

TECHNICAL SPECIFICATION

BLAST RESILIENT AND BLAST RESISTANT CONTROL BUILDINGS/FIELD AUXILIARY ROOMS

DEP 34.17.10.30-Gen.

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DESIGN AND ENGINEERING PRACTICE



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1. INTRODUCTION

1.1 SCOPE

This DEP specifies requirements and gives recommendations for the design, siting and construction of new control buildings and field auxiliary rooms (FARs) in order to minimise the damage in the event of an explosion of a vapour cloud or fire, caused by equipment failure or due to incorrect operation of a plant.

It is a revision of the previous publication of the same number, titled "Reinforced Control Buildings/Field Auxiliary Rooms", dated January 1990.

This DEP provides additional requirements for these buildings, over and above the general requirements for buildings as stated in DEP 34.17.00.32-Gen.

This DEP is intended for use by civil engineers and/or architects involved in the design and engineering of new control buildings and FARs in onshore oil, gas and chemical production facilities. It is not applicable to offshore facilities.

This DEP may also be used for other buildings subject to explosion and/or fire.

For control buildings, it is important that sufficient protection for operators and electronic equipment is provided so that in the event of a calamity, the building may remain functional and emergency actions can be taken to minimise the spread of danger and secondary damage.

For FARs, it is only essential to protect the electronic equipment as such. These buildings are normally unmanned.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by Shell GSI and SIEP, the distribution of this DEP is confined to companies forming part of the Royal Dutch/Shell Group or managed by a Group company, and to Contractors nominated by them (i.e. the distribution code is "C" as described in DEP 00.00.05.05-Gen.).

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

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 more stringent and which combination of requirements will be acceptable as regards 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. Unless otherwise specified and/or agreed by the Principal, the more stringent requirement shall prevail.

1.3 DEFINITIONS

1.3.1 General Definitions

The **Contractor** is the party which 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 which manufactures or supplies equipment and services to perform the duties specified by the Contractor.

The **Principal** is the party which 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** indicates a requirement.

The word **should** indicates a recommendation.

1.3.2 Technical Definitions

For a better understanding of this specification, technical definitions related to explosions are given hereof:

Angle of Incidence - The angle between the direction of the blast wave travel and a line perpendicular to the flat surface (wall) of a structure at the point of interest.

Blast Load - Load generated by an explosion.

Blast Resilient – Describes those structures or structural components which have already a certain elasticity/flexibility in their conventional design to receive some low (limited) blast loads, or those which are designed with an improved conventional (enhanced resilient) design to receive limited blast loads.

Blast Resistant – Describes those structures or structural components which are designed to receive blast loads.

Blast Wave - A transient change in the gas density, pressure and velocity of the air surrounding an explosion.

Conventional Loads - Loads normally considered in structural design such as dead loads, live loads, wind loads and seismic loads.

Ductility Ratio - A measure of the energy absorbing capacity of a structural member/element. The ratio is defined as the element's maximum deformation divided by its yield deformation.

Duration - The time from initial change in pressure to return to ambient pressure.

Dynamic Increase Factor - The ratio of dynamic to static strength that is used to compute the effect of a rapidly applied load to the strength of a structural element.

Elastic Region - The deformation range from zero up to the formation of the first plastic hinge.

Elasto-Plastic Region - The deformation range from formation of the first plastic hinge up to formation of the final plastic hinge (i.e. ultimate capacity).

Electronic equipment includes (processor based) digital control systems, telecommunication facilities, process computer systems, safety systems including gas and fire detection systems.

Free Field - Air or ground blast waves that are unimpeded by obstructions in the path of the wave.

Hinge Rotation - A measure of the energy absorbing capacity of a structural member. This is the angle of deformation at a plastic hinge.

Impulse - The integrated area under the over-pressure time curve.

Inelastic - Beyond the elastic response range.

Linear - A response limited to the elastic range.

Major Hazard Areas - A major hazard area is an area that will be affected by explosion and/or external fire/thermal radiation or toxic. The severity will depend upon the distance between the building's point of consideration and the source of the major hazard(s).

Non-linear - A response which includes the elastic-plastic and/or plastic ranges.

Over-pressure - Pressure rise above ambient produced by a shock wave or pressure wave.

Peak Side-on Over-Pressure - Initial peak pressure rise, above ambient, produced by a shock wave or a pressure wave as felt by a flat surface orientated parallel to the direction of wave propagation.

Plastic Region - The deformation range from ultimate capacity up to failure of the element.

Positive Phase - The portion of the pressure time history where the pressure is above ambient pressure.

Pressure Wave - A blast wave that produces a gradual rise in pressure.

Reflected Over-Pressure - The rise in pressure produced by a shock wave or a pressure wave as felt by a flat surface oriented perpendicular to the direction of wave propagation.

Resistance-Deflection Function - The value of the stress in a structural element as the deformation is increased from zero through the elastic range, the elastic-plastic range, ultimate capacity, and finally to failure of the element.

Safety Glass - Laminated glass panes, consisting of two layers of normal glass (3 mm thick), with an inner layer of polyvinyl butyral (1.9 mm thick).

Shock Wave - A blast wave that produced a near instantaneous rise in pressure.

Sideways - The lateral movement of a structure due to vertical or horizontal loads.

Strain Energy - The energy stored within a structural element deformed due to the application of loads. The value of strain energy is the area under the resistance-deflection function.

Strain Hardening - The observed increase in strength as a material is deformed well into the plastic range.

Strain Rate - The speed at which a load is applied to material. The higher the strain rate, the higher the observed material strength.

Strength Increase Factor - The ratio of actual to nominal strength of a material. This factor takes into account conservatism in the manufacturing process.

Support Rotation - A measure of the blast absorbing capacity of a structural element. This is the same as hinge rotation except that the angle is computed at the member's support location.

Ultimate Capacity - The load applied to a structural element as the final plastic hinge, or collapse mechanism, is formed.

Ultimate Strength - A method of design in which structural members are proportioned by total section capacities rather than by extreme fibre allowable stresses.

1.4 ABBREVIATIONS

DIF - Dynamic Increase Factor

MDOF - Multi Degree Of Freedom

SDOF - Single Degree Of Freedom

SIF - Strength Increase Factor

1.5 CROSS-REFERENCES

Where cross-references to other parts of the DEP are made, the referenced section number is shown in brackets. Other documents referenced by this DEP are listed in (10).

1.6 SUMMARY OF REVISIONS FROM PREVIOUS EDITION

The previous edition of this DEP was dated January 1990. Other than editorial revisions, the following are the main changes to that edition:

Old section	New Section	Change
Title Page	Title Page	Changed title to "Blast Resilient And Blast Resistant Control Buildings/Field Auxiliary Rooms".
2	2	Location considerations are changed and are related to side on-over-pressure and duration occurrence, instead of fixed distances. This information will determine the design requirements.
3.2	3.2	In the old section, only one blast load was indicated. In the new section more blast load values/combinations and related possible design examples of buildings are given. This section will give a quick reference to structural elements of buildings.
5	5	This chapter is completely revised. Instead of equivalent static loads and related calculations for determining the structural elements/parts of buildings, a dynamic loading/calculation approach is adopted. All sections are revised or put into another sequence. Typical parts/elements are not changed, e.g. window design details and related requirements, etc.
5.2.4	4.1.5	Moved (5.2.4) to (4.1.5) and re-numbered the remaining sections of 5.2 accordingly.

2. LOCATION AND BLAST LOAD DESIGN CONSIDERATIONS CONTROL BUILDING/FAR

2.1 LOCATION CONSIDERATIONS

The location of the building shall comply as far as practicable with the considerations listed below in order of importance.

Deviations from these considerations, and the final decision on the control building location, shall be discussed with the Principal and shall have the approval of the Principal.

DEP 34.17.00.32-Gen. gives guidance on the design requirements for explosion, fragment impact and fire resistance of buildings to be considered when siting buildings.

The control building for a new plant (grass roots plant) shall preferably be situated in the main office block in the administration area, combined with common facilities such as the canteen/toilets/showers/offices and laboratory that are located in non-major hazard areas as defined in DEP 34.17.00.32-Gen. The design shall be in accordance with DEP 34.17.00.32-Gen.

If the above applies, the control building shall be interconnected via data transmission cables to FARs.

If the control building is not situated in the main office block, the building, including possible future extensions, shall be located in an area classified as non-hazardous, as described in DEP 33.64.10.10-Gen.

The location shall be at the periphery of the processing plant and at least one side (preferably the back) shall be adjacent to a road or a parking area, see (Appendix 1). The control building shall not be enclosed by equipment on all four sides. The same will apply to FARs.

2.2 BLAST LOAD DESIGN CONSIDERATIONS AND INFORMATION

The blast load (side-on over-pressure) and fragment impact on control buildings and FARs (and if applicable, other buildings) will determine the building's construction and siting. The blast, fragment impact and thermal radiation load information shall be obtained from either a hazard assessment or the Principal. The following parameters, to define the blast load, shall be obtained:

- Peak side-on positive over-pressure, positive phase duration, rise time and the corresponding positive impulse;
- Peak side-on negative pressure, negative phase duration and the corresponding negative impulse.

Note: The negative pressures are generally ignored because they are relatively small or are difficult to quantify. However, the structural components of the building shall take the rebound effects into account.

In the chapters hereof, detailed information and requirements shall be given, but the following common requirements apply to both the control building and the FAR (and if applicable to other buildings) and shall be taken into consideration:

1. For blast loading (peak side-on over-pressure) < 5 kPa or an impulse < 200 kPa-ms, no additional design requirements for resilient or blast resistance are required. Laminated safety glass shall be used.
2. For blast loading (peak side-on over-pressure) between 5 kPa and 20 kPa (estimated duration between 50 ms and 150 ms), resilience in the structure and structure components shall be provided. Laminated safety glass shall be used and the pane area shall be < 1 m². Blast resistant doors shall be used.
3. For blast loading (peak side-on over-pressure) between 20 kPa and 45 kPa (estimated duration between 50 ms and 150 ms), enhanced resilience in the structure and structure components shall be provided. Laminated safety glass shall be used and the pane area shall be < 1 m². Enhanced blast resistant doors shall be used.

4. For blast loading (peak side-on over-pressure) between 45 kPa and 65 kPa (estimated duration between 50 ms and 150 ms), blast resistance shall be required for structure and structure components. Laminated safety glass and catch bars shall be used and the pane area shall be $< 0.25 \text{ m}^2$. Enhanced blast resistant doors shall be used.
5. For blast loading (peak side-on over-pressure) $> 65 \text{ kPa}$, the Principal shall be consulted.
6. If subject to potential fragment impacts (caused by explosions) and at a distance less than 200 m, the outer walls and roof shall be made of reinforced concrete.
7. Where there are prevailing winds, the building shall be located upwind of the prevailing wind direction. Special attention shall be paid to the distance between bitumen blowing facilities and the building to avoid any fouling due to spraying bitumen.
8. The building shall not be located on a lower level than surrounding plants and tank farms. It shall be located away from vibrating or noise-producing equipment, e.g., controlled steam vents, heavy-duty pumps and compressors; see DEP 34.17.00.32-Gen.
9. The building shall preferably be located close to centres of major operational importance, and where appropriate, centrally with regard to future extensions. If future extensions are possible, space shall be reserved for possible extension of the building itself. The building should be located close to activities requiring regular local supervision.
10. For those plants where operating personnel also act as fire-fighting crew, allocated parking spots next to the control building shall be provided.

3. GENERAL DESIGN CONSIDERATIONS

3.1 SIZE OF THE CONTROL BUILDING/FAR

The building shall be as compact as possible. The control building shall only accommodate personnel and equipment directly related to safe and reliable plant operations whereas FARs shall only accommodate essential (electrical and instrument) equipment.

The control building shall be built as a one-storey building and may have a basement if sufficient space is not available. The air-conditioning unit shall be located either on the ground floor or in the basement of the control centre.

FARs shall be built as a one-storey building, without basement.

If, for certain chemical plants, e.g. polymerisation plants, the control building has to be located on the first floor of the plant structure for optimal supervision, this exceptional requirement shall be mentioned specifically by the Principal and a design shall be developed in close consultation with the Principal's civil engineering division.

