FABIG
Fire and Blast Information Group

CATEGORISATION OF BLAST AND FIRE RATED DOORS

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Abstract

Records show that over 50% of all reviewed onshore accidental events include both blast and fire [1]. However, there is currently no standard to assess the resistance of fire and blast doors to blast and fire events occurring sequentially. This paper therefore aims to lay the foundations for bridging the gap between regulatory compliance and fire and blast protection against real accidental scenarios.

This paper describes a new step in the verification of blast and fire doors for industrial facilities by introducing single-sample fire-post-blast tests for doors. Such tests have previously been carried out on panel systems (e.g. by InterDam, Van Dam, SCS) and windows (e.g. by InterDam). However, no successful tests on blast and fire rated doors have been reported until now despite the fact that such tests allow for a more realistic verification of the performance of blast and fire rated doors in the event of an accidental explosion followed by a fire, which is a very likely scenario.

For a typical project where the risk analysis indicates a requirement for protection against fire or blast, several verification methods are possible to assess the resistance of doors to fire and blast. The optimal verification method will depend on the project requirements, and typical verification methods involve a combination of FEM analysis and fire and/or blast tests, with the associated cost varying from one method to another.

Most verification methods are able to predict the outcome of singular events, but cannot be relied upon for predicting the performance of sequential events. As such, single-sample testing is the most reliable verification method to accurately predict the performance of doors when these are subjected to a blast event followed by a fire event. This paper describes the results from two single-sample fire-post-blast tests carried out on doors, and compares these to separate fire and blast tests carried out on doors.

However, it should be noted that single-sample testing might not always be required. This paper proposes to use the fire categories in combination with the blast categories (as proposed by ASCE guidelines [2]) to establish which type of verification method is required. In addition, this paper also refers to usage categories in order to optimise the cost of ownership of blast and fire rated doors.

Finally, this paper provides an example of a typical door schedule that includes the proposed categorisation of blast and fire rated doors as well as other key safety performance criteria including gas tightness, weather tightness, bullet resistance, escape route/access control and operability.

1 Introduction

Accidents or incidents where explosions combined with fires have led to losses of lives and damage to equipment are reported on a regular basis. Causes vary from mechanical failure to human failure or malicious damage, and such accidental events have occurred within various sectors, for instance in fireworks factories, fertilizer plants, power plants and petrochemical facilities. Although the scenarios discussed in this paper focus on events occurring in petrochemical facilities, the lessons learned can be applied to other industries where accidental fire and/or blast events can also occur.

An OGP study of accidental events reported on the top major onshore incidents worldwide [1]. Of the 55 incidents listed, 28 involved a combination of explosion and fire events, and this equated to over 50% of all incidents reported in the list. A fire or explosion event in a petrochemical facility starts with a leak of flammable material. When such a leak occurs, it will result in an explosion or a fire in the event of ignition. Whilst an initial event may be small, events like these can escalate and lead to consecutive - and larger - explosions and fires if not controlled immediately. To minimise the potential for escalation and related significant damage, adequate fire and blast protection should be in place in order to provide separation between hazardous areas. But what can be deemed as adequate? Should a safety barrier be blast resistant or fire resistant, or both? In addition, what other performance criteria are important to keep people and equipment safe during an accidental event, and to minimise collateral damage?

Very often, a trade-off is required for the optimisation of technical properties. To resist blast, a strong, connected structure is required. To resist fire, an insulated and thus a disconnected structure is required. As such, traditional blast doors are usually heavy and not easy to open and close by hand. Automated opening devices can be used, but these require maintenance and add cost to the project. As such, it is key to assess what criterion is more important e.g. fire resistance or blast resistance. Does there need to be a trade-off between these criteria, or can both be met and certified? This paper addresses these issues and proposes a way forward in order to minimise collateral damage in case of fire-post-blast events.

2 Current status for products with fire-post-blast requirements

Although no global standard, such as the IMO standard for marine and offshore vessels [3], include fire-post-blast requirements to date, some national or company standards do.

As such, NORSOK C-002 [4] states in paragraph 7.20:

"Certain doors shall be designed to withstand blast over-pressures. The magnitude of the static and dynamic design pressure (in bar), including impulse duration, shall be in accordance with project requirements.

The door shall be reinforced as required to maintain the given fire rating, integrity and operability (for escape) after the expected blast. Satisfactory laboratory test results (certificates) from a recognised laboratory shall be supplied with all blast resistant doors. The doors shall have been subjected to a full blast test followed by a fire test."

Currently, two companies worldwide (Rapp Bomek and InterDam) mention the ability to provide doors which have been certifiably subjected to a blast followed by a fire. However, compliance with this NORSOK standard seems to be dormant and operators and insurance companies are satisfied with dual-sample testing for fire and blast resistance instead of witnessed single-sample fire-post-blast testing.

Pemex (Mexican state owned oil company) states in their standard NFR-072-PEMEX-2009 [5]:

8.2.4 e: "The ability of the passive fire protection system to remain functional after an explosion."

8.2.7: "The certificate must clearly indicate that the wall against fire exposed to fire is capable of maintaining its properties of stability and integrity following an explosion event."

In this particular standard, the blast has a 0.7 bar overpressure and a 20 msec duration, and is followed by H60 fire. A few companies (InterDam, Van Dam and Dura Systems) have performed tests to actually verify the ability to supply walls according to this standard. Although this specific standard is currently only applicable to blast walls, it might be regarded as best practice with regard to fire-post-blast standards and could form the basis of a fire-post-blast standard for doors.

Oil majors such as Shell also recognise the requirement for doors to remain operable after a blast event and to retain their specified integrity with regard to fire loading. In their design and engineering practices (DEM 1 [6]), the condition of the door after a blast event can fall into two categories namely Category 1 where the door remains operable and fully functional and Category 2 where the door may be rendered inoperable, but shall still retain its specified integrity with regard to fire loading.

3 Door design, verification and procurement process

The procurement process for doors involves sourcing available products within the market according to project-specific requirements. A factor of considerable importance is ability to verify the performance claims in relation to products. A door manufacturer can, for example, claim in a brochure that a certain type of door is both blast and fire resistant, but it is essential that such claims are supported by documents such as type approvals, test reports and witness reports. This section of the paper aims to summarise the key safety performance criteria.

Doors that have obtained a type approval based on fire and/or blast tests have to be produced in exactly the same way as the doors that were tested. Any alterations are required to be assessed by the test laboratory and approved by the certifying body in order to be able to claim the same level of performance. Both institutions will demand an additional full-scale test unless it can be proven beyond any doubt that the specific alteration will have no adverse effect on the performance of the door. For this reason, most door manufacturers test their doors with the vision panels and ensure that door hardware can only be added as an external supplement to the door i.e. not inside the door leaf or frame as this might compromise the performance of the door.

Fire resistance and blast resistance are the main safety performance criteria, but a number of other criteria should also be taken into account by procurement engineers. Criteria like gas-tightness, weather tightness, bullet resistance, escape route/access control, the requirement for vision panels and operability are also key to the safety performance of doors.

3.1 Fire resistance

The fire resistance of doors is generally assessed according to two criteria: thermal fire resistance (or insulation), and flame tightness (or integrity). Another criterion is the temperature difference between the 'hot' and 'cold' sides. Fires are typically categorised as cellulosic (or regular) fires, for which Table 2 provides the related performance criteria, and high-energy hydrocarbon fires, for which Table 1 provides the related performance criteria. The standard fire curves [7] used in design for these two types of fires are shown in Figure 1.

