Pressure Resistant Doors Monograph

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Overview

In the anti-hazard door market, protection against the problems and dangers created in the event of an accidental pressure leak can only be prevented by heavy metal working in conjunction with the proper seals or gaskets. Unlike hazards such as fire or forced entry, where warning by electronic sensing devices provide time for evacuation or response by a counter force. pressure leaks occur instantaneously and require physical protection. Heavy metal pressure-resistant doors, as made by Overly Manufacturing, provide the necessary protection for personnel and/or equipment against these types of incidents.

In a high hazard exposure facility, there are many facets to consider — primarily the structural design of the building itself and the walls, which are the static components of the structure. On the other hand, pressure-resistant doors are dynamic components because of their usage; obviously, they are another facet that must be given serious consideration when developing specifications. In almost every case, extra-heavy-duty hardware of special design is required for pressure-resistant doors where leakage rates must be restricted. This monograph will discuss the basic considerations involved in the design and application of Overly Pressure-Resistant Doors and Sealing Systems.

Defining Pressure-Resistant Doors

The protection and control of our built environment continues to be of increasing interest and importance. A key component of that protection and control are pressure-resistant doors and sealing systems and their surrounding framing and hardware.

The need for such doors and seals has been acknowledged for generations by engineers and architects. Their importance even to homeowners was dramatized by energy conservation awareness some years ago when it was shown that, in a 25 mile an hour wind, an off-the-shelf exterior 3'0" x 7'0" door and frame without weather-stripping will allow more than 500 cubic feet of outside air to come in each minute.

It is necessary for both specifiers and designers to make a distinction between pressure-resistant doors and "con trolled leakage" doors. An installation may require a pressure-resistant door but not necessarily require a gasketing system. For instance, a door subjected to tornado or hurricane force winds, tsunamis (tidal waves), flooding, or pressures generated by ruptured steam or air lines may be required to withstand those pressures and stay in place, but not be required to contain or restrict the flow of the pressurizing medium.

Conversely, the pressure acting against a door may be low (such as in the case of the residential door mentioned above), but a gasketing system is used to keep out the cold or heat, or to prevent the transmission of noxious fumes or liquids.

Weather-stripping isn't new, of course; our ancestors stuffed rags in the chinks around the door to stop drafts or piled sandbags in front of openings to divert flood water. These were adequate solutions to normal, low-level differential pressures. Both approaches worked in household situations, although each made opening and closing the door difficult and time-consuming.

But in the mid-nineteenth century, non-residential needs for pressure-resisting doors began to emerge, and their application has continued to increase ever since.

As a separate and distinct discipline, pressure-resistant doors probably can be traced to the replacement of wood hulled ships with those of iron and steel. While a stoved wooden hull was a matter of concern to the captain and crew, depending on how heavily the vessel was laden, steel hulls had to be compartmentalized with bulkheads and watertight doors to prevent the ship from sinking.

Today, later variations of the basic bulkhead door, originally designed for ships, can be found in nuclear power plants, waste water treatment plants, control rooms for hydroelectric dams or, in some cases, substituting for sand bags as a flood barrier gate.

Similarly, the need has grown for doors to withstand air or gas differential pressures. Office buildings are constructed as tight boxes to accommodate the HVAC systems. Stair wells are isolated and pressurized to prevent the spread of flames up the stairwell and to control smoke while providing egress from the building during a fire. Hazardous fume areas must be isolated. Manufacturing areas must be protected from airborne contaminants. Workers must be protected from the effects of ruptured steam or air lines. The list goes on.

Pressure-Resistant vs. Blast-Resistant

All too often there is confusion as to the difference between pressure-resistant doors and blast-resistant doors. The terms are sometimes used synonymously, which can ultimately cause not only design problems but create a hazardous environment as well. Even though extremely high pressures may be exerted on a door, the phenomenon is different than those forces generated in an explosion or blast. A blast door may be pressure-resistant, but a pressure door is not, necessarily, blast resistant.