3.2 STRENGTH OF BUILDINGS

The design of the building shall depend on the blast load (peak side-on over-pressure) and duration. Fragment impact shall also be taken into account. To take account of blast load (including fragment impact) and duration, buildings could be designed as follows:

- Normal buildings provided with brick or steel wall cladding, designed only for dead, live, wind, and seismic loads (if applicable), if the blast load is < 5 kPa or the impulse is < 200 kPa-ms.
- Resilient buildings provided with e.g., closer spaced steel frames, increased size of anchor bolts, increased cladding profile, increased number of cladding fasteners (with oversized washers to reduce tear-out of siding material), fixed based oversized columns etc., if the blast load is between 5 and 20 kPa, and the duration is between 50 - 150 ms.
- Enhanced resilient buildings provided with e.g. closer oversized spaced steel frames, increased size of anchor bolts, increased cladding profile, increased number of cladding fasteners (with oversized washers to reduce tear-out of siding material), fixed based oversized columns etc., if the blast load is between 20 and 45 kPa, and the duration is between 50 and 150 ms.
- Blast resistant buildings, provided with a reinforced monolithic or prefabricated concrete structure, if the blast load is between 45 and 65 kPa and the duration is between 50 and 150 ms.
- Reinforced concrete outer walls and roof to withstand fragment impact.

The strength of all related components, such as windows, panes, doors, etc. shall also withstand the blast loads. In all cases the buildings shall not collapse.

If there is a possibility that gas, smoke, fire, heat, etc., can enter the control building through damaged windows after an explosion, no windows shall be provided in the outer walls of rooms which are considered as essential for controlling the operation of the plant, see (5.6.2). No windows shall be installed in FARs.

If the omission of windows in control buildings is contrary to local regulations, the architect or the engineering contractor shall, in close contact with the Principal, endeavour to obtain a formal exemption from the local authorities for the restriction of daylight into the building.

3.3 NOISE LEVELS

If noise-generating equipment is installed in the control building, DEP 31.10.00.31-Gen. shall be followed. For noise limits reference is made to DEP 34.17.00.32-Gen.

The level of reflected noise shall be reduced by installing an acoustic ceiling and acoustic material on the upper part of the walls.

When the noise level generated in the computer room is high, double-glazed (sealed) windows shall be used, to attenuate the transmission of noise to other areas in the building, whilst still allowing visual communication with the control room.

3.4 VIBRATION LEVELS FOR THE COMPUTER ROOM

Vibrations in the control room shall be limited in order to ensure continuously reliable operation of the (process) computer equipment.

The maximum allowable vibration intensities as applied to the equipment are:

- sustained vibration (5 s or longer) at frequencies less than 14 Hz : 0.25 mm peak to peak;
- sustained vibration at frequencies of 14 Hz or higher : 0.1 G peak (0.07 G root mean square);
- intermittent vibration (less than 5 s) at frequencies less than 7 Hz : 2.5 mm peak to peak;
- intermittent vibration of 7 Hz and higher : 0.25 G peak (0.18 G root mean square).

These limits are not usually exceeded for:

- sustained vibrations that are perceptible, but not annoying or distracting;
- intermittent vibrations that are annoying or distracting but not intolerable.

3.5 PLANNING OF ACTIVITIES

Any control room, instrument basement, computer room/basement in the control building and any instrument room in a FAR shall be completed and the air conditioning system operating, prior to the installation of its associated computer equipment. In particular, no concrete work shall be done after the installation of this equipment, and pile driving operations shall not take place in the vicinity of the room after the installation of the computer, as these activities could cause the limits of (3.4) to be exceeded and lead to damage.

When the computer rooms are completed, the air-conditioning installation shall be in operation at least one week before the computer equipment is installed. During this period the performance of the air-conditioning equipment shall be checked by means of electric heaters, simulating the heat dissipation of the computer equipment to be installed. The results of this test shall be satisfactory before the installation of the computer equipment can proceed.

After unpacking the microprocessor-based computer equipment has been unpacked, the relevant rooms shall be made dust-free. During the installation and testing period, cleaning shall be carried out in close co-operation with the responsible computer specialist. Dust-producing activities shall be restricted to a minimum. If the plant is not yet commissioned, special attention shall be paid to the availability of electrical power for the air-conditioning system, while the computer is being installed, tested and commissioned.

4. LAY-OUT OF THE BUILDINGS

4.1 LAY-OUT OF THE CONTROL BUILDING

4.1.1 General

The control building will normally comprise:

- the control room;
- the computer room;
- a training/conference room;
- a supervisory area adjacent to the control room;
- an auxiliary instrument and computer room, if required;
- the electrical equipment and battery room;
- the heating, ventilating and air-conditioning machine room;
- the first-aid compartment (provision of a separate room for first-aid depends on other first-aid facilities, e.g. medical centre/staffed during office hours/ permanent);
- the plant laboratory, if necessary;
- the offices and social amenities (mess room, wash, locker and toilet rooms - it is not always necessary to provide locker and washing facilities as part of the control building);
- air sluice(s).

NOTES: 1) To minimise the number of people near potential hazards, and to reduce the size of control buildings, a general site laboratory shall not be part of the control building. The general site laboratory shall be located, if possible, near the administration area and in a non-major hazard area. This laboratory can be built in accordance with DEP 34.17.00.32-Gen.

2) Provision of office space in the control building should be determined per project, taking into account the local organisation (including future plans) and local needs. Office space can vary, depending on whether only shift personnel (supervisors) or all operations personnel (day assistants, plant manager, engineering and technology personnel involved with plant operation on at least a daily basis) are to be accommodated.

3) If sufficient space is not available, a basement may be designed. All utilities and E/I equipment should be located in the basement.

For a typical layout, see (Appendix 2).

4.1.2 Control room

The control room is that section of the control building in which the instrument consoles and the operator computer facilities are accommodated.

The control room shall be designed so that sufficient space for installation of equipment for future extensions is incorporated without the need to extend the reinforced concrete building.

4.1.3 Computer room

A separate room for the accommodation of digital process computers etc. shall be incorporated in the control building. This computer room shall be in such a location that the risk of exposure to fire, water, smoke and dust from adjoining areas and activities is kept to a minimum. This room shall not be located in the basement (if provided).

The computer room shall not be located adjacent to rooms with equipment which could cause electrical interference, such as rotating electrical machinery, transformers or electrical switchgear, unless special precautions have been taken to safeguard the proper functioning of the computer equipment.

A removable partition shall be provided in the computer room for creating a separate storage area for discs, tapes, documentation and spare parts, etc. This storage area shall also serve as an air lock to the computer room.

4.1.4 Instrument basement and computer basement

If a basement is required due to space limitations, auxiliary instrument and computer equipment shall be installed under the control room and the computer room; see (Appendix 2).

The basement shall have sufficient space to accommodate all auxiliary instrument and computer equipment required, with sufficient free working space around this equipment. A reasonable amount of spare space shall be included for future extension.

See also Note 3 of (4.1.1).

4.1.5 Electrical equipment and battery room

Because, in the event of an explosion, the external walls will be subjected to a sudden movement inwards, important equipment, such as panels, switchgear, or radio base stations, etc., shall not be installed against such walls.

Batteries for emergency power supply shall be located in separate rooms (ground level or basement) with separate exhaust facilities. The rooms shall not be located under wash and toilet areas because of possible plumbing leakages.

4.1.6 Heating, ventilating and air-conditioning machine room

The machine room for heating, ventilating and air-conditioning equipment shall be located in the basement (if provided) or on the ground floor. This machine room shall be at least 2 m from the computer room and from electronic instrumentation located in the control room and control room basement, or shall be separated by a 300-mm thick reinforced concrete wall, to reduce mechanical and electrical interference from power cables/switchgear to control and computer cables/equipment. No windows shall be installed in this machine room. To avoid large space requirements for HVAC duct work and/or air distribution problems, the HVAC machine room shall be located as centrally as possible in relation to the vital rooms served.

The entrance to the machine room shall be located in such a way that the HVAC maintenance personnel can reach the machine room without having to pass through the instrument, computer or electrical areas; see drawing of (Appendix 2).

4.1.7 First-aid compartment

A closed compartment shall be provided in the control building for first aid equipment. Generally, local medical policy determines what shall be provided in the first aid kit, for example whether or not oxygen equipment shall be included. The facilities will also depend on the location of the control building (local or remote from the process plant), and on the existence of other medical facilities (medical centre and/or manning). As a minimum, the compartment shall include spare safety equipment such as helmets, gloves and spectacles, and a collapsible stretcher for the transport of injured personnel.

Portable breathing apparatus shall be installed at a convenient height inside the control building, at the exits, for immediate use should the need arise. Each air mask shall be contained in a plastic bag. Canister-type masks are not recommended for rescue work but can be used for personal protection (escape masks).

The booklet "Office Safety of HSE", see (10), gives some general guidelines for the provision of first-aid equipment.

4.1.8 Interconnections

The shift supervisor shall have a view from his office into the control room and equally the operators shall be able to see the control room from the mess room, thus affording quick visual communication, whenever necessary.

The plant laboratory shall be visible from the control room through windows, to allow visual communication between the operators and laboratory personnel.

There shall be no direct connection between the control room (and the basement if provided) and the other rooms in the building by direct doors, by slots in walls, or via the drainage system with exception of the following rooms:

- office (for shift supervisor);
- mess room;
- computer auxiliary room (computer office).

All other rooms shall be connected with the control room and its basement via air locks or corridors (with at least 2 doors to pass).

Each room in which people work, and where there is a chance of fire or gas accumulation, shall have two exits, located so that the chance of being trapped is minimal. The width of doors and passages shall comply with the applicable regulations, permitting free and easy exit in emergencies, as well as easy transportation of equipment.

The plant laboratory, where provided, shall have no direct communication with the rest of the building through doors, movable windows or hatches, to prevent gases from entering the control room. The laboratory shall have two doors: one entrance door to a corridor or air lock of the control building, and one emergency exit door direct to the outside.

Gas cylinders that may be required for the laboratory shall be kept outside the building.

4.2 LAY-OUT OF THE FAR

4.2.1 General

The building will normally comprise:

- the process control and safeguarding room;
- the electrical equipment and battery room (if necessary);
- the heating, ventilating and air-conditioning machine room (if necessary);
- the room for Uninterrupted Power Supply (UPS) equipment (if necessary).

NOTES : 1) The building shall normally be unmanned and therefore no offices shall be designed to accommodate personnel.

2) If the FAR is also used to provide facilities for field operators (e.g. a remote control room) a central access by means of an air lock shall be provided to maintain the required overpressure inside the building.

3) The building shall have no basement.

4.2.2 Process control and safeguarding room

For the installation of such equipment, sufficient space to accommodate the latter shall be designed, taking into account sufficient free working space around this equipment.

A reasonable amount of spare space shall be included for future extension.

4.2.3 Electrical Equipment/battery room

Batteries for emergency power supply shall be located in separate rooms with separate exhaust facilities.

4.2.4 Heating, ventilating and air-conditioning (HVAC) machine room

In order to avoid long ducting, the HVAC room shall be located as centrally as possible with respect to the rooms housing vital equipment.

The HVAC machine room shall be separated by a 300-mm thick reinforced concrete wall to reduce mechanical and electrical interference from power cables and equipment to instrumentation cables and electronic equipment.

The entrance to the air-conditioning machine room shall be located in such a way that the air-conditioning maintenance personnel can reach the HVAC machine room without having to pass through the instrument or electrical areas.

5. DETAILED DESIGN CONSIDERATIONS FOR CONTROL BUILDINGS AND FARs

5.1 GENERAL

The civil engineering of the buildings shall be in accordance with the requirements of this DEP, DEP 34.17.00.32-Gen. and 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 building shall be prepared in close consultation with the Principal.

A recognised (registered) architect or engineer shall be engaged to design and co-ordinate the buildings and their installations. The choice of architect requires prior approval of the Principal.

5.2 BASIC DESIGN REQUIREMENTS

5.2.1 Shape and Height of Buildings

For buildings located in non-major hazard areas there are no requirements as to the shape of the buildings. A simple rectangular building is recommended, with a maximum of two storeys. In order to prevent a build-up of pressure, the shape of buildings in major hazard areas shall be rectangular with no protruding canopies, e.g., no equipment on the roof except for the air intake and exhaust facilities (penthouse), and no re-entrant angles. The roof shall have be flat, or have a maximum pitch of 10°.

The overall height of the building and the flat span of the roof shall be minimized to limit the effects of an explosion.

