

TECHNICAL SPECIFICATION

PORTABLE BLAST-RESISTANT MODULES

DEP 34.17.10.33-Gen.

December 2007

DESIGN AND ENGINEERING PRACTICE



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PREFACE

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The objective is to set the recommended standard for good design and engineering practice applied by Shell companies operating an oil refinery, gas handling installation, chemical plant, oil and gas production facility, or any other such facility, and thereby to achieve maximum technical and economic benefit from standardization.

The information set forth in these publications is provided to Shell companies for their consideration and decision to implement. This is of particular importance where DEPs may not cover every requirement or diversity of condition at each locality. The system of DEPs is expected to be sufficiently flexible to allow individual Operating Units to adapt the information set forth in DEPs to their own environment and requirements.

When Contractors or Manufacturers/Suppliers use DEPs they shall be solely responsible for the quality of work and the attainment of the required design and engineering standards. In particular, for those requirements not specifically covered, the Principal will expect them to follow those design and engineering practices which will achieve the same level of integrity as reflected in the DEPs. If in doubt, the Contractor or Manufacturer/Supplier shall, without detracting from his own responsibility, consult the Principal or its technical advisor.

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- 1) Operating Units having a Service Agreement with Shell GSI or other Shell Service Company. The use of DEPs by these Operating Units is subject in all respects to the terms and conditions of the relevant Service Agreement.
- 2) Other parties who are authorized to use DEPs subject to appropriate contractual arrangements (whether as part of a Service Agreement or otherwise).
- 3) Contractors/subcontractors and Manufacturers/Suppliers under a contract with users referred to under 1) or 2) which requires that tenders for projects, materials supplied or - generally - work performed on behalf of the said users comply with the relevant standards.

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All administrative queries should be directed to the DEP Administrator in Shell GSI.

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1. INTRODUCTION

1.1 SCOPE

This new DEP specifies requirements and gives recommendations for the design of pre-engineered and manufactured portable blast resistant modules (BRMs), rated for a peak side-on over-pressure of 55 kPa and duration of 100 ms, for use as portable occupied buildings.

The Principal may specify other requirements.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by Shell GSI, the distribution of this DEP is confined to Shell companies and, where necessary, to Contractors and Manufacturers/Suppliers nominated by them.

This DEP is intended for use in oil refineries, chemical plants, gas plants, exploration and production facilities and supply/distribution installations.

When DEPs are applied, a Management of Change (MOC) process should be implemented; this is of particular importance when existing facilities are to be modified.

If national and/or local regulations exist in which some of the requirements may be more stringent than in this DEP, the Contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable with regards to the safety, environmental, economic and legal aspects. In all cases the Contractor shall inform the Principal of any deviation from the requirements of this DEP which is considered to be necessary in order to comply with national and/or local regulations. The Principal may then negotiate with the Authorities concerned, the objective being to obtain agreement to follow this DEP as closely as possible.

1.3 DEFINITIONS

1.3.1 General definitions

The **Contractor** is the party that carries out all or part of the design, engineering, procurement, construction, commissioning or management of a project or operation of a facility. The Principal may undertake all or part of the duties of the Contractor.

The **Manufacturer/Supplier** is the party that manufactures or supplies coating materials, equipment and services to perform the duties specified by the Contractor.

The **Principal** is the party that initiates the project and ultimately pays for its design and construction. The Principal will generally specify the technical requirements. The Principal may also include an agent or consultant authorised to act for, and on behalf of, the Principal.

The word **shall** indicate a requirement.

The word **should** indicate a recommendation.

1.3.2 Specific definitions

Area classification

Division of a plant or installation into hazardous areas and non-hazardous areas and the sub-division of hazardous areas into zones.

- NOTES:
1. Area classification shall be in accordance with DEP 80.00.10.10-Gen.
 2. For the installation of electrical equipment in hazardous areas, IEC 60079-14 shall apply.

Non-hazardous area

Area in which an explosive gas atmosphere is not expected to be present in quantities such as to require special precautions for the construction, installation and use of electrical apparatus.

Zone 2

Area in which an explosive gas atmosphere is not likely to occur in normal operation and if it does occur it will exist for a short period only.

Blast Load

Load generated by an explosion

Portable Blast Resistant Modules

Containerized or modular system buildings that can be transported via public roads and that can withstand blast loads as indicated in this DEP. Sanitary facilities are excluded.

PRT

Process Risk Tool, a tool to assess vapour explosions risk at petrochemical processing facilities, e.g. SHEPHERD, FRED.

SHEPHERD

Software Risk Tool for Explosion Exceedance

1.4 CROSS-REFERENCES

Where cross-references to other parts of this DEP are made, the referenced section number is shown in brackets. Other documents referenced by this DEP are listed in (9).

1.5 COMMENTS ON THIS DEP

Comments on this DEP may be sent to the DEP Administrator at standards@shell.com. Shell staff may also post comments on this DEP on the Surface Global Network (SGN) under the Standards folder.

2. GENERAL

2.1 LOCATION OF PORTABLE BRMs

The location of portable BRMs shall be assessed and approved by means of a checklist as given in Appendix B or by using a Process Risk Tool (PRT) as specified by the Principal.

2.2 BUILDING CODES

The design of portable BRMs shall comply with the national and/or local building codes for buildings and as specified in this DEP.

2.3 BRM DIMENSIONS

The BRM dimensions shall be based on standard sizes:

For containers: length x width x height:

6 m x 2.5 m x 2.6 m (20 ft x 8 ft x 8.5 ft); or

12 m x 2.5 m x 2.6 m (40 ft x 8 ft x 8.5 ft)

For modular systems: Suitable sizes for road transport and easy handling

Deviations in size are acceptable provided they are suitable for normal road transport. Containers may be stacked while at the storage area (i.e. when not in use), but if they are stacked at the designated location then (3.3) shall apply.

2.4 FLOOR ELEVATION

The floor elevation of portable BRMs shall be at least 150 mm above surrounding grade to avoid flooding and they shall be placed on top of a concrete foundation slab with sufficient anchoring to avoid overturning and lateral movement in the event of a blast load.

Portable BRMs shall not be elevated or placed on piers, exposing the bottom of the module to blast pressures.

2.5 ENTRANCES AND EXITS

Portable BRMs shall have at least two entrances/exits, located near opposite ends, but not fitted in the same wall.

At least one door shall be of the emergency type, fitted with panic hardware.

The total number and location of emergency exit(s) shall comply with the building and fire codes applicable at the site of installation.

All entrance/exit doors shall open outwards.

2.6 PROVISIONS FOR DISABLED PERSONS AND TOILETS

If required, as specified by the Principal and/or in accordance with the local building code.

2.7 BUILDING USE CONSIDERATIONS

2.7.1 Managing risks due to building deflections

The Contractor shall consider the building response (large and sudden roof and wall deflections) in the placement and anchoring of hardware and furnishings. Care shall be taken to prevent objects close to, or attached to, the roof or exterior walls from becoming a hazard.

2.7.2 Placement of heavy exterior equipment

Heavy exterior equipment, such as transformers, air conditioners, condensers or cooling towers, shall not be mounted on the roof or wall. If this cannot be avoided, such equipment shall be securely anchored and the supporting structural components shall be specifically designed for actual equipment dynamic loads when subjected to a blast.

2.7.3 Interior equipment and furnishings

Tall, heavy objects (e.g. lockers, tall filing cabinets and tall bookshelves) shall be placed away from exterior walls. If this cannot be avoided, the objects shall be anchored or shall be located so that there is a clearance between the object and exterior walls larger than the calculated wall deflection or 150 mm, whichever is greater. If the exterior wall is covered by drywall on the inside face, the space separation between the two panels may be factored into these spacing requirements, provided the interior drywall panel does not deflect with the exterior panel when subjected to a blast load.

Shock-sensitive equipment shall be mounted on interior walls, rather than on the inside of exterior walls. The interior walls shall have sufficient structural strength for fixing this equipment.

Large overhead light fixtures (e.g. the typical fluorescent type) shall not be hung from suspended ceilings, but shall be fixed on structural members.

Heavy interior equipment, such as video monitors, shall not be hung from the ceiling.

Anchorage shall be designed to resist a statically applied force, F , of at least the following:

$$F = 5 \times m \times g$$

where:

F is the force in Newtons;

m is the mass of the object in kilograms;

g is the acceleration due to gravity ($= 9.81 \text{ m/s}^2$).