A pressure-resistant door can be defined as a door where positive or negative pressure loading is applied over a relatively long duration — expressed in seconds, minutes, or longer — and the pressure loading is released from the door over a long period of time.

A blast-resistant door, on the other hand, is normally required to resist a high pressure shock front of very short duration — usually expressed in milliseconds except in the case of nuclear blasts. That front expands outward from the center of the detonation and the intensity of the pressures decay with distance as a function of time. (The exception is a nuclear blast where long durations — expressed in seconds — are common.)

Thus, in general, pressure-resistant doors withstand STATIC pressure loadings, whereas blast-resistant doors withstand DYNAMIC loadings. An extensive analysis of blast phenomena is contained in our monograph "Blast-Resistant Doors," copies of which are available from Overly.

There are cases where doors must withstand both pressure as well as blasts. Two cases in point:

- ❖ A major foreign airline, concerned about potential bombs hidden in luggage, built a drive-through inspection chamber 58 feet long. Carts of luggage and air freight are brought in, the doors closed and sealed, and negative pressures are generated to simulate flight up 60,000 ft. altitude and any other intermediate levels at which a plane might fly during its trip. Some sophisticated bomb mechanisms can detonate when a plane reaches an assigned altitude. Therefore these doors must be pressure-resistant as well as able to withstand a blast in order to conduct the test.

- ❖ Another case involved the establishment of a facility for disarming and detoxifying leaky nerve gas canisters at the Rocky Mountain Arsenal in Colorado. In order to protect against a potential release of lethal gas into the atmosphere in the event of a leak, a negative pressure is maintained within the processing area, while blast resistance is required in the event that one of the explosive charges accidentally detonates during the dismantling process.

As a rule, however, pressure-resistant doors are designed utilizing static analysis, while blast-resistant design almost always requires dynamic analysis, a quite different procedure.

Factors in Pressure Door Design

Despite the differences between water and liquids and air or gases, there are a number of common characteristics in pressure-resistant door design. Seven general factors should be considered in pressure door specifications:

- ❖ Operating pressures and how they are applied to the door/frame/seals system (i.e. whether they tend to seat—and therefore more tightly seal — or unseat the door in a closed position);

- ❖ Whether the pressure is applied by gases or liquids (normally air or water);

- ❖ The acceptable leakage rate, if any (note: if the specifications permits no — "zero" — leakage, then very sophisticated and costly seals must be employed);

- ❖ The environmental conditions such as detrimental chemicals or solvents, temperatures, and radiation exposure;

- ❖ Speed of opening and frequency of use in terms of opening and closing cycles (per hour, per day, per month or per year— this may affect the choice of hardware);

- ❖ Ease of maintenance or replacement (door, hardware, and seal components); and

- ❖ Anticipated service life — in years — of each of the components and a determination as to whether the doors are to be operable after an emergency over-pressure incident.

In some cases conditions exist where there is a need to withstand not only normal pressure differentials but also emergency pressure loadings as well. Such a case might be in a controlled-environment factory located in an area of known or suspected tornado activity or where rupture of steam lines might occur.

A door for such an installation might be considered a "pressure/overpressure" unit. Complicating the design for such a door is the consideration of the allowable leakage rates under either condition. These considerations will be discussed in detail in the following section.

The first element determining door design is the amount of pressure to be exerted upon the opening.

When pressure-resistant doors are expected to withstand only one-direction loading, it is a relatively easy job for the door engineer to design a door and frame unit of sufficient strength and stiffness to withstand the force.

Typically, it is less costly to produce a door when the pressure tends to seat the door against the frame (and seals, if so equipped). This approach permits the use of lighter-duty hardware since the force is distributed evenly along the periphery of the frame instead of being concentrated only at the hinge and latch points.