5.2.2 Flying Glass Fragments

Because flying glass fragments are one of the greatest dangers to occupants of buildings during an explosion, windows in outer walls require special treatment and shall be restricted to offices, mess room and the plant laboratory in the control building only.

5.2.3 Brittle Behaviour

Materials with a brittle behaviour, such as masonry, shall not be used in such a way that they are required to have a structural or resistive function during blast loading.

5.2.4 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 (penthouse) of maximum height 1.8 m, fresh air intake stack, aerials, TV cameras and similar equipment are permitted.

5.2.5 Fragment Impact

The possible consequences of an explosion are flying fragments, e.g., valves, which can penetrate the building. The thickness of the walls shall therefore be sufficient to withstand these fragment impacts. This DEP does not include a calculation method to determine appropriate wall thickness. Additional resources for determining wall thickness, and their ability to withstand fragment impacts, are listed in (11).

5.2.6 Response (Deformation) Range

Buildings 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 buildings, the following response range shall be used:

Response	Description
Low	Localised building/component damage. Building can be used, however repairs are required to restore 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 (5.5.4). For the design of Control Buildings and FARs the low response range shall apply. Other ranges may be used to determine the response range of existing buildings.

The recommended type of building structures, including structural details, related to explosion over-pressure, are described in DEP 34.17.00.32-Gen. and in (2) of this DEP.

5.2.7 Gastightness of Buildings

Buildings located in major hazard areas and which are subject to gas cloud (toxic or explosive) exposure shall be gastight (gasproof). The selection of construction and materials shall be based on this requirement.

5.2.8 Construction and Materials

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

Brittle constructions, such as unreinforced concrete, pre-stressed concrete, unreinforced masonry (bricks or blocks) and cement based panels, shall not be used for load carrying components of blast resilient or resistant buildings, see also (5.2.3).

Advanced materials, such as composites, may be used if adequate test data are available to confirm their satisfactory performance for the intended application, and with the Principal's prior written approval. Such test data shall include the ultimate capacity and behaviour of the material under dynamic conditions representative of blast loading. Performance under seismic conditions below ultimate strength is not sufficient to indicate blast load/resistant capacity.

Reinforced concrete or fully grouted reinforced masonry of appropriate strength and thickness shall be used as cladding where fragment resistance is required as indicated in the Data Sheet, "Blast Load and Building Information"; see (Appendix 7).

5.2.9 Fire Protection

The requirements as indicated in (9) shall be applied.

5.3 BASIS FOR CALCULATION

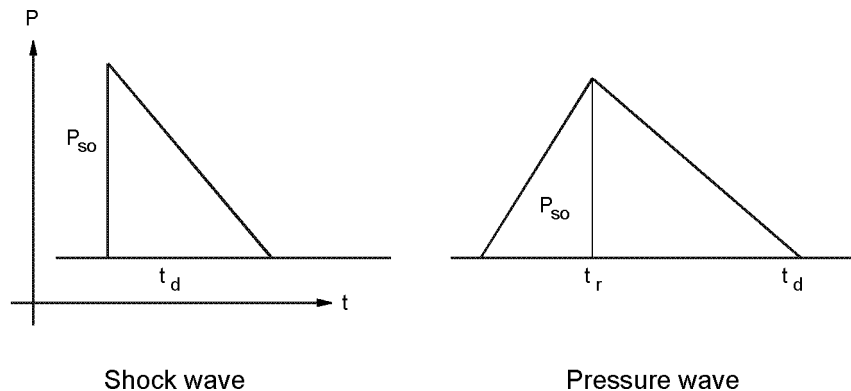
5.3.1 Building Blast Loading Parameters

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

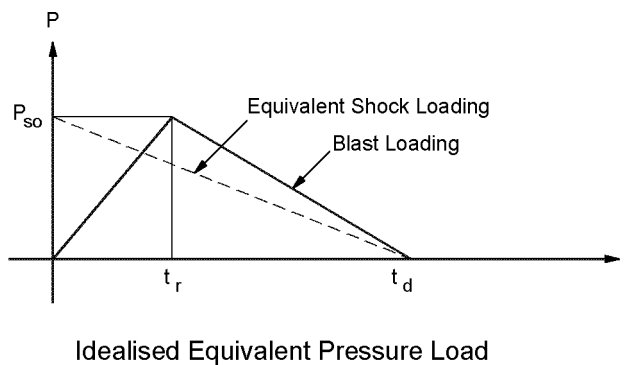
1. Shock or pressure wave;
2. Peak side-on positive (or negative) over-pressure;
3. Positive (or negative) phase duration;
4. Positive (or negative) impulse;
5. Peak reflected pressure;
6. Dynamic (blast wind) pressure;
7. Shock front velocity;
8. Blast wavelength.

5.3.1.1 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 s or m

t_d = positive phase duration in s or m

t_r = rise time in s or m

5.3.1.2 Peak side-on over-pressure

The peak side-on over-pressure (P_{so}) shall be obtained via a hazard assessment or via the Principal. The range of P_{so} is typically between 5 kPa and 65 kPa.

5.3.1.3 Positive (or negative) phase duration or duration.

The positive phase duration or duration shall be obtained from the hazard assessment or the Principal. The value of the t_d is in general less than 150 ms. The negative phase duration may be ignored.

5.3.1.4 Positive (or negative) impulse

The area (see section 5.3.1.1) 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:

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

$$I_o = 0.64 \times P_{so} \times t_d, \quad \text{for a half-sine wave}$$

$$I_o = c \times P_{so} \times t_d, \quad \text{for an exponentially decaying shock wave, in which } c = \text{a value between 0.2 and 0.5 and depends on } P_{so}.$$

Note: * A triangular wave is commonly used.

5.3.1.5 Peak reflected pressure (P_r)

The field blast wave strikes the building 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. To determine the reflection coefficient, the following simple formula, applicable for an incidence of α = 0°, may be used:

$$C_r \approx (2 + 0.0073 \times P_{so}) \text{ Remark: } P_{so} \text{ is in kPa and } C_r \text{ is dimensionless.}$$

If other angles apply, the TNO Green Book, see (10), shall be consulted to determine C_r.

5.3.1.6 Dynamic (blast wind) Pressure

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

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

The net dynamic pressure on a structure is: q_o × C_d. The draft coefficient C_d depends on the shape and the orientation of the building. For a rectangular building, a C_d of 1.0 may be taken for the front wall and a C_d of - 0.4 for the side/rear wall and roof may be taken.

5.3.1.7 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 .

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

5.3.1.8 Blast Wave Length (L_w)

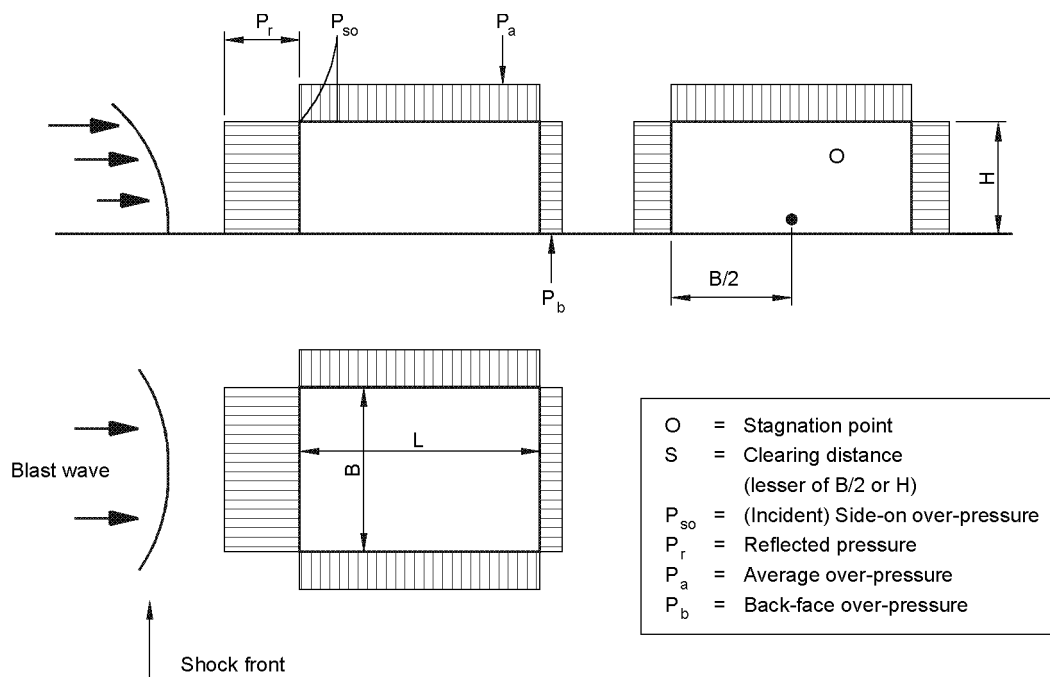
The propagating blast wave at any instant in time extends over a limited radial distance as the shock/pressure front travels outward from the explosion. The pressure is largest at the front and trails off to ambient over a distance L_w . For pressure ranges in this DEP, the blast wave length is approximated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

5.3.2 Building Blast Loading

After determining the building blast loading parameters (5.3.1), the building blast loading can be determined. The blast loading is applicable to rectangular buildings. 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 buildings is given below:



5.3.2.1 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 in s or ms
- Shock front velocity, $U \approx 340 \times [1 + (6 \times P_{so}) / (7 \times P_o)]^{0.5}$ in m/s
- Length of pressure wave, $L_w = U \times t_d$, in m
- Peak dynamic wind pressure, $q_o = 0.0032 \times (P_{so})^2$, in kPa

5.3.2.2 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, $P_r = [2 + (0.0073 \times P_{so})] \times P_{so}$

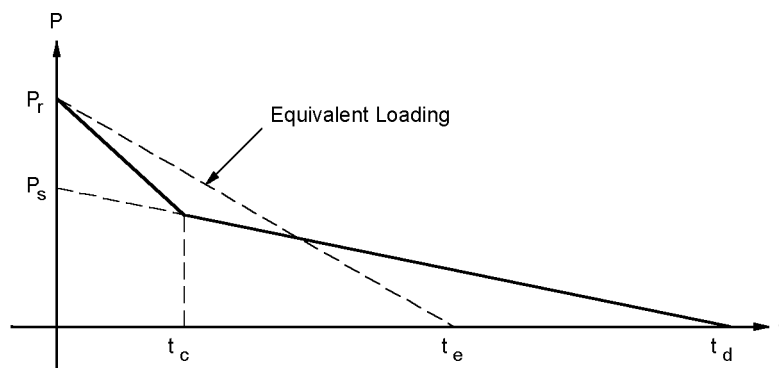
Note: For design purpose, the normal shock reflection conditions (angle of incidence $\alpha=0^\circ$ and the rise, $t_r = 0$ s) shall be assumed or shall be as indicated.

- Clearing distance, $S = \text{minimum of } H \text{ or } B/2$, in which: $H = \text{Height of Building}$
 $B = \text{Width of Building}$
- 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.



Front Wall

Stagnation pressure, $P_s = P_{so} + C_d \times q_o$

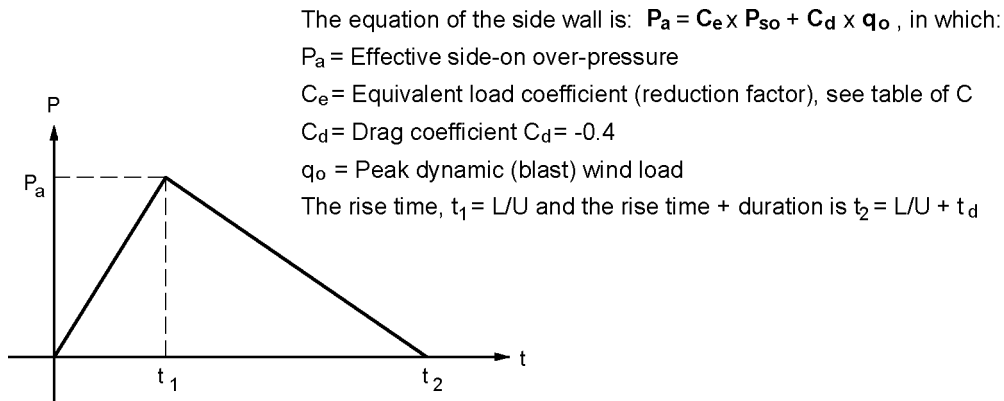
Reflective over-pressure clearing time, $t_c = 3 \times (S/U) < t_d$

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

5.3.2.3 Side Wall Loading.

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



Roof and Side Wall

Table of equivalent load coefficient (C_e), derived from TM 5-1300; see (11).