Some projects require an even higher fire rating such as the jet fire, or even High Heat Flux (HHF) jet fire ratings (see Figure 2), as shown in Table 1. In such cases, tests or simulations can be carried out according to the ISO 22899-1 standard [8]. For tests carried out according to this standard, a gas release of 0.3 kg/s is used to subject a specimen to a heat flux of 250 kW/m^2.

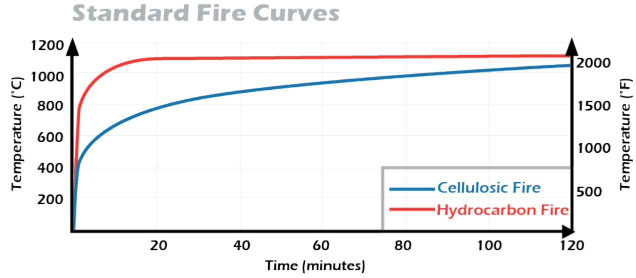


Figure 1 Standard fire curves.

The key factors that influence the behaviour of doors when subjected to a fire are the dimensions of the door leaf, the number of locking points and the number of hinges. All doors are tested at a certain size, and most test procedures allow successfully tested doors to be produced in smaller sizes. The use of doors that are larger than the tested size is however restricted, with the increase in surface area being limited to 10% as compared to that of the tested door [9].

	H-0	H-60	H-120	J-0	J-30	J-60	HHF
Hydrocarbon fires (IMO)	x	x	x	x	x	x	x
Integrity (min.)	120	120	120	60	60	60	PS*
Insulation (min.)	0	60	120	0	30	60	PS*
ΔT max. TC* (°C)	180	180	180	180	180	180	PS*
ΔT ave. TC* (°C)	140	140	140	140	140	140	PS*
Max. furnace temp. (°C)	1100	1100	1100	PS*	PS*	PS*	PS*
Fire test proc. Standard		IMO, 2010 FTP Code			ISO 22899-1		PS*

PS* = Project specific   TC* = Tehrmocouples

Table 1 Overview of performance criteria for hydrocarbon fires.

	A-0	A-15	A-30	A-60	B-0	B-15	EI-30-	EI-45	EI-60	EI-90	EI-120
Celluiosic fires 1 (IMO)	x	x	x	x	x	x					
Celluiosic fires 2 (NEN)							x	x	x	x	x
Integrity (min.)	60	60	60	60	30	30	30	45	60	90	120
Insulation (min.)	0	15	30	60	0	15	30	45	60	90	120
ΔT max. TC* (C	180	180	180	180	225	225	180	180	180	180	180
ΔT ave. TC* (C	140	140	140	140	140	140	140	140	140	140	140
Max. furnace temp. (C	945	945	945	945	945	945	945	945	945	945	945
Fire test proc. Standard			IMO, 2010 FTP Code						EN 1363-1		

PS* = Project specific   TC* = Tehrmocouples

Table 2 Overview of performance criteria for cellulosic fires.

As such, when a project requires a door size that is larger than that covered by a type approval, the door manufacturer can request that the test laboratory make a project-specific assessment that can be used by the certifying authorities to provide project approval. Some door manufacturers (e.g. InterDam, Rapp Bomek) have tested larger doors according to the type approval specifications, allowing double-door structural opening sizes of 4.5 m in height and 3.5 m in width to be included in the type approval (see Figure 3).

Figure 2 J15 HHF test on NORSOK approved sliding door.

Figure 3 Double hinged XL door 4200 x 3250 mm (HCO x WCO) A60 certified.

For a given project, the risk assessment results should provide the required fire rating for each door so as to allow procurement engineers to include these in the door schedule (which lists the requirements for all doors). Moreover, the size of the required doors needs to be checked against the provided type approval certificates.

3.2 Blast resistance

If a project's safety assessment indicates that facilities are required to be blast resistant, industry-wide accepted codes and standards can be applied. Table 3 provides damage estimates for different blast overpressures (1 bar = 14.5 psi = 100 kPa (kilopascal)).

Design against explosions can be carried out according to the ASCE guidelines on 'Design of blast-resistant buildings in petrochemical facilities' [2]. Within such guidelines, Chapter 9.3.1 loosely defines the different ranges of blast-resistant doors:

"Low-Range Door - A door designed to withstand an equivalent static pressure that is less than 3 psi (21 kPa).

Mid-Range Door - A door designed to withstand an equivalent static pressure in the range of 3 psi to 25 psi (21 kPa to 172 kPa).

High-Range Door - A door designed to withstand an equivalent static pressure that exceeds 25 psi (172 kPa)."

The guidelines also state that *"For elastic behaviour, an applied static force is half that of an applied dynamic force of infinitely long duration"*. This is important to note for the early stages of projects as in many instances, only the magnitude of the design pressure is provided i.e. not the type of pressure (either static or dynamic). Accordingly, for instance, a static pressure of 10 psi can be assumed to be equivalent to a dynamic pressure of 20 psi. If only the numerical value of the pressure is given, a conservative assumption would be to assume that pressure to be the static pressure, and allow for a dynamic multiplier factor. However, this could increase the cost of the blast door considerably (and possibly unnecessarily).

Chapter 9.3.3 gives guidelines for blast resistant door design:

"Based on the desired end-use of the door, guidelines for acceptance have been classified into three categories:

Category I: The door is to be operable after the loading event. This category should be specified when the door may be required to withstand repeated blasts or when entrapment of personnel is of concern and the door is a primary exit for the building.

Category II: The door is to be operable after the loading event but significant permanent deformation to the door is permitted. This category should be specified when entrapment of personnel is a concern.

Category III: Non-catastrophic failure is permitted. The door assembly remains in the opening and the door will be rendered inoperable. This category should only be specified when entrapment of personnel is not a possibility."

The results of project's risk assessment should therefore provide the required blast rating as well as the required category (as above), to allow procurement engineers to include these in the door schedule.