Pairs of hinged doors present a more complicated problem. An astragal or stiff mullion member and coordinator may be required because the periphery of a pair of doors is greater than a single door, and there are twice the number of hinges and latching devices.

Horizontally sliding pressure-resistant doors are normally constructed and installed so that pressure will seat the door against the frame. In those instances where the pressure loading is reversed during plant operation, auxiliary locking/latching mechanisms may be required.

Watertight Doors

Bulkhead-type doors, fabricated with stiffeners and reinforcements, resist specified water pressure loadings. The most advanced engineering of these doors, which must be both reliable and give maintenance-free service, includes continuous silicone gaskets that are built into the coaming frame.

Watertight doors are made of steel or corrosion-resistant metals such as aluminum or stainless steel. Because of the possibility of corrosion, they should have stainless steel or bronze operating mechanisms; they should also have protective coatings. Watertight doors may also need to be designed for seismic loadings.

In situations where the door may be used frequently, watertight doors require special, quick-acting latching mechanisms. For a more detailed discussion, see the section on "Hardware" below.

Considerations in Seal Selection

The controlling factor in gasketing or sealing for pressure-resistant doors is the permissible leakage rate, which is a function, in part, of the anticipated pressure differential and its loading on the door faces. The environment in which the seals must operate is often the determining factor with regard to material of choice for the gaskets or seals and can be a major consideration.

Controlling leakage around a door where a constant pressure acts only to seat the door against the seals is a far simpler engineering problem than when pressure is expected to fluctuate from one side to the other. In the latter case, hinges and latching mechanisms must be strengthened to the point that the door is literally clamped against the seals.

Most pressure-resistant door applications involve a limitation on the permissible leakage rate; even though in some applications the doors must be truly airtight or watertight with zero leakage for a specified time.

For controlled leakage rates, flap seals of thin flexible elastomeric material may be applied to the door face and, when the door is closed, pressure forces the material to bridge the gap between door and frame. The higher the pressure, the tighter the seal. Flap seals also have been designed for applications where the pressurization fluctuates from side to side.

The particular virtue of flap seals is that there is no requirement to clamp the door against the seal to achieve low leakage rates. Pressurization alone provides the sealing force driving the very flexible seal into the cracks between the door and the door frame. The major drawback to flap seal systems is that, if a leakage rate must be maintained through a broad range of pressures, the gaskets may not be effective at the extreme ends of the range. Different thickness of gaskets are used for different pressures. There is an optimum thickness for various pressure ranges.

In order for other types of seals to be effective, they require clamping devices of various designs to ensure that the door comes in intimate contact with the seal, normally deforming it slightly in the process. Materials include closed cell elastomers, bulb-type elastomers, and solid elastomeric compounds.

Each of the three types have specific advantages and limitations.

- **Closed cell elastomers** deform under relatively low clamping forces and can provide good leak resistance to smoke and other gasses if pressure differentials are not great (within a range of 0 to 20 psi) and temperatures are not extreme.

- **Bulb-type elastomers** are available in a number of formulations to resist elevated temperatures or corrosive or solvent fumes.

- **Solid elastomers** are widely used in watertight doors where extremely high clamping forces are employed. Normally a two-part silicone material is poured in place in a cavity around the periphery and allowed to cure. Because the silicone is installed in liquid form, even minute porosities around the door are filled in.

Depending upon the pressures and frequency of usage, watertight doors may be equipped with individual locking dogs that clamp the door against a "knife" edge on the frame or, for frequent usage, a multiple locking mechanism actuated by a hand wheel driving the appropriate number of wedge-shaped dogs to clamp the door and frame together.

In both cases leakage through the latching mechanisms is controlled or eliminated by the use of packing glands or "0" rings around the shafts that penetrate the door. Yet one other type of gasketing for low- and zero-leakage doors is the inflatable seal. It has been used not only for both watertight and airtight doors but also for flood barrier gates.

