AERB SAFETY STANDARD NO. AERB/NF/SS/CSE-4

GOVERNMENT OF INDIA

AERB SAFETY STANDARD

DESIGN, FABRICATION AND ERECTION OF EMBEDDED PARTS AND PENETRATIONS IMPORTANT TO SAFETY OF NUCLEAR FACILITIES

ATOMIC ENERGY REGULATORY BOARD

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DESIGN, FABRICATION AND ERECTION OF EMBEDDED PARTS AND PENETRATIONS IMPORTANT TO SAFETY OF NUCLEAR FACILITIES

Atomic Energy Regulatory Board
Mumbai - 400 094
India

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Price:

Orders for this Standard should be addressed to:

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FOREWORD

Activities concerning establishment and utilization of nuclear facilities and use of radioactive sources are to be carried out in India in accordance with the provisions of the Atomic Energy Act 1962. In pursuance of the objective to ensure safety of members of the public and occupational workers as well as protection of environment, the Atomic Energy Regulatory Board has been entrusted with the responsibility of laying down safety standards and framing rules and regulations for such activities. The Board has, therefore, undertaken a programme of developing safety standards, codes of practice and related guides and manuals for the purpose. These documents cover aspects such as siting, design, construction, operation, quality assurance, decommissioning and regulation of nuclear and radiation facilities.

Codes of practice and safety standards are formulated on the basis of internationally accepted safety criteria for design, construction and operation of specific equipment, systems, structures and components of nuclear and radiation facilities. Safety codes establish the objectives and set minimum requirements that shall be fulfilled to provide adequate assurance for safety. Safety guides elaborate various requirements and furnish approaches for their implementation. Safety manuals deal with specific topics and contain detailed scientific and technical information on the subject. These documents are prepared by experts in the relevant fields and are extensively reviewed by advisory committees of the Board before they are published. The documents are revised when necessary, in the light of the experience and feedback from users as well as new developments in the field.

Civil engineering structures in nuclear installations form an important feature having implications to safety performance of these installations. The objective and minimum requirements for the design of civil engineering buildings/structures that shall be fulfilled to provide adequate assurance for safety of nuclear installations in India are specified in the Safety Standard for Civil Engineering Structures Important to Safety of Nuclear Facilities (No. AERB/SS/CSE). The present standard is written to specify guidelines for implementation of the above civil engineering safety standard in design, fabrication and erection of embedded parts and penetrations important to safety.

Consistent with the accepted practice, ‘shall’, ‘should’ and ‘may’ are used in the standard to distinguish between a firm requirement, a recommendation and a desirable option, respectively. Appendices are an integral part of the document, whereas annexures, footnotes, references/bibliography and lists of participants are included to provide information that might be helpful to the user. Approaches for implementation different to those set out in the Standard, may be acceptable, if they provide comparable assurance against undue risk to the health and safety of the occupational workers and the general public and protection of the environment.

For aspects not covered in this standard, applicable and acceptable national and international standards, codes and guides should be followed. Non-radiological aspects of industrial safety and environmental protection are not explicitly considered. Industrial safety is ensured through compliance with the applicable provisions of the Factories Act, 1948 as amended in 1987 and the Atomic Energy (Factories) Rules, 1996.

This Standard has been prepared by specialists in the field drawn from the Atomic Energy Regulatory Board, Bhabha Atomic Research Centre, Nuclear Power Corporation of India Limited, Development Consultants Limited, Tata Consulting Engineers and Bureau of Indian Standards. It has been reviewed by the relevant AERB Advisory Committee on Codes and Guides and the Advisory Committee on Nuclear Safety.

AERB wishes to thank all individuals and organisations who have prepared and reviewed the draft and helped in its finalisation. The list of persons, who have participated in this task, along with their affiliations, is included for information.

(Suhas P. Sukhatme)
Chairman, AERB

DEFINITIONS

Acceptable Limits

Limits acceptable to Regulatory Body for accident condition or potential exposure.

Accident Conditions

Substantial deviations from Operational States which could lead to release of unacceptable quantities of radioactive materials. They are more severe than anticipated operational occurrences and include Design Basis Accidents as well as beyond Design Basis Accidents.

Anticipated Operational Occurrences

An operational process deviating from normal operation which is expected to occur during the operating lifetime of a facility but which, in view of appropriate design provisions, does not cause any significant damage to Items Important to Safety nor lead to Accident Conditions.

Approval

A type of regulatory consent issued by the Regulatory Body to a proposal.

Atomic Energy Regulatory Board (AERB)

A national authority designated by the Government of India having the legal authority for issuing regulatory consent for various activities related to the nuclear and radiation facility and to perform safety and regulatory functions including enforcement for the protection of site personnel, the public and the environment from undue radiation hazards.

Attachment

An attachment is an element in contact with or connected to the inside or outside of a component. It may have either a pressure retaining or non-pressure retaining function.

Construction

The process of manufacturing, testing and assembling the components of a nuclear or radiation facility, the erection of civil works and structures, the installation of components and equipment and the performance of associated tests.

Design Basis Accidents (DBAs)

A set of postulated accidents which are analysed to arrive at conservative limits on pressure, temperature and other parameters which are then used to set specifications that must be met by plant structures, systems and components and fission product barriers. .

Design Leak Rate (for Containment Penetration Assembly)

The maximum permissible leak rate, at design pressure and temperature, through the assembly in the event of a design basis accident inside the reactor containment.

Embedded Parts

Any structural member, plate, angle, channel, pipe sleeve or other section anchored to a concrete structure through direct bond or other anchors.

Embedment

The embedment is that portion of the component in contact with the concrete or grout used to transmit applied loads to the concrete structure through direct bond or other anchors. The embedment may be fabricated lugs, bolts, plates, reinforcing bars, shear connectors, expansion anchors, inserts or any combination thereof.

Examination

An element of inspection consisting of investigation of materials, components, supplies or services to determine conformance with those specified requirements which can be determined by such investigation.

Expansion Fastener

A component installed in hardened concrete for the transfer of loads into the concrete by direct bearing and/or friction.

Guard Pipe

A pipe sleeve used to guard a penetration assembly.

Inspection

Quality control actions which by means of examination, observation or measurement determine the conformance of materials, parts, components, systems, structures as well as processes and procedures with predetermined quality requirements.

Items Important to Safety (IIS)

The items which comprise:

(1) those structures, systems, equipment and components whose malfunction or failure could lead to undue radiological consequences at Plant site or off-site.

(2) those structures, systems, equipment and components which prevent Anticipated Operational Occurrences from leading to Accident Conditions;

(3) those features which are provided to mitigate the consequences of malfunction or failure of structures, systems, equipment or components.

Normal Operation

Operation of a plant or equipment within specified operational limits and conditions. In case of nuclear power plant this includes start-up, power operation, shutting down, shutdown state, maintenance, testing and refueling.

Nuclear Facility

All nuclear fuel cycle and associated installations encompassing the activities covering from the front end to the back end of nuclear fuel cycle processes and also the associated industrial facilities such as; heavy water plants, beryllium extraction plants, zirconium plant, etc.

Nuclear Power Plant

A nuclear reactor or a group of reactors together with all the associated structures, systems, equipment and components necessary for safe generation of electricity.

Peak Stress

The increment of stress which is additive to the primary plus secondary stresses by reason of local discontinuities or local thermal stress including the effects, if any, of stress concentrations. Its basic characteristic is that it does not cause any noticeable distortion and is objectionable only as a possible source of a fatigue crack or brittle fracture. A stress which is not highly localised falls in this category if it is of a type which cannot cause noticeable distortion. Examples of peak stresses are stresses at a local structural discontinuity, certain thermal stresses which may cause fatigue but not distortion, surface stresses produced by thermal shock etc.

Prescribed Limits

Limits established or accepted by the Regulatory Body.

Primary Stress

Any normal stress or a shear stress developed by an imposed loading which is necessary to satisfy the laws of equilibrium of external and internal forces and moments. The basic characteristic of a primary stress is that it is not self-limiting.

Quality

The totality of features and characteristics of an item or service that bear on its ability to satisfy stated or implied needs.

Quality Assurance

Planned and systematic actions necessary to provide adequate confidence that an item or a facility will satisfy given requirements for quality.

Quality Control

Quality Assurance actions, which provide a means to control and measure the characteristics of an item, process or facility in accordance with established requirements.

Records

Documents which furnish objective evidence of the quality of items and activities affecting quality. It also includes logging of events and other measurements.

Responsible Organisation

The organisation having overall responsibility for siting, design, construction, commissioning, operation and decommissioning of a facility.

Safety

The achievement of proper operating conditions, prevention of accidents or mitigation of accident consequences, resulting in protection of site personnel, the public and the environment from undue radiation hazards.

Secondary Stress

Secondary stress is a normal stress or shear stress developed by the constraint of adjacent material or by self-constraint of the structure. The basic characteristic of a secondary stress is that it is self-limiting.

Structure

The assembly of elements which supports/houses the plants, equipment and systems.

Testing (QA)

The determination or verification of the capability of an item to meet specified requirements by subjecting the item to a set of physical, chemical, environmental or operational conditions.

SPECIAL DEFINITIONS

(Specific to the present standard)

Design Service Conditions

The service conditions used as the basis for rating or design qualification of structures, systems, equipment or any other item.

Electric Cable Core Sealing (Power and Control Cables)

A provision made to minimise the leakage of fluids that could escape through the interstices between the insulated cores of a cable.

Electric Cable Strand Sealing (Power Cables)

A provision made to minimise the leakage of fluids that could escape through the interstices between the strands of the conductor of a cable.

Qualified Life

The estimated time, determined by tests (normal or accelerated) for which the embedded parts and penetration assembly will meet all design requirements for the specified service conditions.

Qualified Life Test

Tests performed on preconditioned test specimens to verify that the item will meet the design requirements at the end of its qualified life.

Service Conditions

All conditions expected as a result of normal operating requirements, expected extremes in operating requirements and postulated conditions appropriate for the design basis events of the station, applicable to the penetration assembly and embedded parts.

Vendor

A design, contracting or manufacturing organisation, supplying a service, component or plant.

SYMBOLS

Symbols used in this standard shall have the following meaning, unless otherwise defined elsewhere in this standard. The symbols defined hereunder may not necessarily conform to the symbols adopted elsewhere for national or international use. Unless specified otherwise, SI units are adopted.

A_g	Gross cross-sectional area of concrete members.
A_1	Full cross sectional area of concrete support.
A_2	Area of bearing support; maximum area of the portion of the supporting surface that is geometrically similar to and concentric with the loaded area; same unit as in A_1.
b_w	Web width.
D	Nominal diameter.
DL	Dead load.
d	Effective depth of flexural member, or distance from extreme compression fibre to centroid of tension reinforcement.
E_o	Load effects due to Operating Basis Earthquake, including responses of supported components, piping and equipment, hydrodynamic effects and dynamic effects of surrounding soil.
E_{ss}	Load effects due to Safe Shutdown Earthquake, including responses of supported components, piping and equipment, hydrodynamic effects and dynamic effects of surrounding soil.
F	Loads resulting from the application of prestress.
F_h	Hydrostatic load due to internal flooding.
FF	Load effects due to design basis flood.
f_{ck}	Characteristic compressive strength (in MPa) of 150 mm concrete cube at 28 days.

f_{ut} Minimum specified tensile strength.

f_y Characteristics strength of reinforcing steel, corresponding to 0.2% proof stress for high strength deformed bars or yield stress in case of mild steel.

H Lateral earth pressure.

LL Live loads, including any movable equipment loads, construction and other loads which vary with intensity and occurrence, such as soil pressure; the live load shall be considered to vary from zero to full value for all load combinations.

m Minimum side cover distance.

n Number of threads per cm.

P_a Maximum differential pressure load generated by a postulated design basis accident.

P_d Design pullout load of concrete.

P_t Pressure load during the structural integrity and leak rate tests, where applicable.

P_v Pressure loads resulting from pressure variation either inside or outside the containment.

R_o Pipe and equipment reactions during normal operating or shutdown conditions, based on the most critical transient or steady-state condition, excluding dead load and earthquake reactions.

R_a Pipe and equipment reactions generated by a postulated accident used as a design basis; and including R_o.

T_o Thermal effect loads during normal operation; start-up or shut-down conditions, based on the most critical transient or steady state conditions.

T_a Thermal effect loads generated by a postulated design basis accident and including T_o.

T_t	Thermal effect loads during the test.
t	Nominal plate thickness less corrosion allowance.
WC	Load generated by severe wind.
W_t	Load generated by the design tornado specified for the plant; this includes combined loads due to the tornado wind pressure, tornado created differential pressure and tornado generated missiles.
Y_j	Jet impingement load on structure generated by a postulated accident used as a design basis.
Y_m	Missile impact load on structure, such as pipe whipping generated by or during a postulated accident used as a design basis.
Y_r	Loads on the structure generated by the reaction of the high energy pipe broken due to a postulated accident used as design basis.
μ	Coefficient of friction between steel and concrete.

CONTENTS

1. INTRODUCTION

1.1 General

1.1.1 There is no comprehensive Indian Standard (IS) dealing with the design of embedded parts and penetrations. The design standards of other countries, e.g., USA, Canada, France, etc., were adapted for the engineering of embedded parts and penetrations for previous Indian Nuclear Power Plants (NPPs). One vital question that arose during the time was how to assure the compatibility of Indian materials, used in the construction, with the design specification of other countries' codes. The second important point was about the integration of Indian practice of design and construction with the codal requirements of other countries. In view of this, in 1990, AERB decided to prepare its own document for the design, fabrication and erection of embedded parts and penetrations important to safety of Indian NPPs.

The present document may be viewed as the Indian design standard for the embedded parts and penetrations important to safety of nuclear facilities. To prepare this standard as per the scope mentioned above, CCCSE (Code Committee of Civil and Structural Engineering) derived assistance from the following codes/standards:

(a) ACI 349-85 (1985), Code Requirements for Nuclear Safety Related Concrete Structures (ACI 349-85) and Commentary - ACI 349 R-85, American Concrete Institute, Detroit, Michigan.

(b) ASME (1989), Component Supports, ASME Boiler and Pressure Vessel Code, Section III, Rules for Construction of Nuclear Power Plant Component, Division 1 - Sub-section NF.

(c) CAN3-N287.3-M82, Design Requirements for Concrete Containment Structures for CANDU Nuclear Power Plants, Canadian Standards Association.

(d) CAN3-N287.2-M82, Material Requirements for Concrete Containment Structures for CANDU Nuclear Power Plants, Canadian Standards Association.

(e) IEEE (1984), IEEE Standard for Electrical Penetration Assemblies in Containment Structures for Nuclear Power Generating Stations, The Institute of Electrical and Electronics Engineers, Inc., New York.

(f) IEEE (1980), IEEE Standard for Installation, Inspection and Testing Requirements for Class 1E Instrumentation and Electric Equipment of Nuclear Power Generating Stations.

1.1.2 The functional and safety requirements of the embedded parts and penetrations important to safety of a Nuclear Power Plant (NPP) call for special design requirements. The safety standard for Civil Engineering Structures Important to Safety of Nuclear Facilities, No. AERB/SS/CSE, describes the philosophy, design approach and design requirements of buildings and structures important to safety. This standard describes the criteria and methodology for design, fabrication, testing and erection of embedded parts, penetrations and attachments important to safety in line with the stipulations of AERB/SS/CSE.

1.2 Safety Design Basis

1.2.1 The goal of nuclear safety is to protect site personnel, the public, and the environment by establishing and maintaining effective safety against radiological hazard.

1.2.2 The design of embedded parts, penetrations and attachments in NPPs shall be based on the above safety goal. The penetration assemblies and embedded parts in the containment shall be planned, designed, fabricated, installed and maintained such that they serve their intended functions to restrict the release of radioactivity in the environment within prescribed limits under normal operating condition and within acceptable limits during and following accident condition.

1.2.3 All structures important to safety are classified according to the required safety functions to be performed by the structures satisfying the provisions of sections 2.3 and 2.4 of safety standard No. AERB/SS/CSE. The design conditions and respective load combinations are specified on the basis of their classifications. The summary of classifications of civil engineering structures and the corresponding design conditions with load combinations are given in Table 2.1 of AERB/SS/CSE.

1.3 Scope

1.3.1 The standard deals with methods for implementing the requirements of design, fabrication, inspection, testing and installation of embedded parts, penetrations and attachments important to safety.

1.3.2 The standard covers the following aspects related to embedded parts, penetrations and attachments, which are important to safety:

(a) design requirements;

(b) special requirements;

(c) fabrication and installation requirements;

(d) quality assurance; and

(e) testing.

1.3.3 Exclusion

The standard does not cover the following, unless specified otherwise:

(a) the requirements for external circuits, systems or other elements which may be connected to the penetration assemblies and the embedded parts;

(b) the requirement for special penetrations like the air locks, equipment hatch, and such other large openings;

(c) attachments which fall under the category of component support; and

(d) embedded parts which are not important to safety, such as those required for supporting ladders, hand rails, lifting fixtures, edge protection of concrete, etc.

1.3.4 The data and relationships given in this document are only for the purpose of guidance.

1.3.5 The standard has been prepared primarily for a stationary nuclear power plant. However, the provisions of this standard may be found useful for other nuclear facilities, failure of which may cause a radiological hazard in public domain.

1.3.6 Use of the Standard

The standard shall be used in conjunction with relevant AERB safety codes, standards, guides, and other applicable standards. In case of any conflict, the provisions of this standard shall prevail upon the others.