3. STRUCTURAL CONSIDERATIONS

3.1 GENERAL

Portable BRMs shall be designed for the blast loading as well as for all gravitational, wind, and other applicable loading conditions as specified in:

- DEP 34.00.01.30-Gen.
- DEP 34.17.00.32-Gen.
- DEP 34.17.10.30-Gen.

The design live loads for the floor shall be 3 kN/m^2 or as indicated by local requirements.

3.2 BLAST RESISTANCE PERFORMANCE

A fixed base shall be assumed for design purposes when evaluating blast loads on the BRM.

The blast performance of the BRM shall be stated on a nameplate, which shall be secured to the outside wall next to the primary entrance door. The nameplate shall at least include:

- a) The BRM Manufacturer, an identification or serial number, the date of manufacture, the latest inspection date, the BRM size, the BRM mass, the nominal 55 kPa blast rating, the blast capacity, and any anchorage requirements to prevent overturning due to blast loads (see (3.5) for anchorages).
- b) For calculation purposes, a peak side-on overpressure of 55 kPa for a duration of 100 ms shall be assumed.

3.3 MULTIPLE BRMs

BRMs may be stacked if blast load calculations are made to verify the stacked design. If stacked, the modules shall be bolted or secured together and the amount of bolting and structural reinforcement shall be determined by the blast load calculations.

Buildings may be composed of multiple BRMs at the same level provided blast load calculations are carried out to verify the design requirements.

3.4 BLAST LOADS

Blast loads on individual BRM surfaces shall be computed from the specified side-on pressure using the methods defined in Appendix A and DEP 34.17.10.30-Gen. Section 5. Blast loads shall be assumed to come from all directions. Appendix A specifies requirements for BRMs using DEP 34.17.10.30-Gen. Section 5 as the basis, with some modifications.

Blast loads shall be assumed to act as shock waves.

Structural components, doors, or appurtenance on an exterior surface of a BRM shall be designed for the blast load applicable to that surface.

3.5 ANCHORAGE CONSIDERATIONS

BRMs shall have sufficient mass and a centre of gravity to prevent overturning under blast loading, otherwise anchorage (designed for blast loading) shall be provided if this requirement cannot be met.

The requirement for anchorage to prevent overturning due to blast loading shall be stated in the BRM nameplate specified in (3.2).

Lateral anchorage movement during a blast load shall not be allowed.

Due to the blast load requirements of BRMs, anchoring to resist any wind or seismic loads should not be taken into account.

See Appendix A for additional foundation requirements.

3.6 CONSTRUCTION AND MATERIALS

The structural system and materials shall be selected to:

- o Provide the most economical design.
- o Promote ductile behaviour in the ultimate limit state (brittle materials shall therefore not be used). Unless unavoidable, shear failure shall not be the governing design case.

All performance requirements specified in this DEP and by local regulations shall be met.

3.7 DETAILED DESIGN CONSIDERATION FOR BRMs

3.7.1 General

Appendix A shall be applied to the design of BRMs.

3.7.2 Response (Deformation) Range

For BRMs, the response range shall be "HIGH", as specified in Appendix A.

3.7.3 Blast doors

All external doors shall be designed as category II blast doors as specified in DEP 34.17.10.30-Gen. (see Appendix A).

3.7.4 Windows

There shall be no windows.

3.7.5 Surface Protection

If the structural system and material is of steel the surface protection shall be as indicated in DEP 30.48.00.31-Gen. and the painting systems shall be as indicated below or similar (subject to approval). For other structural systems and materials the Principal shall indicate the surface protection (if required).

SURFACE PREPARATION	PAINT SYSTEM		
	Primer	Inter-coat	Top coat
Sa 2½	Alkyl zinc silicate DFT 75 µm	High build, epoxy sealer DFT 75 µm	High build, aliphatic polyurethane DFT 75 µm

4. ELECTRICAL AND IT SYSTEMS

4.1 GENERAL

The design of electrical systems shall be in accordance with DEP 33.64.10.10-Gen. and comply with national requirements. The design shall take into account the portability and/or modular system of the BRM.

Fluorescent luminaires with type of protection Ex'e' shall be used.

BRM containers of 20 ft shall have at least 4 socket outlets. For design requirements, reference is made to DEP 33.64.10.10-Gen.

4.2 EMERGENCY LIGHTING

BRMs shall have adequate emergency lighting, with Ex'e protection, to allow a safe and orderly exit in the event of a main power outage.

Emergency lighting shall be designed in accordance with DEP 33.64.10.10-Gen.

4.3 EARTHING

The electrical systems in each BRM shall have a separate earthing installation. Each installation shall have one common earth grid. The earth grid shall comprise stranded copper earthing cables with green/yellow PVC sheathing. Reference is also made to DEP 33.64.10.10-Gen. and/or local requirements.

4.4 PENETRATIONS

Conduit and cable penetrations in exterior walls shall be sealed for weather and blast protection and shall be in accordance with (A.6.4) and DEP 34.17.10.30-Gen. Sections 5.6.4 and 5.6.11.

Multi-conductor cable entries and conduits shall be designed and sealed in accordance with DEP 33.64.10.10-Gen.

4.5 MANUAL SHUTDOWN AND AUTOMATIC SWITCH

A switch for manually and automatic shutting down all electrical power supplies shall be installed to safeguard the BRM in the event of evacuation or gas detection. This requirement does not apply to BRMs sited in non-hazardous areas, as indicated on the area classification drawings.

4.6 TRIP FUNCTION

A trip function shall be installed in the event of gas detection, to de-energise all non-Zone-2 classified equipment (e.g. computers). This requirement does not apply to BRMs sited in non-hazardous areas, as indicated on the area classification drawings.

4.7 IT SYSTEMS

IT systems shall be designed in accordance with the local requirements and shall take into account the portability and/or modular system of the BRM in both the "put-together" phase and the removal phase.

5. HEATING, VENTILATION AND AIR CONDITIONING

5.1 GENERAL

BRMs shall be provided with single or multi-split air conditioners for heating or cooling, mounted on the floor or wall with account being taken of the requirements as mentioned in (2.7).

5.2 SPECIAL SAFETY HVAC DESIGN CONSIDERATIONS

5.2.1 Zone 2 area classification

All HVAC parts of the units shall comply with the requirements of the Zone 2 classification, as specified in DEP 33.64.10.10-Gen. Fresh air intakes may be implemented, but are not required. This requirement does not apply to BRMs sited in non-hazardous areas, as indicated on the area classification drawings.

5.3 BUILDING DESIGN CONDITIONS

The HVAC shall be designed to maintain the following conditions inside the BRM in line with DEP 31.76.10.10-Gen.

1. Room Temperature:
 - a) Summer: $24\text{ }^{\circ}\text{C} \pm 1\text{ }^{\circ}\text{C}$
 - b) Winter: $22\text{ }^{\circ}\text{C} \pm 1\text{ }^{\circ}\text{C}$
2. Relative humidity between 10 % and 90 %.

5.4 AMBIENT DESIGN CONDITIONS

Ambient design conditions shall be based on national and/or local regulations.

5.5 COMBUSTIBLE AND TOXIC GAS DETECTORS

Combustible and/or toxic gas detectors are required for Zone 2 classified areas. DEP 32.30.20.11-Gen. shall be used to determine requirements. Gas detection shall activate the trip switch indicated in (4.6). This requirement does not apply to BRMs sited in non-hazardous areas, as indicated on the area classification drawings, or as indicated in an HSE assessment.

5.6 FIRE DAMPERS/EXPLOSION PROTECTION VALVES

Fire dampers are only required if partitions are provided in the BRM. Explosion valves are required for inlets (e.g. fresh air) and outlets (e.g. extraction fans).

5.7 NOISE ABATEMENT/VIBRATION

Noise abatement/vibration requirements shall comply with DEP 34.17.00.32-Gen. In general this means that the threshold value of 45 dB shall not be exceeded.

6. PIPING

6.1 UTILITIES

Flammable or combustible liquids or gases shall not be routed into BRMs. Water lines shall not be routed over electronic equipment or over cable trays that lead to electronic equipment.

6.2 PENETRATIONS

Piping penetrations in exterior walls shall be sealed for weather protection and protected against explosion as specified in (A.6.4) and DEP 34.17.10.30-Gen. Section 5.6.4.