(A flood barrier gate is usually an unhinged partial panel that is manually installed in an opening only when a flood is anticipated.) The inflatable seal is also particularly effective if a leakage rate must be maintained over a broad pressure range. The gasket does not lose its effectiveness at the extreme ends of the pressure range.

As its name indicates, an inflatable seal is a fabric reinforced elastomeric compound that when inflated — normally with pressurized air — expands to seal off the space between the door and the frame. Often it is equipped with redundant air or gas emergency supply (via bottle or reservoir; in the event regular air service is interrupted. In flood barriers the seal is applied around the edges to expand against the frame and threshold.

Inflatable seals frequently are specified for zero-leakage doors, particularly when electromechanical latching devices are used. Such an approach eliminates penetrations through the door panel and thus potential areas for leaks.

Environments and Materials

While environmental conditions may be a minor consideration in specifying most pressure-resistant doors, it can become a major factor with many types of controlled-leakage doors. And it may affect not only the door itself but the hardware as well.

It has been found, for example, in watertight and airtight doors for sewage treatment plants, that stainless steel is not the preferred metal because the concentrations of chlorine in parts of these plants tenets to cause pitting. The material of choice in these locations is aluminum. either plain or anodized. with chrome-plated locking dogs. Similarly, in corrosive marine atmospheres. Type 316L stainless steel doors and stainless steel hardware provide the requisite protection against corrosion. Type 316L is preferable to architectural grade 302 or any of the 400 series stainless steels.

A Brief Note on Hardware

Pressure-resistant doors are heavy and. therefore, require hardware that is rugged enough to withstand both the design overpressure and normal usage. More often than not, extra-heavy-duty hardware of special design is required, particularly where leakage rates must be restricted.

Heavy-duty versions of standard builders hardware style hinges and latching mechanisms may provide satisfactory service in low air pressure differential applications. At higher differentials, and in applications where a door is operated frequently, hinges and lock-sets of proprietary design can provide improved service life.

Panic exit bars and lever handles for use with these locking systems must also be designed for heavy-duty use. Proper design is particularly important for panic exit applications because lifesaving considerations are involved. Also, depending on application, pressure-releasing or equivalence or balancing devices may be required.

Hardware for watertight doors, particularly latching/locking mechanisms, is usually made of investment-cast stainless steel for both strength and corrosion resistance.

For doors that are used infrequently, individual locking dogs can provide tight sealing but are cumbersome and time consuming when the unit must be operated.

A preferred solution for watertight doors that are frequently used are multiple bolt mechanisms connected to a geared hand wheel. Some models incorporate an overload clutch to prevent over tightening, while others may have a key-locked hand wheel that prevents unauthorized operation.

Conclusion

When a client specifies a door opening that will seal against pressure, the architect/engineer must contemplate the unit as a complete mechanical system incorporating the door, framing, sealing system, and hardware. A technically competent door manufacturer should be able to satisfy almost any requirement if the performance levels required are clearly stated.

On the next few pages, we have included a checklist for water/liquid tightness and air/gas tightness. Architect and engineers may find it useful to incorporate this data into their performance specifications. The checklist can also be sent to a door manufacturer for review, budget analysis, or questions of supply.

Appendix A: Checklist for Water/Liquid Tightness

1. What is the fluid involved? ______________________________
   Specific Gravity, if not water? ______________________________
2. If water, what contaminants, including organic or inorganic chemicals, may it contain?
   ____

3. What is the anticipated hydrostatic pressure? __________ psi
   Head of fluid in __________ feet?

4. 1. Continuously applied against door? ______________________________

4. 2. Intermittently applied against door? ______________________________

4. 3. Are wave, tidal and/or seismic loads involved? ______________________________
   If so. describe.______________________________

4. 4. Is pressure explosively applied against door? ______________________________
   If so. provide anticipated dynamic loads:
   Flow rate: __________ gpm
   Room dimensions: ______________________________
   Area of orifice: ______________________________