1.4 Quality Assurance

Complete quality assurance programme for the design, fabrication and erection of embedded parts, penetrations and attachments important to safety shall be developed in line with the provisions of section-9 of AERB/SS/CSE and section-7 of this standard.

1.5 Approval of Special Design and Construction Techniques

1.5.1 For novel or unproven methods of analysis, design and construction or for use of special construction materials (not covered in this standard), prior approval shall be obtained from AERB after ensuring comparable safety.

1.6 Structure of the Document

1.6.1 This standard comprises of eight sections. Each section is divided into a number of sub-sections which are further subdivided into a number of paragraphs or clauses.

1.6.2

Section-2	:	Embedded parts, penetrations and attachments
Section-3	:	Design requirements
Section-4	:	Special requirements of embedded parts
Section-5	:	Special requirements of penetration assemblies
Section-6	:	Fabrication and installation requirements of embedded parts, penetration assemblies and their components
Section-7	:	Quality assurance
Section-8	:	Testing

2. EMBEDDED PARTS, PENETRATIONS AND ATTACHMENTS

2.1 General

2.1.1 The general function of embedded parts and attachments is to transmit the load of the supported system to the supporting structure. Typical details of steel inserts, embedments and anchors are shown in Figs. 2.1-1 to 2.1-6.

2.1.2 The general function of the mechanical penetration assemblies (Figs. 2.1-7 to 2.1-10) is to allow the transfer of fluids, or fuel elements into or out of the containment or other structures, while maintaining their integrity. The electrical penetration assembly (Figs. 2.1-11 to 2.1-16) provides for safe passage of one or more electrical cables through a single aperture in the containment structure/cell[1].

2.2 Embedded Parts

The material, design, fabrication and erection of the various components of embedded parts shall meet the basic requirements stated hereinafter.

2.2.1 Embedded Steel

The steel components partly or fully embedded in concrete, used to transmit load to the concrete structures, are considered as embedded steel.

2.2.2 Inserts

Commercially available or predesigned or prefabricated embedment installed prior to concrete placement, which are specifically designed for attachment bolted/welded connection. A typical example of insert is given in Type A of combination embedments of Fig. 2.1-1.

2.2.3 Anchor Bolts

Anchor bolts, studs or bolts (Figs. 2.1-1 and 2.1-2) which transmit the part or total loads of supported system to the concrete structure.

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1 Cell structures referred hereto are those of Fast Breeder Reactor (FBR) and other nuclear installations.

2.2.4 Anchor Head

A nut, washer, plate, stud or bolt head or other steel component used to transmit anchor loads to the concrete by bearing. Typical anchor heads are shown in Figs. 2.1-1 and 2.1-2.

2.2.5 Expansion Fasteners

2.2.5.1 Expansion fasteners are inserted into hardened concrete. They engage into the surrounding concrete by lateral enlargement of the whole or part of their embedded portion for the purpose of transmitting the pull-out and shear loads to the concrete structure by direct bearing and/or shear friction.

2.2.5.2 The expansion fasteners should not be used where alternative arrangement is available, particularly in the case of dynamic load of long duration. In structures where the expansion anchor is to be used, it can be done by satisfying the requirements of cl. 2.6.7.1, 8.2, 8.3 and 8.6 of this standard, except in the case of pre-stressed concrete structures where prior approval of the designer is mandatory. When the use of expansion fasteners becomes unavoidable for long-duration vibrating loads, suitable safety factors as per recommendations of the designer shall be applied to the loads established by tests as per cl. 8.2, 8.3 and 8.6 to find out safe loads during use. However, the design load of the anchor should not be more than the value specified by the manufacturer.

2.3 Penetrations

2.3.1 Penetration assemblies are defined as parts or appurtenances required to permit piping, mechanical devices, or electrical connections to pass through the pressure retaining boundary of a containment, or through other structures.

2.3.2 Unless specified otherwise, the material, design, fabrication and erection of the various components of penetration assemblies shall meet the requirements stated hereinafter.

2.3.3 In containment structures, penetrations should be circular in shape, as far as possible. Where rectangular penetrations are essential, provision should be made for effective concreting/grouting in the shadow.

2.3.4 Mechanical Penetration Assemblies

The penetration assemblies used for mechanical services are referred to as mechanical penetrations. The mechanical penetration assemblies (Figs. 2.1-7 to 2.1-10 allow the transfer of fluids, or fuel elements into or out of the containment structure, reactor building or from one area of the safety-related building into another. The penetration assembly shall not adversely affect containment integrity.

2.3.4.1 The penetration assemblies and its components of metal containment structure which conform to sub-section NE (class MC components) of the ASME Boiler and Pressure Vessel Code, Section III, Division 1, are shown in Fig. 2.1-7. Penetration assemblies and its components of concrete structure which conform to sub-section CC of ASME Boiler and Pressure Vessel Code, Section III, Division 2 are shown in Figs. 2.1-8 to 2.1-10. High standards of engineering, design and workmanship shall prevail in all aspects of components and assemblies. Proven techniques shall be used in all stages of design and fabrication. The penetration assembly, though essentially of tubular construction, can have different configurations. The sharp edges/corners shall be rounded off.

2.3.5 Electrical Penetration Assembly

2.3.5.1 An electrical penetration assembly provides a means for the passage of one or more electrical cables through an aperture in the containment wall and other pressure boundaries. The penetration assembly shall not adversely affect the containment integrity.

2.3.5.2 Cabling, associated with instrumentation and control for the reactor, will also pass through electrical penetration assemblies.

2.4 Attachments

2.4.1 Attachments on Steel Structures

Temporary or permanent lugs, brackets and other attachments can be connected to steel structures, liners to support systems or equipment while maintaining the integrity of the structure/liner. However, external attachments to liners are best avoided.

2.4.1.1 Temporary or permanent brackets and attachments shall be designed to resist the design loads without adversely affecting the structural integrity due to excessive deformation or load.

2.4.1.2 The loading combinations for attachment shall conform to that of the steel structure/liner to which it is attached, taking into account all the loads coming from the systems and/or equipment connected to the attachment.

2.4.1.3 Brackets and attachments connected to the structural steel/liner shall be designed and analysed using acceptable techniques.

2.5 Safety Classification and Seismic Categorisation

The embedded parts, penetrations and attachments shall have the same safety classification and seismic categorisation as that of their supporting structures.

2.6 Materials

2.6.1 Unless specified otherwise, the materials for embedded parts, penetrations and attachments should be selected in accordance with the provisions given hereinafter.

2.6.2 Welding and brazing material used in the manufacture of items should comply with an SFA specification in part C of the ASME Boiler and Pressure Vessel Code, Section II. Appropriate provision shall be made to prevent excessive heating of the surrounding concrete when the penetration assembly is welded to the embedded part. These requirements need not apply to hard surfacing or a corrosion-resistant weld metal overlays not exceeding 10 percent of the base metal thickness.

2.6.3 Embedded Parts and Attachments

Unless otherwise specified, materials of construction should conform to the provisions of standard on Design, Fabrication and Erection of Steel Structures Important to Safety of Nuclear Facilities, No. AERB/SS/CSE-2, and guide on Materials of Construction for Civil Engineering Structures Important to Safety of Nuclear Facilities, No. AERB/SG/CSE-4, or equivalent. For materials of embedded parts and attachment in concrete containment structures, requirements of ASME Boiler and Pressure Vessel Code, Section

III, Division 2 should be satisfied.

2.6.4 Penetration Assembly

Materials for all penetration assemblies in containment should be in accordance with the requirements of ASME Boiler and Pressure Vessel Code, Section III, Division 1, sub-section NE, and Division 2, sub-section CC and/or AERB/SS/CSE-2 as applicable.

2.6.4.1 Piping

The piping material used in the fabrication of penetration assemblies should conform to the following specifications or their equivalents.

(a) carbon steel pipe:

(i) up to 150 mm NPS[2] - IS 1239-1978/ASME SA 106 seamless;

(ii) greater than 150 mm NPS - IS 3589-1978/ASME SA 134.

The welded pipes should be fabricated from IS 2062 (grade b or c)/2002 plate with fusion welding process.

If IS 3589 pipes are used as pressure ($\geq$ 0.035MPa) retaining component, the welds shall be D.P./M.P. tested on root and final passes and shall be 10 percent spot radiographed. Alternatively, the weld can be subjected to 100 percent radiography. The material properties of the plates which act as pressure barrier (for design pressure ($\geq$ 0.035MPa) shall satisfy the requirements of ASME, Section III, Division 2, CC-3000.

(b) stainless steel pipe:

(i) up to 300 mm NPS - ASME SA 376/SA 312;

(ii) greater than 300 mm NPS - ASME SA 358.

2.6.5 Bellows

All elements of the bellows should be hydraulic or expansion formed from a corrosion resistant material such as austenitic stainless steel. The starting cylinder used in the manufacture of bellows shall have minimum practical

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2 NPS - Nominal Pipe Size

number of longitudinal joints. No circumferential seam welds shall be located on bellow to form the corrugations. The cylinder shall not be corrugated until all welds are found to be acceptable.

2.6.5.1 The material for bellows shall conform to the requirements of ASTM A 240, Type 304L, 316, 321, inconel or equivalent.

2.6.5.2 The weld ends of the bellows shall be made either of the same base material as that of the containment penetration nozzle and/or sleeve associated with the structure to satisfy welding requirements or of a material that conforms to the requirements of the ASME Boiler and Pressure Vessel Code, and that is compatible to both the expansion bellows and the nozzle and/or sleeve.

2.6.6 Cooling Coil

Tubular coils embedded in concrete for cooling shall be made from a suitable compatible material with adequate corrosion allowance. Grades of steel like SS-304L, 316L, SA 106 and 15-Mo-3 are some of the acceptable materials.

2.6.7 Embedded Parts (EPs), Anchor Bolts

2.6.7.1 Material used for anchor bolts, collars, load-bearing closure plates, test-closure assemblies and temporary test channels shall be compatible to each other so as to minimise any need for dissimilar weldments in the field. In general, such materials should conform to the following standards:

(a) Plates, anchor bolts and rolled sections: IS 2062: ‘Steel for General Structural Purpose’. For female concrete inserts, H.Y.S.D. bars conforming to IS 1786 can also be used.

(b) Plates and anchor bolts: IS 961: ‘Specification for Structural Steel (High Tensile)’.

(c) Test channels/temporary structurals used in testing: IS 1977: ‘Specification for Structural Steel (Ordinary Quality)’.

2.6.7.2 When EPs form part of the stainless steel piping where a part of the system piping is embedded, such as active water floor drain, large and small LOCA

