free Air Burst

When a detonation occurs adjacent to - and above - a protective structure, and so near that no amplification of the initial shock wave occurs between the explosion source and the door, then the blast loadings acting on the door are defined as "Free air burst blast pressures".

As the pressure wave moves radically away from the center of the explosion, it contacts the door and - upon contact - the initial wave pressures are reinforced and reflected.

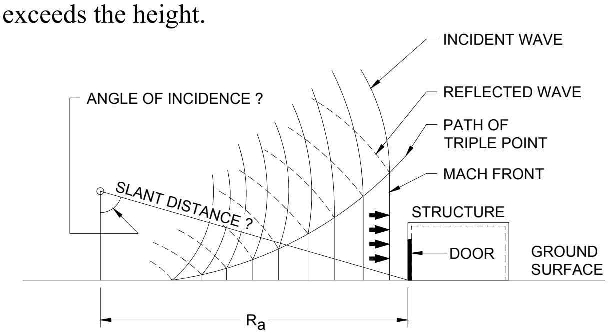
The variation of the pressure on the door surface is a function of the "angle of incidence": The angle of incidence is formed by a line which defines the normal distance between the point of detonation and the door, and a line which defines the path of shock propagation between the center of the explosion and any other point of the structure in which the door is located.



Air Burst

An "air burst" blast environment is produced by detonations which occur above the ground surface and at some distance away from the door, so that the initial shock wave propagating away from the explosion impinges on the ground surface prior to its arrival at the door.

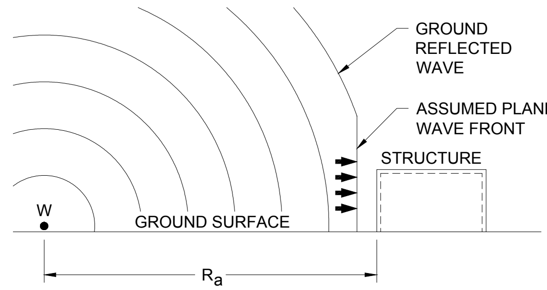
As the blast wave continues to propagate outward, a front known as the "mach front" is formed by the interaction of the initial wave and a reflected wave which resulted from reinforcement of the incident wave by the ground. The height of the mach front increases as the wave propagates away from the center of the detonation. This increase in height is referred to as the path of the triple point and is formed by the intersection of the initial reflected and mach waves. A structure is subjected to a plane wave (uniform pressure) when the height of the triple point exceeds the height.



Surface Burst

A charge located on the ground surface - or very near to it - is considered to be a "surface burst". In a surface burst, the initial wave of the explosion is reflected and reinforced by the ground surface to produce a reflected

wave. Unlike the air burst, the reflected wave merges with the incident wave at the point of detonation. This forms a single wave similar in nature to the reflected wave of the air burst, but essentially hemispherical in shape.



Partially Confined Explosions

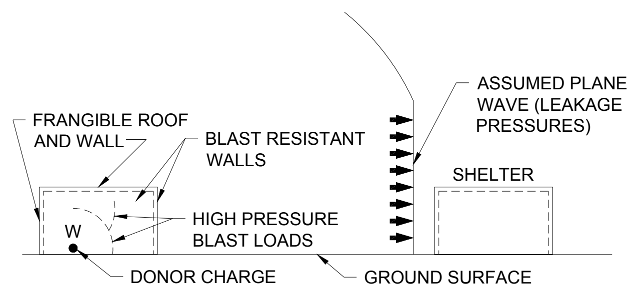
When an explosion occurs within a structure , the peak pressures associated with the initial shock front are extremely high and are amplified by their reflections within the structure. Additionally, the accumulation of gasses from the explosion exert more pressure and they increase the load duration within the structure. The combined effects of both pressures can destroy a structure unless adequate venting is provided.

The use of cubical type structures with one or more surfaces either sufficiently frangible or open to atmosphere will normally provide adequate venting. This type of structure permits a blast wave from an internal explosion to spill over onto the exterior ground surface in a condition known as "leakage pressure".

Exterior, or leakage pressure loads result when the detonation occurs near the ground surface and behind an obstruction which interferes with the shock wave before it reaches the door.

Interior, or high pressure loads result when the detonation is located within - or immediately adjacent to - a structure, and blast pressures are amplified due to multiple reflections by the structure as a result of its closeness to the explosion. The pressures reflected and reinforced within the structure are referred to as "interior shock front pressures", while those pressures accumulated from the gaseous products of the explosions are identified as "gas pressures".

The term "frangible" pertains to those elements of a structure whose strength and mass or anchorage are sufficiently weak to minimize the amplification of the shock front pressures and reduce confinement of the explosive gases by breaking up, falling away, or opening slightly to provide relief from
pressure.



Unconfined Explosions

We previously defined free air bursts, air bursts, and surface bursts. Of those categories, air bursts are seldom encountered and a free air burst is the least likely to occur.

Free air burst loads: For this type loading the blast wave propagates away from the center of the explosion, striking the door without intermediate amplification of the initial shock wave.

Air burst loads: For this type loading the explosion is located at a distance away from and above the door so that the ground reflections of the initial wave occur before the blast wave reaches the door.
Surface burst loads: For this type loading the explosion is located close to - or on - the ground so that the shock wave is amplified at the point of detonation due to ground reflections.

Protection Categories

Protection afforded by a door and the facility in which it is installed is subdivided into four protection categories:

Class A: Provides life safety; protects personnel from fragments, falling portions of a structure or equipment; attenuates blast pressures and structural motion to a level consistent with safety requirements.

Class B: Protects equipment and supplies from fragment impact, blast pressures, and structural motions; protects against uncontrolled releases of hazardous materials including toxic chemicals, radioactive materials, biological materials, and similar items.