5. If pressures act to both seat and unseat door, provide duplicate information on items above for each face.
6. Is there an acceptable leakage rate? ______________________________
   If so,specify: ______________________________
7. Acceptable test methods:
   1. Hydrostatic Chamber: ______________________________
   2. Chalk Line: ______________________________
   3. Ultrasonic: ______________________________
   4. Soap Bubble: ______________________________
   5. Other (specify): ______________________________
8. Is galvanic or electrical bonding required? ______________________________
9. For operating parts of product, are the following metals: Mandatory (M). Preferred (P), or Optional (O)?
   Stainless Steel: ______________________________
   Aluminum: ______________________________
   Silicon Bronze: ______________________________
10. Accessories:
    1. Integral pump connections: ______________________________
    2. Sight gauges: ______________________________
    3. Hose connect or pass-throughs: ______________________________
    4. Pressure breakers (to relieve or equalize pressure): ______________________________
    5. Expected life of seals: __________ yrs.
    6. Depending upon exposures and pressures, seals can be one of four types indicated below. If any of them are unacceptable, check the the unacceptable varieties:
       solid elastomer
       closed-cell sponge elastomer
       bulb-type pneumatic elastomer
       inflatable pneumatic elastomer
    7. Is compressed air available if inflatable seals are required? ○ Yes, ○ No
    8. Other (specify):

Appendix B: Checklist for Air/Gas Tightness

1. 1. What gas is on the positive pressure side of the door? ____________________
   2. What gas is on the negative pressure side of the door? ____________________
2. 1. What is the pressure on the positive pressure side of the door?
      ________psf ________ in. water gauge or ________ mercury
   2. What is the pressure on the negative pressure side of the door?
      ________psf ________ in. water gauge or ________ mercury
3. Which pressure tends to seat the door? ____________________
   Which pressure tends to unseat the door? ____________________
4. Is pressure loading continuous? ____________________
5. 1. Will pressure differentials ever be applied against opposing faces of the door? ○ Yes, ○ No
      If so, describe applicable pressures: ____________________
   2. Will normally negative pressure side of door ever become the positive pressure side of the door through pressure differential transfer? ___________. If so, provide data on pressures, frequency, etc. ____________________
      ____
6. What is permissible leakage rate? ___________ cfm at ___________ in.
   water gauge or ___________ psi per linear foot ___________ of perimeter seal.
7. Measurement test method:
   1. Soap Bubble: provide pressure ____________ time period _________________
   2. Halogen Leak Test: provide pressure ____________ time period ____________
   3. Smoke Test: ____________________
8. 1. Expected life of seal? ____________ years.
   2. How many spare sets are required? ____________________
   3. Depending on exposures and pressures, seals can be one of four types listed below. If any of them are unacceptable, place a check in the box next to the unacceptable varieties:
      ○ solid elastomer
      ○ closed cell sponge elastomer
      ○ bulb-type pneumatic elastomer
      ○ inflatable pneumatic elastomer
9. Is compressed air available if inflatable seals are required? ○ Yes, ○ No

Appendix C: Certificate of Compliance

Finally, the Architect / Engineer should expect his client to be provided with a "Certificate of Compliance" by the door manufacturer indicating test results performed on the required product prior to shipment or incorporation into the building structure.
The following is a sample "Certificate of Compliance" provided by Overly Door Company.

Customer: ____________________
Address: ____________________
Title: ____________________
Attention:

Subject: Facility: ____________________
Location: ____________________
Purchase Order No: ____________________
Specification No: ____________________
Overly Job No: ____________________

Pressure Resistance Certification
Reference: Mark No(s): ____________________
Description: ____________________
Pressure: ____________________

We hereby certify that the above referenced mark number(s) have been designed for the pressure requirements of the purchase order and specifications.
Overly Door Company

Name: ____________________
Title: ____________________

Sworn and subscribed before me this ___________________
Day of ________________________, 20________________