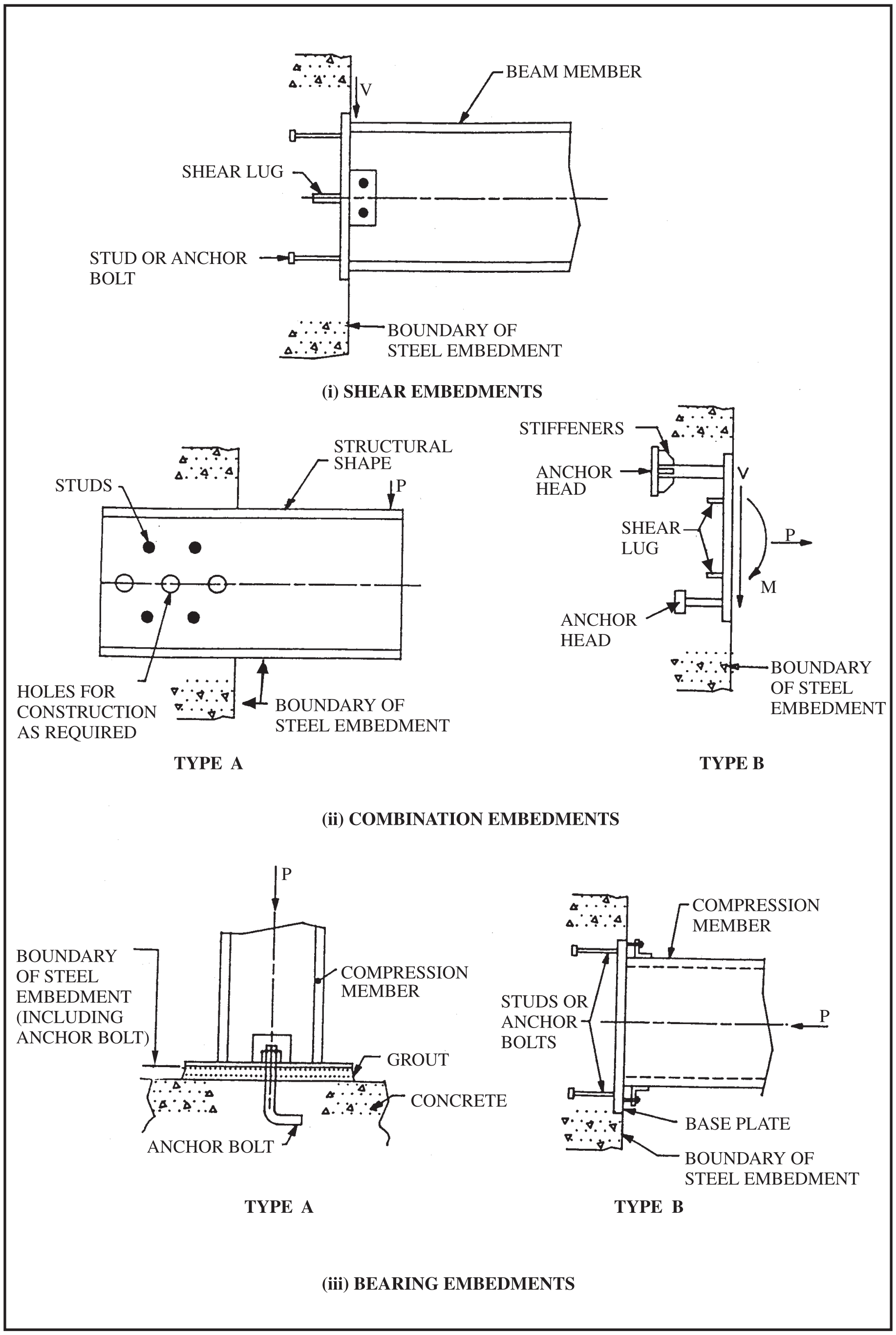


FIG. 2.1-1 TYPICAL EMBEDMENTS DETAILS

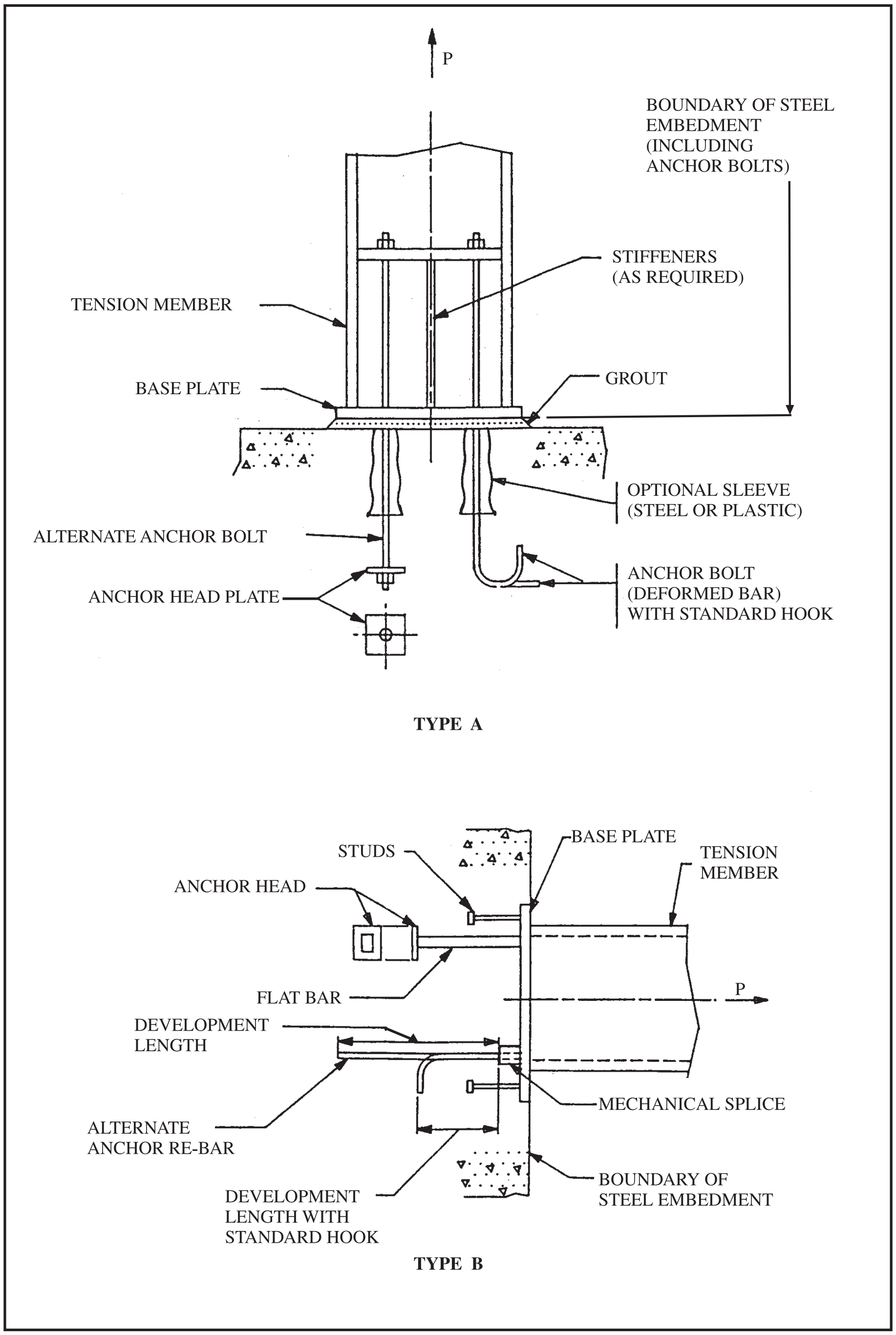


FIG.2.1-2 : TENSION EMBEDMENTS - TYPICAL EMBEDMENT DETAILS

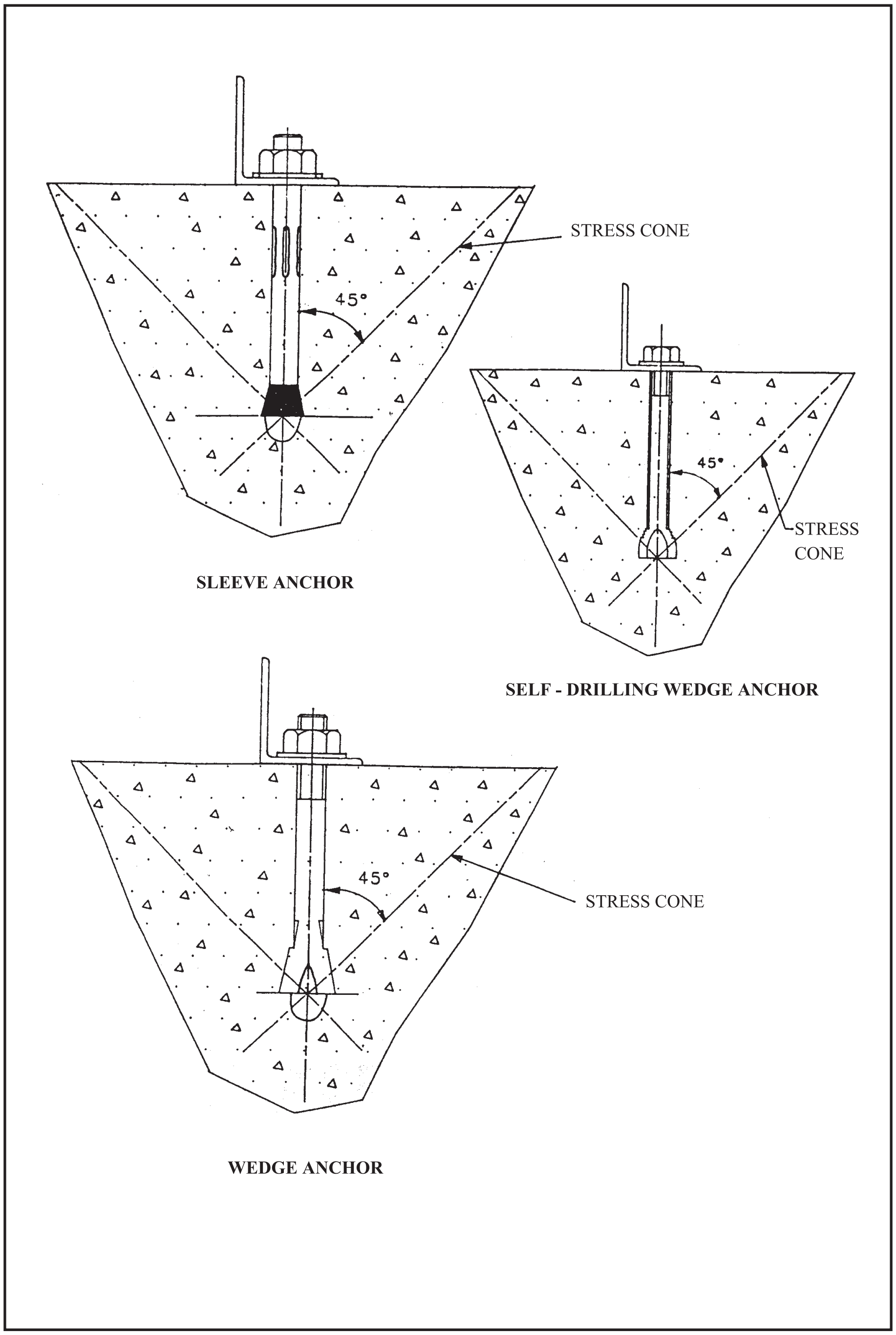
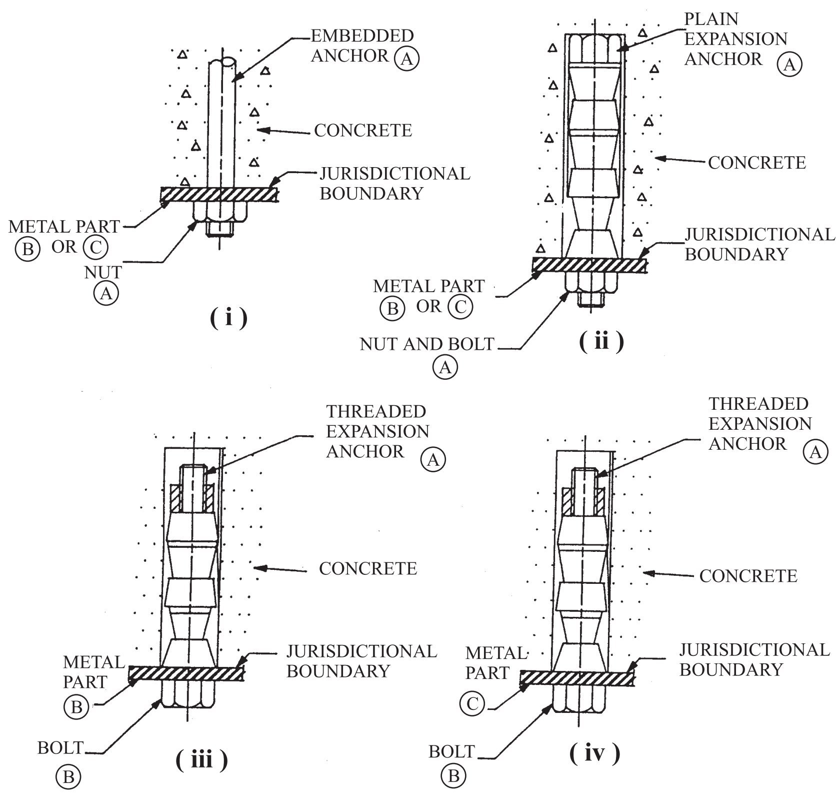


FIG. 2.1-3 : TYPICAL DETAILS OF EXPANSION ANCHOR

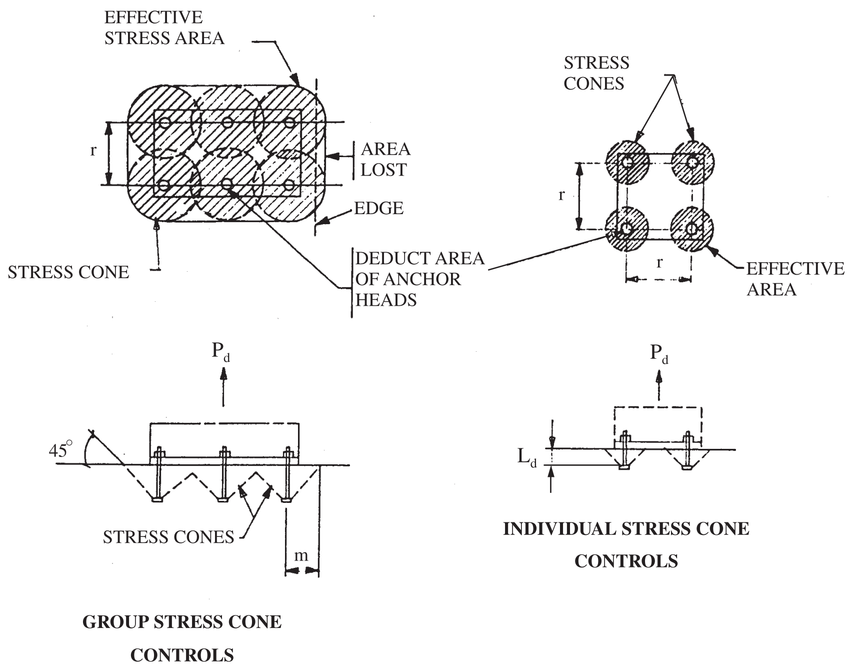


(A) COMPONENTS AND PARTS INCLUDING METALLIC PARTS EMBEDDED IN AND ANCHORED TO THE CONCRETE.

(B) COMPONENTS AND PARTS WHICH CONFORM TO THE REQUIREMENTS OF NUCLEAR SYSTEM AS PER ASME SECTION III DIVISION 1.

(C) COMPONENTS AND PARTS WHICH CONFORM TO STANDARDS APPLICABLE TO THEIR FUNCTION AS NON-NUCLEAR SYSTEM.

FIG. 2.1-4 : TYPICAL DETAILS OF ANCHORS AND JURISDICTIONAL BOUNDARIES



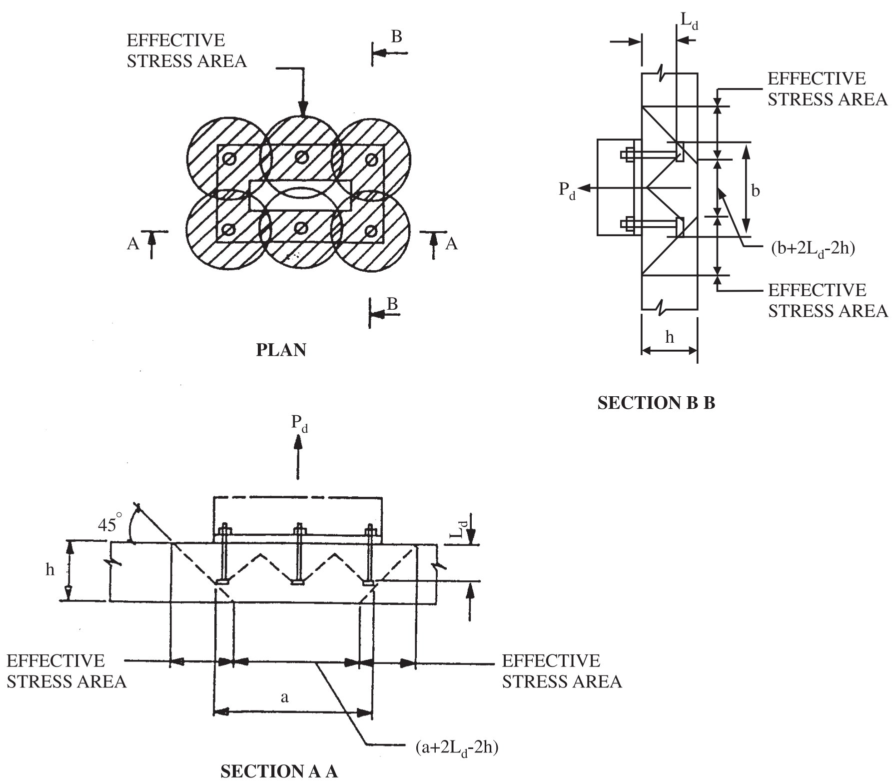
NOTE : GROUP EFFECT IS GOVERNING WHEN **r** IS EQUAL OR LESS THAN 1.66 L_d.

r = CENTRE TO CENTRE DISTANCE BETWEEN ANCHORS IN mm.

m = MINIMUM SIDE COVER DISTANCE FROM THE CENTRE OF AN ANCHOR TO THE EDGE OF THE CONCRETE IN mm.

L_d = EMBEDMENT DEPTH FOR TENSILE ANCHORAGE MEASURED FROM ANCHORAGE BEARING SURFACE TO CONCRETE SURFACE IN mm.