7. FIRE FIGHTING FACILITIES/FIRE PROTECTION/FIRE AND GAS DETECTION

7.1 FIRE EXTINGUISHERS

Fire extinguishers shall be provided as required by local regulations.

In any case, two hand-operated fire extinguishers shall be installed strategically close to all exit areas.

Fire-fighting water hose reels are not required.

7.2 INTERNAL FIRE AND GAS DETECTION

Internal fire and gas detection is not required.

7.3 FIRE PROTECTION

For explanation of terms used and tests mentioned in this DEP, see BS 476.

Where ducts or piping/cabling pass through roofs, walls or floors, the surrounding gaps shall be closed air and water tight by non-combustible materials and constructed in such a way as to allow essential thermal movements. The surrounding gaps shall also be protected against external explosions.

Insulation materials used inside the BRM shall be e.g. mineral wool blankets with galvanised wire netting with no flammable materials attached to them (in wall cladding, ceilings, partition walls, etc.).

7.4 FIRE RESISTANCE

The minimum fire rating values of the elements of the BRM shall be as follows:

- Roof and outside walls, (including doors) shall have a smoke and fire resistance period of minimum one hour.
- Internal walls shall have a smoke and fire resistance period of minimum one hour.
- Walls of offices and social amenities shall be designed as partitions with no fire resistance. However, all materials for walls and ceilings shall be of a non-combustible type.
- Floors shall have a smoke and fire resistance period of minimum one hour.

NOTE: All penetrations, both inside and outside, shall be well sealed according to the required fire resistance.

7.5 SURFACE SPREAD OF FLAME

Lining materials for walls and ceilings shall be of non-combustible materials with a resistance to surface spread of flame corresponding to BS 476-7, Class 1.

7.6 EXTERNAL FIRE EXPOSURE AND HEAT RADIATION

The roof of the BRM shall satisfy the classification of BS 476-3, Class AA, without developing cracks or holes. The BRM shall be insulated to give the occupants protection against a heat radiation of 5 kW/m².

NOTE: In principle occupants should be evacuated in the event of a nearby fire.

8. DOCUMENTATION

8.1 DESIGN PHASE

The location of portable BRMs shall be assessed in accordance with a checklist as given in Appendix B or as specified by the Principal.

In the design phase of the BRM, the following drawings shall be produced, if applicable:

- a) Floor plan
- b) Elevation
- c) Structural drawings
- d) Single-line electrical drawing of the power system
- e) HVAC system drawings
- f) Piping and plumbing drawings

All the above design drawings shall be submitted to the Principal for approval.

Structural calculations, including blast design calculations, shall be submitted to the Principal for approval.

8.2 AT BRM ACCEPTANCE

At BRM acceptance, the following documents shall be submitted to the Principal:

- a) As-built drawings.
- b) Operating and maintenance manuals and recommended spare parts lists for the BRM equipment.

9. REFERENCES

In this DEP, reference is made to the following publications:

- NOTES:
1. Unless specifically designated by date, the latest edition of each publication shall be used, together with any amendments/supplements/revisions thereto.
 2. The DEPs and most referenced external standards are available to Shell staff on the SWW (Shell Wide Web) at <http://sww05.europe.shell.com/standards/>.

SHELL STANDARDS

Painting and coating of new equipment	DEP 30.48.00.31-Gen.
Heating, ventilation and air conditioning for plant buildings	DEP 31.76.10.10-Gen.
Fire, gas and smoke detection systems	DEP 32.30.20.11-Gen.
Electrical engineering guidelines	DEP 33.64.10.10-Gen.
Minimum requirements for structural design and engineering	DEP 34.00.01.30-Gen.
Geotechnical and foundation engineering	DEP 34.11.00.12-Gen.
Design and engineering of buildings	DEP 34.17.00.32-Gen.
Blast resilient and blast resistant control buildings/field auxiliary rooms	DEP 34.17.10.30-Gen.
Reinforced concrete structures	DEP 34.19.20.31-Gen.
Steel structures	DEP 34.28.00.31-Gen.
Area classification (amendments/supplements to IP 15)	DEP 80.00.10.10-Gen.

AMERICAN STANDARDS

Structures to resist the effects of accidental explosions	ARMY TM 5-1300
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Issued by:
United States Army Corps of Engineers Publication Depot
ATTN: CEHEC-IM-PD
2803 52nd Ave.
Hyattsville, MD 20781-1102, USA

Design of blast resistant buildings in petrochemical facilities	ASCE 40265
---	------------

Issued by:
American Society of Civil Engineers.
1801 Alexander Bell Drive,
Reston, VA 20191,
USA

Standard specification for carbon structural steel	ASTM A 36
Standard specification for high-strength low-alloy structural steel, up to 50 ksi [345 Mpa] minimum yield point, with atmospheric corrosion resistance	ASTM A 588

Issued by:
American Society for Testing and Materials
100 Barr Harbor Drive, West Conshohocken
PA 19428-2959
USA

BRITISH STANDARDS

Fire tests on building materials and structures	BS 476
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Fire tests on building materials and structures –

Part 3: Classification and method of test for external fire exposure to roofs BS 476-3

Fire tests on building materials and structures –

Part 7: Method of test to determine the classification of the surface spread of flame of products BS 476-7

Steel for the reinforcement of concrete – Weldable reinforcing steel – Bar, coil and decoiled product – Specification BS 4449

Code of practice for thermal insulation of pipework and equipment in the temperature range –100 °C to +870 °C BS 5970

Issued by:
British Standards Institution
389 Chiswick High Road
London W4 4AL
UK

DUTCH STANDARDS

Methods for determining the potential damage to humans and the surrounding area resulting from the release of hazardous substances ("Green Book") PGS 1

The document number was changed from CPR 16 to PGS 1.

Methods for the Calculation of Physical Effect ("Yellow Book") PGS 2

The document number was changed from CPR 14E to PGS 2.

Issued by:
Department of VROM, Dutch Government,
Postbus 30945
2500 GX The Hague
The Netherlands

EUROPEAN STANDARDS

Hot rolled products of structural steel EN 10025

Issued by:
CEN
Rue de Stassart 36
B-1050 Brussels
Belgium

Copies can also be obtained from national standards organizations.

INTERNATIONAL STANDARDS

Electrical apparatus for explosive gas atmospheres – Part 14: Electrical installations in hazardous areas (other than mines) IEC 60079-14

Issued by:
Central Office of the IEC
3, Rue de Varembe
CH 1211 Geneva 20
Switzerland

Copies can also be obtained from national standards organizations.

Mechanical properties of fasteners made of carbon steel and alloy steel – Part 1: Bolts, screws and studs ISO 898-1

Hexagon bolts for high-strength structural bolting with large width across flats (thread lengths according to ISO 888) – Product grade C – Property classes 8.8 and 10.9 ISO 7411

Aluminium structures – Material and design – Ultimate limit state
under static loading

ISO TR 11069

Issued by:
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Copies can also be obtained from national standards organizations.

APPENDIX A REQUIREMENTS FOR BRMs, BASED ON DEP 34.17.10.30-Gen.

This appendix specifies requirements for BRMs, following the numbering and headings of DEP 34.17.10.30-Gen., Section 5.

A.1 GENERAL

The civil engineering of the BRMs shall be in accordance with the requirements of this DEP and national and/or local building regulations. Unless otherwise specified and/or agreed by the Principal, the more stringent requirements shall be followed.

A general arrangement drawing showing the internal layout of the BRM shall be prepared in close consultation with the Principal.

A recognised (registered) engineer, if required by national and/or local authorities, shall be engaged to design and co-ordinate the BRMs and their installations. The choice of architect requires prior approval of the Principal.

A.2 BASIC DESIGN REQUIREMENTS

A.2.1 Shape and height of BRMs

Dimensions shall be as specified in (2.3).

A.2.2 Roof

The roof shall be well insulated, but shall not be covered with gravel or loose concrete tiles as these will fly in the event of an explosion. On the roof, only the air intake and exhaust facilities of maximum height 1.8 m, fresh air intake stack, aerials, TV cameras and similar equipment are permitted.

A.2.3 Fragment impact

The possible consequences of an explosion are flying fragments, e.g., valves, which can penetrate the BRM. The thickness of the walls shall therefore be sufficient to withstand these fragment impacts. This specification does not include a calculation method to determine appropriate wall thickness. Additional resources for determining wall thickness, and their ability to withstand fragment impacts, can be found in PGS 2.