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

Note 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.

Note 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.

Note 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, $I_s = 0.5 \times t_2 \times P_a$

5.3.2.4 Roof Wall Loading

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

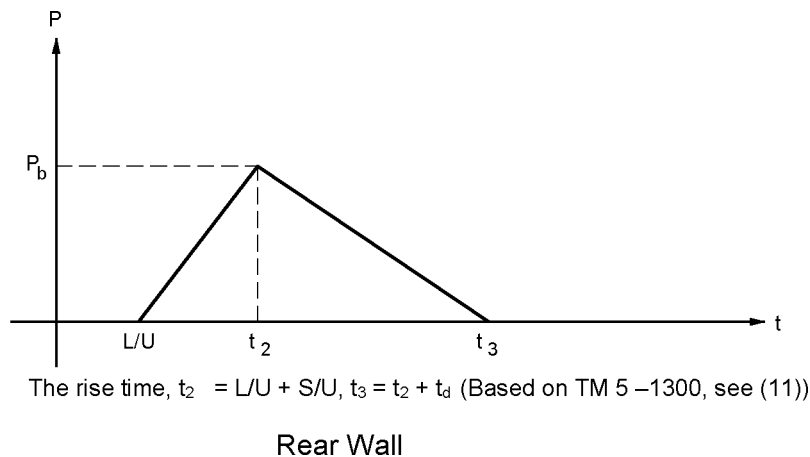
5.3.2.5 Rear Wall Loading

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 (5.3.2.3).

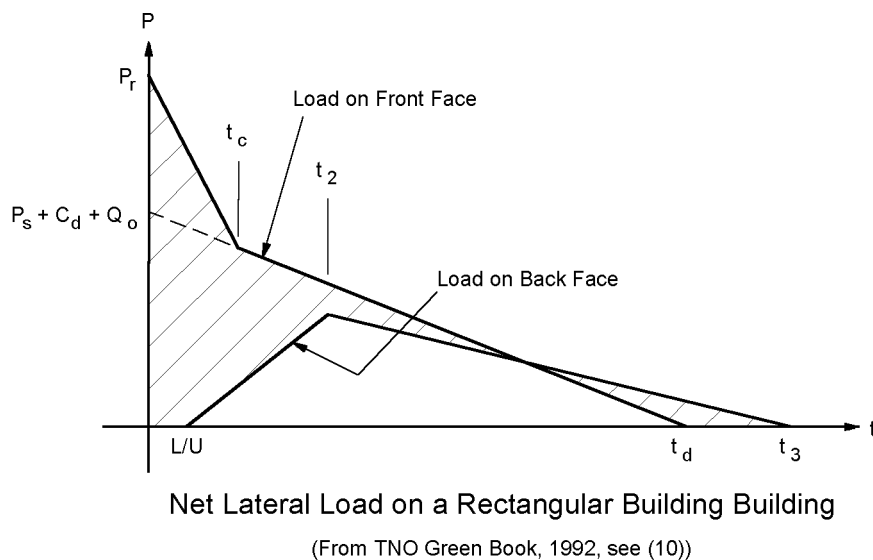
The drag coefficient, $C_d = -0.4$



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

5.3.2.6 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 building 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.



5.3.2.7 Negative Pressure and Rebound Loading

The components of the building 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 building 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.

5.3.3 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.

5.4 MATERIAL PROPERTIES

5.4.1 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 (5.4.3); SIF is the strength increase factor as defined in (5.4.2).

2. Dynamic design stress, F_d , used to compute the dynamic capacity of structural components shall be based on the values listed in Tables 4 and 5 for structural steel and reinforcing steel, respectively.
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 (5.4.3).

5.4.2 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
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
Cold Formed Steel Cladding Panels (BS 5970) with yield strength of 460 MPa or less (BS 4449)	1.2
Concrete and Masonry	1.0
Other Materials	1.0

5.4.3 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 Tables 2 and 3.

Table 2 Dynamic Increase Factors for Reinforced Concrete/Masonry

Stress Type	DIF			
	Reinforcing Bars		Concrete	Masonry
	(F_{dy}/F_y)	(F_{du}/F_u)	(f'_{dc}/f'_c)	(f'_{dm}/f'_m)
Flexure	1.17	1.05	1.19	1.19
Compression	1.10	1.00	1.12	1.12
Diagonal Tension	1.00	1.00	1.00	1.00
Direct Shear	1.10	1.00	1.10	1.00
Bond	1.17	1.05	1.00	1.00

Table 3 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 A36	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 4 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.

Table 5 Dynamic Design Stress for Concrete Reinforcing Steel

Type of Stress	Type of Reinforcement	Maximum support Rotation (degrees)	Dynamic Design F_{ds}
Bending	Tension and Compression	$0 < \theta < 2$	F_{dy}
		$2 < \theta < 5$	$F_{dy} + (F_{du} - F_{dy})/4$
		$5 < \theta < 12$	$(F_{dy} + F_{du})/2$
Direct Shear	Diagonal Bars	$0 < \theta < 2$	F_{dy}
		$2 < \theta < 5$	$F_{dy} + (F_{du} - F_{dy})/4$
		$5 < \theta < 12$	$(F_{dy} + F_{du})/2$
Diagonal Tension	Stirrups	All	F_{dy}
Compression	Column	All	F_{dy}

Where θ = support rotation (degrees).

5.5 STRUCTURAL DESIGN

5.5.1 Design Methods and Procedures

All blast resistant buildings and their structural components may be designed using the methods provided in the ASCE "Design of Blast Resistant Buildings in Petrochemical Facilities", see (11). Other design methods may also be used as long all the methods meet the requirements of this DEP.

5.5.2 Load Combinations

1. 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 which will be normally blown away by a blast wave and live loads, e.g., personnel and furniture which 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.

5.5.3 Analysis Methods

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. The report ASCE "Design of Blast Resistant Buildings in Petrochemical Facilities" (10) may be used. The following requirements shall apply:

5.5.3.1 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 "Design of Blast Resistant Buildings in Petrochemical Facilities", TM 5-1300 (11), or other similar references for the approximate solution of the elastic-plastic SDOF system may be used in determining the required resistance.

5.5.3.2 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.

5.5.4 Response (Deformation) Limits

5.5.4.1 Parameters

Structural members shall be designed based on maximum response (deformation) consistent with the performance requirements or permissible damage level specified in (5.2.6). Deformation limits shall be expressed as ductility ratio (μ), support rotation (θ), or frame sideway, as appropriate.

5.5.4.2 Building Response Range

The design response range or permissible damage level (Low, Medium, or High) shall be based on the building design requirements provided in (5.2.6).

5.5.4.3 Response Limits

Maximum response shall not exceed the limits specified in Tables 6, 7, and 8 for structural steel, reinforced concrete, and reinforced masonry, respectively.

Table 6 Response (Deformation) Limits for Structural Steel

Element Type	Response Range ⁽²⁾					
	Low		Medium		High	
	μ_a	θ	μ_a	θ	μ_a	θ
Beams, Girders, 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 = story height)
Medium = $H/35$
High = $H/25$

2. Response parameter:

μ_a = Allowable ductility ratio
 θ = support rotation (degrees)

Table 7 Response (Deformation) Limits for Reinforced Concrete

Element Type	Controlling Stress	Ductility Ratio, μ_a	Support Rotation $\theta^{(2)}$		
			Low	Medium	High
Beams	Flexure	N/A	1	2	4
	Shear: ⁽¹⁾				
	- concrete only	1.3			
	- concrete + stirrups	1.6			
	- stirrups only	3.0			
	Compression	1.3			
Slabs	Flexure	N/A	2	4	8
	Shear ⁽¹⁾	1.3			
Beam-Columns	Flexure	N/A	1	2	4
	Compression	1.3			
	Tension ⁽³⁾				
	Shear ⁽¹⁾	1.3			
Shear Walls,	Flexure	3	1	1.5	2
Diaphragms	Shear ⁽¹⁾	1.5			

Notes:

- (1) Shear controls when shear resistance is less than 120 % of flexural resistance.
- (2) Stirrups are required for support rotations greater than 2 degrees.
- (3) Ductility ratio = $0.05 (p - p')$, where p and p' are the tension and compression reinforcement ratios, respectively. Ductility ratio shall be < 10 .

Table 8 Response (Deformation) Limits for Reinforced Masonry

Element Type	Ductility Ratio, μ_a	Support Rotation, θ (degrees)		
		Low	Medium	High
One-way	1	0.5	0.75	1
Two-way	1	0.5	1	2

5.5.5 Component Design

5.5.5.1 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 "Design of Blast Resistant Buildings in Petrochemical Facilities", see (10).
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). Except as noted for reinforced concrete members, the deformation limits indicated in Tables 6, 7, and 8 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. Design for 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.

5.5.5.2 Reinforced Concrete

Reinforced concrete components shall be designed in accordance with the provisions of DEP 34.19.20.31-Gen. For additional information, the "Design of Blast Resistant Buildings in Petrochemical Facilities" may be consulted, see (10). 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 a yield strength (f_y) between 240 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. Walls and roofs shall be designed for a considerable ductile response in order to absorb blast energy without transmitting it to the supporting elements. Internal shear walls are allowed.
5. Slenderness effects shall be included for load bearing walls and members with significant axial loads.
6. Support shall be provided for roof slab to prevent failure during rebound. Headed studs may be used for this purpose; however, they should be located and spaced to minimise composite action unless composite action is required and specifically designed for.
7. The concrete walls and slabs shall be reinforced on each side in the main direction. For steel bars with a yield strength (f_y) of 240 N/mm², there shall be a minimum of 1 % on both sides of the concrete cross section; for steel bars with a yield strength of 460 N/mm², a minimum of 0.6 % on both sides of the concrete cross section. For steel bars with yield strengths other than aforementioned, the minimum percentage shall be:

$$\text{Minimum Percentage} = 240/f_y$$

In the other direction on both sides, a distribution reinforcement of at least 20 % of that in the main direction shall be applied. Maximum spacing of bars shall be 150 mm centre

to centre. It is preferable for the wall and roof thickness to be between the limits of 250 mm and 400 mm in order to facilitate the placing of the required reinforcing bars.

If the dynamic calculation indicates that more reinforcement is required, it shall be provided. Strength reductions and reductions of development lengths are not allowed.

Criteria intended to reduce cracking at service load levels shall not be applied to load combinations which include blast loads.

8. Shear reinforcement shall be applied in beams only and shall be a combination of stirrups and horizontal side bars. This combination is known as web reinforcement.

The web reinforcement requirements are:

- When the shear stress is less than 1.3 N/mm^2 , web reinforcement is not required.
- When the shear stress is more than 1.3 N/mm^2 but less than 4.5 N/mm^2 , web reinforcement will be required for this acting shear stress minus 1.3 N/mm^2 .

At least 50 % of the bottom main reinforcement shall extend over the face of the support providing a good anchorage between the supports.

9. In general, special attention shall be paid to ensure continuity and a minimum of local stress concentration. Adequate lapping of reinforcement is required.
10. Pre-stressed concrete shall not be used, due to its non-ductile behaviour.

5.5.5.3 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.

5.5.5.4 Cold Formed Steel

Cold formed steel, such as cladding and decking roof/wall panels, may be used for low blast pressure ($< 20 \text{ kPa}$) applications. The yield strengths may vary from 220 N/mm^2 to 450 N/mm^2 . If fragment hazards may arise, cold formed steel shall not be used. The following specific requirements shall apply:

1. Ultimate resistance shall be determined using a factor of 0.9 applied to the plastic moment capacity.
2. Tensile membrane capacity of wall panels may be used if adequate anchorage of panel ends is provided.
3. Tensile membrane capacity of cold-formed girths and purlins may be utilised in the design if they are supported on the exterior face of a frame member and are continuous over three or more spans.

4. Oversize washers should be provided for wall panel anchorage screws to prevent failure due to rebound or negative phase loads.
5. Symmetric, closed sections shall be used wherever possible.

5.5.5.5 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.