FIG. 2.1-5 : STRESS CONE CONTROLS FOR EMBEDDED ANCHORS



h = OVERALL THICKNESS OF CONCRETE

A_r = STRESS AREA REDUCTION FOR LIMITED DEPTH h

A_r = $(a+2L_d-2h)\ (b+2L_d-2h)$

EFFECTIVE STRESS AREA = $(a+2L_d)\ (b+2L_d) - A_r$

FIG. 2.1-6 : DETAILS OF STRESS AREA CALCULATION FOR EMBEDDED ANCHORS

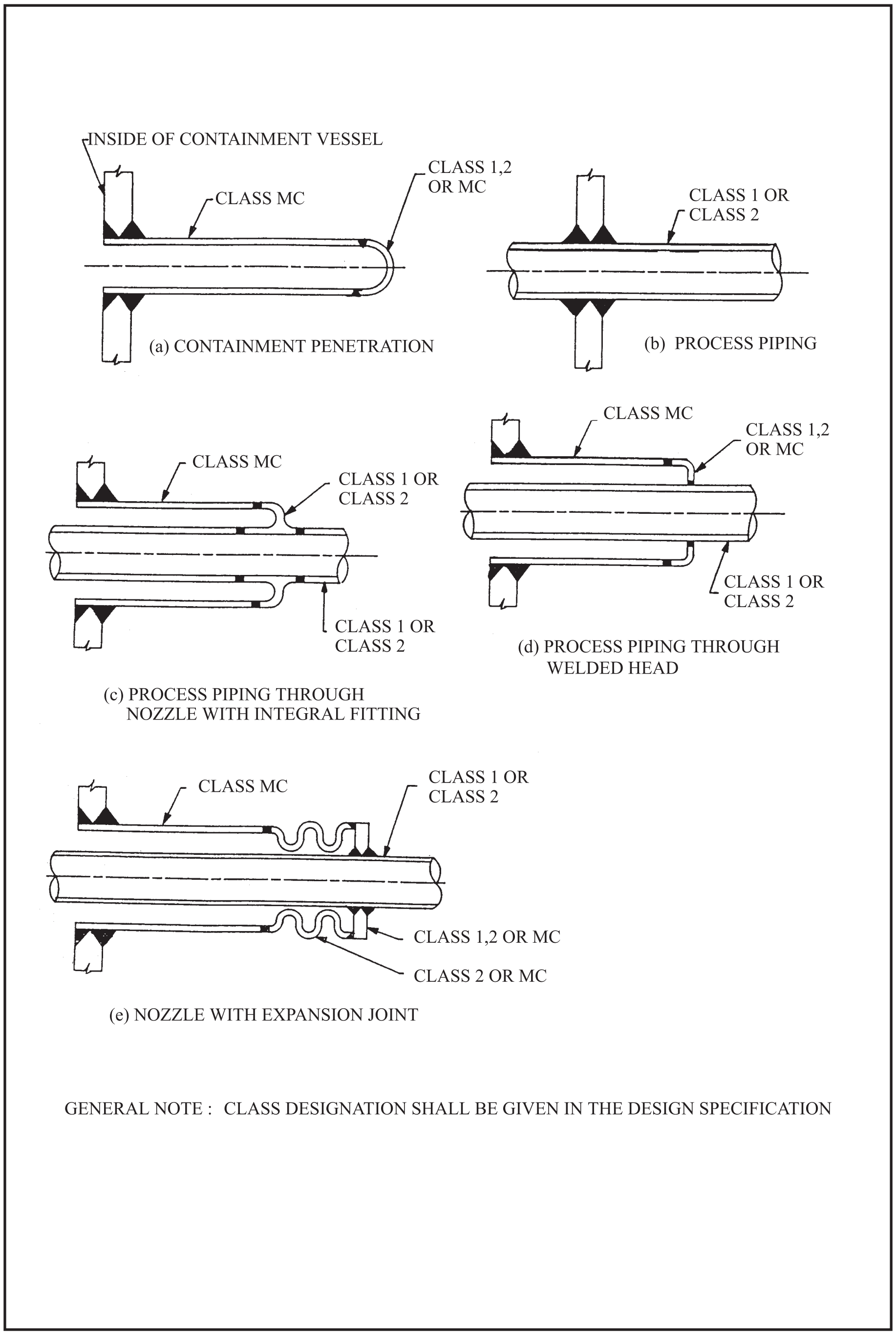


FIG. 2.1-7 : TYPICAL METAL CONTAINMENT PENETRATIONS

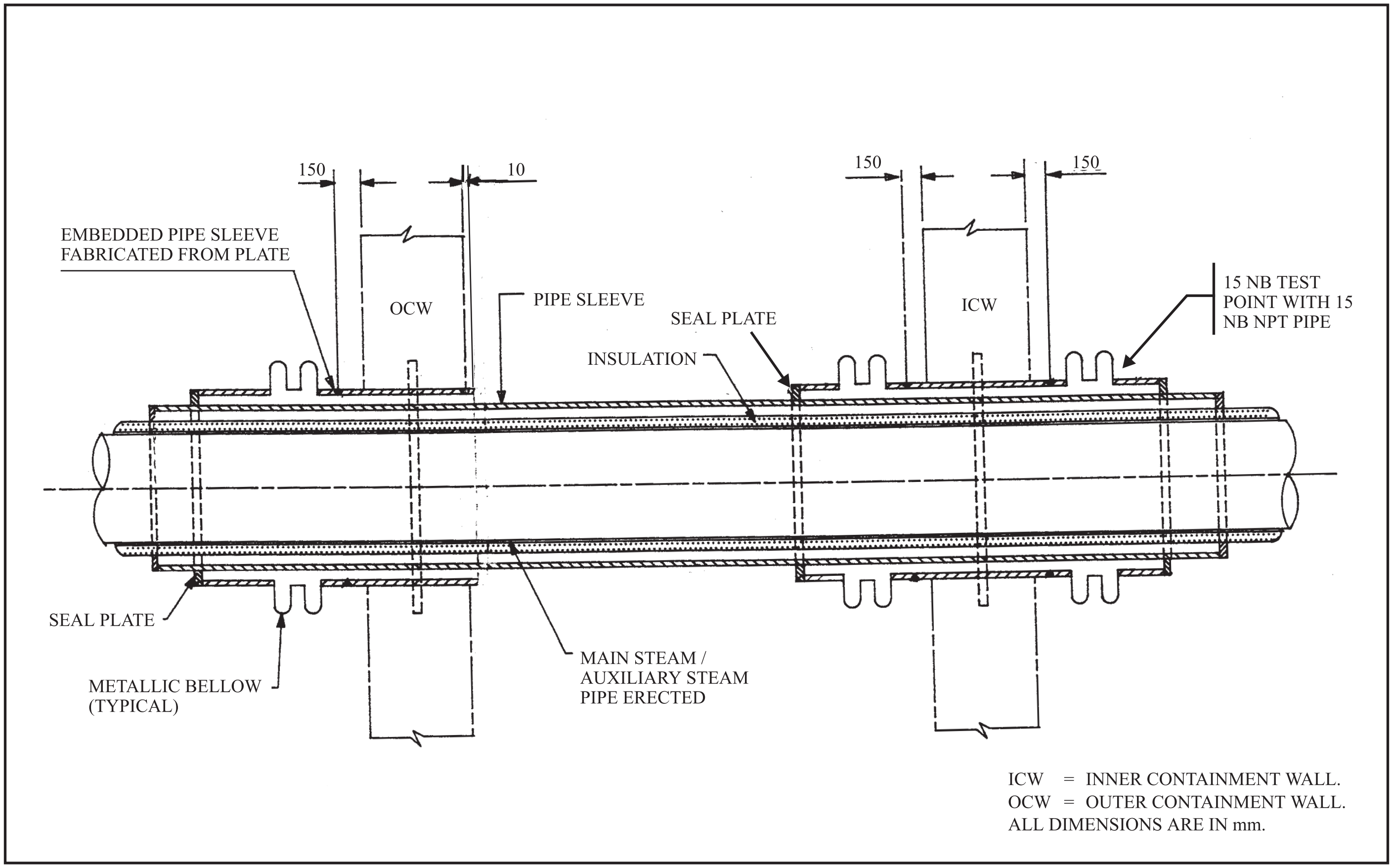


FIG. 2.1-8 : TYPICAL DETAIL OF PENETRATION FOR MAIN STEAM LINE

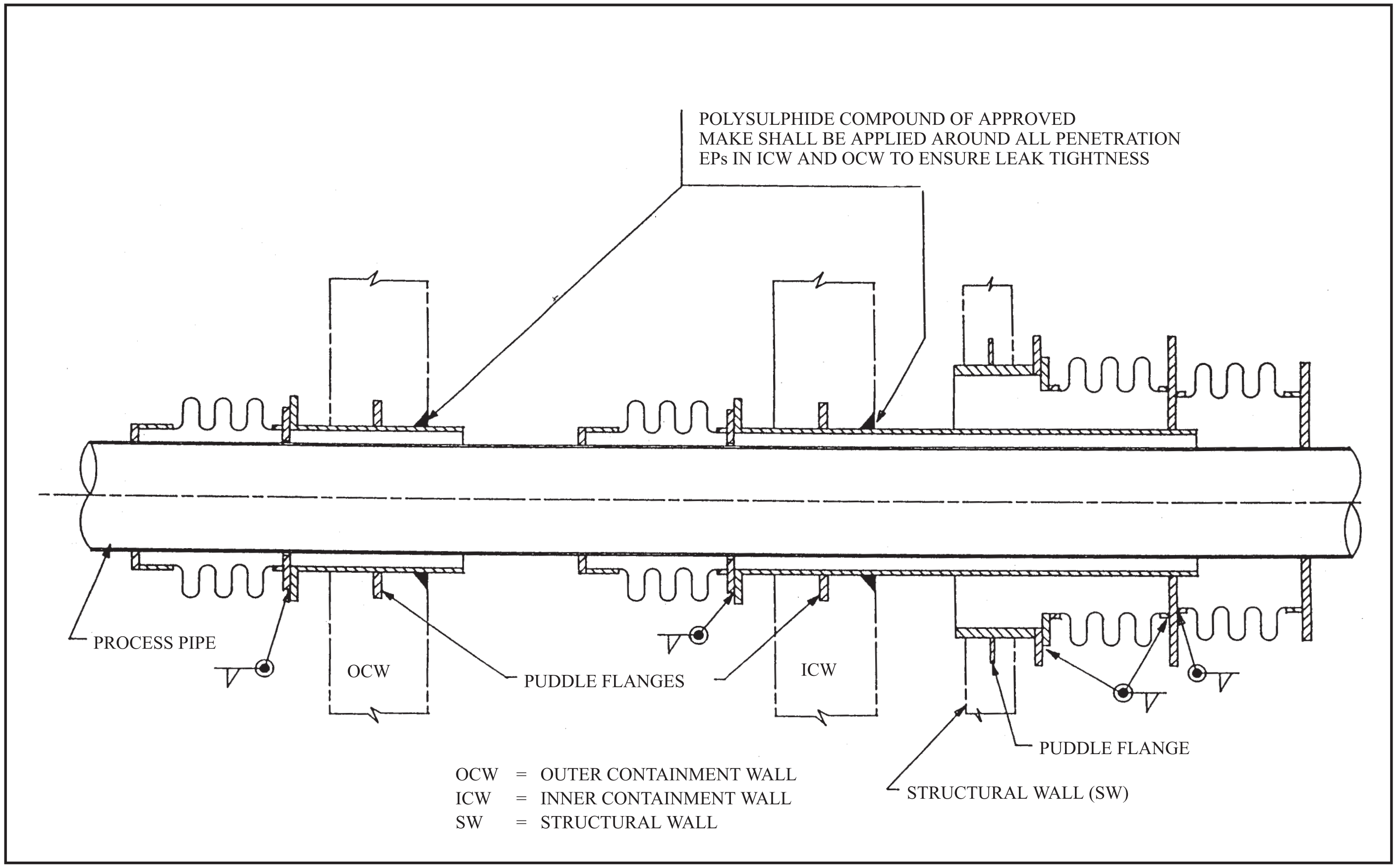
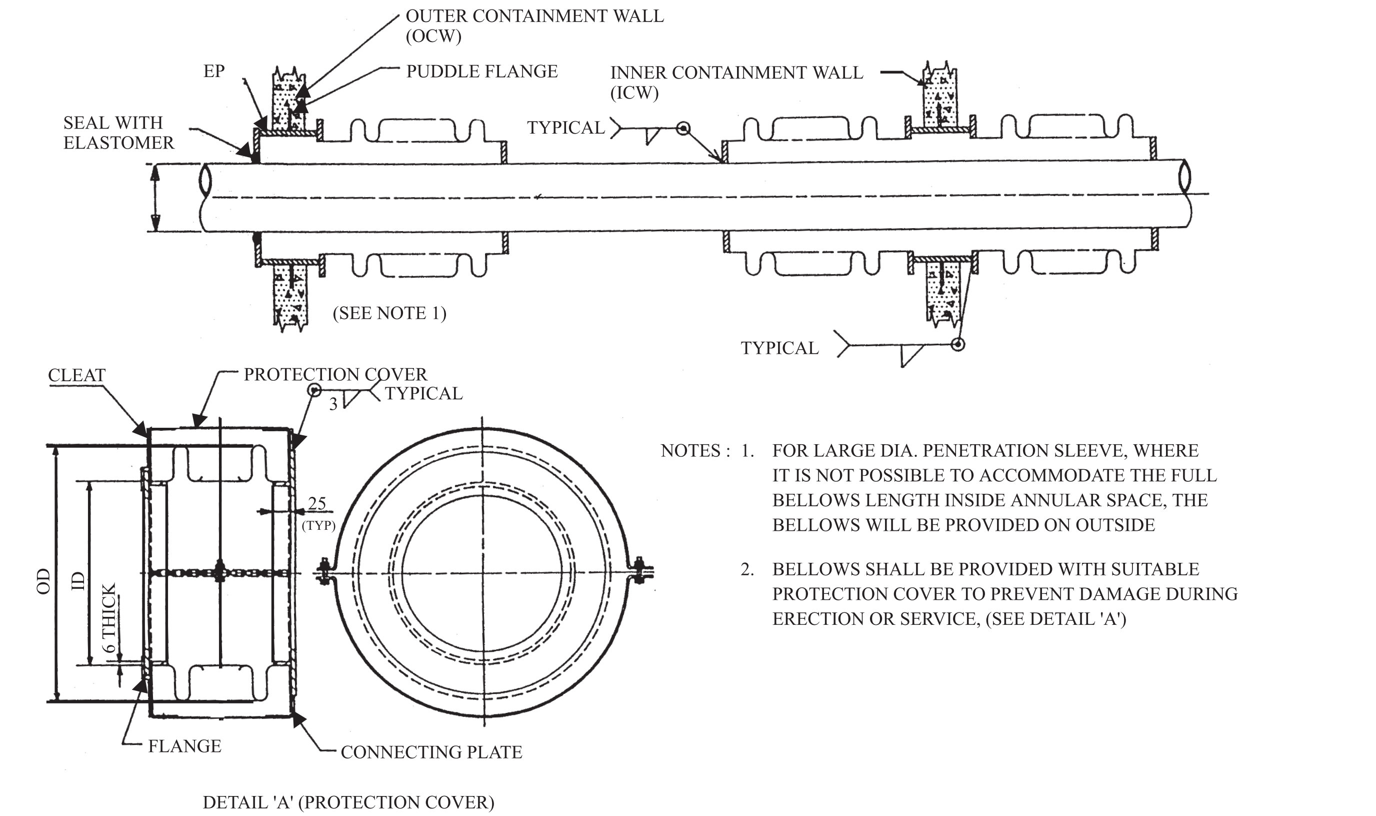


FIG. 2.1-9 : TYPICAL LOCATIONAL DETAIL OF PENETRATION BELLOWS IN OCW, ICW AND SW



NOTES :

1. FOR LARGE DIA. PENETRATION SLEEVE, WHERE IT IS NOT POSSIBLE TO ACCOMMODATE THE FULL BELLOWS LENGTH INSIDE ANNULAR SPACE, THE BELLOWS WILL BE PROVIDED ON OUTSIDE

2. BELLOWS SHALL BE PROVIDED WITH SUITABLE PROTECTION COVER TO PREVENT DAMAGE DURING ERECTION OR SERVICE, (SEE DETAIL 'A')

FIG. : 2.1-10 : TYPICAL DETAILS OF PENETRATION ASSEMBLY WITH EXPANSION BELLOWS IN ICW AND OCW.

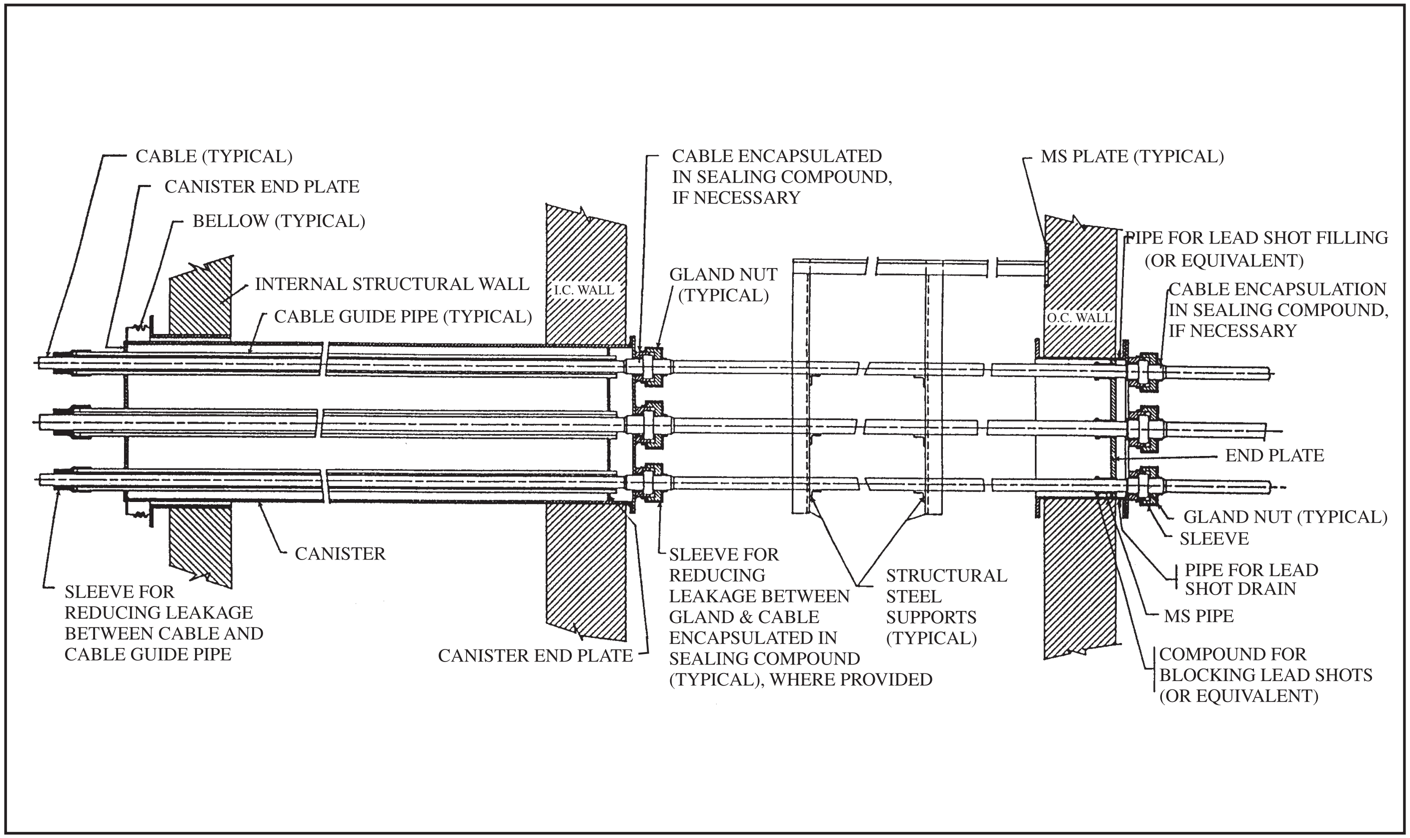
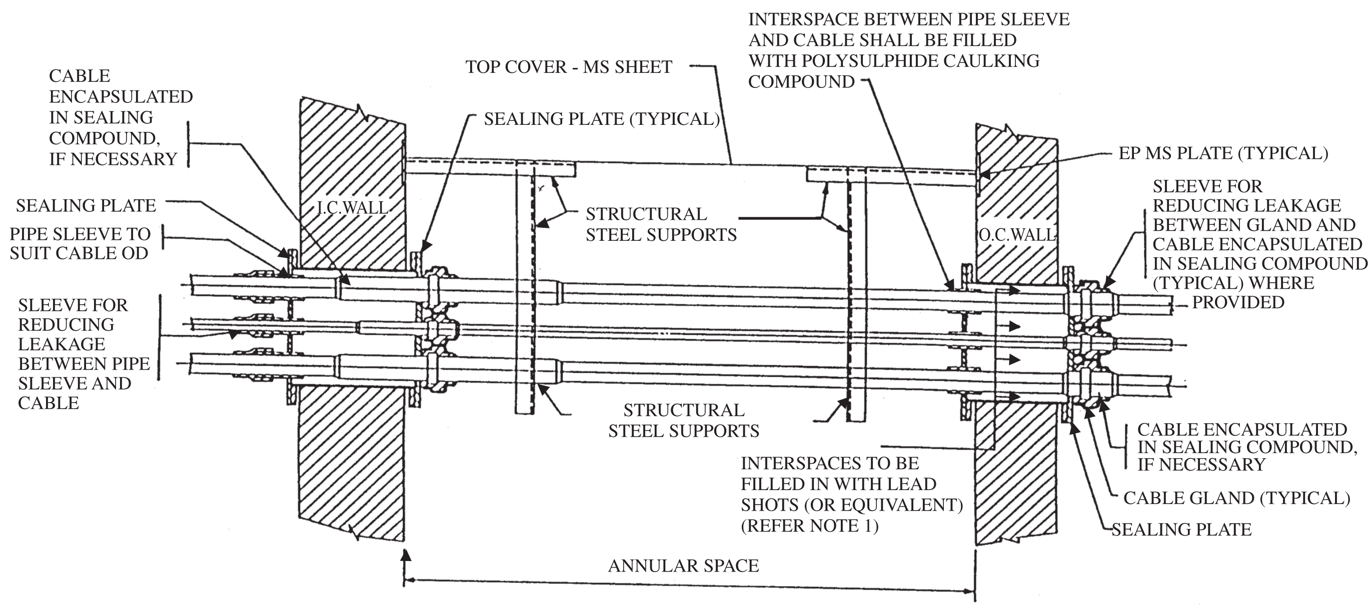


FIG. 2.1.11 : TYPICAL ARRANGEMENT FOR CABLE PENETRATION AND SEALING AT OCW, ICW AND STRUCTURAL WALL



NOTES :