DAMAGE **PRODUCED BY BLAST OVERPRESSURE**	PRESSURE (psig)	PRESSURE (BAR)
Annoying noise (137 dB), if of low frequency	0.02	0.001
Occasional breakage of large glass windows already under strain	0.03	0.002
Loud noise, occasional glass breakage - 5% window shattering	0.04	0.003
Loud Noise (143 dB). Sonic boom glass failure	0.04	0.003
Breakage of small windows under strain	0.1	0.007
Typical pressure for glass failure	0.15	0.01
Some damage to ceilings, limit of missiles	0.3	0.02
50% window shattering	0.3 - 0.35	0.02 - 0.025
Limited minor structural damage	0.4	0.03
Large and small windows usually shattered, occasional damage to window frames	0.5 - 1.0	0.034 - 0.069
Minor damage to house structures 20 - 50% tiles displaced	0.75	0.05
Roof damage to oil storage tanks	0.9	0.06
Partial demolition of houses, made uninhabitable	1.0	0.07
Total breaking of glass windows	1.0	0.07
Corrugated asbestos shattered	1.0 - 2.0	0.07 - 0.14
Corrugated steel or aluminium panels, fastening fail, followed by buckling	1.0 - 2.0	0.07 - 0.14
Wood panels (standard housing) fastenings fail, panels blown in	1.0 - 2.0	0.07 - 0.14
Steel frame of clad buildings slightly distorted	1.3	0.09
Slight damage to window frames and doors	1.5	0.10
Partial collapse of walls and roofs of houses. Loadbearing brickwork unaffected, 30% trees blown down	2.0	0.14
Lower limit of serious structural damage	2.0	0.14
Some frame distortion of steel framed buildings	2.0 - 2.5	0.14 - 0.17
Concrete or cinder brick walls 8 - 72", not reinforced shattered	2.0 - 3.0	0.14 - 0.21
90% trees blown down Steel framed buildings distorted and pulled away from buildings demolished foundations. Frameless, self-framing, steel panel	3.0	0.21
Rupture of oil storage tanks	3.0 - 4.0	0.21 - 0.28
Collapse of self-framing steel panel building 0.2 - 0.3	3.0 - 4.0	0.21 - 0.28
Ripping of empty oil tanks 0.2-0.3	3.0 - 4.0	0.21 - 0.28
Small deformations on pipe bridge 0.2-0.3	3.0 - 4.0	0.21 - 0.28
Oil storage tanks distorted	3.5	0.24
Cladding of light industrial buildings ruptured	4.0	0.28
Severe displacement of motor vehicles	4.0 - 5.0	0.28 - 0.34
Severe distortion to frames of steel girder framed buildings, paneling torn-off	4.5	0.31
Wooden utility poles snapped	5.0	0.34
Nearly complete destruction of houses	5.0 - 7.0	0.34 - 0.48
Total destruction of houses	6.5	0.45
Rail cars overturned	7.0	0.48
Brick panels (8 - 1 2'),not reinforced, fail by flexure	7.0 - 8.0	0.48 - 0.55
Collapse of steel girder framed buildings	7 - 9	0.48 - 0.62
Cars severely crushed	7 - 10	0.48 - 0.69
Movement of round tank, failure of connecting piping	7 - 14.5	0.48 - 1.0
Brick walls completely demolished	8 - 10	0.55 - 0.69
Heavy damage to industrial machinery	9	0.62
Collapse of steel truss type bridges Loaded train wagons completely demolished	9	0.62
Destruction of reinforced concrete walls	10	0.69
Heavy machine tools moved and badly damaged	10	0.69
Complete destruction of all unreinforced buildings	>10	>0.69
18" brick walls completely destroyed	13	0.90
Collapse of heavy masonry or concrete bridges	70	4.83
Lip of crater	280	19.31

Table 3 Damage estimates for common structures based on overpressure [10].

3.3 Gas tightness

Depending on the area considered, doors may require a certain level of gas-tightness in order to maintain a positive air pressure differential with the building, usually 50 Pa, so as to avoid any ingress of toxic gas or smoke should an accidental event occur. NORSOK C-002 [4] states in paragraph 7.19:

"Gas-tight doors are normally located in the perimeter of areas where an air pressure differential shall be maintained, or where specified in the door schedule.

Gas-tight doors shall maintain a pressure differential between adjacent areas, where the allowable leakage rate shall not exceed 0.5 m3/m2 h @ 50 Pa (5 x 10-4 bar) over pressure, following prolonged use, or as specified by the projects. A satisfactory test certificate shall be provided with each door type."

An example of door undergoing a gas-tightness test is shown in Figure 4 and Figure 5.

Figure 4 Gas tightness test.

Figure 5 Bubbles indicating a small gas leak at a corner of the door.

As not all fire and/or blast rated doors require a gas-tightness rating, this requirement should be included in the door schedule where necessary and the gas-tightness should be certified by a recognised laboratory. Where gas-tightness after an explosion event is required, this should also be stated in the project requirements.

3.4 Weather tightness

Weather-tightness and **water**-tightness are often used interchangeably in specifications. However, the key difference is as follows:

- **Water-tight** doors can cope with a water column of a number of metres on the external side.
- **Weather-tight** doors can cope with heavy rain and storm on the external side.

All external doors that are not properly sheltered against rain by a weather hood should be **weather-tight** in order to avoid water ingress. In order to verify weather-tightness, each door type can be tested onsite as illustrated in Figure 6. NORSOK C-002 [4] states in paragraph 7.18:

"Where weather tightness is required, weather tight seals shall be added. The weather tightness shall be verified by hose testing from the outside after installation. The water pressure shall be at least 0.2 MPa (2 bar), and the nozzle shall be held at a distance of maximum 1.5 m from the door. No leakage shall be accepted.''

Figure 6 Weather-tightness test of hinged door according to Norsok C-002 [4].

Water-tight doors are designed to prevent water ingress in the event of flooding of the adjacent area. This is only required for cases where a water column of a certain height can be expected, for instance on the hull of a ship. In cases where water-tightness is required, a water column of a specific number of metres should be specified e.g. + 5 mWC (meter water column). As most doors on structures in hazardous environments are required to be water-tight, no further reference on water-tightness is made in this paper. Weather-tightness requirements should therefore be specified by procurement engineers in the door schedule where necessary.

3.5 Bullet resistance

In areas where there is a chance of a terrorist attack on critical equipment, bullet-proof doors might be required to protect both people and equipment. Fire and/or blast resistant doors can be tested for bullet resistance as well, either as an entire door or as a sample of the door leaf as shown in Figure 7.

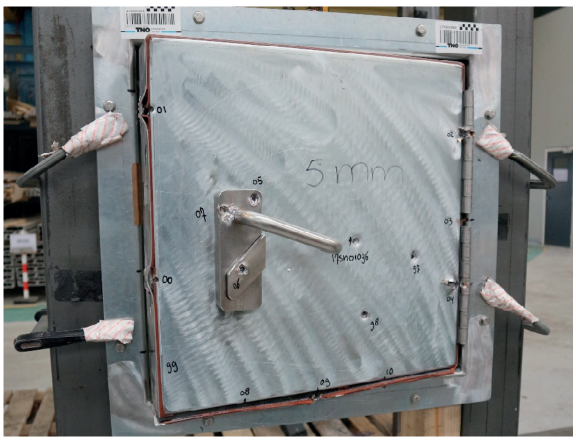


Figure 7 Bullet test (TNO, 2015).

If a project requires bullet-proof doors, the procurement engineer should clearly state the required classification as well as the procedure according to which it should be tested, as shown in Figure 8.

BS EN 1522 1999
Windows, Doors, Shutters and Blinds
Test & Classification for Bullet Resistance

	Class Threat Level	Type of Weapon	Calibre	Ammunition	No of Shots	Velocity (m/s)	Test Range (m)	Spacing (mm)
	FB1	Rifle	.22 LR	L/RN	3	360 +/- 10	10	120 +/- 10
	FB2	Hand Gun	9mm Luger	FJ1/RN/SC	3	400 +/- 10	5	120 +/- 10
	FB3	Hand Gun	.357 Magnum	FJ1/CB/SC	3	430 +/- 10	5	120 +/- 10
	FB4	Hand Gun	.44 Rem Magnum	FJ2/FN/SC	3	440 +/- 10	5	120 +/- 10
	FB5	Rifle	5.56x45	FJ2/PB/ SCP 1	3	950 +/- 10	10	120 +/- 10
	FB6	Rifle	7.62x51	FJ1/PB/SC	3	830 +/- 10	10	120 +/- 10
	FB7	Rifle	7.62x51	FJ2/PB/ HC 1	3	820 +/- 10	10	120 +/- 10
	FSG	Shot Gun	12/70	Solid Slug 3	3	420 +/- 20	10	-

Ammunition Legend:
L - lead
CB - coned bullet
FJ - full metal jacket bullet
FN - flat nose
HC1 - steel hard core
PB - pointed bullet
RN - round nose
SC - soft core (lead)
SCP1 - soft core (lead) and steel penetrator (type SS109)

Notes:
1) Full Steel Jacket (plated)
2) Full Copper Alloy Jacket
3) Brenneke 12G solid slug

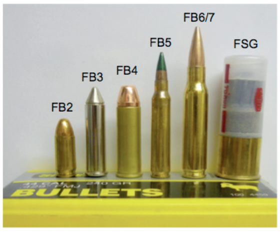


Figure 8 FB Standard 1-7 [11].