5.5.5.6 Reinforced Masonry

Design of reinforced masonry shall be in accordance with BS 5628, or UBC 1997 (11), supplemented by the following specific requirements:

1. strength reduction factors shall not be applied;
2. hollow sections shall be fully grouted;
3. reinforcement shall be in accordance with the requirements of (5.5.5.2);
4. connections to roof and floor slabs or grade beams shall develop the full flexural capacity of the wall.

5.5.6 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.

5.5.7 Foundation Design

Foundation design shall be based on geotechnical requirements, as per DDD 34.11.00.12-Gen and the geotechnical data summarised in (Appendix 7). The structure shall be firmly embedded in the ground, i.e., the vertical walls extending to at least 1.5 m below High Point of Paving and having the same strength as the wall's above-ground level. Relative displacements between columns and walls shall be minimised in order to maintain structural integrity, e.g. by using grade beams to tie together spread footings or pile caps, or by using combined mat foundation (more or less similar to seismic designs).

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.

5.5.7.1 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, factors of safety for overturning shall be 1.2, and 1.0 for sliding.

5.5.7.2 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 building 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.

5.5.7.3 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 building.

5.6 ANCILLARY AND ARCHITECTURAL ITEMS

5.6.1 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 as specified in (Appendix 7). The response limits and other requirements shall be as given in Table 9.

Table 9 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. In buildings large enough to require more than one exit door according to the requirements in local building codes, at least two doors shall be designated as exit doors for the purpose of limiting the damage to these doors when subjected to blast loads. Designated exit doors shall not be located on the same side of the building.
3. Doors, doorframes, and door hardware shall be designed for the performance criteria and applied blast loads specified in (Appendix 7).
4. Outward opening doors shall be provided at two sides of the control building for ease of access to process areas and shall seat against the frame under the positive phase blast wave. Air locks shall be installed to maintain the required over-pressure inside the building. All outer doors shall be provided with automatic door closers.
5. Means of escape, including emergency exit(s), shall be provided from at least three sides of the control building. The emergency exit(s) shall be installed at the rear side of the building, not facing the process area. If only to be used for emergencies, the exit door does not need an air lock.

6. No windows shall be provided in the outer doors; only small peepholes shall be provided to check, in the event of fire, that the area outside the door is safe to permit evacuation of the building.
7. The outer and inner doors shall have a good seal between door and frame to maintain the different pressures between the various rooms and the outside of the building.
8. There are no special requirements for blast resistant or resistant inner doors of airlock systems.
9. Blast door Manufacturers shall provide calculations or test data to verify adequate blast resistance and door performance for the design load conditions.
10. 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.
11. Equipment (Double) access doors shall be designed so that instrumentation, computer equipment and air-conditioning equipment etc. can be transported into the control room basement and FARs. The size of these equipment doors will depend on the dimensions of the equipment but they shall be at least 1.8 m x 2.5 m. When not in use, equipment doors shall be bolted to the steel doorframe and the seal shall be air-tight. If the doorway is also to be used as a passageway, a single door shall be installed in the equipment door, and the seal shall be airtight when the door is closed.

5.6.2 Windows

The design of window frames and anchorage shall be included. The following requirements shall be applied:

5.6.2.1 Rooms without windows

The following rooms are considered essential for controlling the operation of the plant, and shall have no windows in the outer walls:

- the control room;
- the computer room;
- the instrument and computer room;
- the electrical equipment and battery room;
- the heating, ventilating and air-conditioning machine room;
- the shift supervisor's office;
- the air locks;
- the first aid compartment/room;
- the social amenities with exception of the mess room;
- all rooms in FAR.

5.6.2.2 Rooms with small windows

Other offices, plant laboratory and mess room in the control building may have small windows in the outer walls. These windows shall comply with the requirements described below.

5.6.2.3 Dimensions of external windows

The total external window area shall not exceed 7 % of the wall area, measured inside the building from top of floor to underside of roof. The clear pane area shall be 0.25 m² maximum. The windows shall be equi-spaced over the total wall area, in order to maximise the area of concrete between each window.

NOTE : These requirements are to prevent the over-pressure, caused by an external explosion and entering the building through shattered windows, from exceeding the limits where people inside could receive permanent hearing damage or lung injuries.

5.6.2.4 Type of glass in external windows

For external windows, laminated glass panes shall be used consisting of two layers of normal glass, each at least 3 mm thick, with a polyvinyl butyral (PVB) interlayer at least 1.9 mm thick.

Double-glazing units can be considered for climatic conditions and to prevent condensation on the windows. If double-glazing units are applied, both panes shall be laminated-type glass.

HVAC considerations shall determine whether double-glazing is required (refer to DEP 31.76.10.10-Gen.).

The thick interlayer will keep the two glass sheets together even when the pane has been blown out of its frame and folded itself around the catch bar as described in (5.6.2.5). This will prevent injuries from flying glass fragments providing the thickness of the interlayer is not less than that specified.

5.6.2.5 Fixing of glass in external window frames

To keep the glass pane in the window frame for as long as possible after an explosion, the following requirements shall apply:

The window frame shall be made of galvanised steel capable of transferring the explosion pressure (blast load) on the windowpane to the surrounding structure. The normal rebate width of 12 mm shall therefore be increased to at least 30 mm to achieve this requirement.

The glass pane shall be fitted into the window frame using an adhesive compound (polysulphide) that will remain flexible and have maximum adhesive properties.

The pane shall be fixed with steel beads, screwed to the frame.

NOTE: Aluminium or plastic window frames are not allowed because they are not sufficiently strong to cope with forces resulting from explosions. Plastic frames will also produce fumes and harmful gases in the event of fire.

5.6.2.6 Catch bars for external windows

All external windows shall be provided with a vertically mounted solid steel catch bar, 20 mm diameter, securely welded to the inside of the window frame, or built into the concrete structure. The centre line of the catch bar shall be located at least 70 mm behind the glass pane. The dimensions of windows, provided with a catch, shall be limited to 0.5 m x 0.5 m.

NOTE: If the glass pane is blown inwards, it will fold round this bar and will stay there, resting on the window sill.

With a horizontal bar the glass pane will return around the bar and will then fly inwards and can still injure personnel.

5.6.2.7 Elevation

The underside of external windows in the plant laboratory and offices shall be 1 m above the finished floor level.

5.6.2.8 Sun protection

Louvres, canopies or venetian blinds are not allowed at the outside of the building. Interior sun protection may be provided. Blinds shall be designed using materials resistant to intense heat.

5.6.2.9 Windows in partition walls

Partition walls between the control room and the plant laboratory, computer room, office, mess room, etc. shall have fixed windows to allow uninterrupted vision between rooms. These windows shall have a maximum clear pane area of 1 m².

5.6.2.10 Type of glass for internal laboratory windows

Transparent, laminated Georgian polished wired glass with fire- and explosion-resisting properties shall be used for the internal windows between the control room and the plant laboratory, if provided. The glass panes shall be fixed in steel frames with screwed metal beads. The laminated glass panes shall consist of one layer of float glass at least 3 mm thick and one layer of wired glass, with a polyvinyl butyral (PVB) interlayer at least 1.9 mm thick.

5.6.2.11 Type of glass for internal windows

Normal glass with a minimum thickness of 3 mm shall be used for internal windows between the control room and the mess room, office, computer room, etc. The panes shall be fitted in steel frames composed of standard sections, and fixed with a non-hardening, non-staining type of putty. Glass in internal timber doors shall be fixed with screwed hardwood beads.

NOTE : Normal glass can be used for these windows, because the over-pressure inside a building without outer windows, or with only a few very small windows, will be low enough during an explosion to prevent fragmented glass flying.

5.6.3 Openings

Large openings in the building 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 m^2 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.

5.6.4 Penetrations

Wall and roof penetrations in reinforced concrete and masonry shall be sleeved. Sleeves shall be anchored with a minimum of 2 each M16 diameter with 100 mm long headed studs.

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

5.6.5 Suspended Items

Equipment and furnishings such as ceilings, HVAC ductwork, and light fixtures suspended from the roof inside the building 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.

5.6.6 Externally Mounted Items and Air Intake Stack

- 5.6.6.1 To avoid the potential for hazardous debris, large non-structural features such as canopies and signs on the building exterior shall be minimised. However, small items such as instruments, fire alarms, lights, strobes and beacons may be mounted on the exterior walls.
- 5.6.6.2 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 actual equipment dynamic loads when subjected to the blast.

- 5.6.6.3 Equipment and other items mounted on the exterior surfaces (walls or roof) of the building 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.
- 5.6.6.4 The stack for fresh air intake on the penthouse shall be designed for wind loading only. The height of the stack (level of air intake) shall be 12 m above plant level. Blast valves/dampers shall not be installed in this air intake, but shall be installed in the reinforced concrete roof floor.

5.6.7 Equipment and Internally Mounted Items

- 5.6.7.1 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.
- 5.6.7.2 All fixed floor supported items, such as lockers, electrical cabinets, racks, etc. 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 building sideways plus any wall component(s) deflection and shall be computed based on the maximum blast loads defined in (Appendix 7). Supports and anchorage for such equipment shall be designed to resist a lateral force equal to 20 % of the equipment weight.

5.6.8 Floors

5.6.8.1 Cavity floors

The control room, computer room (including storage area), the computer basement, the instrument basement and the electrical equipment room in the control building shall have a cavity floor supported by a recessed reinforced concrete floor.

If the above equipment areas are located on the ground floor level as in a one-storey building and FARs, they shall also have a cavity floor.

The elevated floor shall be flush with the surrounding floor finishes.

For all other areas, the floor construction and finish shall be in accordance with DEP 34.17.00.32-Gen.

The removable panels shall be 600 mm x 600 mm and 40 mm thick, constructed of a non-combustable material, finished with 2 mm thick, factory-applied, anti-static, wearing surface at the top and aluminium foil at the bottom. The material shall not emit toxic gas under high temperatures or in case of fire.

The floor panels shall rest on adjustable pedestals manufactured of mild steel with mild steel foot and top plates.

The pedestals shall be glued to the concrete floor, adjustable in height, providing a distance between the top of the cavity floor and the top of the concrete floor of 750 mm. The adjustable part shall have automatic positive locking. Electrical requirements shall be in accordance with IEC 60364.

Bracings shall be installed to prevent lateral movement of the flooring system.

Separate steel structures to be provided to support electrical equipment and battery benches.

Each floor panel shall be capable of supporting a concentrated load of 4450 N, applied on an area of 650 mm² at any point, or 15 kN/m² with a maximum deflection of 1 mm.

The size and location of cut-outs in the floor panels will be specified separately. The complete floor system shall be free from vibration, rocking, rattles and squeaks. The system shall ensure that the panels remain in place, even when adjacent panels have been removed.

5.6.8.2 Channel inserts

Steel channel inserts shall be cast in the concrete basement ceiling for fixing instrument equipment. For type and location, see (Appendix 3) and (Appendix 6).

5.6.8.3 Plinth for instrument panels

Unless otherwise specified by the Principal, the instrument panels in the control room shall be placed on a concrete plinth except where the control room has a cavity floor.

Special attention shall be paid to a smooth finish and exact level of this plinth.

5.6.8.4 HVAC machine room

In the HVAC machine room the floor shall be constructed with door thresholds of 100 mm minimum height, to prevent condensate and other leakages from entering other parts of the building. Drain facilities shall be installed in the machine room.

5.6.8.5 Floor level

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

Approaches to the main entrances shall be ramps with a slope of not more than 1 in 8 with a non-slip finish of the top surface.

When the building is located in an area where ice and snow can make the slopes slippery, steps also shall be built in the slopes near the entrances. In some extremely cold temperature areas, heated slopes and/or steps may be considered.

5.6.8.6 Control room floor

The floor between the control room and the basement shall preferably be made of flat slab type of construction i.e. without beams and supporting columns; see also (5.6.8.1). For cable passages through this floor, see (5.6.11.4).

5.6.9 Hoisting area

If applicable, a travelling crane of sufficient length and lifting capacity of 2 tonnes (see also DEP 34.17.00.32-Gen) shall be installed over the hoisting area, for lowering equipment into the basement of the control building. Free access to the basement shall be maintained to allow for later additions/replacements of equipment.

5.6.10 WALLS AND CEILINGS

5.6.10.1 Wall tiles

Wall tiles shall be avoided or glued firmly to the wall with special tile adhesive, to prevent them from coming loose in the event of an explosion.

5.6.10.2 Ceilings

The aluminium grid ceiling in the control room 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.