1. OPENING FOR FILLING AND DRAINING OF LEAD SHOTS (OR EQUIVALENT) CAN BE PROVIDED ON THE SEALING PLATE ON THE INNER FACE OF OC WALL
2. NIPPLES FOR PRESSURE TEST OF PENETRATION ASSEMBLY IN IC WALL ARE TO BE PROVIDED

FIG. 2.1-12 : TYPICAL ARRANGEMENT OF CABLE SEALING AT OPENINGS IN REACTOR BUILDING ICW AND OC W

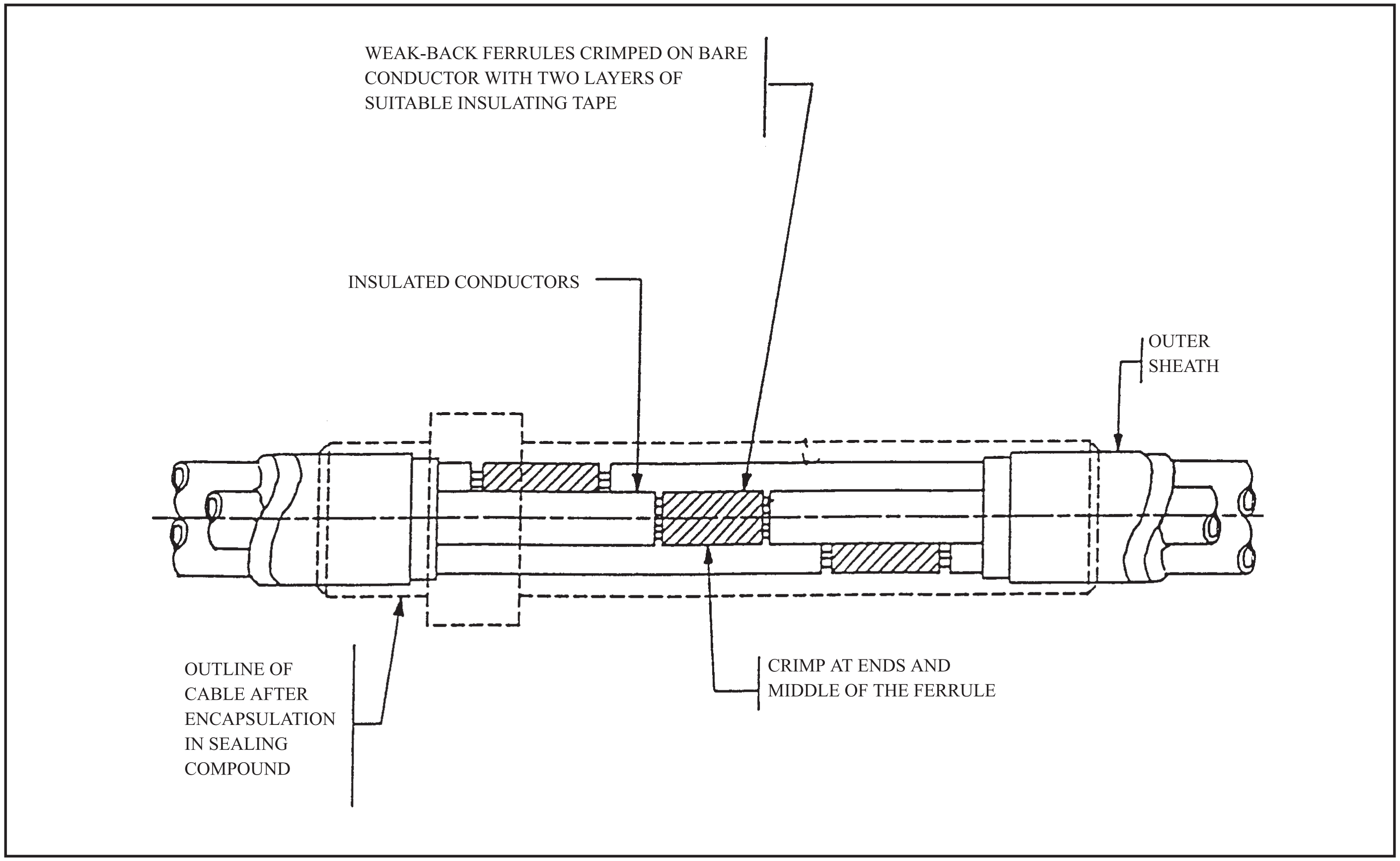


FIG. 2.1-13 : TYPICAL ARRANGEMENT OF STRAND SEALING OF POWER CABLES

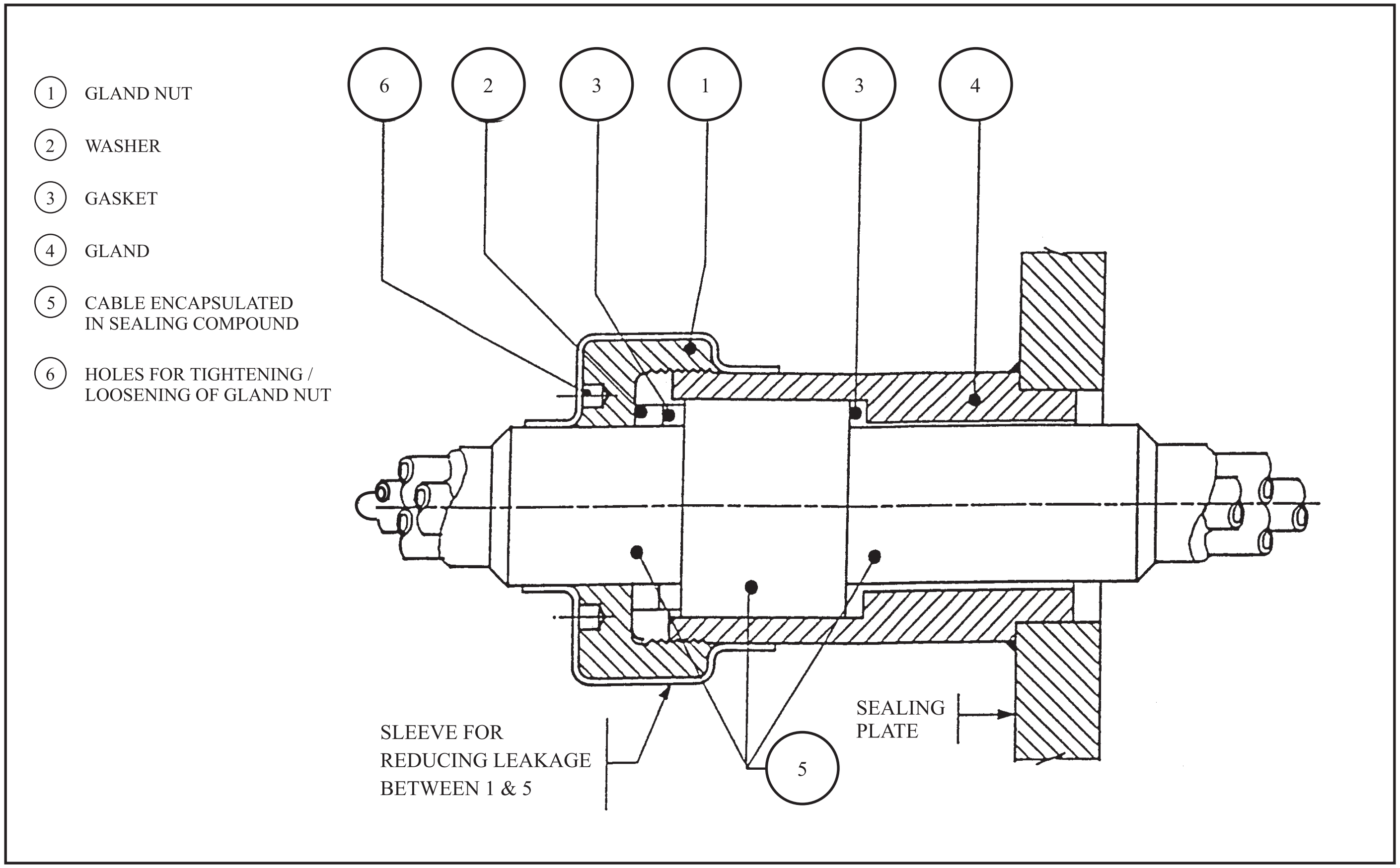


FIG. 2.1-14 : ARRANGEMENT OF CABLE SEAL ASSEMBLY

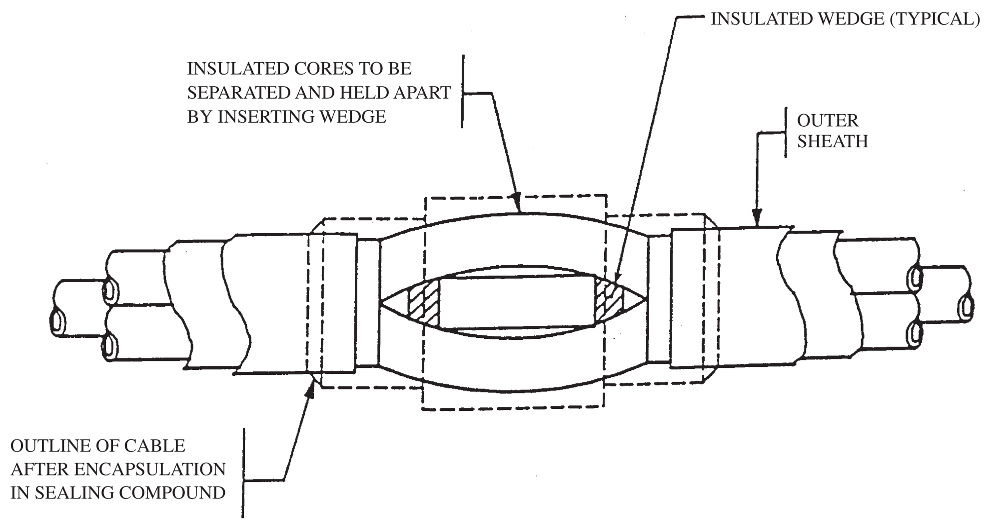


FIG. 2.1-15 : TYPICAL CONSTRUCTION OF CORE SEALING OF POWER CABLE AND BUNCH OF COAXIAL SOLID CONDUCTOR CABLES

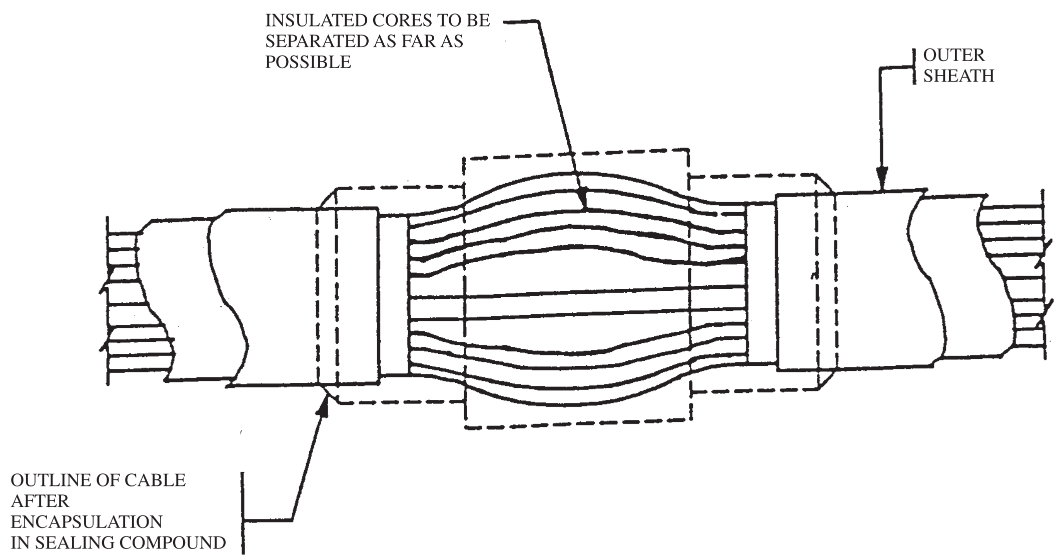


FIG. 2.1-16 : TYPICAL ARRANGEMENT OF CORE SEALING OF MULTI CORE CONTROL CABLES

3. DESIGN REQUIREMENTS

3.1 General

(a) The provisions given hereinafter provide minimum requirements for design of embedded parts, penetration and attachment.

(b) The penetrations and embedded parts shall be installed in such a manner that they do not provide any significant path for leakage or radiation streaming.

(c) On walls, floors or other structures, which are to provide radiation shielding, penetration assemblies shall be so configured and placed that shielding requirements are fully satisfied.

(d) Tests and inspections of penetrations, embedments and anchors shall be done according to the provisions of section 8 of this standard.

(e) The limitations on leakages at the location of penetrations, inserts, embedments and anchors on concrete containment wall shall conform to the provisions of the standard on Design of Nuclear Power Plant Containment Structures, No. AERB/SS/CSE-3.

3.2 Design Life Span

Embedded parts, penetration assemblies and attachments should normally be designed for a period which spans the plant life.

3.3 Methods of Design

3.3.1 High standards of engineering and design shall prevail in all aspects of components and assemblies. Limit state and allowable stress design methods are acceptable unless otherwise specified. The embedment shall be designed to withstand safely all loads likely to act on it throughout its life for the following design conditions:

(a) Normal design conditions which include the load combinations LC1 and LC2, i.e. Normal and Severe Environmental Load Combinations respectively.

(b) Abnormal design conditions which include load combinations LC3, LC4, LC5 and LC6, i.e., extreme environmental, abnormal,

piping, etc., the system piping specifications shall govern the EPs as well.
abnormal-severe environmental, and abnormal extreme environ-mental load combinations respectively.

3.3.2 The following methods of design for the penetration assemblies, attachments, inserts, embedded parts and their components are permissible.

3.3.2.1 Design by Analysis

Design by accepted method of analysis is permissible. Proven techniques of modelling wherever necessary, shall be used at all stages. All stresses/strains and deformations shall be within the allowable limits.

Anchorage system shall be designed to have a ductile failure of embedded steel prior to failure of the concrete. Full load transfer from anchor to concrete shall be accomplished by an anchor head or a reinforcing bar with appropriate development length.

3.3.2.2 Design by Test

If the design is based on test, the test shall be conducted to verify that the penetration assemblies, embedded parts, attachments and inserts have adequate strength to bear all applicable test loads. The applicable test loads shall include safety margins.

3.3.2.3 Design by Manufacturer's Catalogue

When the design is based on the manufacturer's catalogues, care shall be taken in the selection of appropriate margins while converting the static failure loads to failure loads under static and dynamic load conditions.

3.4 Load

3.4.1 (a) Embedded parts, penetrations and attachments should be designed to have design strengths (determined according to the limit state of strength) at all sections at least equal to the required strengths calculated for the factored loads and forces as stipulated in cl. 3.4.3 through cl. 3.4.8 and as combined in accordance with the provisions specified in cl. 3.5.2.3.

(b) The loading combinations for embedment design shall conform to that/those of the structure to which the embedment is attached, taking into account all the loads coming from the system attached to the embedment part, penetration and attachment.

3.4.2 The safety margin shall not be less than that adopted in design by analysis. In the design, consideration should be given to the effects created by the application of loads and their interaction with the structure. Response of the structure to vibration, impact, differential settlement, creep, shrinkage, thermal expansion, and any type of transients should also be considered.

3.4.3 Normal Loads

DL - dead load,

H - lateral earth pressure,

LL - live load,

P_v - pressure loads resulting during normal operating condition,

P_t - pressure load during structural integrity and leak rate tests, where applicable

T_t - thermal effect loads during test,

R_o - pipe and equipment reactions during normal operating or shutdown conditions,

T_o - thermal effect loads during normal operating, start-up or shutdown conditions,

F - loads resulting from the application of prestress.

3.4.4 The dynamic effects of live load should be considered in the analysis. In case where a detailed dynamic analysis is performed for the crane systems, elevators, or other moving machinery, the resulting load with dynamic amplification should be used. If such an analysis is not performed, the following increases over the static effects should be used to account for the dynamic effects.

- for supports of elevators - 100 %
- for cab operated travelling crane, support girders and their connectionss - 25 %
- for pendant operated travelling crane support girders and their connection - 10 %
- for supports of light machinery, shaft or

	motor driven equipment	- not less than 20 %
-	for supports of reciprocating machinery or power-driven unit	- not less than 50 %
-	for hanger supports	- 33 %

3.4.5 Crane Runway Horizontal Forces

In addition to the above, the horizontal forces on the crane runway should be considered in the live load *LL*. Lateral forces on the crane runways due to the effects of moving crane trolleys should, if not otherwise specified, be 20 percent of the sum of the weights of the lifted load and that of the crane trolley, but exclusive of other parts of the crane. The longitudinal forces should, if not otherwise specified, be taken as 10 percent of the maximum wheel loads of the crane applied at the top of the rail.

3.4.6 Severe Environmental Loads

E_o - load generated by operating basis earthquake,

WC - load generated by severe wind,

FF - load resulting from design basis flood.

3.4.7 Extreme Environmental Loads

E_{ss} - load generated by safe shutdown earthquake,

W_t - the wind-induced load including missile generated due to extreme wind.