3.6 *Escape route / access control*

Doors that are part of the escape route require a panic bar that is able to override the door lock, as shown in Figure 9.

Figure 9 Panic bar on IDM SLH H120 door.

Some buildings require restricted access and access control can be installed to achieve this. For doors which are not fire or blast rated, more access control options are available as in the case of fire and/or blast rated doors, which are required to maintain their fire and/or blast rating at all times, electric strike plates might compromise their fire and/or blast resistance. As such, these cannot be used unless fully tested and certified.

Additional hardware, however, can be used to allow controlled access on fire and/or blast rated doors, such as an electromagnet. From the outside, the electromagnet can be deactivated via a key or card reader, and from the inside, the panic bar can be equipped with a limit switch that deactivates the electromagnet as shown in Figure 10.

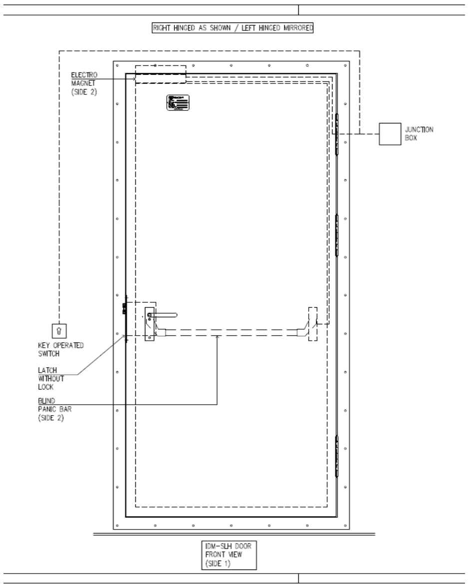


Figure 10 Technical drawing of access control equipment including panic bar with electro magnet deactivation switch.

For safety purpose, vision panels are required on all escape route doors to facilitate the detection of incoming personnel as well as potential hazards on the other side of the door. In case of an accidental event, vision panels enable personnel to find the best route to safety (see Figure 11).

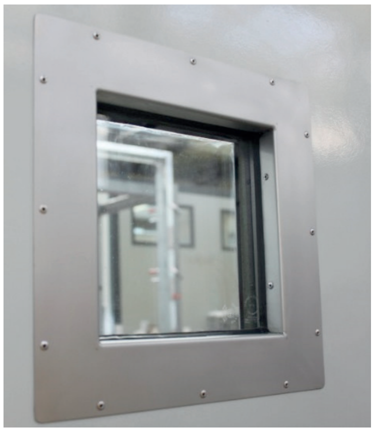


Figure 11 Vision panel in H120 door.

NORSOK C-002 [4] states in paragraph 7.14:

"The vision panels shall be positioned to ensure good line-of-sight through the panel whilst operating the door. The vision panels shall be an integral part of the certified door."

As such, doors to be tested for fire and blast resistance should include a vision panel to confirm that it does not weaken the door. Procurement engineers should include panic bars and vision panels on all escape doors, and also include built-up hardware on all access-controlled doors.

3.7 Operability

Doors are included in buildings in order to allow for easy and safe access & exit. However, doors have different usages and can be categorised according to their frequency of use. Their design should be optimised to meet relevant functional requirements whilst minimising cost (including maintenance cost).

Usage category I: Door is used as a main entrance to daily occupied building in hazardous area. It is required to be operable at all times. Maximum door hardware performance and maintenance required. Heavy-duty hinges, with 1+ additional hinge installed to distribute door leaf weight to further minimize wear and tear. An example of category I door is shown in Figure 12.

Usage category II: Door is used for access to buildings that are only entered in case of service/maintenance of equipment. Not used daily on a regular bases. Medium door hardware performance and maintenance required. Fit for purpose hinges.

Usage category III: Door is used as an escape door in case of panic only. Not used daily. Minimum wear and tear of door hardware expected. Medium door hardware performance and maintenance required. Fit for purpose hinges. An example of Category III door is shown in Figure 13.

Introducing the usage categories is a practical way to enhance safety whilst lowering the CAPEX per door. Fit-for-purpose design and maintenance should be addressed in the design stage, since doors should perform according to their design and certification requirements throughout their entire life-span. Blast resistant doors tend to be of a considerable weight, and there is a logical relationship between blast rating, weight and the longevity of doors, especially with regard to door hardware. The usage category should therefore be included within all blast rated doors' specifications.

Figure 12 H120 1.6 bar blast door, blast, fire and usage category I for main entrance of control room, including hydraulic door closer and access control.

Figure 13 Blast, fire and usage category III, two hours EW fire rated escape door with corroded hardware due to insufficient maintenance. Access may be compromised in case of an accidental event.

3.8 Other door design, verification and procurement criteria

A number of other criteria can be required from doors as listed below. NORSOK C-002 [4] states the following in Chapter 7:

Clear opening: *"minimum clear opening: typically 750 mm x 2050 mm for escape route doors."*

Pirate locks: *"use of pirate lock on hinges: for doors on installations in potential pirate areas."*

Preservation: *"doors shall be suitably preserved and protected against damages in the transportation, storage and construction phase."*

Opening force: *"the maximum acceptable opening force in an accidental situation shall never exceed 250 N for doors in main escape routes."*

Acoustic requirements: *"the sound reduction value of the door could be less than the partition in which the door is installed, but the total partition should meet the required sound reduction value (Rw)."*

Thermal insulation: *"the thermal insulation value of the door could be less than the partition in which the door is installed, but the total partition should meet the required thermal insulation value (U or R value)."*

Materials: *"for heavy-duty doors, minimum 2 mm steel is recommended for the door leaf and 4 mm for the door frame. Steel should either be mild steel or AISI 316L."*

Thresholds: *"all required thresholds shall be dimensionally as low as possible, without impairing function with regard to fire rating, noise reduction and ability to stop ingress of water."*

3.9 Trade-offs on performance criteria

A number of trade-offs should be recognised and optimised during the design and procurement phase of fire and/or blast resistant doors.

To improve the **blast resistance** of doors, the capacity of the door leaf to resist bending needs to be optimised, as well as the ability to transfer the forces from the door leaf to the door frame. To increase the bending resistance of the door leaf, welded stiffeners are typically added, with the inner and outer sheets preferably strongly inter-connected. Some designs even use concrete as filler of the door leaf, in order to increase the bending resistance. This is however in contradiction with design principles for fire resistance and reliability, as such doors have door leaves with connected skins and can become quite heavy, therefore resulting in wear and tear of the hardware or the requirement for additional opening devices.

To improve the **fire resistance** of doors, the inner and outer sheets of the door leaf are typically disconnected as much as possible to avoid thermal bridging (see section 5.7 of this paper).

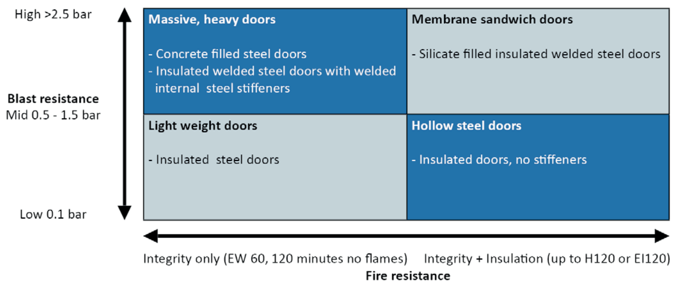


Figure 14 Trade-offs between blast and fire resistance.