Class C: Protects against communication of detonation by fragments and high blast pressures.

Class D: Protects against mass detonations of explosives as a result of sympathetic detonations produced by communication of detonation between two adjoining areas.

Fragmentation

In some situations, primary fragments from cased explosives can be, depending upon their mass, the controlling factor in the design of a blast resistant door. The mass velocity characteristics of the primary fragments also depend upon the properties of the explosive.

Heavy high velocity primary fragments may penetrate a door, depending upon its thickness and other characteristics, while lightweight fragments seldom achieve penetration. However, both light and heavy fragments may ricochet into protected areas and cause injury to personnel, damage equipment, or detonation of other explosives.

For protection against primary fragments, a sufficient structural thickness must be provided to prevent penetration.

Explosive Materials

Explosive materials are classified according to their physical state, which consists of solids, liquids, and gasses.

Solid explosives are primarily high explosives. However, other material such as chemicals and propellants also can be classified as potentially high explosive materials. The blast pressure environment produced will vary among different solid explosive materials, and can also vary for a particular material. The blast effects of solid materials (which consist of the blast pressure impulse, durations, and other effects) have been well established and charted and are often stated as to their equivalence in pounds of TNT.* See Bibliography notations.

The explosive properties of such materials determine limitation of the detonation process and, thereby, result in either high order or low order detonation. With high order detonation the process is generally compete and results in a maximum pressure output for any given type and amount of material. If the detonation is incomplete, a large quantity of explosives is consumed by deflagration (a sudden and violent combustion), thus reducing blast pressure.

Unlike high explosive materials, other solid, liquid, and gaseous explosive materials exhibit variations of their blast pressure output due to the fact that an explosion of these materials in many instances is incomplete, with only a portion of the total mass involved in the detonation process. The remainder of the mass usually is consumed by deflagration with a large amount of the material's energy being dissipated in thermal energy.

Designing Blast Resistant Doors

Now if all this information seems complicated and confusing it's because the entire task of designing a blast resistant door system is complicated and confusing. And if the topics discussed appear to warrant much deeper discussion, it's because a complete treatise on blast resistant door systems would fill many volumes.

There is no such thing as a "stock or standard" blast resistant door, simply because there are no stock blast situations to protect against. Each installation invariably presents new challenges, new parameters of explosive and distance, and combined hazards from inside and out. True expertise in designing successful blast resistant door systems derives only from years of experience and considerable special training for the entire design/build team.

The variables are so numerous that highly sophisticated computer programs are used today to arrive at practical solutions. And only the most competent and qualified specialists can be expected to turn the solutions into operating reality. Since these solutions frequently impinge on other structural components of a facility, it is wise to tackle preliminary design of the blast resistant door systems early in the design stage of any project where their need will exist.

While blast resistant door systems may be required in many high technology industrial buildings, as well as military applications, project designers of those buildings cannot be expected to have the specialized knowledge needed to completely plan for an adequate blast resistant installation. So it is important to establish an early relationship with a reputable blast resistant door manufacturer to avoid expensive redesigns and project delays.

Data the manufacturer's will need start with the type and amount of explosives involved, the type blast to be anticipated, and the construction in which the blast resistant door systems must be located. These three are only the starting point; the rest is up to the specialists.

But if you want to be truly helpful in design of the door system, determine all pertinent information needed to fill in the blanks on the following list. You will speed up the process if you do.

Seven Questions to be Considered and Answered

1.0 Is design analysis to be ○ dynamic or ○ static?

2.0 If static analysis, the maximum blast loading that the door will be subjected to in ______ psi or ______ psf.

3.0 If dynamic analysis, one of the following combinations of data must be furnished, using these definitions.

W is known load in equivalent pounds, tons, Ktons, or Mton of TNT.

r is the slant distance from the explosion in feet.

T_o is the duration of the positive pressure in seconds or milliseconds.

$P^P fa$ is peak free air pressure in psi.

PsP is peak incident pressure (reflected pressure in psi)

3.1 W __________, r __________

3.2 W __________, T_o __________

3.3 W __________, r __________, T_o ____________

3.4 W _________, P^Pfa _________, T_o ____________

3.5 T_o ____________, P^Pfa ____________

3.6 r ____________, P^Pfa ____________

3.7 r _________, P^Pfa __________, T_o ____________

3.8 PsP ____________, T_o ____________

3.9 PsP ____________, r ____________

3.10 PsP __________, r __________, T_o ____________

3.11 W __________, P^Pfa _________, r ____________

4.0 If dynamic analysis, the following data must also be provided:

4.1 Angle of incidence in degrees (if this data is not available, assume 0° angle, which provides maximum pressure)

4.2 If atmospheric blast, specify if air __________ or surface burst ____________.

4.3 If confined or partially confined blast, furnish sketch showing dimensions or room or test cell including height, locations of door and explosion, confined gas pressure in psi and duration of gas pressure in seconds __________ or milliseconds __________.

5.0 The following data is required for either dynamic or static analysis:

5.1 Direction of initial blast force:

5.1.1 To seat door ____________.

5.1.2 To unseat door ____________.

5.2 Is plastic (permanent) deformation permitted? (not permitted for static design).

5.2.1 Ductility ratio ____________ or

5.2.2 Total permissible deflection ____________ or

5.2.3 Degree of rotation ____________.

5.3 Allowable elastic deflection ____________. Unless otherwise specified, doors are normally designed with deflection limited to L/60 for all components.

5.4 Doors must be designed for 100% rebound pressure when static analysis is used. For dynamic analysis door will be designed for rebound as determined by the dynamic response.

6.0 What level of blast protection is required: ○ A, ○ B, ○ C or ○ D?

7.0 If additional requirements such as fire rating, security, shielding or acoustical performance are required please list.

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