3.4.8 Abnormal/Accidental Loads

F_h - hydrostatic load due to internal flooding,

MA - load and other effects of aircraft impact,

ME - load of missiles due to external events other than those related to wind or tornado, explosions in transportation systems, disintegration of turbine and other components,

MI - loading due to internal missiles,

MT - loading due to missiles, wind and over pressure generated from explosions in transportation systems, on land, water or in air,

M_t - loading effect of turbine missile,

P_a - maximum differential pressure load generated by postulated design basis accident,

R_a - pipe and equipment reactions generated due to design basis accident,

T_a - thermal loads generated due to design basis accident,

Y_j - jet impingment load,

Y_m - impact load such as pipe whipping,

Y_r - reaction due to the broken high-energy pipe.

3.5 Design of Concrete for Embedment Effects

3.5.1 Both limit state and allowable stress design methods are acceptable in the design of concrete. The provision of AERB/SS/CSE-1 shall be adopted wherever no guidelines are given hereinafter on the subject matter.

3.5.2 Limit State Method of Design

3.5.2.1 Akin to the Limit State Design of Non-Prestressed Reinforced Concrete Structures in section-3 of AERB/SS/CSE-1, the design shall satisfy the requirement of limit state by complying with the following criteria.

$$F_{sd} \leq R_{sd} \qquad (3.5\text{-}1)$$

where,

F_{sd} = Design value of structural response for a particular failure mode of a given limit state (ref. cl 3.1.3 through 3.1.10 of AERB/SS/CSE-1).

R_{sd} = Design value of resistance of the member or the structure against the failure mode of the given limit state considered in the design or the limiting value of design state which is under consideration.

3.5.2.2 Design value of structural response for the i^{th} load combination shall be calculated using the following expression.

F_{sdi}	=	$F_s(F_{di})$	(3.5-2)

where,

$F_s(F_{di})$	=	Structural response determined by structural response analysis for i^{th} load combination, F_{di}	
F_{di}	=	$\psi_i \sum \gamma_{fij} F_{ij}$	(3.5-3)
ψ_i	=	Load combination factor	
γ_{fij}	=	Partial safety factor of load (load factor) for j^{th} individual load in i^{th} load combination	
F_{ij}	=	j^{th} characteristic load for i^{th} load combination	

3.5.2.3 Load Combinations and Partial Factor of Safety for Loads (Load Factors) for Limit State of Strength

(a) Unless specified otherwise, load combinations (ref. equation 3.5-3) given in Table 3.1 shall be used.

(b) Load combination No. 18 of LC6 is applicable for reactor building only.

(c) For safety class-3 and design class DC3 structures which do not perform the safety functions associated with supporting the emergency core cooling systems and other systems related to safe shutdown of reactor or to prevent/mitigate the consequences of accident which could result in potential off-site exposure: applicable load combinations do not include LC3 and LC6.

(d) For safety class-4 structures applicable load combinations are LC1 and LC2. The value of load combination factor ψ_i for load combination numbers 7 to 9 for load combination type LC2 is 0.75.

(e) The structural response should be evaluated, both for short term and long term (considering the creep effect in case of concrete), for all applicable load combinations.

(f) The effect due to the shrinkage and heat of hydration in concrete could be considered as per *DL*. When these effects are taken in load combinations Nos. 1,3,7 the load combination factor Ψ_i may be taken as 0.75 to obtain design value.

(g) Wherever applicable, impact effect of moving load should be included in the live load.

3.5.2.4 Unless specified otherwise, design value of strength for a given limit state of strength shall be calculated from the following:

$$R_{sd} = R_s(R_d) \qquad (3.5\text{-}4)$$

where,

$R_s(R_d)$ = Computed resistance of member cross-section which is determined from R_d

and

$$R_d = \frac{1}{\gamma_m} R(f_k)$$

γ_m = Partial factor of safety for materials given in Table 3.2

$R(f_k)$ = Expression of respective material strength under consideration and is expressed in terms of f_k which are given in Table 3.3

f_k = Characteristic strength of materials

Values of γ_m which are given in Table 3.2 shall be applied to relevant material strength denoted by $R(f_k)$ given in Table 3.3.

The design pull-out strength of concrete, p_d , for any embedement shall be based on uniform tensile stress $R(f_k)$ acting on an effective stress area which is defined by the projected area of the stress cones and limited by overlapping stress cones, by the intersection of the cones with the concrete surfaces, by the bearing area of anchor heads, and by the overall thickness of the concrete (see Figs. 2.1-5 and 2.1-6).

3.5.2.5 Limit State of Serviceability

(a) Unless otherwise stated, following limit states of serviceability should be considered:

- Deflection
- Cracking

(b) Unless specified otherwise, the value of γ in equation (3.5-1) shall be taken as unity (1.0).

(c) Load combinations given in Table 3.4 shall be used unless otherwise stated.

(d) In lieu of using the load combinations given in (c) above for limit state of deflection and cracking, the structural response may be computed by the factored load analysis corresponding to the load combination given in cl. 3.5.2.3 and divided by factor $\square_a$. Unless otherwise determined by computation, the factor $\square_a$ shall be as follows:

For load combinations	1, 3, 5, 6, 7, 9	,	$\square_a$	=	1.5
For load combinations	2, 4, 8, 10	,	$\square_a$	=	1.2
For load combinations	11 to 18	,	$\square_a$	=	1.0

3.5.3 Allowable Stress Design Method

3.5.3.1 The allowable stresses $\square_a$ shall be determined from the following expression:

$$\square_a = \square_n R(f_k) \qquad (3.5\text{-}6)$$

where,

$\square_n$ = Factor representing safety and is given in Table 3.5

$R(f_k)$ = Expression of respective stresses under consideration, expressed in terms of f_k (ref. Table 3.6)

f_k = Characteristic strength of materials

3.5.3.2 When effects of temperature changes and shrinkages are considered, the value of $\square_n$ may be increased upto 1.15 times the value given in Table 3.5.

3.5.3.3 However, the value of $\square_n$ when increased in view of cl. 3.5.3.2 shall not exceed 0.67 for concrete and 1.0 for steel.

TABLE 3.1 : LOAD COMBINATIONS FOR LIMIT STATE OF STRENGTH

Design condition and load combination type		**Load combi-na-tion No.**	**Load combi-nation fact-or Ψ_i**	**Load Factors γ_{fij}**																
				DL	$H^{(1)}$	$H^{(2)}$	R_a	T_o	P_t	P_v	E_o or *WC/FF*	E_{ss} or W_t	P_a	R_a	T_a	Y_j	Y_m	Y_r	*MA/ME MI/MT or* M_t	F_h
Normal Design Condition																				
LC1:	Normal	1	1.0	1.4	1.6	1.6	1.6	-	-	-	-	-	-	-	-	-	-	-	-	-
	Load	2	0.75	1.4	1.6	1.6	1.6	1.4	-	-	-	-	-	-	-	-	-	-	-	-
	Comb.	3	1.0	1.4	1.6	1.6	1.6	-	-	1.6	-	-	-	-	-	-	-	-	-	-
		4	0.75	1.4	1.6	1.6	1.6	1.4	-	1.6	-	-	-	-	-	-	-	-	-	-
		5	1.0	1.4	1.6	1.6	-	-	1.6	-	-	-	-	-	-	-	-	-	-	-
LC2:	Severe	6	1.0	0.9	-	-	-	-	-	-	1.6	-	-	-	-	-	-	-	-	-
	Env. Load	7	1.0	1.4	1.6	1.6	1.6	-	-	-	1.6	-	-	-	-	-	-	-	-	-
	Comb.	8	0.75	1.4	1.6	1.6	1.6	1.4	-	-	1.6	-	-	-	-	-	-	-	-	-
		9	1.0	1.4	1.6	1.6	1.6	-	-	1.6	1.6	-	-	-	-	-	-	-	-	-
		10	0.75	1.4	1.6	1.6	1.6	1.4	-	1.6	1.6	-	-	-	-	-	-	-	-	-
Abnormal Design Condition																				
LC3:	Extreme	11	1.0	0.9	-	-	-	-	-	-	-	1.0	-	-	-	-	-	-	-	-
	Env. Load	12	1.0	1.0	1.0	1.0	1.0	-	-	-	-	1.0	-	-	-	-	-	-	-	-
	Comb.	13	1.0	1.0	1.0	1.0	1.0	1.0	-	-	-	1.0	-	-	-	-	-	-	-	-

TABLE 3.1 : LOAD COMBINATIONS FOR LIMIT STATE OF STRENGTH (contd.)

Design condition and load combination type		**Load combination No.**	**Load combination factor Ψ_i**	**Load Factors γ_{fij}**																		
				DL	$H^{(1)}$	$H^{(2)}$	R_a	T_o	P_t	P_v	E_o or WC/FF	E_{ss} or W_t	P_a	R_a	T_a	Y_j	Y_m	Y_r	MA/ME MI/MT or M_t	F_h
LC4:	Abnormal load comb.	14	1.0	1.0	1.0	-	-	-	-	-	-	-	1.25	1.0	1.0	-	-	-	-	1.0
		15	1.0	1.0	1.0	1.0	1.0	1.0	-	1.0	-	-	-	-	-	-	-	-	1.0	-
LC5:	Abnormal Severe Env. Load Comb.	16	1.0	1.0	1.0	-	-	-	-	-	1.15	-	1.15	1.0	1.0	1.0	1.0	1.0	-	-
		17	1.0	1.0	1.0	1.0	1.0	1.0	-	1.0	1.0	-	1.0	-	-	-	-	-	1.0	-
LC6:	Abnormal Extreme Env. Load Comb.	18	1.0	1.0	1.0	1.0	-	-	-	-	-	1.0	1.0	1.0	1.0	1.0	1.0	1.0	-	-

Note: (1) All load combinations shall be checked for full and zero live load condition.
(2) Effect of lateral earth pressure shall be considered in design when it is critical.

TABLE 3.2 : PARTIAL FACTOR OF SAFETY FOR MATERIALS FOR LIMIT STATE OF STRENGTH

Design Condition	γ_m	
	Concrete (γ_c)	**Steel** (γ_s)
Normal	1.5	1.15
Abnormal	1.3	1.0

TABLE 3.3 : EXPRESSIONS OF R(f_k) FOR LIMIT STATE OF STRENGTH

Material	**Limit States**	***R*(f_k) (*MPa*)**
Concrete	Direct compression	0.6 f_{ck}
	Flexure compression	0.67 f_{ck}
	Direct Tension	$0.35(f_{ck})^{1/2}$
	Flexure Tension	$0.55(f_{ck})^{1/2}$
	Pullout Tension	$0.35(f_{ck})^{1/2}$ (ref. notes (1), (2)) $0.3(f_{ck})^{1/2}$ (ref. note (3))
	Shear	Ref. Cl. 3.6.2 of AERB/SS/CSE-1
	Bond[4] : Deformed bars in tension	$0.45(f_{ck})^{1/2}$
	Bond[4] : Plain bars in tension	$0.28(f_{ck})^{1/2}$
Reinforcing steel	All limit states	f_y

Notes:

(1) Embedment anchored beyond the far face reinforcement of member.

(2) Embedments anchored in a compression zone of a member, or embedments anchored in a tension zone of a member where the concrete tension stress (based on an uncracked section) at the concrete surface is less than $0.30(f_{ck})^{1/2}$.

(3) Cases not covered by (1) and (2) above.

(4) For bars in compression, these values should be increased by 25%.

(5) f_{ck} is in MPa.

TABLE 3.4 : LOAD COMBINATIONS FOR LIMIT STATE OF SERVICEABILITY

Design condition and load combination type		Load combination No.	Load Factors γ_{fij}																
			DL	$H^{(1)}$	$H^{(2)}$	R_a	T_o	P_t	P_v	E_o or *WC/FF*	E_{ss} or W_t	P_a	R_a	T_a	Y_j	Y_m	Y_r	*MA/ME MI/MT* or M_t	F_h
LC1:	Normal Load Comb.	1	1.0	1.0	1.0	1.0	1.0	-	1.0	-	-	-	-	-	-	-	-	-	-
		2	1.0	1.0	1.0	-	-	1.0	-	-	-	-	-	-	-	-	-	-	-
LC2:	Severe Env. Load Comb.	3	1.0	1.0	1.0	1.0	1.0	-	1.0	1.0	-	-	-	-	-	-	-	-	-
LC3:	Extreme Env. Load Comb.	4	1.0	1.0	1.0	1.0	1.0	-	-	-	1.0	-	-	-	-	-	-	-	-

TABLE 3.4 : LOAD COMBINATIONS FOR LIMIT STATE OF SERVICEABILITY (contd.)

Design condition and load combination type		Load combination No.	Load Factors γ_{fij}																
			DL	$H^{(1)}$	$H^{(2)}$	R_a	T_o	P_t	P_v	E_o or *WC/FF*	E_{ss} or W_t	P_a	R_a	T_a	Y_j	Y_m	Y_r	*MA/ME MI/MT* or M_t	F_h
LC4:	Abnormal Load Comb.	5	1.0	1.0	1.0	-	-	-	-	-	-	1.0	1.0	1.0	-	-	-	-	1.0
		6	1.0	1.0	1.0	1.0	1.0	-	1.0	-	-	-	-	-	-	-	-	1.0	-
LC5:	Abnormal Severe Env. Load Comb.	7	1.0	1.0	1.0	-	-	-	-	1.0	-	1.0	1.0	1.0	-	-	-	-	-
LC6:	Abnormal Extreme Env. Load Comb.	8	1.0	1.0	1.0	-	-	-	-	-	1.0	1.0	1.0	1.0	1.0	1.0	1.0	-	-

Note: (1) All load combinations shall be checked for full and zero live load condition.

(2) Effect of lateral earth pressure shall be considered in design when it is critical.

TABLE 3.5 : VALUES OF $\square_n$ FOR ALLOWABLE STRESS DESIGN METHOD

Design condition	Stress parameters		$\square_n$	
			Concrete	Reinforcing steel
Normal	Compression	Direct	0.25	0.45
		Bending	0.33	0.55
	Tension	Direct	0.30	0.55
		Bending	0.50	0.55
		Pullout	0.30[1,2]	0.55
			0.25[3]	0.55
	Shear		0.40	0.55
	Bond[4]	Plain bars	0.25	—
		Deformed bars	0.35	—
	Bearing		0.30	—
Abnormal	Compression	Direct	0.50	0.75
		Bending	0.60	0.87
	Tension	Direct	0.50	0.87
		Bending	0.67	0.87
		Pullout	0.50[1,2]	0.87
			0.40[3]	0.87
	Shear		0.50	0.87
	Bond[4]	Plain bars	0.50	—
		Deformed bars	0.67	—
	Bearing		0.67	—

Notes: For (1), (2), (3) refer Table 3.3

(4) For bars in compression, increase $\square_n$ by 25%.

TABLE 3.6 : $R(f_k)$ FOR DIFFERENT STRESS PARAMETERS IN ALLOWABLE STRESS DESIGN METHOD

Material	**Stress parameters**	***R*(f_k) (MPa)**
Concrete	Compression	f_{ck}
	Tension	$0.7(f_{ck})^{1/2}$
	Shear[1]	$0.18\beta(f_{ck})^{1/2}$
	Bond	$0.7\,(f_{ck})^{1/2}$
	Bearing Whole area Local area[2]	 f_{ck} βf_{ck}
Reinforcing steel	For all stress parameters	f_y

Notes:

(1) β = 1, when there is no axial force

β = 1-(P/P_r), when member is subjected to axial tensile force of P;

where $P_r = 0.2\,(f_{ck})^{1/2}\,b_w d$

β = $1+(5P/A_g\,f_{ck}) \leq 1.5$, when member is subjected to axial compressive force of P

(2) $$\beta = \left[\frac{A_1}{A_2}\right]^{\frac{1}{2}} \leq 2.0$$

A_1 = supporting area for bearing which in sloped or stepped footing may be taken as the area of the lower base of the largest frustum of a pyramid or cone contained wholly within the footing, and having for its upper base, the area actually loaded and having side slope of one vertical to two horizontal

A_2 = loaded area at the column base

(3) f_{ck} is in MPa.

3.6 Design of Steel Attachment/Embedment

3.6.1 Both allowable and plastic design methods are acceptable for attachments. The design of embedments and penetrations shall be based on allowable stress design method. The provisions, including those for design allowables of AERB/SS/CSE-2, shall be adopted wherever no guidelines are given hereinafter on the subject matter.

3.6.2 Allowable Stress Design Method

3.6.2.1 Embedded parts, penetrations and attachments shall be designed to have design strength at all locations at least equal to the required strength calculated for the applicable loads and forces.

3.6.2.2 Load combination for design shall satisfy the following expression:

$$F_{di} = \gamma_{fij} F_{ij} \qquad (3.6\text{-}1)$$

where,

F_{di} = i^{th} load combination

γ_{fij} = Load factor for j^{th} characteristic value of individual load in i^{th} load combination

F_{ij} = j^{th} characteristic load for i^{th} load combination

3.6.2.3 Load Combinations

(a) Unless specified otherwise, load combinations given in Table 3.7 shall be used.

(b) Load combination number 12 of LC6 is applicable for reactor building.

(c) For safety class 3 embedments or attachments, which do not perform the safety functions associated with supporting the emergency core cooling systems and other systems related to safe shutdown of reactor or to prevent/mitigate the consequences of accident which could result in potential off-site exposure, comparable to relevant AERB guidelines, the applicable load combinations are LC1, LC2 and LC5.

(d) Effects of shrinkage and creep of surrounding concrete on embedments shall be considered with dead load.

3.6.2.4 The design strength of steel should be in accordance with the requirements given in AERB/SS/CSE-2.

3.6.3 Plastic Design Method

3.6.3.1 Attachment subjected to heavy impact and fatigue over 20,000 cycles shall not be designed on the basis of plastic design method. Load combinations for plastic design shall satisfy the equation (3.6-1).