5.6.10.3 Wall and ceiling finishes

All surface finishing materials for walls and ceilings in the control room, 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, including the space under the cavity floor, where dust is liable to accumulate shall be sealed with epoxy paint or PVC coating.

5.6.11 CABLE ENTRIES AND PASSAGES

5.6.11.1 Entries in basement walls

The cable entries for instrument cables into the building shall preferably be distributed over the longest wall of the instrument basement/room; see (Appendix 2).

Cables for electric power and lighting, as well as utility piping, shall preferably enter the building on any other side of the building; see (Appendix 2).

No piping for drainage or utility except for instrument air supply shall be routed through the instrument auxiliary room and computer basement or the electrical equipment and battery room. No electric cables, except for instrument/computer electricity supply and illumination, shall be routed through the instrument auxiliary room.

5.6.11.2 Level of entries

Entries into the building shall be made below ground level and above ground water level at such a level as to exclude any chance of rainwater, fire-fighting water, oil, liquefied gas or other liquids finding their way into the building.

5.6.11.3 Sealing of entries

The holes for cable entries shall be sealed gas-/watertight, preferably Multi Cable Transit (MCT) blocks shall be used. Unused cable entries shall be closed with spare solid blocks.

All other service entries shall be sealed gas-/water tight. Unused entries shall be closed with watertight brickwork.

5.6.11.4 Cable passages through floors

Cable passages through the floor from the control room to the basement shall be made of 150-mm diameter plastic pipes. The holes shall have chamfered edges to prevent damaging of the cables during cable pulling. The same type of cable passages shall also be made between the computer room and the basement.

Holes shall also be provided for possible future computer consoles. These holes shall be positioned so as to clear the reinforcement bars in the floor.

6. HEATING, VENTILATING AND AIR CONDITIONING

The building shall be provided with a system for heating, ventilating and air conditioning, as specified in DEP 31.76.10.10-Gen.

Certain aspects of particular relevance for the improved safety of the building in the event of external explosions are described below.

Explosion protection valves, mounted in a concrete box on top of the building (penthouse), shall protect the air intake and the air exhaust openings. During an explosion the blast-resistant valves shall close automatically and protect the building against over-pressure or suction through the ventilation ducting. These valves shall open automatically when the pressure is back to normal.

Air-cooled condensers shall be located next to the building at grade level and not on top of the building; see (Appendix 1).

7. ELECTRICAL INSTALLATION

7.1 GENERAL

The electrical installation for power and lighting, etc., shall be in accordance with DEP 33.64.10.10-Gen. Illumination/lighting shall be designed in such a way as to avoid reflection/glaring on computer screens.

In addition, the following requirements related to socket outlets and instrument electricity supply shall apply.

7.2 SOCKET OUTLETS

In addition to the usual number of socket outlets required throughout the building, an extra socket outlet shall be provided at each 3-console section, for maintenance tools. The electrical supply shall be 220/240 V AC and/or 110 V AC as required. The socket outlets shall be mounted on an adjacent wall of the control room and the control room basement.

The computer room may also require a number of additional socket outlets for computer maintenance and testing.

7.3 INSTRUMENT ELECTRICITY SUPPLY

This supply will be designed for each project, depending on instrument and electrical requirements, and may require accommodation for batteries, emergency generator, etc.

8. TELECOMMUNICATIONS

The plant telecommunication (radio, telephone, paging and CCTV) system shall be in accordance with DEP 32.71.00.10-Gen.

9. FIRE-FIGHTING FACILITIES/FIRE PROTECTION/FIRE AND GAS DETECTION

9.1 GENERAL

The fire-fighting systems shall be in accordance with DEP 80.47.10.30-Gen., DEP 80.47.10.31-Gen. and the requirements specified below.

9.2 FIRE EXTINGUISHERS

Hand-operated fire extinguishers shall be installed strategically throughout the building and at least close to all exit areas.

Fire-fighting water hose reels shall not be installed in the building.

9.3 FIRE AND GAS DETECTION

The building shall be provided with a sampling-type smoke detection system; see also DEP 32.30.20.11-Gen. This system shall cover as a minimum all normally unmanned areas and enclosed cabinets, e.g. basements in general, cavity floors, cable channels, computer and computer tape room and all cabinets where smoke from hot spots could develop.

The battery room and storage room shall be provided with heat detectors.

The laboratory room shall be provided with combined smoke/heat detectors.

Large central computer systems and tape rooms shall be provided with a sampling-type smoke detection system.

In the unmanned computer room an automatic clean agent flooding system may be considered.

9.4 FIRE PROTECTION

9.4.1 General

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

Where ventilation or other 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 layout of the building shall be such that the maximum travel distance from any point of a floor in the building to the nearest exit of that floor is 25 m.

Insulation materials used inside and outside the building shall be e.g. mineral wool blankets with galvanised wire netting and with no flammable materials attached to them (used in wall cladding, ceilings, partition walls, etc.). As an exception to this, built-up bituminous roofing felt, glass fibre based, is allowed but should, where possible, be avoided.

Staircases shall be separated from corridors by automatic closing doors. These doors shall be smoke-tight.

9.4.2 Fire resistance

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

- roof and outside walls, (including doors but not windows) shall have a smoke and fire resistance period of minimum two hours;
- doors of air locks only shall have a smoke and fire resistance period of minimum one hour for each door;
- internal walls of control/computer/instrument aux./UPS/electrical/ battery rooms and plant laboratory 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. Raised floors (computer floors) shall have a smoke and fire resistance period of half an hour.

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

9.4.3 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.

9.4.4 External fire exposure

The roof of the building shall satisfy the classification of BS 476-3, Class AA, without developing cracks or holes.

10. REFERENCES

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

NOTE: Unless specifically designated by date, the latest edition of each publication shall be used, together with any amendments/supplements/revisions thereto.

SHELL STANDARDS

Index to DEP publications and standard specifications	DEP 00.00.05.05-Gen.
Noise control	DEP 31.10.00.31-Gen.
Heating, ventilating and air-conditioning for plant buildings	DEP 31.76.10.10-Gen.
Fire, gas and smoke detection systems	DEP 32.30.20.11-Gen.
Plant telecommunication	DEP 32.71.00.10-Gen.
Electrical engineering guidelines	DEP 33.64.10.10-Gen.
Geotechnical and foundation engineering	DDD 34.11.00.12-Gen.
Design and engineering of buildings	DEP 34.17.00.32-Gen.
Reinforced concrete foundations and structures	DEP 34.19.20.31-Gen.
Steel structures	DEP 34.28.00.31-Gen.
Assessment of the fire safety of onshore installations	DEP 80.47.10.30-Gen.
Active fire protection systems and equipment for onshore facilities	DEP 80.47.10.31-Gen.
Office Safety of HSE	HSE 004: June, 1986

AMERICAN STANDARDS

Design of Blast Resistant Buildings in Petrochemical Facilities	ASCE
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Issued by:
American Society of Civil Engineers
1801 Alexander Bell Drive
Reston, VA 20191 USA

BRITISH STANDARDS

Fire tests on building materials and structures -

Part 3: External fire exposure roof test	BS 476-3
Part 7: Method of test to determine the classification of the surface spread of flame of products	BS 476-7
Thermal insulation of pipework and equipment in the temperature range – 100 Degrees C to + 870 Degrees C)	BS 4449
Code of practice for the use of masonry	BS 5628
Carbon steel bars for the reinforcement of concrete	BS 5970

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

DUTCH STANDARDS

Method for the Determination of Possible Damage to
People and Objects Resulting from Releases of
Hazardous Materials (CPR 16E-1992)

TNO Green Book

Issued by:
Sdu Uitgeverij Plantijnstraat
Afdeling Verkoop Arbeidsinspectie, K 2301
Postbus 20014
2500 EA Den Haag The Netherlands

INTERNATIONAL STANDARDS

Electrical Installations of Buildings

IEC 60364

Issued by:
International Electrotechnical Commission
3 Rue de Varembe
CH 1211 Geneva 20
Switzerland

Mechanical Properties of fasteners made of carbon
steel and alloy steel -
Part 1: Bolts, Screws and Studs

ISO 898-1

Hexagon Head Bolts - Product Grades A and B,
Third Edition

ISO 7411

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

ISO/TR 11069

Issued by:
International Organization for Standardization
1, Rue de Varembe
CH-1211 Geneva 20
Switzerland

NOTE: Copies can also be obtained from National Standards Organizations

NOTE: The DEPs and most referenced external standards are available for Shell users on the SWW (Shell Wide Web) at
address <http://sww.shell.com/standards>.

11. BIBLIOGRAPHY

Structures to Resist the Effects of Accidental
Explosions

ARMY TM 5-1300

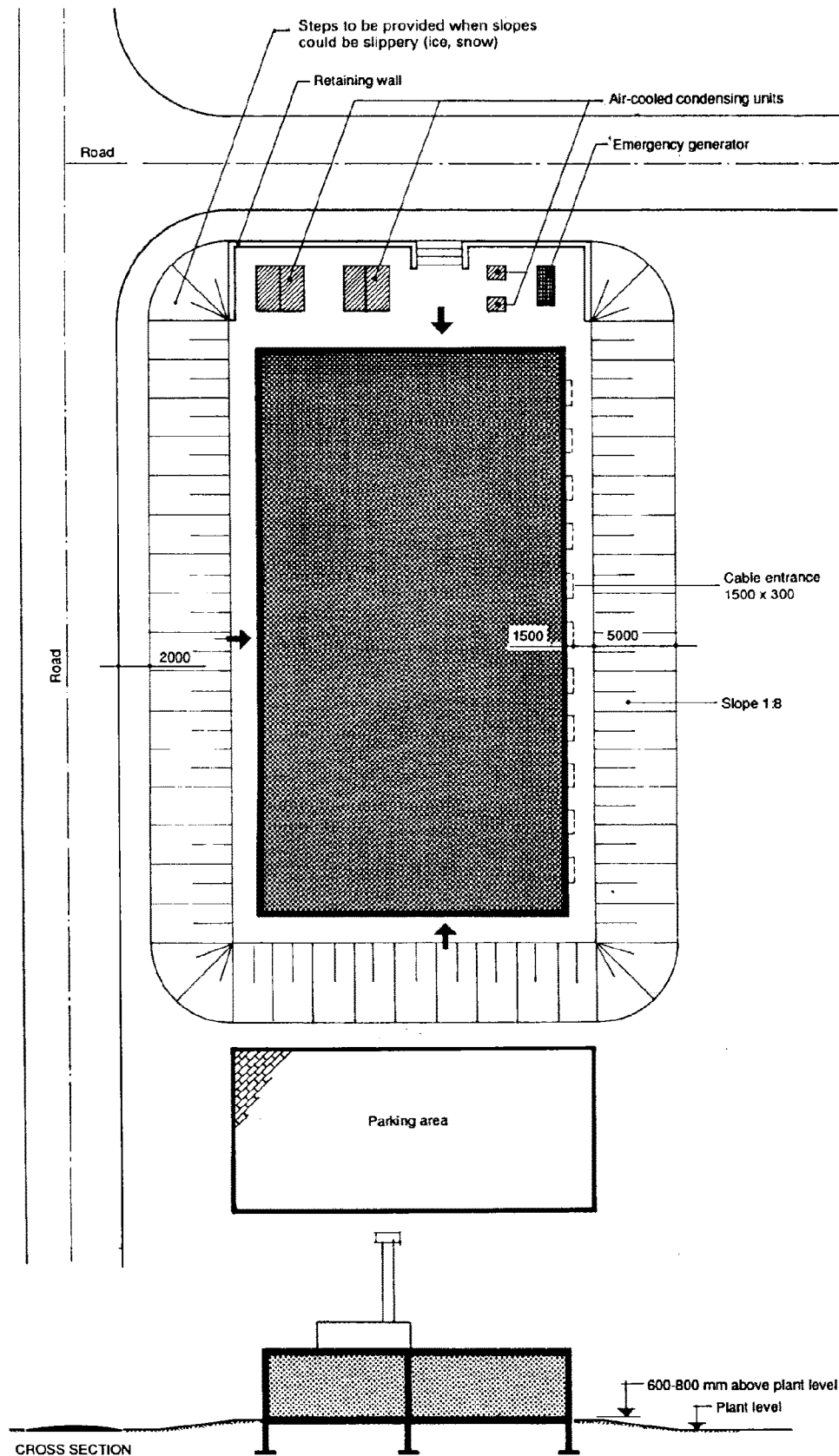
Issued by:
Department of the Army, Navy, and Air Force
Washington, DC USA