CAPEX vs. OPEX: Medium-duty doors are usually produced according to medium-duty specifications, resulting in a lower capital expenditure (CAPEX). However, when these doors are used in a harsh industrial or salty environment, the operating expenditure (OPEX) might increase to an unacceptable level as hinges, locks or entire door leaves will need to be regularly replaced due to corrosion. On several projects, medium-duty doors which were installed as external doors had to be replaced with heavy-duty doors within five years of the project going live.

Door design and procurement departments should take this CAPEX versus OPEX trade-off into consideration and specify fit-for-purpose door types. The best doors will require no compromise and will fulfil all the project-specific requirements, but might come with a higher CAPEX.

Another trade-off can be found in the **access control vs. escape route**. An escape route should always be readily accessible and preferably from both sides of the door (from the inside so as to evacuate the building and from the outside to allow firefighters to enter freely during an event). However, some buildings require (remote) controlled access, which might impair the ease of access during an event. In such cases and when a door is equipped with an electromagnet attached to a key card reader, the magnet should be de-activated when the power is turned-off and should be automatically de-activated by pushing the panic bar from the inside. This would ensure that escape routes remain readily accessible during an event, but adds to the complexity of the door.

Thresholds: Logistically, the most convenient way to install a door is to have no threshold, as this ensures easy access for personnel and trolleys, etc. However, the presence of a threshold provides additional blast resistance as indicated in Figure 15.

4 Design verification for fire and blast resistance

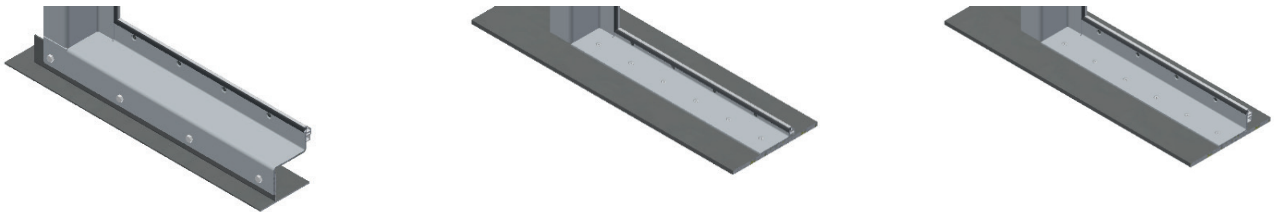
There are typically three possible options to verify that the fire and/or blast resistant doors will actually perform as intended:

1. Analysis;
2. Tests, single sample or split sample;
3. A combination of the above.

Nowadays, smart Final Element Modelling (FEM) programs are quite capable of predicting the behaviour of singular events i.e. a fire or a blast. These models are typically calibrated according to data from actual tests, and the use of FEM modelling negates the requirement of having to carry out tests for cases which only deviate slightly from tests previously carried out. For example, if an A60 fire rated door of 2200 mm in height and 1100 mm in width has been tested and has a proven 120 min fire resistance , for cases where only a lower 60 min fire resistance is required, the door could potentially be enlarged to 2500 mm x 1250 mm if required provided that the FEM analyses indicate that the required fire resistance is provided. The same is true for blast doors: the use of FEM modelling allows the (safe) extrapolation of test results to provide alternative door dimensions.

When assessing the resistance of doors to singular events (i.e. fire OR blast), the verification process can be as described above. However, if there is a requirement to assess the resistance of doors in the case of sequential event i.e. fire-post-blast, the most realistic way to assess the behaviour of a specific door is to sequentially carry out a blast resistance test followed by a fire resistance test on the door.

There have been many instances in the past where manufacturers used separate blast and fire resistance tests to justify the fire-post-



(a) standard threshold of 111 mm, maximum blast-resistance capabilities.

(b) lowest threshold of 25 mm, minimum blast-resistance capabilities.

(c) optimized threshold of 55 mm, medium blast-resistance capabilities.

Figure 15 Different types of door thresholds.

blast resistance of fire and blast resistant barriers (e.g. walls, doors) instead of conducting fire-post-blast tests. The cost associated with such type of verification is relatively low as compared to single-sample fire-post-blast testing. The objective here is to ensure that the effect of the damage to the door caused by a blast on the fire resistance is determined. For Category I doors where the door must remain intact and operable following a blast, verifying the fire-post-blast resistance requirement using separate blast and fire resistance tests can be viable, provided that any additions to the fire tested doors to make them withstand a blast have been checked and approved by both the laboratory and the certifying body and that identical samples are used for both tests.

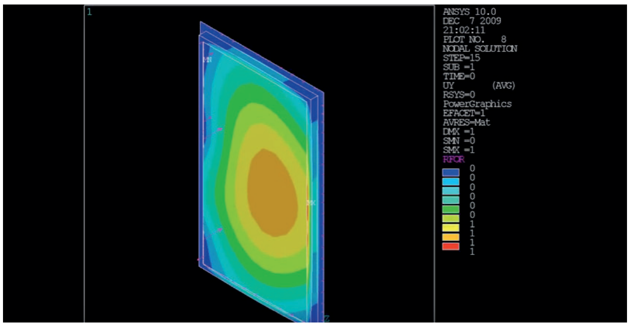


Figure 16 FEM modelling of blast door.

However, the most robust option for assessing the response of a door when subjected to a fire after a blast (i.e. fire-post-blast rating) is to carry out a single-sample blast test followed by a fire test on the same door, witnessed by a certified body, as described in Section 5 of this paper. As indicated above, conducting separate fire and blast tests could suffice provided that the door has not sustained any plastic deformations and is still operable after the blast, and provided that both samples have been designed and produced in exactly the same way.

Table 4 indicates the suitability of the possible verification methods as well as their relative cost for assessing the resistance of doors to fire and explosion events.

5 Analysis of recent fire-post-blast tests

5.1 Blast test series on A60 fire door with vision panel

In 2016, a series of blast tests were conducted at the TNO site in the Netherlands [12]. Four windows and two doors were tested for blast resistance in their large blast simulator as shown in Figure 17. Two of the windows were fitted with fire-rated glass, and the objective was to conduct a fire test on all the windows and doors post blast. This chapter gives a brief overview of the test setup and results. All the tests (01 to 06 were performed in July 2016).

Figure 17 Overview of test setup with the door and support frame.

The testing procedures were in compliance with NEN-EN 13124-1 [13], and the blast tests of the specimens were witnessed by Lloyd's Register. The door shown in Figure 17 was subjected to a blast pressure of 50 kPa and the objective was to ensure that its fire integrity was maintained post blast. For that purpose, the same door was officially fire tested afterwards. In order to verify the authenticity of the door for the fire test, the sample was marked with the official LR stamp by the LR surveyor that witnessed the blast test.

This IDM SLH A60 steel fire door shown in Figure 17 is the standard InterDam fire door which has been fire tested and type approved for an A60 fire rating. The only modification made for the blast test was the addition of a third latch to the standard two-way latching

VERIFICATION TYPE	SUITABILITY FOR SINGULAR EVENTS	SUITABILITY FOR SEQUENTIAL EVENTS	RELATIVE COST OF VERIFICATION
FEM fire analysis	o/+	--	-
FEM blast analysis	o/+	--	-
Fire test only	++	--	-
Blast test only	++	--	-
Fire <u>or</u> blast test + FEM analysis	++	-	o
Separate sample fire <u>and</u> blast test	++	++ (only for doors not sustaining plastic deformation)	++
Single sample fire-post-blast test	++	++	++

Table 4 Suitability and relative cost of possible verification options for assessing the resistance of doors to fire and blast events. Key: ++ = most positive, o/+ = mildly positive, o = neutral, - = negative, -- = not suitable.

mechanism. The door was fitted with a standard fire-rated window of 400 mm x 400 mm. The objective of the blast test was to demonstrate that the door assembly was able to resist the reflected overpressure.