3.6.3.2 Unless specified otherwise, load combinations given in Table 3.8 shall be used.

(a) Load combination number 14 of LC6 is applicable for reactor building.

(b) For safety class 3 attachments, which do not perform the safety functions as specified in cl. 3.6.2.3 (c), the applicable load combinations are LC1, LC2 and LC5.

(c) In the above load combination, wherever applicable, impact effect of moving load is included in live load.

3.6.3.3 The design shall be made in accordance with AERB/SS/CSE-2 for plastic design method.

3.7 Miscellaneous Design Aspects

3.7.1 Shear-Friction

The shear-friction provisions shall be as given in AERB Safety Standard, Design of Concrete Structures Important to Safety of Nuclear Facilities, AERB/SS/CSE-1. The design yield strength f_y shall not exceed 425 N/sq.mm. The coefficient of friction μ shall be as follows:

(a) 0.9 for concrete or grout against as-rolled steel, with the contact plane a full plate thickness below the concrete surface.

(b) 0.7 for concrete or grout against as-rolled steel, with contact plane coincidental with the concrete surface.

TABLE 3.7 : LOAD COMBINATIONS FOR DESIGN OF STEEL STRUCTURES

Design condition and load combination type	Load combination No.	Load Factors γ_{fij}																
		DL	$H^{(1)}$	$H^{(2)}$	R_a	T_o	P_t	P_v	E_o or WC/FF	E_{ss} or W_t	P_a	R_a	T_a	Y_j	Y_m	Y_r	MA/ME MI/MT or M_t	F_h
Normal Design Condition																		
LC1: Normal	1	1.0	1.0	1.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Load	2	1.0	1.0	1.0	1.0	-	-	-	-	-	-	-	-	-	-	-	-	-
Comb.	3	1.0	1.0	1.0	1.0	1.0	-	-	-	-	-	-	-	-	-	-	-	-
LC2: Severe	4	1.0	1.0	1.0	-	-	-	-	1.0	-	-	-	-	-	-	-	-	-
Env. Load	5	1.0	1.0	1.0	1.0	-	-	-	1.0	-	-	-	-	-	-	-	-	-
Comb.	6	1.0	1.0	1.0	1.0	1.0	-	-	1.0	-	-	-	-	-	-	-	-	-
Abnormal Design Condition																		
LC3: Extreme	7	1.0	1.0	1.0	-	-	-	-	-	1.0	-	-	-	-	-	-	-	-
Env. Load	8	1.0	1.0	1.0	1.0	-	-	-	-	1.0	-	-	-	-	-	-	-	-
Comb.	9	1.0	1.0	1.0	1.0	1.0	-	-	-	1.0	-	-	-	-	-	-	-	-

TABLE 3.7 : LOAD COMBINATIONS FOR DESIGN OF STEEL STRUCTURES (contd.)

Design condition and load combination type		Load combination No.	Load Factors γ_{fij}																
			DL	$H^{(1)}$	$H^{(2)}$	R_a	T_o	P_t	P_v	E_o or WC/FF	E_{ss} or W_t	P_a	R_a	T_a	Y_j	Y_m	Y_r	MA/ME MI/MT or M_t	F_h
LC4:	Abnormal load comb.	10	1.0	1.0	1.0	-	-	-	-	-	-	-	1.0	1.0	1.0	-	-	-	-
LC5:	Abnormal Severe Env. Load Comb.	11	1.0	1.0	1.0	-	-	-	-	1.0	-	1.0	1.0	1.0	1.0	1.0	1.0	-	-
LC6:	Abnormal Extreme Env. Load Comb.	12	1.0	1.0	1.0	-	-	-	-	-	1.0	1.0	1.0	1.0	1.0	1.0	1.0	-	-

Note: (1) All load combinations shall be checked for full and zero live load condition.

(2) Effect of lateral earth pressure shall be considered in design when it is critical.

TABLE 3.8 : LOAD COMBINATIONS FOR PLASTIC DESIGN

Design condition and load combination type		Load combination No.	Load Factors γ_{fij}																
			DL	$H^{(1)}$	$H^{(2)}$	R_a	T_o	P_t	P_v	E_o or WC/FF	E_{ss} or W_t	P_a	R_a	T_a	Y_j	Y_m	Y_r	MA/ME MI/MT or M_t	F_h
Normal Design Condition																			
LC1:	Normal	1	1.7	1.7	1.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Load	2	1.7	1.7	1.7	1.7	-	-	-	-	-	-	-	-	-	-	-	-	-
	Comb.	3	1.3	1.3	1.3	1.3	-	-	-	-	-	-	-	-	-	-	-	-	-
LC2:	Severe	4	0.9	-	-	-	-	-	-	1.7	-	-	-	-	-	-	-	-	-
	Env. Load	5	1.7	1.7	1.7	-	-	-	-	1.7	-	-	-	-	-	-	-	-	-
	Comb.	6	1.7	1.7	1.7	1.7	-	-	-	1.7	-	-	-	-	-	-	-	-	-
		7	1.3	1.3	1.3	1.3	1.3	-	-	1.3	-	-	-	-	-	-	-	-	-
Abnormal Design Condition																			
LC3:	Extreme	8	0.9	-	-	-	-	-	-	-	1.0	-	-	-	-	-	-	-	-
	Env. Load	9	1.0	1.0	1.0	-	-	-	-	-	1.0	-	-	-	-	-	-	-	-
	Comb.	10	1.0	1.0	1.0	1.0	-	-	-	-	1.0	-	-	-	-	-	-	-	-
		11	1.0	1.0	1.0	1.0	1.0	-	-	-	1.0	1.0	1.0	-	-	-	-	-	-

TABLE 3.8 : LOAD COMBINATIONS FOR PLASTIC DESIGN (contd.)

Design condition and load combination type		Load combination No.	Load Factors γ_{fij}																
			DL	$H^{(1)}$	$H^{(2)}$	R_a	T_o	P_t	P_v	E_o or WC/FF	E_{ss} or W_t	P_a	R_a	T_a	Y_j	Y_m	Y_r	MA/ME MI/MT or M_t	F_h
LC4:	Abnormal Load Comb.	12	1.0	1.0	-	-	-	-	-	-	-	1.25	1.0	1.0	-	-	-	-	-
LC5:	Abnormal Severe Env. Load Comb.	13	1.0	1.0	-	-	-	-	-	1.15	-	1.15	1.0	1.0	1.0	1.0	1.0	-	-
LC6:	Abnormal Extreme Env. Load Comb.	14	1.0	1.0	1.0	-	-	-	-	-	1.0	1.0	1.0	1.0	1.0	1.0	1.0	-	-

Note: (1) All load combinations shall be checked for full and zero live load condition.

(2) Effect of lateral earth pressure shall be considered in design when it is critical.

(c) 0.55 for grouted conditions, with the contact plane between grout and as-rolled steel exterior to the concrete surface.

A combination of bearing and shear friction mechanisms shall not be used to develop the required strength.

3.7.2 Side Covers

The side cover distance for bolts, studs and bars shall not be less than the following:

$m = D\ \{ f_{ut}/4.2 f_{ck}^{1/2} \}^{1/2}$ (for tension)

$m = D\ \{ f_{ut}/0.55 f_{ck}^{1/2} \}^{1/2}$ (for shear)

The side cover distance shall not be less than one third of the above values where reinforcement is provided to prevent failure of the concrete in tension.

3.7.3 Effective Area of Threaded Anchor

3.7.3.1 The tensile stress area of a threaded anchor in sq. cm. shall be taken as:

$0.25\ \pi\ [D - 0.975/n]^2$

where D is the major thread diameter in cm. and n is the number of threads per cm.

3.7.3.2 The tensile stress area shall be applied to all threaded anchors, subject to direct tensile and shear stress.

3.7.4 Bearing Strength

3.7.4.1 The bearing requirements shall be met at a shear lug or anchor head, except at post- tensioning anchorage for pre-stressed concrete and except as permitted in cl.3.7.5.

3.7.4.2 Design bearing resistance on concrete shall not exceed $\phi\ (0.68\ f_{ck}\ A_1)$, where A_1 = loaded area, and the capacity reduction factor ϕ = 0.70, except as follows:

(a) where the supporting surface on all sides is wider than the loaded area, design bearing strength on the loaded area may be multiplied by $(A_2/A_1)^{1/2}$, but not more than 2, where A_2 = maximum area of the portion of the supporting surface that is geometrically similar to and concentric with the loaded area.

(b) where the supporting surface is sloped or stepped, A_2 may be taken as the area of the lower base of the largest frustum of a right pyramid or cone contained wholly within the support and having for its upper base the loaded area, and having side slopes of one vertical to two horizontal.

3.7.5 Anchor Head

The bearing requirements do not have to be met if the anchor head at the base of the tensile stress component satisfies the following conditions:

(a) the bearing area of the anchor head (excluding the area of the tensile stress component) is at least 1.5 times the area of the tensile stress component.

(b) the thickness of the anchor head is at least 1.0 times the greatest dimension from the outermost bearing edge of the anchor head to the face of the tensile stress component.

(c) the bearing area of the anchor head is approximately evenly distributed around the perimeter of the tensile stress component.

3.8 Corrosion Protection

3.8.1 Minimum Thickness of Metal

Except where other requirements call for thicker elements of components, the minimum thickness of metal for any component shall be as follows:

(a) steelwork directly exposed to weather - where the steel is directly exposed to weather and is fully accessible for cleaning and repainting, the thickness shall not be less than 6 mm and where the steel is directly exposed to weather and is not accessible for cleaning and repainting, the thickness shall not be less than 8 mm.

(b) steelwork not directly exposed to weather - the thickness of steel in main members not directly exposed to weather shall not be less than 6 mm.

3.8.2 Special Provisions

(a) Sealed sections shall have special protections against corrosion, such as use of special paints or metal plating.

(b) For protection against chemical attack, added material thickness and other protections, as may be necessary, shall be provided.

4. SPECIAL REQUIREMENTS OF EMBEDDED PARTS

4.1 General

The provisions given herein and in sections 2 and 3 of this standard provide minimum requirements for design and anchorage of steel embedments used to transmit loads from attachments into reinforced and pre-stressed concrete structures by means of tension, bearing, shear, friction, or any combination permitted therein.

4.1.1 The thickness of steel embedment plate and the number of anchors shall be suitably designed to prevent separation of plate from concrete surface as a result of welding connections on to it for supports. Unless justified otherwise, the thickness of plate EPs should not be less than 10 mm.

4.1.2 The embedded parts on a containment structure shall satisfy the additional design requirement that the leakage at interface of concrete and steel is limited to a level as low as practical.

4.2 Expansion Anchors

4.2.1 The expansion anchors shall be selected so that they conform to the best engineering judgement. For a component or equipment having a single isolated support, there shall be a minimum of three expansion anchors. Under special circumstances, the number may be reduced to two if approved by the designer. Typical details of expansion anchors are shown in Figs. 2.1-3 and 2.1-4.

4.2.2 Depending upon the type of arrangement and loading, the expansion anchors can be subjected to tension or combined tension and shear. The expansion anchor shall be designed according to the loads transmitted to it. The requirements of material shall be in accordance with cl. 2.6. The factor of safety over the forces under design load combinations shall not be less than the value recommended by the manufacturer.

4.2.3 Design Method

The design shall be as per the manufacturer's catalogue or on the basis of tests.

4.2.4 Testing

Pullout, shear and combined pullout and shear tests shall be performed in accordance with cl. 8.3.

5. SPECIAL REQUIREMENTS OF PENETRATION ASSEMBLIES

5.1 Electrical Penetration Assembly (EPA)

5.1.1 Cables entering the reactor building shall be appropriately sealed at the entry and exit points at both the outer containment wall, and inner containment wall, to maintain containment integrity.

5.1.2 Each electrical penetration assembly at IC wall shall have a provision for periodic testing at site in order to verify that the leak rate through the assembly is within permissible limits, at the specified design pressure and at ambient temperature.

5.1.3 Consideration should be given to accessibility of the electrical penetration assembly for

- testing of the assembly after installation at site, and during service life;
- periodic maintenance or replacement of cable seal.

In certain cases where a structural wall concentric to a containment wall has been provided, special arrangements may be required, as shown in Fig.2.1-11.

5.1.4 Means shall be provided to accommodate thermal expansion/contraction of the cable and the components of the assembly.

5.1.5 The materials used in the electrical penetration assembly, when subjected to a radiation dose of specified value, shall maintain the physical and electrical properties required to meet the service conditions.

5.1.6 The dielectric strength of the insulation of a cable at the penetration assembly shall not be less than the value required for the voltage rating of that particular system.

5.1.7 The cable sealing arrangement at the EPA shall not degrade the performance of a cable at the electrical penetration assembly below the acceptable limits.

Parameters like temperature rise of the cable at the electrical penetration assembly shall be within acceptable limits.

5.1.8 Each penetration assembly shall be effectively grounded.

5.1.9 The assembly shall be designed to safely withstand the effects of short circuit currents flowing in a cable on account of a through fault external to the assembly.

5.1.10 Where applicable, the design should take into account effects of electromagnetic heating of the relevant components of the electrical penetration assembly.

5.2 Mechanical Penetration Assembly

The mechanical penetration assembly can generally have the following components.

5.2.1 Guard Pipe Penetration

Where a guard pipe is required for a penetration assembly (ref. Fig. 2.1-8), the diameter of the guard pipe should be large enough to allow insulation around the process line to fit in the annular space with adequate clearance. In case a rigid connection of the guard pipe to the flued embedment could lead to overstressing of the attachment as a result of high loading caused during an accident, the guard pipe should be equipped with bellows to accommodate differential movements.

5.2.2 The design pressure of the guard pipe shall be assumed to be equal to the design pressure of the contained process pipe for the purpose of calculating the wall thickness of the guard pipe. The maximum operating pressure of the process pipe shall be considered in the calculation of reaction load on the concrete structure from the guard pipe.

5.2.3 Bellows Expansion Joints

Where a single bellow is used in a mechanical penetration assembly on the primary containment, a steel liner should be provided to protect the element of the bellow against direct impingement of any jet in the event of a rupture of the process pipe.

5.2.3.1 The bellows expansion joint, though providing for flexibility, must provide a leak-tight seal between the containment structure and the penetration assembly.

5.2.3.2 The bellows shall be designed to withstand a specified number of cycles of expansion and compression due to thermal, seismic and other loads.

5.2.4 Insulation and Jacketing

5.2.4.1 Insulation should be provided to limit the rise of temperature in the structure around the penetration assembly. Regardless of the amount of temperature reinforcement, the concrete temperature shall not exceed the values given below over a long term period (during normal operation or post-accident conditions over prolonged periods):

(a) Large areas : 65°C.

(b) Local areas : 95°C.

5.2.4.2 For penetrations, which require in-service inspection of welds, the insulation and protective covering shall be designed so as to permit easy removal and reinstallation.

5.2.5 Ring Sealing Device

For the purpose of air testing of penetration assemblies, independent of the pressure test of the containment, the penetration assemblies may be provided with removable sealing devices of the split-ring type.

5.3 Fire Resistant Design

5.3.1 Penetration EPs should be protected, where required, against fire hazard, either by a fire resistant design or by passive provisions such as fire resistant coatings, intumescent paints, barriers, etc.

5.3.2 The design criteria for fire resistance should be such that the components sustain their integrity against a fire of specified intensity and period.

5.3.3 Where the fire resistant design approach is adopted, the design basis fire shall correspond to that which may develop from the fire load in a given fire zone.

5.3.4 Where fire rating approach is adopted, the rating of different structural components to be considered in the design shall comply with the requirements of safety standard, 'Civil Engineering Structures Important to Safety of Nuclear Facilities', No.AERB/SS/CSE.

5.3.5 Subsequent to a major fire, the EPs or penetrations in the affected areas should be surveyed to assess possible deterioration/serviceability.

5.3.6 A classification of EPs in the reactor buildings of Indian PHWRs for fire resistance consideration is given in Annexure-I (ref.: NPCIL (1994), Report of the Committee on Fire Resistance Requirements for EPs in Reactor Building and Containments of Indian PHWRs, June 1994).

6. FABRICATION AND INSTALLATION REQUIREMENTS OF EMBEDDED PARTS, PENETRATION ASSEMBLIES AND THEIR COMPONENTS

6.1 General

Penetration assemblies shall be fabricated and installed in accordance with the requirements of this section. The requirements shall depend on whether the fabrication is done in a shop or at the field. Unless otherwise indicated, the term component shall be understood to include parts and appurtenances of the penetration assembly.

6.1.1 If, during fabrication of the component, the material is subjected to conditions which cause a change in the principal characteristics that have not been accounted for in the design and that may change any property from the specified value, the design tests shall be repeated or additional tests made for the purpose of acceptance.

6.1.2 As far as possible, piping and cable penetrations through primary containment should have provisions for leak checks during in-service containment leak testing. However, it is recognised that closure panels for openings in the containment for installation of steam generators (SGs) can only be checked during testing for containment integrity and in-service leak rate.

6.2 Fabrication and Installation

6.2.1 The practices followed in fabrication and installation of containment structures, penetration assemblies and appurtenances shall be consistent with the overall objective of achieving high reliability of containment integrity. Due care shall be taken in certification of the materials, cleanliness and qualification of fabrication processes including requirements of heat treatment, etc. Adequate inspection and testing coverage shall be given to all fabricated parts to build up assurance.