A.2.4 Response (deformation) range

BRMs that are subject to blast loading will respond (deform). This response will depend on the ductility ratio and rotation of structural members. For review and design of BRMs, the following response range shall be used:

Response	Description
Low	Localised building/component damage. Building can be used, however repairs are required to restore the integrity of the structural envelope. Total cost of repairs is moderate.
Medium	Widespread building/component damage. Building cannot be used until repaired. Total cost of repairs is significant.
High	Building/component has lost structural integrity and may collapse due to environmental conditions (e.g. wind, snow or rain). Total cost of repairs approach replacement cost of building.

The related response criteria for ductility ratio and rotation are given in (A.5.4). For the design of BRMs the **HIGH** response range shall apply.

A.2.5 Gas tightness of BRMs

There are no special requirements for gas tightness, but the selection of construction and materials shall be such that there are no gaps. In the event of an explosion the rubbers of the doors shall close any possible gap.

A.2.6 Construction and materials

The structural system and materials shall be selected to provide the most economical design. All performance requirements as mentioned in this DEP and as indicated by local requirements shall be met, including those specified by the Principal.

For BRMs, modified steel containers shall be used that can withstand an overpressure of 55 kPa for a duration of 100 ms.

A.2.7 Fire protection

The requirements as indicated in this DEP (7) shall be applied.

A.3 BASIS FOR CALCULATION

A.3.1 BRM blast loading parameters

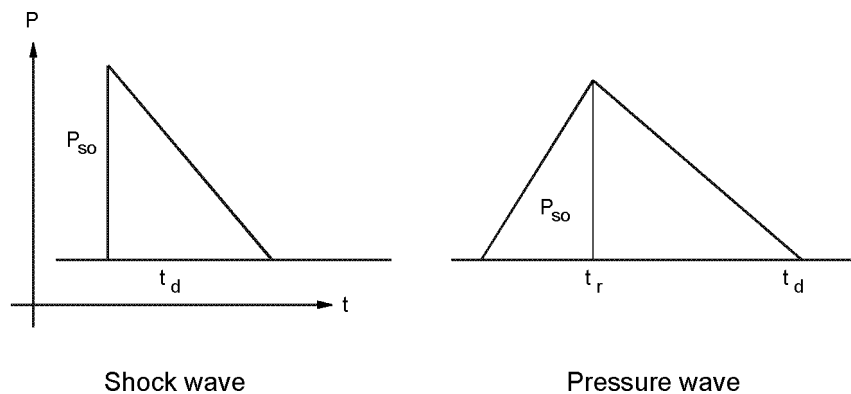
A.3.1.1 General

The input of the dynamic calculations for the structure and structural elements of the BRM subject to blast loads shall be based on the following blast wave parameters:

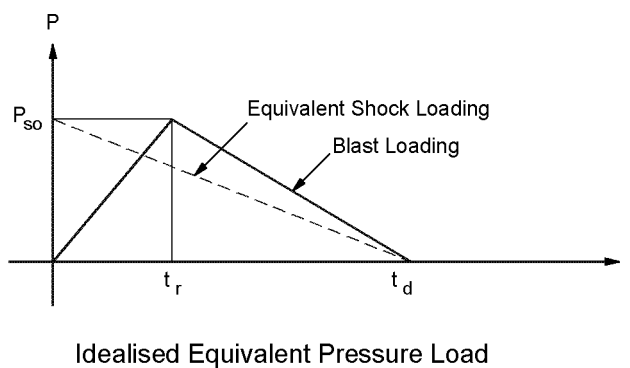
1. Shock or pressure wave;
2. Peak side-on positive (or negative) over-pressure;
3. Positive (or negative) phase duration;
4. Positive (or negative) impulse;
5. Peak reflected pressure;
6. Dynamic (blast wind) pressure;
7. Shock front velocity;
8. Blast wavelength.

A.3.1.2 Shock or pressure wave

The shape of shock and pressure waves is idealised in the figures below.



For the pressure wave, an idealised equivalent pressure load may be used, as indicated below.



The negative part of the wave may be ignored.

Nomenclature:

P = Pressure in kPa

P_{so} = Peak incident over-pressure in kPa

t = time in ms

t_d = positive phase duration in ms

t_r = rise time in ms

A.3.1.3 Peak side-on over-pressure

The peak side-on over-pressure (P_{so}) shall be obtained via a hazard assessment or shall be specified by the Principal, but shall not be less than 55 kPa.

A.3.1.4 Phase duration

The positive phase duration (t_d) shall be obtained from the hazard assessment or shall be specified by the Principal, but shall not be less than 100 ms. The negative phase duration may be ignored.

A.3.1.5 Positive (or negative) impulse

The area (see A.3.1.2) under the pressure-time curve is the corresponding impulse of the blast wave. The peak side-on over-pressure and the duration of the wave will determine this area. The negative impulse may be ignored. The corresponding impulse (I_o) may be defined as follows:

$$I_o = 0.5 \times P_{so} \times t_d \quad \text{for a triangular wave}$$

NOTE: A triangular wave is commonly assumed.

A.3.1.6 Peak reflected pressure (P_r)

The field blast wave strikes the BRM surface and will be reflected. The magnitude of the reflected pressure (P_r) is determined as an amplifying of the incident pressure (P_{so}) and is determined as follows: P_r = C_r × P_{so}. C_r is the reflection coefficient and will depend on the peak over-pressure and the angle of incidence of the wave front relative to the reflecting surface. The angle of incidence shall be assumed to be 0° (i.e. the worst case, perpendicular). To determine the reflection coefficient, the following simple formula may be used:

$$C_r \approx (2 + 0.0073 \times P_{so})$$

NOTE: P_{so} is in kPa and C_r is dimensionless.

A.3.1.7 Dynamic (blast wind) Pressure

The dynamic pressure (q_o) is to be calculated with the following empirical formula:

$$q_o \approx 0.0032 \times (P_{so})^2 \quad \text{in kPa}$$

The net dynamic pressure on a structure is: q_o × C_d. The drag coefficient, C_d, depends on the shape and the orientation of the BRM. For a rectangular BRM, a C_d of 1.0 shall be taken for the front wall and a C_d of -0.4 shall be taken for the sidewalls, rear walls and roof.

A.3.1.8 Shock front velocity

In the free field, the blast wave from an explosion travels at or above the acoustic speed for the propagating medium. The following relationship may be used to determine the shock front velocity, U.

$$U \approx 340 \times [1 + (6 \times P_{so}) / (7 \times P_o)]^{0.5} \quad \text{in m/s in which } P_o \text{ is ambient pressure (= ~100 kPa)}$$

A.3.1.9 Blast Wave Length (L_w)

The propagating blast wave at any instant in time extends over a limited radial distance as the shock/pressure front travels outward from the explosion. The pressure is largest at the front and trails off to ambient over a distance L_w . For pressure ranges in this specification, the blast wavelength is approximated as $L_w \approx U \times t_d$, in m.

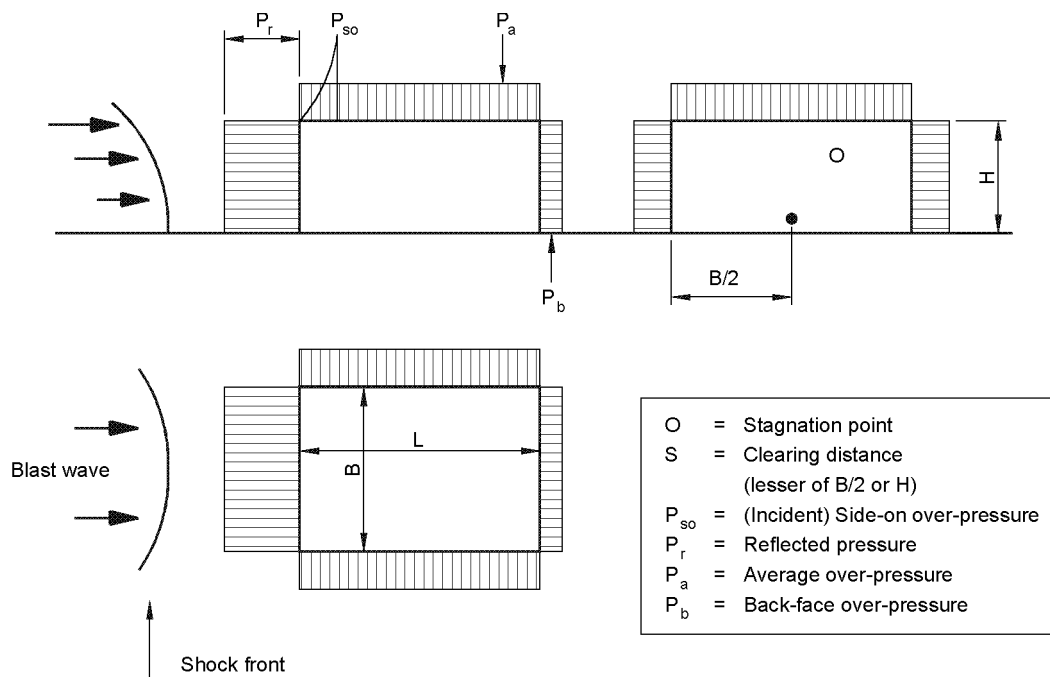
A.3.2 BRM blast loading

A.3.2.1 General

After determining the BRM blast loading parameters (A.3.1), the BRM blast loading can be determined. The blast loading is applicable to rectangular BRMs. The following loading cases shall be established:

1. Blast Loading;
2. Front Wall Loading;
3. Side Wall Loading;
4. Roof Loading;
5. Rear Wall Loading;
6. Frame Loading;
7. Negative Pressure and Rebound Loading.

A general arrangement of the blast loading for rectangular BRMs is given below:



A.3.2.2 Blast loading

The information of the blast loading shall be determined via a major hazard assessment or given by the Principal. The information shall consist out of:

- Peak side-on over-pressure, P_{so} , in kPa.
- Duration, t_d , expressed in s or ms
- Shock front velocity, $U \approx 340 \times [1 + (6 \times P_{so}) / (7 \times P_o)]^{0.5}$, expressed in m/s
- Length of pressure wave, $L_w = U \times t_d$, expressed in m

- Peak dynamic wind pressure, $q_0 = 0.0032 \times (P_{s0})^2$, expressed in kPa

A.3.2.3 Front wall loading

The front wall that is facing the explosion source is assumed to span vertically from the foundation to the roof. A typical wall segment is assumed to be 1 m wide. For the front wall loading, the following formula is given:

- Reflected over-pressure, $P_r = [2 + (0.0073 \times P_{s0})] \times P_{s0}$

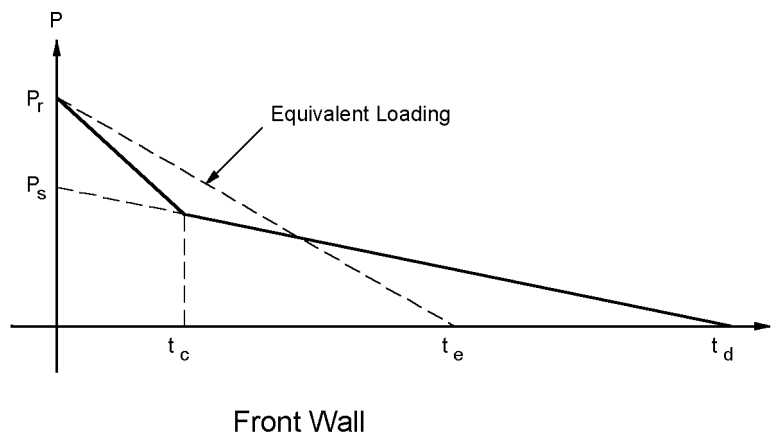
NOTE: For design purpose, the normal shock reflection conditions (angle of incidence $\alpha=0^\circ$ and the rise, $t_r = 0$ s) shall be assumed or shall be as indicated.

- Clearing distance, $S = \text{minimum of } H \text{ or } B/2$, in which: $H = \text{Height of BRM}$
 $B = \text{Width of BRM}$
- Reflected clearing over-pressure time, $t_c = 3 \times (S/U) < t_d$, in s
- Drag coefficient, $C_d = 1.0$
- Front wall impulse, $I_w = 0.5 \times (P_r - P_s) \times t_c + 0.5 \times P_s \times t_d$, in kPa.s

NOTE: Applicable for an equivalent triangle wave.

- Effective duration of the equivalent triangle, $t_e = 2 \times I_w / P_r$, in s

The reflected over-pressure shall decay to the stagnation pressure, P_s , in the clearing time, t_c and is defined in the figure below.



Stagnation pressure, $P_s = P_{s0} + C_d \times q_0$

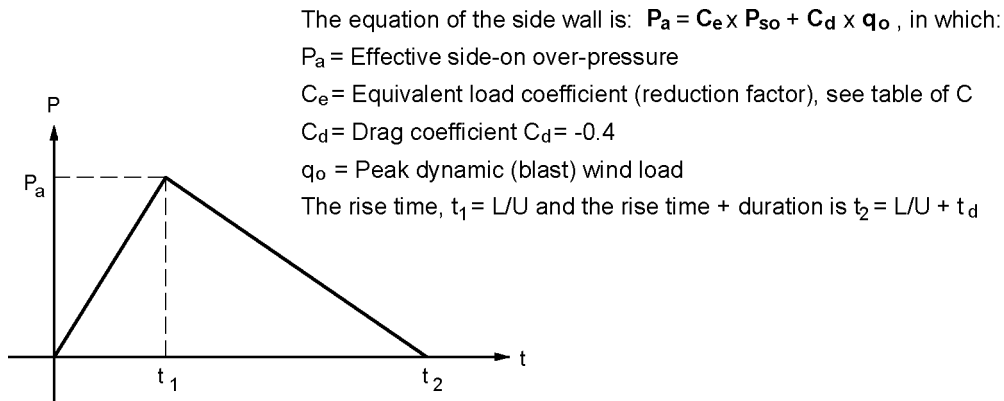
Reflective over-pressure clearing time, $t_c = 3 \times (S/U) < t_d$

Front wall impulse, $I_w = 0.5 \times (P_r - P_s) \times t_c + 0.5 \times P_s \times t_d$

Effective duration, $t_e = 2 \times I_w / P_r = (t_d - t_c) \times P_s / P_r + t_c$

A.3.2.4 Side wall loading

The sidewalls will receive less blast loading due to lack of reflection. In certain cases, the actual sidewall loading shall be combined with other blast induced forces, such as in-plane forces of shear walls. The form of the sidewall blast loading (excluding other induced blast forces) is given below.



Roof and Side Wall

Table of equivalent load coefficient (C_e), derived from ARMY TM 5-1300.

L_w/L	0.5	0.6	0.7	0.8	0.9	1	2	3	4	5	6	7	8	9	10
C_e	0.23	0.28	0.32	0.4	0.42	0.45	0.6	0.7	0.8	0.95	1	1	1	1	1

- NOTES
1. L_w is the blast wave length and is $U \times t_d$. L is the length of the structural element, in the direction of the travelling blast wave.
 2. If the blast wave is travelling perpendicular to the span, then L shall be equal to a nominal unit width of the structural element.
 3. An element of e.g. 1 m may be taken or in case over-pressure is needed, the entire width of the wall shall be taken into account. The value of C_e then becomes less than one and the value of P_a may be reduced. The rise time will become significant.

The impulse of the side wall, $I_s = 0.5 \times t_2 \times P_a$

A.3.2.5 Roof wall loading

The roof wall loading will receive the same blast loading as the sidewall loading. The calculation is similar as the sidewall blast loading.

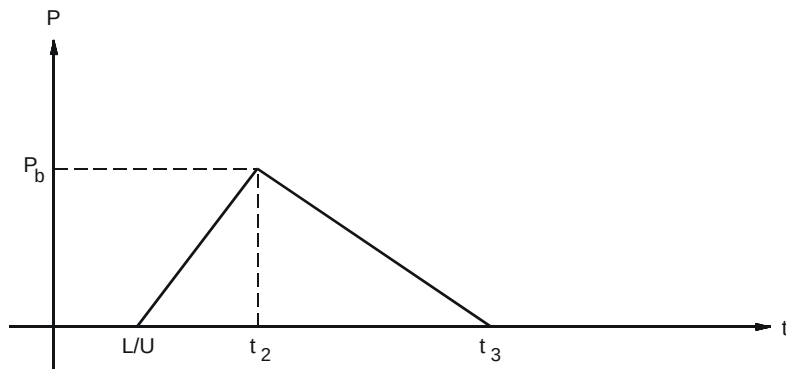
A.3.2.6 Rear wall loading

The rear wall loading shall be used to determine the net overall frame loading.