Test 05-1

The setup before the test is shown in Figure 18, and the measurements are provided in Figure 19 and Table 5. The setup after the test is shown in Figure 20. A video recording of this test is available online [14].

Figure 18 Setup for Test 05-1.

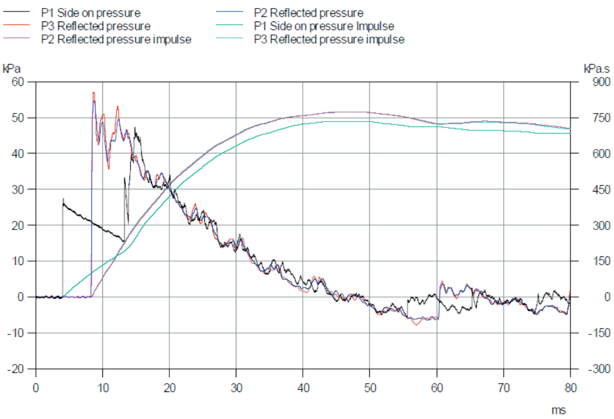


Figure 19 Pressure and calculated impulse for Test 05-1.

Figure 20 Setup after Test 05-1.

	MAX PRESSURE	AT TIME	MAX IMPULSE	AT TIME
P1 side-on Pressure *	26.7 kPa	4.1 ms	735.4 kPa.s	44.5 ms
P2 reflected Pressure	54.6 kPa	8.7 ms	774.4 Kpa.s	48.4 ms
P3 reflected Pressure	57.1 kPa	8.6 ms	774.0 kPa.s	45.2 ms

* first peak; second peak is a reflection of the shocktube

Table 5 Maximum values for Test 05-1.

Test 05-1 was successful as the specimen resisted the blast loading. The glass panel and the lock mechanism remained intact. As no contamination with the witness paste was observed (door leaf covered with a paste that would attach itself to the mounting frame in case of direct contact caused by deformation during the blast load), it was concluded that the door leaf (during the rebound) did not come into contact with the mounting frame of the blast simulator. In addition, the door handle and all the other parts showed no damage, and the door was operable following the blast without any visual damage. Operability was verified by the LR surveyor [12].

5.2 Blast test series on A60 fire door without vision panel

The setup before the test is shown in Figure 21, and the measurements are presented in Figure 22 and Table 6. The setup following the blast test is shown in Figure 23.

Figure 21 Setup before Test 06-1.

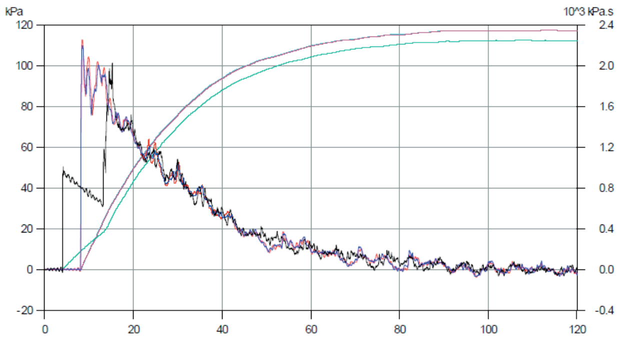


Figure 22 Pressure and calculated impulse for Test 06-1.

	MAX PRESSURE	AT TIME	MAX IMPULSE	AT TIME
P1 side-on Pressure *	49.4 kPa	4.1 ms	2250.6 kPa.s	107.5 ms
P2 reflected Pressure	109.9 kPa	8.5 ms	2348.8 Kpa.s	113.2 ms
P3 reflected Pressure	112.8 kPa	8.4 ms	2348.3 kPa.s	113.0 ms

Table 6 Maximum values for Test 06-1.

Figure 23 Setup following Test 06.

The specimen also resisted the blast loading during Test 06-1, and the door leaf and lock mechanism remained intact. The door leaf was covered with a witness paste that would attach itself to the mounting frame should its deformation due to the blast lead to direct contact between the two. No witness paste contamination was observed, and it was concluded that the door leaf (during the rebound) did not come into contact with the mounting frame of the blast simulator. However, the door handle got detached following several blast loading and unloading sequences (it was intact following the first blast loading) and the cover plate of the escutcheon came loose. Small cracks were visible in the welds in the corners of the door frame (the butt-welds were ground flush and insufficient weld penetration led to an insufficient weld thickness), and the adhesive bond between the door plating and the rigid insulation core was lost. However, after re-installation of the door handle, the door was still operable post blast. Again, the operability was verified by the LR surveyor [12].

5.3 Fire-post-blast test on A60 fire door with vision panel

The fire resistance of the door subjected to the blast (InterDam IDM-SLH-A60 0.56 bar blast/fire door) was determined according to the IMO Standard for A60 [3] with the door opening away from the fire. For the test, which was carried out in September 2016 by Efectis Nederland, the door was installed in a steel bulkhead of 3180 mm in height and 3000 mm in width and was insulated with FireMaster Marine Plus blanket insulation. The door was heated for a period of 180 min and the outcomes of the test are summarised in Table 7. The integrity of the vision panel was maintained until the 89th minute, after which it was covered with mineral wool. As such, the integrity of the door and door frame including the vision panel was maintained for a test duration of 89 min. The integrity of the door and door frame without the vision panel was intact for the whole duration of the test i.e. 180 min. The thermal insulation criterion for the door and door frame including the vision panel was met for a test duration of 68 min. The temperatures recorded on the door leaf during the test are shown in Figure 24, and the curving of the door during the fire test is shown in Figure 25.

It was concluded that the IDM-SLH-A60 0.56 bar blast/fire door, opening away from the fire, performed according to the criteria specified in the IMO MSC.307(88) resolution [3] when mounted in a A-60 bulkhead. It was therefore classified as an A-60 door [3].

CRITERION	TIME (min)	RESULT
Integrity (E)		
↘ Cotton pad	89	Failure*
↘ Calibre:		
↘ Ø 6 mm	89	Failure*
↘ Ø 25 mm	89	Failure*
↘ Sustained flaming > 10 sec.	89	Failure*
Insulation (I) - Door		
↘ Average temperature rise	126	Failure
↘ Maximum temperature rise I_2	68	Failure at TC 7 (>180°C)
Insulation (I) - Window		
↘ Average temperature rise	83	Failure
↘ Maximum temperature rise	86	Failure at TC 8 (>180°C)

Notes:
The heating was discontinued after 180 min after consulting the client.
*The vision panel was covered with mineral wool at the 89th minute. The Integrity Criterion E for the door and door frame (excl. the vision panel) was intact until the end of test i.e. 180 min. The Thermal Insulation criterion I of the door and door frame was maintained for a test duration of 68 min.

Table 7 Summary of results of fire test after blast test against performance criteria.