Uniform Building Code

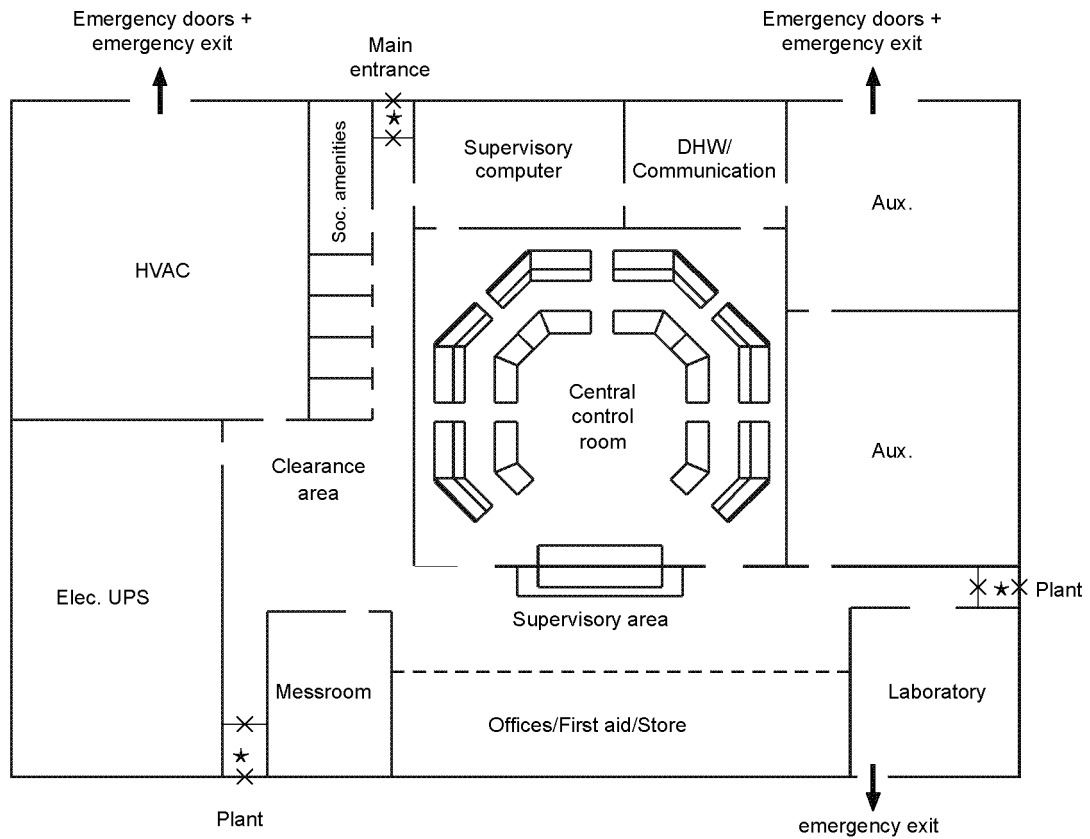
UBC

Issued by:
ICBO Headquarters
5360 Workman Mill Road
Whittier, California 90601-2298
USA

APPENDIX 1 TYPICAL LOCATION OF CONTROL BUILDING

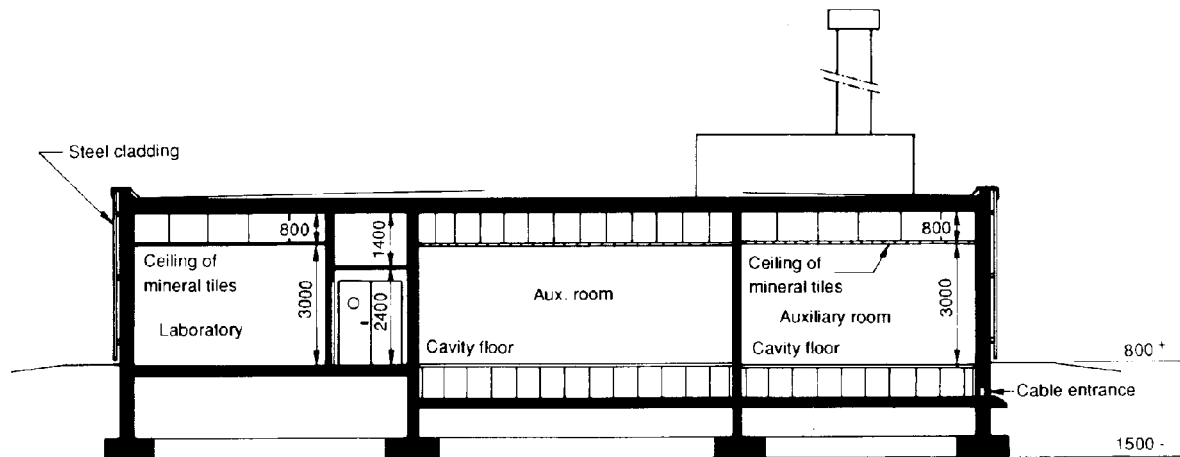
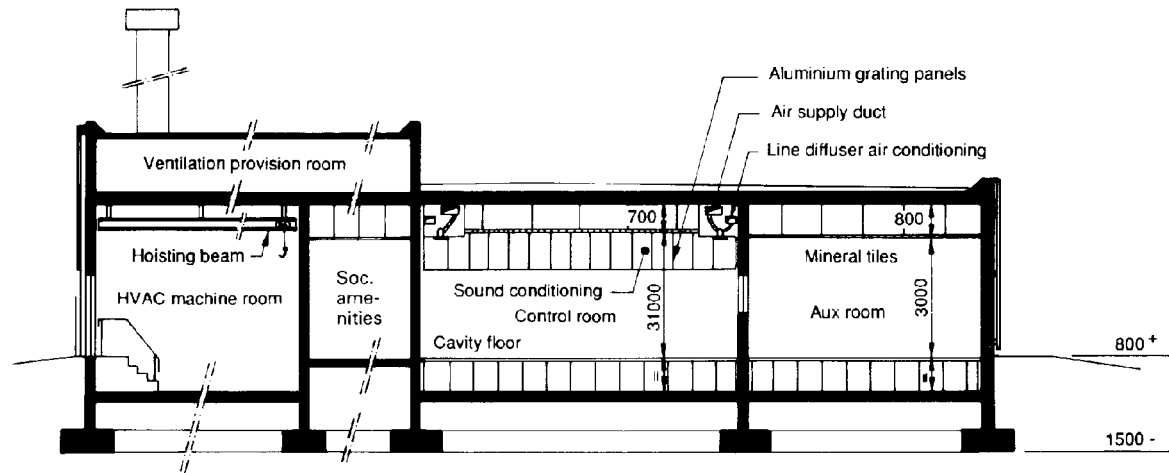