The rear face over-pressure, $P_b = C_e \times P_{so} + C_d \times q_o$

The effective loading coefficient, C_e , can be found in DEP 34.17.10.30-Gen. Section 5.3.2.3.

The drag coefficient, $C_d = -0.4$



Rear wall

Rise time $t_2 = L/U + S/U$

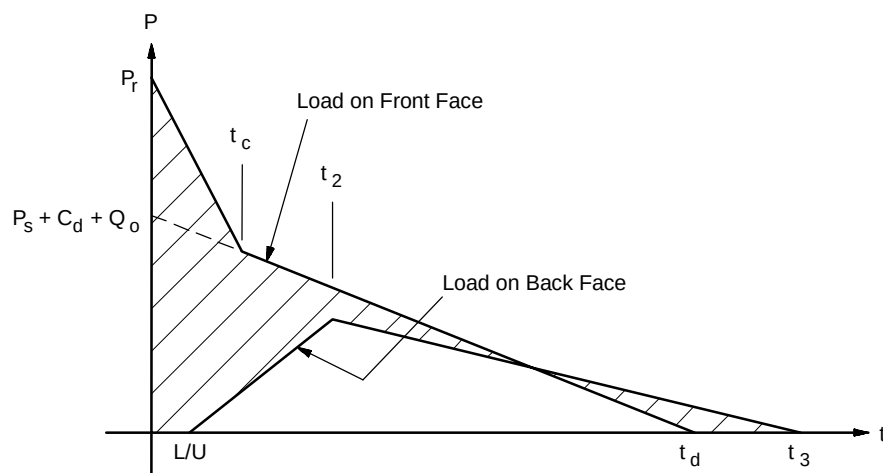
$T_3 = t_2 + t_d$

(based on ARMY TM 5-1300)

The impulse of the rear wall, $I_r = 0.5 \times t_3 \times P_b$, expressed in kPa.ms

A.3.2.7 Frame loading

The framing system will receive the diffraction loading which is the net loading on the front and rear walls taking into account the time phasing. During the time, L/U , that it takes for the blast wave to travel from the front to the back of the BRM the structural framing will be subjected to the large horizontal unbalanced pressure on the front wall. After that time the front wall loading is partially offset by the rear wall loading. The figure below shows the general form for the lateral frame loading.



Net lateral load on a rectangular building (from GPS 1)

A.3.2.8 Negative pressure and rebound loading

The components of the BRM will also experience blast load effects, opposite in direction to the primary blast load effects, due to negative phase (suction) of the blast wave, together with the rebound of the structural components from the inertial effects of the over-pressure loading. The negative pressure forces are generally ignored because they are relatively small or unquantified for vapour cloud explosions. However, the structural components of the BRM shall be adequately designed to perform satisfactorily for the rebound effects. These effects shall be quantified from the time history dynamic analysis of the structural components by performing a dynamic analysis method. For simple cases the "Single Degree Of Freedom" (SDOF) may be used, but normally computer software based on the "Finite Element Analysis Methods", e.g., STAAD III shall be used.

A.3.3 Design philosophy

Materials that receive a dynamic loading achieve a strength increase, which will significantly enhance structural resistance. These structures will undergo plastic (permanent) deformation to absorb the explosion energy. The design shall therefore be based on the plastic hinge design philosophy, also referred to as ultimate strength principle, which recognises the redistribution of internal forces that takes place when complete yielding develops at regions of high bending moment. Applying this philosophy, the factor of safety against collapse, i.e. when the structure develops a sufficient number of plastic hinges to permit unrestrained deformation, shall be 1.1.

For dynamic analysis methods, the "Single Degree of Freedom (SDOF)" may be used. The "Finite Element Analysis Method" shall be used for comprehensive and complicated structures. The computer software for this purpose shall have a proven track record, e.g., STAAD III.

A.4 MATERIAL PROPERTIES

A.4.1 Dynamic material strength

1. Dynamic yield stress, F_{dy} , shall be computed as follows:

$$F_{dy} = F_y \times SIF \times DIF$$

F_y is the specified minimum static yield stress; DIF is the dynamic increase factor as defined in (A.4.3); SIF is the strength increase factor as defined in (A.4.2).

2. Dynamic design stress, F_d , used to compute the dynamic capacity of structural components shall be based on the values listed in Table 3.
3. Dynamic ultimate strength, F_{du} shall be computed as follows:

$$F_{du} = F_u \times DIF$$

F_u is the specified ultimate strength; DIF is the dynamic increase factor as defined in (A.4.3).

A.4.2 Strength Increase Factor (SIF)

A strength increase factor shall be applied to the specified minimum yield strength of structural materials to estimate the actual static value. The SIF shall be taken from Table 1 below.

Table 1 Strength increase factors for structural materials

Structural Material	SIF	Remarks
Structural Steel with a Yield of 355 MPa or Less	1.1	
Concrete Reinforcing Steel Hot rolled mild or high yield strength of 460 MPa or less (BS 4449)	1.1	NA

Cold Formed Steel Cladding Panels (BS 5970) with yield strength of 460 MPa or less (BS 4449)	1.2	
Concrete and Masonry	1.0	NA
Other Materials	1.0	NA

A.4.3 Dynamic Increase Factor (DIF)

To account for strain rate effects caused by rapidly applied blast loads, dynamic increase factors shall be applied to the static material yield and ultimate strengths to determine their dynamic values in accordance with Table 2.

Table 2 Dynamic increase factors for steel and aluminium

Material	DIF		
	Yield Stress		Ultimate
	Bending/Shear	Tension/compression	Stress
	(F_{dy}/F_y)	(F_{dy}/F_y)	(F_{du}/F_u)
EN 10025 or ASTM A 36	1.29	1.19	1.10
EN 10025 or ASTM A588	1.19	1.12	1.05
Stainless Steel Type 304	1.18	1.15	1.00
ISO/TR 11069 Aluminium, 6061-T6	1.02	1.00	1.00

Table 3 Dynamic design stress for structural steel

Type of Stress	Maximum Ductility Ratio	Dynamic Design Stress (F_{ds})
All	$\mu < 10$	F_{dy}
All	$\mu > 10$	$F_{dy} + (F_{du} - F_{dy}) / 4$

NOTE: F_{du} = dynamic ultimate strength; F_{dy} = dynamic yield stress.

A.5 STRUCTURAL DESIGN

A.5.1 Design methods and procedures

All blast resistant BRMs and their structural components may be designed according to the methods provided in ASCE 40265. Other design methods may also be used as long as all the methods meet the requirements of this DEP.

A.5.2 Load combinations

- In addition to the load combinations as prescribed in DEP 34.17.00.32-Gen., a blast resistant structure shall be designed for the blast load condition as follows:

$$U_{(t)} = D + (A \times L) + B_{(t)}$$

where:

$U_{(t)}$	=	total applied time dependent load or its effect
D	=	static dead load
$B_{(t)}$	=	time dependent blast load or its effect (horizontal & vertical)

L	=	conventional static live load
A	=	reduction factor ¹ (normally zero) applied to conventional live loads to reflect the portion of live load expected to occur simultaneously with the blast load.

NOTE 1: Live loads that will be normally blown away by a blast wave and live loads, e.g. personnel and furniture that will not increase the inertia of a supported member, shall not be included in the mass calculation. This means that in most cases the reduction factor will be zero.

2. The blast load combination may consider either the direct loads or their effects. In combining blast load effects with those from static dead and live loads, the time dependence of the blast loading shall be taken into consideration.
3. Wind and seismic loads shall not be combined with blast loading.
4. Rebound effects shall be computed and combined with the effects of negative phase blast loads, if any, based on time dependent response.

A.5.3 Analysis methods

A.5.3.1 General

The Contractor shall use analysis methods appropriate for the specific blast design. The selected methods shall adequately model the dynamic response of the structure to the applied blast loads and the structural component interaction. ASCE 40265 may be used. A.5.3.2 and A.5.3.3 shall apply:

A.5.3.2 Single Degree-of-Freedom (SDOF)

The required resistance for each structural component shall be based on the peak blast pressure (or load) and duration, the natural period of the component, and the maximum allowable response (deformation). An SDOF analysis can be used where the connected component differs in natural period by a factor of 2 or more. The formulas and charts provided in either ASCE 40265, ARMY TM 5-1300, or other similar references for the approximate solution of the elastic-plastic SDOF system may be used in determining the required resistance.