Fabrication, installation and examination as per ASME Section III, Division 1, NE-4000/5000 for metal containment and ASME Section III, Division 2, CC-4500, 4600, 5500, 5600 for concrete containment are adequate to meet the objective of this clause.

6.2.2 Fabrication and erection of EPs for other structures shall comply with the requirements for AERB Standard No. AERB/SS/CSE-2.

6.2.3 The embedded parts and penetration assemblies shall be installed following a well laid out procedure which will prevent any damage to the assembly during its installation and concreting. All fabricated items shall be installed only after their inspection and acceptance. EPs shall not be supported to the structural reinforcement by welding during concreting.

6.2.4 The anchorage systems, such as grouted anchors, expansion anchors and inserts used to support:

(a) seismically qualified equipment,

(b) special components, and

(c) vibrating and rotating equipment

shall be installed by qualified personnel following well-defined construction and installation procedures, as a safeguard against any possible failure due to unplanned workmanship.

7. QUALITY ASSURANCE

7.1 General

7.1.1 A Quality Assurance Programme (QAP) pertaining to EP, penetration assemblies and attachments covering all phases of activities shall be developed and implemented so as to achieve adequate assurance of quality and safety. The Responsible Organisation (RO) shall ensure that overall QAP satisfies the requirements of Code of Practice on Quality Assurance (QA) for Safety in Nuclear Power Plants, AERB/SC/QA and section 9 of AERB Safety Standard No. AERB/SS/CSE.

7.1.2 The QAP shall contain details in respect of the following :

- Policy
- Management
- Performance function
- Quality control, which broadly includes verification and corrective functions
- Documentation

7.1.3 For items not covered by this standard, the quality assurance requirements shall be developed in accordance with the guidelines of the standard on Quality Assurance for Construction of Civil Engineering Structures Important to Safety of Nuclear Facilities, AERB/SG/CSE-3.

7.2 Verification

The methods of acceptance may include source verification, inspection on receipt, suppliers' certificate of conformance, post installation tests, or a confirmation thereof.

7.3 Non-Conformance

The owner/purchaser should develop procedures for identification, control and disposition of documents, items and services, which do not meet the specified requirements. The procedures for control of non-conformance and disposition shall contain provisions for dealing with matters like:

(a) review of non-conformance;

(b) decision regarding acceptance or corrective measures for each item;

(c) verification of disposition and implementation of corrective mesures;

(d) maintenance of records of non-conformances and modifications to base documents so as to provide as-built information.

7.4 Calculations

Calculations related to the design and analysis of EPs shall be well documented, listing all assumptions made in the design. The source of input data used in the calculations shall be adequately referenced so that all data are readily traceable. When a computer aided analysis and design is adopted, the analysis and design assumptions, input data and output results should be made part of the calculations. The calculations shall be checked independently.

7.5 Drawings

Copies of EP drawings and specifications shall be approved and signed by the authorised engineer.

7.6 Surveillance and In-service Inspection

7.6.1 Surveillance

The surveillance and test requirements, forming a part of the performance function, shall in general, meet the requirements of the following:

(a)	AERB/SG/O-2	In-service Inspection of Nuclear Power Plants
(b)	AERB/SG/O-7	Maintenance of Nuclear Power Plants
(c)	AERB/SG/O-8	Surveillance of Items Important to Safety in Nuclear Power Plants
(d)	ASME	Boiler and Pressure Vessel Code, Section XI
(e)	AERB/SG/CSE-3	Quality Assurance for Construction of Civil Engineering Structures Important to Safety of Nuclear Facilities

7.6.2 In-Service Inspection

A list of all items, which will require in-service inspection, shall be prepared along with identification of the parameters, which will require in-service inspection. The design of the penetrations and EPs shall give careful consideration to provide access to both visual and non-destructive in-service inspection of the penetration components. The requirements of and the procedures for such inspections shall be in accordance with the requirements of the ASME Boiler and Pressure Vessel Code, Section XI and AERB Safety Manual 'In-Service Inspection of Civil Engineering Structures Important to Safety of Nuclear Power Plants', AERB/SM/CSE-2.

7.7 Data and Documentation

Data for penetration assemblies shall be recorded and maintained as part of QA documentation. Any modification or revision at any stage shall be recorded by the owner. The data of penetration assemblies shall cover the following as a minimum:

(a) manufacturer's name and year of manufacture;

(b) unique identification number;

(c) qualified radiation life (qualified life under radiation in the radiation field of placement);

(d) list of replacement components along with time required for replacements;

(e) design pressure;

(f) continuous maximum temperature under normal conditions;

(g) radiation type and integrated dose, as applicable to the location;

(h) for electrical penetration assembly:

- (i) rated voltage,
- (ii) rated continuous current,
- (iii) rated short-time overload current and duration,
- (iv) rated short-circuit current where applicable,
- (v) continuous temperature design limits for electrical insulation.

8. TESTING

8.1 General

8.1.1 When it is not possible to qualify by analysis, EPs shall be tested under design load combinations to demonstrate that these will develop the design strength and the deformations will be within the specified limit.

8.1.2 Specimens used in qualification tests of EPs shall meet the following requirements:

(a) it shall be of the same generic design as that of the production units.

(b) it shall be manufactured using production facilities and processes which are representative of those used for production units.

(c) it shall have such shape and configuration that will stimulate thermal, electrical and mechanical stresses as stipulated in the design under qualification.

8.1.3 In order to verify that the penetration assembly meets the specified requirements and will operate satisfactorily, the assembled unit shall be tested for all the specified loading conditions to the extent possible. However, when it is not possible to perform full load testing and for specially designed tailor-made EPs, qualification by analysis will be acceptable.

8.1.4 The requirements of instrumentation, acceptance criteria, leakage rate calculations, etc., pertaining to proof and leakage rate testing of penetrations are covered in safety guide 'Proof and Leakage Rate Testing of Reactor Containments', AERB/SG/O-16.

8.2 Anchors

8.2.1 Anchors shall be tested to verify the ability of the anchor mechanism to develop the required tensile strength.

8.3 Installed Expansion Anchors, Grouted Anchors and Inserts

8.3.1 This clause covers the requirements for in-situ testing of grouted anchors, expansion anchors and inserts used to support:

(a) seismically qualified equipment,

(b) special component, and

(c) vibratory and rotating equipment.

8.3.2 Anchorage systems where workmanship could be a possible cause of failure, shall be tested as follows:

(a) the system shall be tested to a static tensile force equal to 75 percent of the specified yield strength of the bolt.

(b) one unit of each operator's weekly anchorage production or one of each 50 consecutively installed anchorages of each type, whichever is less, shall be selected at random for testing.

8.3.3 Anchors that fail in the test shall be removed and replaced. In addition, two adjacent anchors or two anchors chosen at random from the same group shall be tested. Should the additional anchors too fail in the test, further installation shall be stopped unless corrective action is taken and the installation procedure is requalified.

8.4 Tests on Electrical Penetration Assembly

8.4.1 Tests on Electrical Penetration Assemblies (EPA) and components can be classified as follows:

(a) typical and routine tests conducted by the manufacturer to ensure that the assembly and its components meet the design intent and the quality requirement of workmanship.

(b) field testing at site.

8.4.2 Typical tests are performed on representative samples to verify the adequacy of the design. These tests on EPA and its components can include the following tests:

(a) verification of chemical composition and key mechanical properties of the main materials used in the EPA.

(b) cumulative radiation dose-withstanding capability of the main primary insulating materials. The value for cumulative radiation dose used during type testing should include a margin. This margin should not be less than 10 percent of the accident dose used.

(c) gas leak rate test on representative assembly should be carried out using nitrogen. The pressure for leak test shall be same as containment test pressure.

(d) thermal ageing tests should be conducted on important insulating materials and gaskets in order to assess their qualified life. The test need not be carried out on items in use showing satisfactory operating experience.

(e) the electrical penetration assembly should safely withstand the effects of category I seismic conditions. The seismic withstanding capability of EPA should be established either by testing or by analysis or by combination of both. The seismic qualification procedure should take into account the presence of cables passing through the EPA.

8.4.3 Routine tests are performed on all components, sub-assemblies or assemblies as required, to verify the quality of workmanship. Routine inspection of EPA and its components shall include the following tests:

(a) verification of dimensions;

(b) visual inspection .

8.4.4 Field testing at site shall/should include the following tests:

(a) measurement of insulation resistance of each core of the cables provided with core sealing or strand sealing.

(b) leak rate test should be conducted on each assembly, with compressed air at appropriate pressure. Provision for periodic in-service leak check with compressed air should be provided on each electrical penetration assembly for ascertaining its integrity in service.

8.5 Field Testing of Mechanical Penetration Assemblies

8.5.1 The penetration assembly shall be tested in accordance with ASME Boiler and Pressure Vessel Code. For metal containment, the requirements of Division 1, Section III, sub-section NE for class MC components and for concrete containment, relevant requirements of Section III, Division 2 of the same ASME Code should be complied with.

8.5.2 Mechanical penetration assemblies having double bellows/seals shall have provisions for the pneumatic leak test. The pneumatic pressure test shall be conducted at a pressure not less than 1.1 times the design pressure of the penetration assembly. The pressure shall be maintained for a minimum of 10 minutes and the leakage should be less than the specified value.

8.6 Special Tests

8.6.1 Seismic Qualification Test

Embedded inserts and expansion anchors used to support seismically qualified equipment shall be seismically qualified. A minimum of three specimens, randomly selected, shall be tested in cyclic tensile loading and shear loading. The frequency and sequence of cyclic loading shall be given by the designer. The material for the test shall be identical to the embedment material to be used in the actual application.

8.6.2 Tests for Qualified Life

Tests should be performed to assess the qualified life of the product of each generic design using acceptable methods. These tests may be necessary where qualified life cannot be conveniently determined by analytical methods.

ANNEXURE - I

CLASSIFICATION OF REACTOR BUILDING EPs FOR FIRE RESISTANCE

I-1 From fire resistance point of view, reactor building EPs could be divided into certain categories as follows:

Category - I	:	Through-wall EPs in inner containment.
Category - II	:	Through-wall EPs in outer containment.
Category - III	:	Through-wall EPs in internal walls and floors of the reactor building.
Category - IV	:	Non-through-wall EPs.

I-2 Category-I : EPs

Through-wall EPs in the inner containment wall are mostly for allowing the passage of pipes, ducts and cables through the containment wall. The other kind of EPs are for main and emergency airlocks, which allow access to the reactor building for movement of men and materials and the dome closure EPs which are permanently sealed after initial installation of equipment.

I-2.1 Category-I : Conduit EPs

The EPs which convey rigid conduits like pipes and ducts through containment wall are generally steel circular sections embedded in the wall and sealed by bellows on both ends, welded between the conduit and the EP. The bellows are required to accommodate movement of pre-stressed concrete inner containment wall due to pressure, thermal shrinkage, creep and seismic effects, along with maintaining a leak-tight containment boundary.

The containment should be considered as a fire barrier to limit the consequences of a fire from the view point of three considerations:

1. stop an external/internal fire from spreading inside/outside.
2. maintain structural integrity during fire.
3. provide a fire compartment totally surrounding the reactor systems.

As part of the containment, the EPs will be required to act as a flame stop from the first consideration. Flame stop would mean that as an assembly, the EP should not allow flame travel from the face to which it is applied, to the other unexposed face, i.e. if flame is applied to the inner bellow it should not emerge from the outer bellow. The flame could only pass through if both inner and outer bellows get punctured. Absence of puncture in any one bellow would stop the flame.

The structural integrity requirement for containment during fire is not influenced by EPs, as they do not serve a structural function in the containment; they are sealing units in this case. Also, the fire compartment requirement of the containment is met if EPs act as flame stop. Thus, the requirement for ICW (Inner Containment Wall) bellows for fire resistance should be the absence of puncture in any one of the two bellows, when any one of them is exposed to flame. After any significant fire event, the affected EPs will however be required to be examined for serviceability to ascertain containment integrity during operation.

I-2.2 Category-I : Cable EPs

The EPs which serve as cable passages are different from conduit EPs since the former do not employ bellows. The cable is continuous through the EP in the ICW in Indian PHWRs, unlike LWR containments where cables terminate on the EP plates on both sides of the wall and a separate feed through connects both the ends. As per the practice followed in Indian PHWRs, the standard conductor is crimped to make it solid and the cable is moulded in an epoxy compound to seal the gaps between the cores, sheath and conductor. Further, the sealing between the sealing plate and cable is provided by passing the cable through a gland and nut assembly with necessary gaskets.

The EP itself is a rectangular box section embedded inside the ICW with closure plates at both ends to which glands are welded for passage of cables as described above. As discussed for conduit EPs, the requirements during a fire for the EPs would be to act as a flame stop. In case of cable EPs this would require that the sealant compound should not propagate the flame, as this sealant is blocking the flame passage between the metal wires and the metal EP plate. A sealant compound tested for the required flame-proof characteristics would be required for this.

Another way of fire propagation through cable would be the heating of metal wires in the cable in the area exposed to flame and conduction of this heat via metal wires to the other side of EP, possibly igniting the sheath. To counter this type of fire propagation, the cables on both sides of the EP will have to be coated by fire retardant material for a suitable length.

I-2.3 Category-I : Airlock EPs

The description given below is applicable only for new designs of 220 MWe PHWRs- Kaiga onwards. However, the general principles related to fire safety are also applicable to 500 MWe design which follows a two-door concept for all the three airlocks (additional airlock for F/M movement) and does not have a separate structural wall inside the containment.

There are two airlocks in the containment, main air lock (MAL) and emergency air lock (EAL). Large circular EP is located in the ICW to provide space for the airlock barrel to pass through. The space between the airlock barrel and the EP is sealed by a large circular bellow, welded to EP on outside and a flange on the barrel on the inside. Unlike conduit EPs, there is only one sealing bellow on the ICW, while the other sealing bellow is on OCW (Outer Containment Wall). The airlock barrel, which passes through the EPs starts from the structural wall inside the containment. The barrel is fixed to the structural wall by a bolted connection, which is not a sealed point, but only has a very narrow leak path. Inside the barrel there are three doors which divide it into two compartments, the inner (towards containment) and the outer (away from containment). At any time when men or equipment are passing through the airlock, three conditions may exist:

1. inner compartment in communication with inner containment.
2. inner compartment and outer compartment in communication.
3. outer compartment in communication with outside.

The above discussion is intended for considering the paths available for flame travel through the EP and the barrel. Considering a fire inside the containment, the flame path outside the barrel would be through the bolted joint of the barrel to the structural wall and then the EP bellow. It is considered here that in the space between the structural wall and ICW in this area, there is nothing flammable. This path has two obstructions and a large distance separating them. Thus, for the steel bellow, there is no possibility of any direct flame impingement. Besides, the areas in the containment in front of these airlocks are required to be kept free for movement of personnel and equipment. As such, any significant fire in these areas is ruled out. Apart from the above, airlocks also serve as escape routes for persons trying to come out in case of a fire and provide access for manual fire-fighting by the fire personnel. Thus, any requirements of a sealed fire barrier or fire stop cannot be strictly applied to the airlock doors.

However, even as a remote eventuality if a fully-developed fire inside the containment in front of an airlock was to be considered from the flame travel point of view, the neoprene rubber seals of the doors are the elements which may give way. But because of large distance between the doors and the absence of any flammable material between them, it is unlikely that flame would cross via this path. The same would apply for flame travel in the opposite direction.

I-2.4 Category-I : Dome sealing EPs

These EPs are steel circular rings, to which steel dished ends are welded, sealing the openings kept in ICW and OCW to allow passage of SGs (steam generators), whenever required. The requirement for these EPs is to act as a flame stop, which would be the case as they are full steel sections.

I-3 Category-II : EPs

These are the EPs, which are located in OCW (outer containment wall). Most of these are corresponding EPs to those in ICW, as the same pipes, ducts and cables which pass through ICW also pass through OCW. At many locations, the corresponding EPs in ICW and OCW are offset to avoid possible radiation streaming. The MAL, EAL and dome EPs of ICW also have corresponding OCW EPs. Apart from these, there are some large EPs in OCW only. These are closable doors for approaching the annular space. The ICW-OCW annulus space is a leak-tight envelope surrounding the containment, designed for low excess pressure.

As described above, the ICW is considered a fire barrier, which completely surrounds the reactor and associated systems. The OCW need not be considered as a fire barrier. The only requirement to be met by the OCW would be maintaining structural integrity in event of a fire. This would be required from the consideration that many pipes, cables and ducts are supported or passing through the wall and its collapse may cause their failure or may cause damage to the ICW.

As far as the flame stop requirements are concerned for OCW EPs, it is not strictly needed, because ICW EPs are to serve as flame stops. However, precautions are taken in OCW EPs to ensure that an external fire coming in annular space via an EP would not propagate in the annular space to engulf a large area. This would require enough separation and avoiding cross-connections of cables between EPs.

Another solution would be to put flame stops for OCW EPs on the outside face (away from the containment). In this case flame stops on ICW outer face would not be necessary. Flames propagating outwards from inside the containment would be stopped at the structural wall and the flames propagating from outside the containment to inside would be stopped by the OCW outer face flame stop. However, an initiation of fire in the annular space would still require the precautions against spread of fire in the annular space to be effective.

I-4 Category-III : EPs

Through-wall EPs in internal walls and floors of the reactor building, which separate fire areas, should be provided with appropriate fire-resistant sealant.

I-5 Category-IV : EPs

Fire-resistance rating of these EPs is not relevant.

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