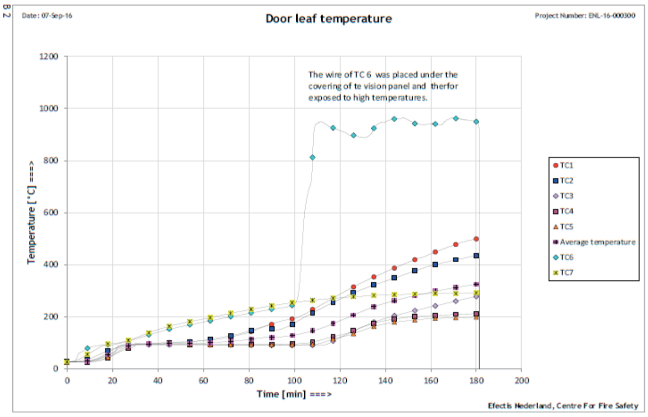


Figure 24 Door leaf temperature

Figure 25 Curving of door 58 min into the fire test.

5.4 *Fire post 1.1 bar blast test on A60 fire door without vision panel*

The fire resistance of a door which was previously subjected to a 1.1 bar blast test (InterDam IDM-SLH-A60 1.11 bar blast/fire door, as shown in Figure 26 and Figure 27), opening away from the fire, was assessed according to EN 1634-1 [15] and IMO Resolution MSC.307(88) [3]. The door was installed in a steel bulkhead of 3180 mm in height and 3000 mm in width and was insulated with FireMaster Marine Plus blanket insulation. The duration of the fire test, which was carried out in October 2016 by Efectis Nederland, was 240 min. Table 8 summarises the outcomes from the fire test.

Figure 26 Test specimen 240 min into the fire test.

Figure 27 Test specimen following the test, seen from the exposed side.

CRITERION	TIME (min)	RESULT
Integrity (E)		
➘ Cotton pad	240	Not determined
➘ Gap Gauge:		
↘ Ø 6 mm	240	Not determined
↘ Ø 25 mm	240	Not determined
➘ Sustained flaming > 10 sec.	240	No Failure
Insulation (I)		
➘ Average temperature rise	106	Failure
➘ Maximum temperature rise I_2	50	Failure at TC 7
Heat radiation (W)	max. 1.5 kW/m² at 240 min	

Notes:
The heating was terminated after 240 minutes after consulting the client.
Classification according to EN 13501-2 [16] was described in a separate report.
The construction will be classified as follows: E240, EI2 45, EW 120

Table 8 Test results of fire after blast offset against criteria.

To achieve A60 or EI 60 fire rating, the temperature change on the cold side should be below 180˚C. This maximum allowable temperature change was reached after 50 min at the location of Thermocouple No.7. Since the integrity criteria were met for a duration of 240 minutes (no flames and no hot air on the cold side), this door achieved an Integrity (E) rating of 240 min i.e. E 240.

5.5 *Results of fire (non-blast) test on A60 and H120 fire doors*

In 2008, InterDam tested an A60 fire rated single leaf hinged door, as shown in Figure 28, in accordance with IMO Resolution A.754(18) [17]. The test report was published in March 2008 by BRE in the UK, and the door was certified as A60 class by Lloyd's Register as a result. Its integrity and insulation were maintained until flaming occurred from the bottom edge of the leaf/frame gap 78 min into the fire test. This door was tested without a vision panel and with two locks.

Figure 28 Fire test setup at BRE (UK).

In 2009, InterDam also tested an H120 fire-rated single-leaf hinged door, as shown in Figure 29, in accordance with IMO Resolution A.754(18) [17]. The test report was published in March 2009 and the door was certified as H120 class as a result. The integrity and insulation of the door were maintained for the whole duration of the test i.e. 180 min.

Figure 29 H120 fire door test including a 200 mm x 200 mm vision panel, seen from the exposed side (several glass layers melted during the test).

5.6 *Differences in behaviour of fire-post-blast and fire (non-blast tested) doors*

Based on the tests described in the previous paragraphs and summarised in Table 9, it can be concluded that as long as the door does not sustain plastic deformations following the blast test, the fire rating will likely not be compromised.

The door which was blast tested with a 1.11 bar overpressure did not meet the insulation criterion as the maximum temperature was reached at 50 min for one of the thermocouples, which probably occurred due to plastic deformation of the door.

In case of plastic deformation of the door, its thermal insulation performance could be compromised. As such, two options are possible if a higher blast rating combined with thermal insulation is required:

1. Further strengthening of the door by adding a number of locks and hinges;
2. Providing a stronger thermal insulation barrier by using higher specification fire rated doors, such as an H120 door for a 1.0 bar blast overpressure A60 door.

If a project has a specific fire-post-blast requirement, this can be optimised by combining the results of the test to project specific FEM analysis.

DOOR TYPE	FAILURE BASED ON INSULATION CRITERION (MIN)	FAILURE BASED ON INTEGRITY CRITERION (MIN)
IDM-SLH-A60 0,56 bar	68	180 (89 for window)
IDM-SLH-A60 1,11 bar	50	240 (no window)
IDM-SLH-A60	78	78 (sustained flaming bottom edge)
IDM-SLH-H120	180	180 (including window)

Table 9 Summary of test results of fire-post-blast doors.

5.7 *Expected behaviour of different types of fire doors on fire-post-blast event.*

Technically, fire and blast doors can be categorised into four different types:

Massive, **heavy blast resistant doors** will have an excellent blast rating as well as fire rating based on integrity criterion. Due to the solid connection between the internal and external door leaf, the fire insulation properties will however be minimal.

Hollow steel doors, on the other hand, can be expected to perform well in terms of fire insulation and integrity criteria, but will lack blast resistance capabilities.

Insulated welded steel doors with welded internal steel stiffeners can be expected to have sufficient blast resistance. The fire insulation rating, however, will depend on whether the stiffeners are disconnected from one of the sides of the door. If the stiffeners are welded to both sides of the door leaf, a thermal bridge and will result in a loss of insulation.

Membrane sandwich doors as described in this section can be fire-post-blast resistant provided that plastic deformations are minimised.

Based on the above four types of fire and blast doors, only two types can be considered when fire resistance post blast is required. FEM analysis of these doors provides the results shown in Figure 30 and Figure 31.

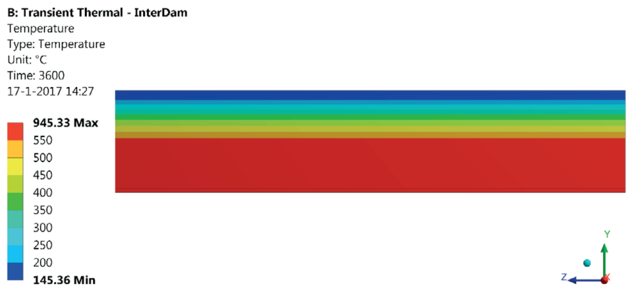


Figure 30 CaSi filled A60 InterDam Door.

As shown in Figure 30, the highest temperature on the cold side of the A60 InterDam membrane door with 70 mm of CaSi insulation was 145˚C, which is an acceptable temperature following 60 min of exposition to a fire. As such, no additional stiffening is required.

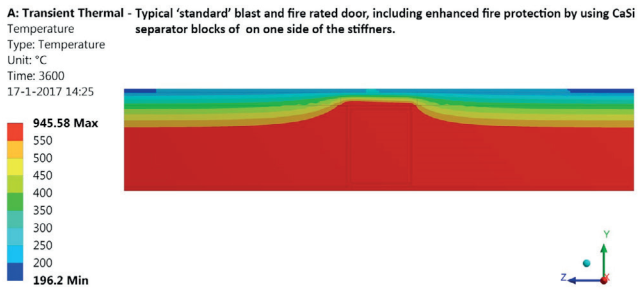


Figure 31 Wool filled and steel stiffened blast and fire door.

Figure 31 shows the FEM model of a typical standard blast resistant fire door cross-section for an analysis of its fire resistance (but without having been subjected to blast beforehand). It shows that the maximum recorded temperature on the 'cold' side is 280˚C, therefore failing the A60 criterion which requires the maximum temperature to be less than 180˚C. A blast might lead to plastic deformation of part of the 10 mm thick CaSi block and a significant portion of the blast load on the door leaf would be absorbed by the stiffeners. Currently, no such blast doors have been successfully tested on EI, A or H fire ratings.

6 Classification

Safety is a key concern for all organisations who have people working in hazardous areas. From a technical perspective, it is possible to aim for maximum safety on blast rating, fire rating and reliability of doors.

This, however, might not be required since these requirements can be categorised based on type of use. Such a categorisation allows for the specification of fit-for-purpose doors, thus optimising costs without compromising on safety. Based on the desired end-use of the door, guidelines for acceptance have been listed in Table 10. As blast resistant doors tend to be of a considerable weight, there is a logical relationship between blast rating, weight and the longevity of doors, especially with regard to door hardware. The usage category should therefore be included within all blast rated doors' specifications.

CATEGORY	DESCRIPTION
Blast-rating category I:	Door is to be operable after the loading event. Door may be required to withstand repeated blasts. Entrapment of personnel is of concern and the door is a primary exit from the building.
Blast-rating category II:	Door is to be operable after the loading event but significant permanent deformation to the door is permitted. Door must remain operable and this category should be specified when entrapment of personnel is a concern.
Blast-rating category III:	Non-catastrophic failure to the door is permitted. The door assembly remains in the opening. Door will be rendered inoperable. Entrapment of personnel is not a possibility.
Fire-rating category I:	In immediate zone of considerable fire risk. Temperature and integrity should be maintained to allow people and critical equipment to remain safe within a specified period. This includes occupied buildings or buildings for critical equipment. A60, H60, H120, EI60, EI120
Fire-rating category II:	The door is not in immediate zone of considerable fire risk. This includes occupied buildings or buildings for critical equipment. A60, EI60
Fire-rating category III:	The door is not in the immediate risk zone from either side. This includes non-occupied buildings and those with no critical equipment. Fire rating on integrity only will suffice to control fire. A0, EW or E rating
Usage category I:	Door is used as a main entrance to daily occupied building in hazardous area. It is required to be operable at all times. Maximum door hardware performance and maintenance required. Heavy-duty hinges, with 1+ additional hinge installed to further minimize wear and tear.
Usage category II:	Door is used for access to buildings that are only entered in case of service/maintenance of equipment. Not used daily on a regular basis. Medium door hardware performance and maintenance required. Fit-for-purpose hinges.
Usage category III:	Door is used as an escape door in case of panic only. Not used daily. Minimum wear and tear of door hardware expected. Medium door hardware performance and maintenance required. Fit-for-purpose hinges.

Table 10 Introduction of fire rating and usage categories in addition to the ASCE blast rating category [2] for fire and blast rated doors

If a door falls within Category I for both fire and blast, the door should be able to withstand a blast followed by a fire. To confirm its fire-post-blast resistance, single-sample fire-post-blast tests can be carried out as described in this paper. As the door for fire and blast category I needs to be fully functional after a blast, FEM analysis for fire resistance after the blast test would suffice.

For doors falling within Category II or III for blasts as well as within Category I or II for fire, fire-post-blast tests are required in order to adequately assess the door response, since the ability to predict the response of the door deformed by a blast when subjected to a fire is low when using other methods.

Based on the categories listed in Table 10, the recommended types of verification method based on the various combinations of fire and blast categories are described in Table 11. This table could be used to prescribe the required (and optimal) verification method.

BLAST	FIRE	VERIFICATION METHOD
I	I	Single-sample test or blast test + FEM (door to remain intact and operable after blast)
II	I	Single-sample test
I	II	Split-sample test or single sample test
II	II	Single-sample test
III	-	Blast test only, door is not fire rated
-	III	Fire test only, door is not blast rated
III	III	Invalid combination; after blast damage, door will not be fire rated
II	III	Single-sample test, fire integrity only, insulation not required
III	II	Contradictory combination, after blast damage, door cannot be fire rated

Table 11 Correlation between fire and blast categories and recommended verification method for doors.

7 Door schedule

In order to minimise the risk of misalignment between the required door specification and the characteristics of the door actually supplied, the fire, blast and usage categories should be included in a typical door schedule of fire and blast rated doors as shown in Table 12.

A door schedule should also state opening dimensions and opening directions. If the doors must meet additional requirements such as being bullet proof, this can also be included.

Three typical types of doors are listed in the door schedule shown in Table 12. The first door listed is a main entrance door of a control room, positioned in a medium blast zone, but critical fire zone. This door should be certified to withstand a fire after a blast through verification by single-sample fire-post-blast test. The door will be opened and closed many times within a day as it is the main entrance door of the control room. Therefore, heavy-duty hinges, including an additional hinge, are required. The peak reflected overpressure (in bar) that it needs to withstand is stated in the schedule as well as the predicted duration of the blast. The fire rating is H120 i.e. the integrity and insulation criteria should be for 120 min during a hydrocarbon fire. The gas-tightness should be better than 0.5 $m^3/m^2/hour$ at

DOOR NUMBER	LOCATION	BLAST CAT.	FIRE CAT.	USAGE CAT.	BLAST RATING (ref. overpressure) duration	FIRE RATING	GAS TIGHTNESS (m^3/m^2/hour @ 50Pa)	ACCOUSTIC INSULATION dB (A)	WEATHER TIGHT	PANIC BAR	VISION PANEL	ACCESS CONTROL	WIND BREAK	EARTHING	THRESHOLD DIMENSIONS
1	Main entr.	II	I	I	0.5 bar, 120 msec	H120	<0.5	36	Yes	Yes	Yes	Yes	Yes	No	Low
2	Escape	I	I	III	8 psi, 80 msec	EI160	<0.5	31	Yes	Yes	Yes	No	Yes	Yes	Standard
3	Switch	II	III	III	6 psi, 60 msec	2 hours	<1.0	n.a.	Yes	Yes	Yes	No	Yes	No	Low

Table 12 Typical door schedule including categorisation of fire and blast rated doors

50 Pa pressure difference, and the required acoustic insulation is 36 dB(A). The door should be weather-tight and, as it is an escape door, equipped with a vision panel and panic bar. Access control is also required as it is critical to know who is inside the building at all times, and access by unauthorised people should be prevented. To avoid the door from being slammed into the wall due to heavy wind, a windbreak is also required. The second door is an escape door in a critical blast and fire zone. As the door must remain operable without any plastic deformation after a blast, its fire-post-blast performance can be verified via a single-sample fire-post-blast test or a blast test combined to FEM analysis. Fit-for-purpose hinges are also required. The third door would be typical for the entrance to a switch gear room, and would only be in use during service/maintenance of the instruments. As this door is in a medium blast zone and low fire zone, single-sample fire-post-blast testing would be required to verify the fire integrity after a blast. Fit-for-purpose hinges are also required.

If a project requires fire and blast rated doors to protect people and equipment during an accidental fire and/or blast event, the inclusion of the blast, fire and usage categories on the door schedule is an effective way of clarifying the specifications for all parties involved in the design and construction of buildings. In addition, one can refer to this paper for elaboration on the categories and required verification methods, especially to Table 10 and Table 11, or attach these tables to any door schedule that includes blast and fire rated doors for a clear understanding of the specific requirements.

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