A.5.3.3 Multi Degree-of-Freedom (MDOF)

A MDOF analysis shall be used where the structural component interaction cannot be adequately modelled using the simpler equivalent static load or SDOF methods. This method shall involve finite element analysis requiring the use of a special or general-purpose structural analysis computer program with non-linear transient dynamic analysis capability.

A.5.4 Response (deformation) limits

A.5.4.1 Parameters

Structural members shall be designed based on maximum response (deformation) consistent with the performance requirements or permissible damage level specified in (A.2.6). Deformation limits shall be expressed as ductility ratio (μ), support rotation (θ), or frame sideways, as appropriate.

A.5.4.2 BRM response range

The design response range or permissible damage level (= High) shall be based on the BRM design requirements specified in (A.2.6).

A.5.4.3 Response limits

The response range shall be "**HIGH**". Maximum response shall not exceed the limits specified in Table 4.

Table 4 Response (deformation) limits for structural steel

Element Type	Response Range ⁽²⁾					
	Low		Medium		High	
	μ_a	θ	μ_a	θ	μ_a	θ
Beams, Girths, Purlins	3	2	10	6	20	12
Frame members ⁽¹⁾	1.5	1	2	1.5	3	2
Single Sheet Metal Panels	1.75	1.25	3	2	6	4
Open-Web Joists	1	1	2	1.5	4	2
Plates	5	3	10	6	20	12

NOTES:

1. Sideways deflection (δ) limits for steel frames:

Low = $H/50$, (H = storey height)

Medium = $H/35$

High = $H/25$

2. Response parameter:

μ_a = Allowable ductility ratio

θ = support rotation (degrees)

A.5.5 Component design

A.5.5.1 General

Ultimate strength (Limit State) methods shall be used for designing structural components for blast resistance. The ultimate strength capacity shall be determined in accordance with the applicable codes, practices and guides as specified, subject to the following additional requirements:

1. In-plane and secondary bending stresses shall be accounted for in the design.
2. Interaction of forces in two directions, including biaxial bending, shall be considered. Information may be obtained from ASCE 40265.
3. Dynamic strength properties shall be used to reflect increased material strength under rapidly applied loads.
4. Load and resistance factors shall be taken as equal to 1.0 in all blast load combinations.
5. Composite sections may be used for design; however, adequate rebound resistance shall be provided to ensure satisfactory response under rebound or negative phase loads.
6. Components shall be adequately laterally braced to prevent premature buckling failure during the positive and rebound response.
7. Connections shall be designed for 120 % of the member's controlling resistance (flexure or shear, whichever is lower). The deformation limits indicated in Table 4 are based on flexure-controlled resistance. To use these limits, the member's shear capacity shall be at least 120 % of the flexural capacity.
8. The design of compression elements, such as load bearing walls and columns, should consider bending effects including secondary effect* (P-delta effects) and slenderness.

NOTE *: The secondary effect on shears, axial forces and moments of frame members induced by the vertical loads acting on the laterally displaced building system.

A.5.5.2 Reinforced concrete

Reinforced concrete components for the foundation shall be designed in accordance with the provisions of DEP 34.19.20.31-Gen. For additional information, see ASCE 40265. The ultimate strength methods shall be used.

The following specific requirements shall also apply:

1. Deformation limits as noted for shear shall be used where the member's shear capacity is not at least 120 % of the flexural capacity.
2. The concrete shall be at least grade 30. For existing concrete structures, the compressive strength shall be determined by means of destructive tests.
3. Hot-rolled steel bars with yield strength (f_y) between 240 N/mm² and 460 N/mm², and a minimum elongation between 24 % and 12.5 %, shall be used for reinforcement of the concrete. The design stresses of those structural elements subject to blast loads shall be the yield strength of the applied steel bars and the failure stress of the concrete, i.e. 0.8 times the characteristic cube strength. Independent of steel/concrete quality, the safety coefficient shall be 1:1. For existing reinforced bars, the type of bar shall be determined by means of a destructive test. To ensure ductility, cold rolled bars and meshes shall not be used.
4. In general, special attention shall be paid to ensure continuity and a minimum of local stress concentration. Adequate lapping of reinforcement is required.

A.5.5.3 Structural steel

Structural steel components shall be designed in accordance with the provisions of DEP 34.28.00.31-Gen., supplemented by the following requirements:

1. High tensile bolt connections shall not be used. Steel bolts of grade 8.8 conforming to ISO 898-1 and ISO 7411 shall be used for bolted connections. Steel members shall be sufficiently laterally braced and connected to avoid buckling and instability problems, so that large deformation, without failure, can be achieved.
2. Materials with a specified yield strength of 355 MPa or less shall be used for flexural design. Higher strength materials may be used where ductile behaviour is not required.
3. Oversize holes shall not be used in connections that are part of the lateral force resisting system.
4. Column base plates shall be designed to develop the peak member reactions applied as a static load. Dynamic material properties may be taken into account in the design of base plates.
5. Flexural members shall be laterally braced on both faces to provide consistent moment capacity in both positive and rebound response.

A.5.5.4 Cold-formed steel

Cold-formed steel shall not be used.

A.5.5.5 Open web steel joist

Open web steel joists may be designed for blast loads using published load tables for static, working loads with appropriate factors applied to obtain the ultimate capacities with the following limitations.

1. A reduction factor of 0.9 in ultimate moment capacity shall be used unless special provisions are made to enhance ductility of the joist.
2. Lateral bracing shall be provided for the top and bottom chords as required to provide the necessary rebound resistance and positive moment capacity.

A.5.5.6 Reinforced masonry

Not applicable.

A.5.6 Structural framing design

Design of the overall structural framing system shall include analysis of global response including sideways, overturning, and sliding. Sideways analysis shall be performed with and without leeward side (rear wall) blast loads.

A.5.7 Foundation design

Foundation design shall be based on geotechnical requirements in accordance with DEP 34.11.00.12-Gen. The separate concrete base structure shall be firmly embedded in the ground so that overturning shall not take place.

Foundation components shall be designed to resist the peak reactions produced by supported components resulting from the dead, live, and blast loads, treated either statically or dynamically, as noted below.

A.5.7.1 Static analysis

Static application of the peak dynamic reactions from the wall and roof components may be used to design supporting members and compute overturning and sliding effects. For blast load combinations, the factors of safety shall be 1.2 for overturning, and 1.0 for sliding.

A.5.7.2 Static capacity

Foundations shall be designed using vertical and lateral soil capacities as follows:

1. Vertical – 80 % of the ultimate net soil bearing capacity for shallow foundations, including footings and mats. For piles and other deep foundations, 80 % of the ultimate static capacities in compression and in tension may be used.
2. Lateral - Passive resistance of grade beams may be used to resist lateral loads if compacted fill is placed around the BRM perimeter. Frictional resistance of spread footings and floor grade slabs shall be based on the coefficient of friction determined by the geotechnical study. The normal force shall be taken as the sum of the dead loads and the vertical load associated with the ultimate resistance of the roof. Frictional resistance of floating slabs shall not be used.
3. Where only passive resistance, frictional resistance, vertical piles, or battered piles are used to support the lateral blast loading, the resistance shall be taken as 80 % of the ultimate static value. However, if two or more of these resistances are used to support the lateral blast loads, the lateral capacity shall be limited to 67 % of the combined ultimate static resistance.

A.5.7.3 Dynamic analysis

To optimise the foundation design, its components shall be analysed dynamically for the calculated reaction-time history of the supported components. The required dynamic material properties of the foundation soils, including resistance and stiffness, shall be based on an appropriate geotechnical investigation. No deformation limits are specified for dynamic response of foundations. The Contractor shall determine whether the predicted maximum response is acceptable for the permissible damage level of the BRM.

A.6 ANCILLARY AND ARCHITECTURAL ITEMS

A.6.1 Blast doors

Blast resilient or resistant doors shall be provided according to the following requirements:

1. The performance category for the blast resistant doors shall be category II. The response limits and other requirements shall be as given in Table 5.

Table 5 Blast door performance requirements

Category	Door Condition after Blast	Panels	Ductility Ratio Limit	Edge Rotation (θ) (degrees)	Door Function
I	Operable	Elastic	1.0	1.2	Primary exit or repeated blast
II	Operable	Significant damage	3	2	Prevent entrapment
III	Inoperable	Substantial damage	10	8	Prevent blast from entering building
IV	Inoperable	Failure in rebound	20	12	Prevent door from becoming debris hazard.

*NOTE: The following categories shall be used to determine the requirements for blast resistant or resilient doors.

Category I: The door shall be operable after the loading event, and pre-established design criteria for stress, deflection, and the limitation of permanent deformation shall not be exceeded. This category shall be specified if the door should be required to withstand repeated blasts or if entrapment of personnel is of concern and the door is a primary exit to the building.

Category II: Non-catastrophic failure is permitted. The door assembly remains in the opening. No major structural failure occurs in the panel structure, the restraining hardware system, the frame or the frame anchorage that would prevent the door assembly from providing a barrier to blast wave propagation. However the door will be rendered inoperable. This category should only be specified if entrapment of personnel is not a possibility.

Category III: Non-catastrophic failure is permitted. The door assembly remains in the opening. No major structural failure occurs in the panel structure, the restraining hardware system, the frame or the frame anchorage that would prevent the door assembly from providing a barrier to blast wave propagation. However the door will be rendered inoperable. This category should only be specified if entrapment of personnel is not a possibility.

Category IV: Outward rebound force and resulting hardware failure is acceptable.

2. BRMs shall have at least two doors as exit doors for the purpose of limiting the damage to these doors when subjected to blast loads and of which one is for emergency purposes. Designated exit doors shall not be located on the same side of the BRM.
3. Doors, doorframes, and door hardware shall be designed for the performance criteria and applied blast loads specified in this specification (e.g. 55 kPa for a duration of 100 ms)
4. Outward opening doors shall be provided at two sides of the BRMs, of which one is for emergency purposes. The doors shall not be located at the same wall and shall seat against the frame under the positive phase blast wave. Over-pressure inside the BRM is not required. All outer doors shall be provided with automatic door closers.
5. No windows shall be provided in the outer doors; only small peepholes may be provided to check, in the event of fire, that the area outside the door is safe to permit evacuation of the BRM.
6. The outer and inner doors shall have a good seal between door and frame to maintain the gas tightness.

7. There are no special requirements for blast resistant or resistant inner doors.
8. Blast door Manufacturers shall provide calculations or test data to verify adequate blast resistance and door performance for the design load conditions.
9. Manually operated exit doors shall not exceed a maximum opening force of 25 N (measured at the door handle) or shall meet the requirements of the local building codes for the maximum opening force. Power-operated doors shall be used for exit doors that exceed the maximum opening force.

A.6.2 Windows

Windows are not allowed in BRMs.

A.6.3 Openings

Large openings in the BRM envelope, such as intake ducts, shall be designed to prevent entry of excessive blast pressures. The following shall be taken into account:

1. Blast valves, blast attenuators, or other devices shall be used to limit excessive blast pressure entry into the structure. Test data and calculation shall substantiate performance of the blast valve or attenuator.
2. Blast valves shall be provided for openings greater than 0.1 m² in any surface in which the peak applied pressure is greater than 0.07 MPa. Blast dampers may be used for these openings if the peak-applied pressure is greater than 0.035 MPa.

NOTE: Either blast valves or dampers may be used, as the peak applied pressure is 55 kPa.

A.6.4 Penetrations

Penetrations in metal clad structures shall be anchored with substantial framing attached to structural steel members.

A.6.5 Suspended items

Equipment and furnishings such as ceilings, HVAC ductwork, and light fixtures suspended from the roof inside the BRM shall be secured to structural framing members. Anchorage shall be designed to resist a peak, statically applied force equal to the mass of the item times the maximum acceleration of the roof or five times the weight of the item, whichever is the lesser.

A.6.6 Externally mounted items and air intake stack

- A.6.6.1 To avoid the possibility of hazardous debris, large non-structural features such as canopies and signs on the BRM exterior shall be minimised. However, small items such as instruments, fire alarms, lights, strobes and beacons may be mounted on the exterior walls.
- A.6.6.2 Roof and wall mounted equipment (e.g. HVAC equipment) should be avoided. If approved by Principal, such equipment shall be securely anchored and the supporting structural components shall be specifically designed for the actual equipment dynamic loads when subjected to the blast.
- A.6.6.3 Equipment and other items mounted on the exterior surfaces (walls or roof) of the BRM shall be designed similar to the structural components if they are to withstand the applied blast loads. The reactions from such items shall be considered in the design of the supporting structural components.

A.6.7 Equipment and internally mounted items

- A.6.7.1 Instrumentation or electrical equipment shall not be mounted on the interior face of walls subjected to blast loads without the written approval of the Principal.
- A.6.7.2 All fixed floor supported items, if any, shall have a minimum clearance from exterior walls equal to the maximum calculated lateral blast load deflection. The maximum deflection shall consider both the overall BRM sideways plus any wall component(s) deflection and shall be computed based on the maximum blast loads. Supports and anchorage for such equipment shall be designed to resist a lateral force equal to 20 % of the equipment weight or as otherwise indicated in this DEP.

A.6.8 Floors

A.6.8.1 Cavity floors

Not applicable.

A.6.8.2 Channel inserts

Not applicable

A.6.8.3 Plinth for instrument panels

Not applicable

A.6.8.4 HVAC machine room

Not applicable

A.6.8.5 Floor level

The top of the finished floor of the BRM shall be at least 150 mm above the surrounding ground level. Underground cables entering the floor shall be covered with a layer of sand of 600 mm minimum thickness.

Approach to the main entrance shall be a ramp with a slope of not more than 1 in 8 with a non-slip finish of the top surface.

A.6.9 Hoisting area

Not applicable.

A.6.10 Walls and ceilings

A.6.10.1 Wall tiles

Not allowed.

A.6.10.2 Ceilings

The aluminium grid ceiling, if applicable, in the BRM shall be constructed in such a way that the panels are secured in position and cannot fall down during an explosion.

This applies also to the lighting fixtures, etc.

A.6.10.3 Wall and ceiling finishes

All surface finishing materials for walls and ceilings in the portable BRM, the computer room, and the instrument auxiliary/computer basement/room etc. shall be fire-resistant or non-combustible and shall have no loose fibres.

In these spaces, the surface of all walls, ceilings and floors, where dust is liable to accumulate shall be sealed with epoxy paint or PVC coating.

APPENDIX B PORTABLE BLAST RESISTANT MODULE CHECKLIST FOR SITES WITHOUT PRT (PROCESS RISK TOOL)

This checklist shall be completed and approved prior to the occupancy of the portable building.				
Building:	Person conducting assessment (please print):		Date:	
Location of Building:	Estimated duration of siting:		Building Type: Portable BRM	
Items for Blast Resistant Module	Yes	No	NA	Comments
1. Building is a BRM with a blast rating of 55 kPa and duration 100 ms				
2. Location is at least 45 m from process units.				
3. Location is at least 30 m for process equipment/storage that present a significant risk.				
4. Location is at least 15 m from furnaces, atmospheric storage tanks, and associated loading and unloading facilities associated with flammable products.				
5. Location is at least 15 m from boilers.				
6. Location is at least 8 m from above ground pipes containing flammable, toxic, or other, hydrocarbons.				
7. Location is located outside dike walls used for product containment.				
8. Location is where, if the building becomes involved in a fire, it does not impact hydrocarbon lines, electrical systems, or other infrastructure systems.				
9 Egress from building is located to minimize risks.				
10 Emergency response equipment is available and access is not obstructed.				
11 Building is included in emergency response plan and evacuation and emergency response instructions have been posted.				
12. Location meets electrical equipment classification requirements.				
13 Sewer connections properly sealed to prevent ingress of vapours.				
14 Large office equipment or stacks of materials inside building are secure.				
15 Location is where heavy lifting does not occur near the building.				
16 Location is lowest risk location that provides appropriate access.				
Other Items				
Yes – Item in place No – Item is not in place and is needed prior to occupancy. NA (Not Applicable) – This checklist may or may not be appropriate for every particular circumstance. The location shall be re-assessed when the items checked “No” have been completed. Signature of Assessor: A risk-based analysis using this Checklist has been conducted for the siting of this building. The location siting has been approved. Signature of Assessor: Building Owner (print name): Signature:				