APPENDIX 2 TYPICAL LAY-OUT OF CONTROL BUILDING

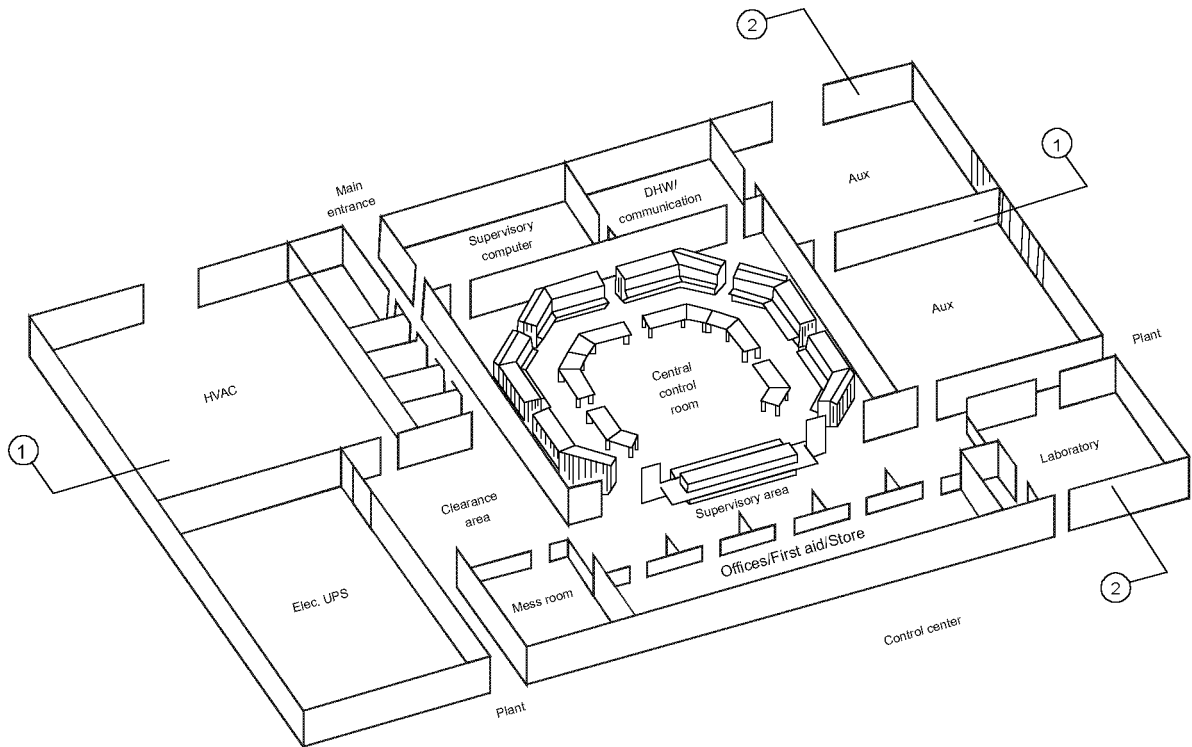


⊠ Air lock

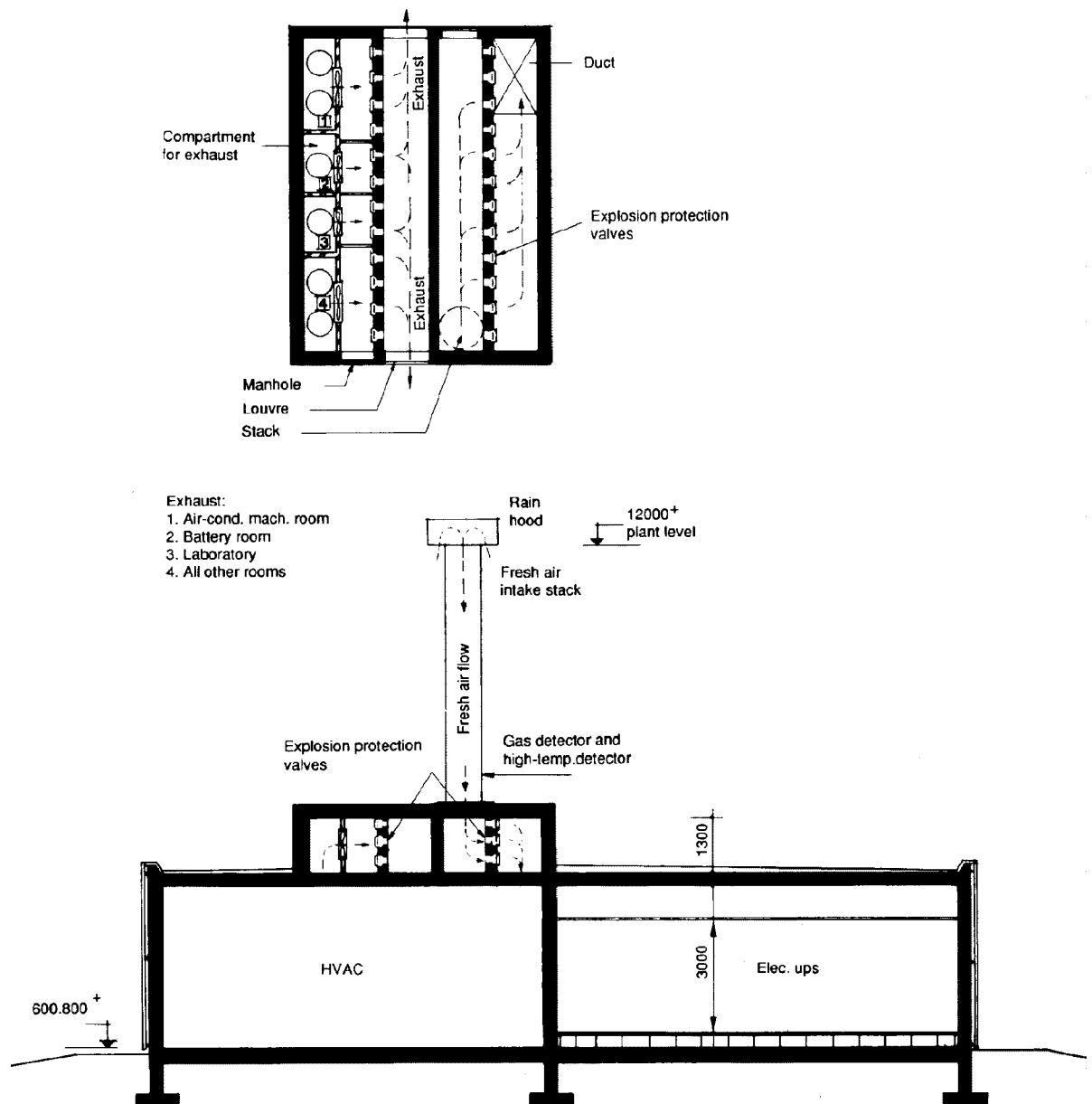
APPENDIX 3 TYPICAL CROSS SECTIONS OF CONTROL BUILDING



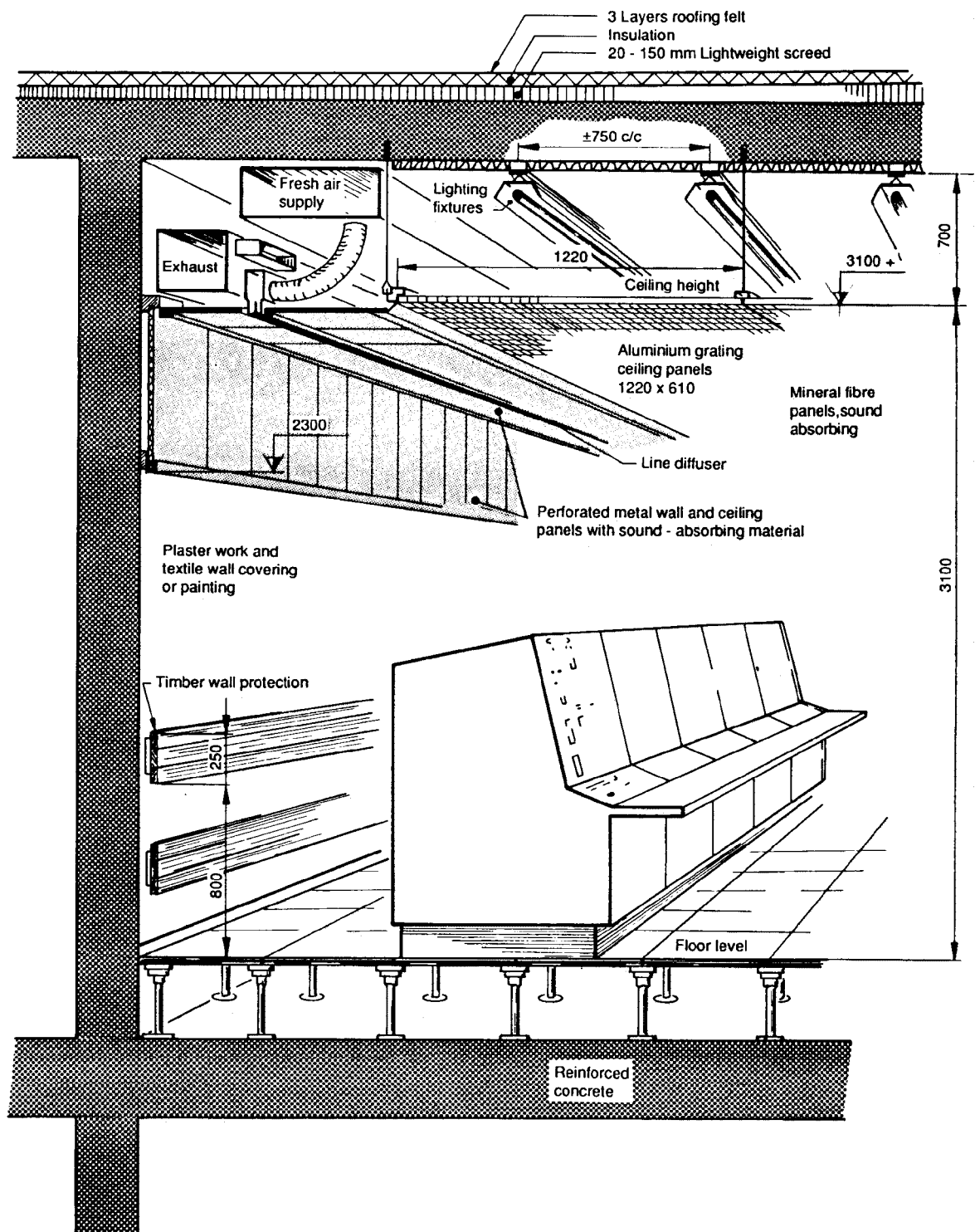
APPENDIX 4 BIRD'S EYE VIEW OF A CONTROL BUILDING



APPENDIX 5 TYPICAL CROSS SECTION OF CONTROL BUILDING WITH VENTILATION PROVISIONS



APPENDIX 6 TYPICAL CROSS SECTION OF CONTROL ROOM



APPENDIX 7 BLAST LOAD AND BUILDING INFORMATION DATA SHEET

Facility Name: _____ Project Number: _____
 Building Name: _____
 Location: _____ ☐ New Date: _____
 _____ ☐ Existing Revision No: _____

 _____ Checked by: _____

Blast Resistant Building Construction Information

Building Response (Deformation) Range ☐ Low ☐ Medium ☐ High

Building's Structural System

<u>Frame</u>	<u>Wall</u>	<u>Roof</u>
☐ Cast-In-Place Concrete	☐ Cast-In-Place Concrete	☐ Cast-In-Place Concrete
☐ Hot Rolled Steel	☐ Pre-Cast Concrete	☐ Pre-Cast Concrete
☐ Pre-Engineered Steel	☐ Single Sheet Panel	☐ Single Sheet Panel
☐ Load Bearing	☐ Insulated Metal Sandwich Panel	☐ Insulated Metal Sandwich Panel
☐ Other: _____	☐ Reinforced Masonry	☐ Insulated Metal Deck
	☐ Masonry	☐ Composite Concrete Deck
	☐ Other: _____	☐ Other: _____

Fragment Impact Resistance Required: ☐ Yes ☐ No ☐ NA

Blast Load Design Requirements

For each load case, the blast on each surface shall be determined using the procedures provided in section 5.3 of DEP 34.17.10.30-Gen, based on the peak side-on over-pressure and corresponding duration or impulses as indicated below:

Blast Load Parameters ^(1,2,3)

(4) Load Case	Description	Reflected Wall (4) (N, S, E or W)	Angle and Dimensions Building B = Width, L = Length and H = Height in m α = angle of incidence				Peak Side-On Over-Pressure kPa		Duration in ms		
			B	L	H	$\alpha^{(5)}$	P ₁	P ₂	T ₁	T ₂	T ₃

Notes: (1) Blast loads shall be computed at the wall nearest the blast centre.

(2) Roof shall be considered to be loaded by the peak side-on over-pressure.

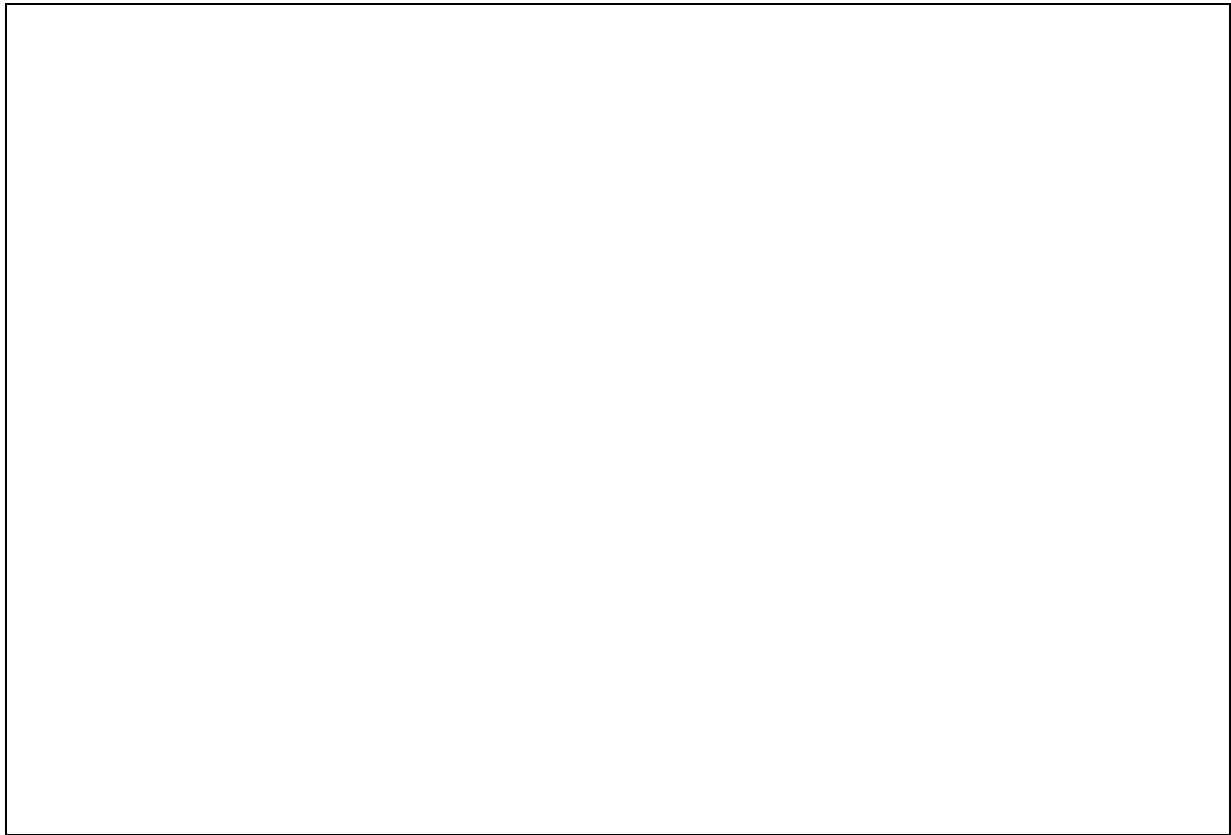
(3) Depending on the load shape, some of the parameters may not be applicable.

(4) Each load case may see a different reflected wall. Indicate the wall (N,S,E or W) facing the blast for the current load case. Figure 1 indicates the contour of the building and N,S,E or W facing to the blast source.

(5) Indicate angle of incidence in degrees, measured from the line normal to the reflected wall.

Blast Load and Building Information Data Sheet (Continued)

Figure 1: Contour and Building/Door Orientation (N,S,E or W) ⁽¹⁾



Note: (1) Indicate also the distance from the building to the explosion source or epicentre.

Blast Door Requirements

The table below summarises the design requirements for each blast door located in the exterior walls of blast resistant buildings (Door shall be indicated in figure 1).

[illegible]

Blast Load and Building Information Data Sheet (Continued)

Geotechnical Requirements

Foundation Type

☐ Mat Foundation ☐ Spread Footing ☐ Piling ☐ Other: _____

Mat Foundation

Item	Value	Unit
Ultimate Net Bearing Capacity at Depth		
Dynamic Modulus of Subgrade Reaction		
Sliding Friction Coefficient		
Passive Pressure Coefficient		

Spread Footing Foundation

Item	Value	Unit
Ultimate Net Bearing Capacity at Depth		
Dynamic Modulus of Subgrade Reaction		
Passive Pressure Coefficient		

Piling Foundation

Pile description		
Item	Value	Unit
Maximum Horizontal Pile Capacity		
Vertical Pile Spring Constant		
Horizontal Pile Spring Constant		

Other Requirements

☐ Blast Valves ☐ Blast Attenuators ☐ Blast Dampers
☐ Gas Detection ☐ Automatic Door Closer ☐ Other

Special Requirements:

Remarks:
