

American National Standard



concrete radiation shields



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Concrete Radiation Shields

Secretariat
American Nuclear Society

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Approved December 22, 1972
American National Standards Institute, Inc.

American National Standard

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Foreword

(This Foreword is not a part of American National Standard for Concrete Radiation Shields, N101.6-1972.)

The American Nuclear Society's Subcommittee for Radioactive Materials Handling Facilities and Specialized Equipment, ANS-11, is responsible for developing standards for the design and construction of radioactive materials handling facilities and special remote-handling and associated equipment. This Subcommittee, sponsored by the ANS Remote Systems Technology Division, is responsible for issuing the series of standards which will constitute *A Guide for Good Practice for Hot Cell Design and Construction*.

The purpose of this Guide is to provide documentation and definition of practices proven by actual experience in hot cell facilities. The Guide is intended for use by architect-engineers, facility planners, designers, and operators in the design and construction of hot laboratory facilities, including shielded pilot plants and production, experimental, and storage facilities. Portions of the Guide are applicable to other shielding structures such as those for nuclear reactors. The Guide will consist of the following sixteen standards:

- ANS-11.1 *Interface and Trade-off Considerations for Hot Cell Design*
- ANS-11.2 *Radioactive Materials Flow Schemes*
- ANS-11.3 *Shielding Wall Penetrations for Manipulators, Viewing Devices, and Services*
- ANS-11.4 *Direct Viewing Windows*
- ANS-11.5 *Indirect Optical Viewing Devices*
- ANS-11.6 *TV Viewing*
- ANS-11.7 *Access Doors and Transfer Devices for Personnel and Equipment*
- ANS-11.8 *Illumination*
- ANS-11.9 *Manipulator Devices*
- ANS-11.10 *Elementary Materials Handling Devices*
- ANS-11.11 *Hot Cell Atmosphere Control Systems*
- ANS-11.12 *In-Cell Utility Requirements*
- ANS-11.13 *Concrete Radiation Shields*
- ANS-11.14 *Hot Cell Fire Prevention and Controls*
- ANS-11.15 *Wall Finishes and Protective Coatings*
- ANS-11.16 *Gloveboxes*

The Subcommittee has deliberately avoided discussion of operating philosophies except where absolutely necessary to support a particular design feature. It is not the intent of this Guide to describe safety practices and procedures except where they are directly related to facility design. Safety practices and procedures are the province of other committees and are beyond the scope of the Guide.

Many standards are being developed which relate to this standard. Of particular interest are those listed above which will comprise *A Guide to Good Practice for Hot Cell Design and Construction* and ANSI N45.2.5, *Installation, Inspection, and Testing of Structural Steel and Concrete During the Construction Phase of Nuclear Power Plants*. These standards will be referenced in future editions of N101.6-1972 as they are approved.

The American National Standards Committee N101, Atomic Industry Facility Design, Construction, and Operation Criteria, which reviewed and approved this standard in 1972 had the following membership:

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American National Standard for Concrete Radiation Shields

1. Scope

This standard covers requirements and recommended practices for the construction of concrete radiation shielding structures and for certain elements of design that relate to problems unique to this type of structure. It includes discussions of aggregates, design of concrete mixtures and forms, placement of concrete, design and installation of penetrations, embedments, metal liners, and penetration plugs, and an outline of testing and quality assurance provisions needed to verify that the desired quality of design and construction has been achieved. The standard does not include detailed treatments of structural design or determination of shield thickness, which are adequately covered in other documents (see Appendix A).

1.1 The standard applies primarily to shielding structures for hot laboratories, radiochemical plants, experimental facilities, and similar applications. Much of the information included, however, may be applicable to shielding structures for reactors and other nuclear and non-nuclear facilities which require concrete radiation shields.

1.2 The purpose of this standard is to provide documentation and definition of practices that have been proven by actual experience in the construction of concrete radiation shields. The standard incorporates existing industry standards insofar as practicable to describe methods and materials that are accordant with current practice, and provides the additional design features, information, and special practices unique to this application.

2. Applicable Documents

The following documents supplement this standard and are a part of it to the extent indicated where cited in the text. Current issues shall apply.

2.1 Standards of the American National Standards Institute.

- N5.9-1967 *American National Standard for Protective Coatings (Paints) for the Nuclear Industry*
- N18.9-1972 *American National Standard Program for Testing Biological Shielding in Nuclear Reactor Plants*
- N45.4-1972 *American National Standard for Leakage-Rate Testing of Containment Structures for Nuclear Reactors*
- N101.4-1972 *American National Standard for Quality Assurance for Protective Coatings Applied to Nuclear Facilities*

2.2 Standards of the American Welding Society. American Welding Society, 2501 N.W. 7th Street, Miami, FL 33125.

- AWS D1.0 *Code for Welding in Building Construction*

2.3 Standards of the American Concrete Institute. American Concrete Institute, P. O. Box 4754, Redford Station, Detroit, MI 48219.

- ACI 211 *Recommended Practice for Selecting Proportions for No-Slump Concrete*
- ACI 211.1 *Recommended Practice for Selecting Proportions for Normal Weight Concrete*
- ACI 214 *Recommended Practice for Evaluation of Compression Test Results of Field Concrete*
- ACI 305 *Recommended Practice for Hot Weather Concreting*
- ACI 306 *Recommended Practice for Cold Weather Concreting*
- ACI 318 *Building Code Requirements for Reinforced Concrete*
- ACI 347 *Recommended Practice for Concrete Formwork*
- ACI 506 *Recommended Practice for Shotcreting*

ACI 614 *Recommended Practice for Measuring, Mixing, and Placing Concrete*

2.4 Committee Reports of the American Concrete Institute. American Concrete Institute, P. O. Box 4754, Redford Station, Detroit, MI 48219.

SP-19 *Cement and Concrete Terminology*

SP-304 *Preplaced Aggregate Concrete for Structural and Mass Concrete*

SP-349 *Criteria for Reinforced Concrete — Nuclear Containment and Reactor Structures*

2.5 Standards of the American Society for Testing and Materials. American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM A 185 *Welded Steel Wire Fabric for Concrete Reinforcement*

ASTM A 615 *Deformed Billet-Steel Bars for Concrete Reinforcement*

ASTM C 31 *Making and Curing Concrete Compressive and Flexural Strength Test Specimens in the Field*

ASTM C 33 *Specifications for Concrete Aggregates*

ASTM C 39 *Test for Compressive Strength of Molded Concrete Cylinders*

ASTM C 42 *Obtaining and Testing Drilled Cores and Sawed Beams of Concrete*

ASTM C 94 *Specifications for Ready-Mixed Concrete*

ASTM C 125 *Terms Relating to Concrete and Concrete Aggregates*

ASTM C 138 *Weight per Cubic Foot, Yield, and Air Content of Concrete*

ASTM C 139 *Specifications for Concrete Masonry Units*

ASTM C 143 *Test for Slump of Portland Cement Concrete*

ASTM C 150 *Specifications for Portland Cement*

ASTM C 172 *Sampling Fresh Concrete*

ASTM C 175 *Specifications for Air-Entraining Portland Cement*

ASTM C 260 *Specifications for Air-Entraining Admixtures for Concrete*

ASTM C 294 *Descriptive Nomenclature of Constituents of Natural Mineral Aggregates*

ASTM C 403 *Test for Time of Setting of Concrete Mixtures by Penetration Resistance*

ASTM C 494 *Specifications for Chemical Admixtures for Concrete*

ASTM C 618 *Specifications for Fly Ash and Raw Calcined Natural Pozzolans for Use in Portland Cement Concrete*

ASTM C 637 *Specifications for Aggregates for Radiation-Shielding Concrete*

ASTM C 638 *Descriptive Nomenclature for Constituents of Aggregates for Radiation-Shielding Concrete*

ASTM D 659 *Evaluating Degree of Resistance to Chalking of Exterior Paints*

ASTM D 714 *Evaluating Degree of Blistering of Paints*

ASTM D 772 *Evaluating Degree of Resistance to Flaking of Exterior Paints*

ASTM D 1056 *Specifications for Sponge and Expanded Cellular Rubber Products*

ASTM E 329 *Inspection and Testing Agencies for Concrete and Steel as Used in Construction*

ASTM *Manual for Testing Concrete (see Vol. 10, Annual Book of ASTM Standards)*

2.6 Standards of the American Association for Contamination Control. American Association for Contamination Control, 6 Beacon Street, Boston, MA 02108.

AACC CS-1 *Standard for HEPA Filters*

AACC CS-8 *Standard for High-Efficiency Gas-Phase Adsorber Cells*

2.7 Publications of the Concrete Reinforcing Steel Institute. Concrete Reinforcing Steel Institute, 228 North LaSalle Street, Chicago, IL 60601.

CRSI Design Handbook

2.8 Publications of the American Society of Mechanical Engineers. American Society of Mechanical Engineer, 345 East 47th Street, New York, NY 10017.

Boiler and Pressure Vessel Code, Section VIII, Pressure Vessels, Division 1

*Boiler and Pressure Vessel Code,
Section IX, Welder Qualification*

2.9 Army Corps of Engineers Handbook of Concrete and Cement. U. S. Government Printing Office, Washington, DC 20402.

CRD-C-79 *Method of Test for Flow of Grout Mixtures*

CRD-C-84 *Method of Test for Compressive Strength of Preplaced-Aggregate Concrete*

CRD-C-85 *Method for Selecting Proportions for Intrusion Grout Mixtures*

CRD-C-119 *Method of Test for Flat and Elongated Particles in Coarse Aggregate*

CRD-C-400 *Requirements for Water for Use in Mixing and Curing Concrete*

CRD-C-566 *Specifications for Grout Fluidizer*

2.10 Publications of the Bureau of Reclamation, U. S. Department of the Interior. U. S. Government Printing Office, Washington, DC 20402.

Concrete Manual

2.11 Code of Federal Regulations. U. S. Government Printing Office, Washington, DC 20402.

10 CFR 50 *Licensing of Production and Utilization Facilities*

3. Terms and Definitions

3.1 Admixture. A material other than water, aggregate, or cement that is used as an ingredient of concrete, mortar, or grout and that is added to the batch immediately before or during its mixing.

3.2 Alpha, Alpha Radiation. Radiation due to positively charged alpha particles emitted in the process of radioactive decay. An alpha particle is made up of two neutrons and two protons and is therefore identical with the nucleus of a helium atom. Alpha particles are the least penetrating of the three common types of radiation and may be stopped by as little as a piece of paper or paint. Alpha is not dangerous to plants, animals, or man unless the radiation-emitting substance enters or contaminates the surface of the body. Airborne alpha-emitting

substances are particularly hazardous from an inhalation standpoint.

3.3 Anchor, Concrete Anchor. A member, usually a steel rod with one end bent at a right angle or a headed bolt, embedded in the concrete and to which an embedment or surface-mounted item is welded or otherwise firmly attached to keep the item from pulling away from the hardened concrete.

3.4 Atomic Number. The number of protons in the nucleus of an atom; also the measure of the positive charge of the nucleus.

3.5 Beta, Beta Radiation. Radiation of negatively charged electrons emitted in the process of radioactive decay. Beta radiation is more penetrating than alpha radiation but can be stopped with a thin layer of shielding material; beta radiation can cause skin burns and some beta-emitting substances are extremely harmful if they are ingested or enter the body.

3.6 Concrete Placement. The deposition of concrete or the ingredients for concrete into forms or into members of a structure which serve as forms. The following methods are considered in this standard:

3.6.1 Conventional Placement. The method in which ingredients (portland cement, water, and fine and coarse aggregate) are mixed in a batch plant or mix truck, transferred to the forms by conveyor, pumping, carts, buckets, or barrows, and poured into the forms by gravity.

3.6.2 Preplaced Aggregate (PA) Method. The method in which forms are filled with graded coarse aggregate and the voids of the aggregate mass are then injected with structural quality grout under pressure.

3.6.3 Puddling Method. The method in which several inches of mortar are placed in forms and covered with a layer of coarse aggregate which is rodded or internally vibrated to achieve complete dispersion of the aggregate into the mortar. The process is repeated until the forms are filled to the desired level.

3.6.4 Pressure Grouting. The method of grout or mortar placement in which a fluidized mixture of cement and water (and sometimes sand) is pumped into a cavity under pressure. The process may be used to fill cavities or voids

that were unavoidably or inadvertently left during placement of concrete by other methods.

3.6.5 Shotcrete Method. The method in which mortar is conveyed pneumatically through a hose and projected at high velocity onto a surface or into forms or other cavities in the structure.

3.7 Decontamination (radioactive). The removal of radioactive contaminants from surfaces or equipment, usually by vacuum-cleaning, dry-wiping, washing, mechanically removing a portion of the surface, or treatment with chemicals.

3.8 Design Basis Accident. A set of hypothetical and highly improbable conditions postulated as "credible" by the designer as a basis for design and safety features required to provide an essentially leaktight barrier against the uncontrolled release of fission products to the environment under any mishap, up to and including the worst accident that can be reasonably hypothesized for the operations that will be carried out in the cell. The conditions provide a framework within which to review the response of the cell and its safety features to accident conditions.

3.9 Embedment. An item encased or partially encased in the concrete such as a penetration liner (see 3.23), screed (see 3.33), electrical junction box, pipe, duct, cable way, or conduit. Reinforcing steel and structural members are not considered as embedments for the purpose of this standard.

3.10 Gamma, Gamma Radiation. Electromagnetic (wave type) radiation emitted in the process of radioactive decay or in the process of nuclear fission or fusion. Gamma rays are very penetrating but may be effectively shielded against by water and dense materials such as lead. Gamma rays are similar to xrays but are characteristically of higher energy because they arise from transitions of the nucleus of the atom, whereas xrays arise from transitions of the electrons which surround the nucleus.

3.11 Geometry. The spatial configuration, pattern, or relationship of components or surfaces in an assembly.

3.12 High Density Concrete. Concrete made with special heavy aggregates to improve its shielding characteristics. Density may range from 160 to more than 300 lb per cu ft. Also called heavy concrete.

3.13 Hot. Highly radioactive.

3.14 Hot Cell, Cave. A heavily shielded enclosure in which radioactive materials can be handled safely by persons working from outside of the shield, using remote tools and manipulators, and viewing the work through special lead glass or zinc-bromide-filled windows or optical devices.

3.15 Jacket. A complete or partial metal covering on a penetration plug or shielding block.

3.16 Liner. A permanent metal or other rigid, sheet-type covering attached to the surface of a concrete radiation shielding structure. The liner may be partial, covering only the floor or part of the walls, or may form a complete leak-tight enclosure within the shield. A liner may also be a metal or sheet-type covering over the exposed surfaces of a penetration as, for example, a shielding-window liner.

3.17 Liner Screed. An embedded member, usually a rolled structural shape, to which a liner is attached.

3.18 Movable Shielding Wall. A section of shielding wall that can be moved as a unit (see 3.31, removable shielding wall).

3.19 Neutron. An uncharged elementary particle having a mass nearly equal to that of the hydrogen atom and present in all known atomic nuclei except the lightest isotope of hydrogen. Neutrons are emitted naturally by fission of certain materials and are emitted by materials when undergoing certain nuclear transformations as occur in a nuclear reactor. High energy neutrons are best stopped or shielded against by light elements, such as hydrogen, which approach the mass of the neutron. Neutron reactions, especially capture, generally result in the generation and emission of other forms of radiation, especially gamma rays, in the shielding material.

3.20 Neutron Source. An assembly of materials that emits neutrons, often used as a supply of neutrons for testing and experimental purposes.

3.21 Normal Concrete. Concrete made from commonly available mineral aggregates and having a density of about 150 lbs per cu ft.

3.22 Open Void System. A mass of aggregate having voids totaling more than 45% of its volume.

3.23 Penetration. A built-in cavity or hole in or through a shielding wall used for installation of a shielding window, viewing device, pipe, electrical conduit, manipulator, or other device or service. The penetration is usually metal lined with a penetration liner.

3.24 Photon. A unit quantity, or quantum, of electromagnetic radiation having both energy and effective momentum, but no rest mass or electrical charge.

3.25 Plug, Penetration Plug, Shielding Plug, Roof Block. A removable radiation shield that fits into a penetration to prevent streaming of radiation through the penetration.

3.26 Pour Slip. A ticket (printed form) used as an aid for scheduling the pouring of concrete and related craft work in an intricate construction project.

3.27 Pumping Method. A method of transporting concrete, mortar, or grout to the point of deposition by pumping through a rigid or flexible conduit.

3.28 Radiation. Any electromagnetic (gamma, xray) or particulate (neutron, beta, alpha) radiation capable of producing ions, directly or indirectly, by interaction with matter.

3.29 Radiation Shield. A barrier of material placed between personnel and a radiation source, having the purpose of reducing ionizing radiation to biologically permissible levels.

3.30 Radiation Streaming. Transmission of radiation through a hole, slit, or crack in a radiation shield.

3.31 Removable Shielding Wall. A permanent or temporary shield built up of blocks or other precast units of shielding materials, which can be disassembled; a removable wall may be used to provide temporary or spot shielding inside a cell or to close a seldom used opening to a cell.

3.32 Retempered Concrete. Concrete to which additional water, in excess of that required for the specified mixture proportion, has been introduced, accompanied by additional mixing, to restore slump or to avoid stiffening before discharge from the mixer or carrier.

3.33 Screed. A member permanently or temporarily embedded in the concrete surface to aid in leveling and finishing the concrete (see 3.17, liner screed).

3.34 Service Environment, Service Conditions. The conditions of heat, cold, humidity, pressure, corrosion, abrasion, shock, vibration, or other environmental factors to which the radiation shield will be subjected under normal conditions.

3.35 Thermalize. To slow or moderate neutrons until they are in thermal equilibrium with the material of the shield in order to facilitate their capture by the shield material and thereby prevent their escape.

3.36 Window, Shielding Window, Viewing Window. A direct viewing device in a radiation shield, made from special high density radiation-resistant glass, or in the form of a tank with glass cover plates, containing a radiation-absorbing liquid, such as zinc-bromide solution, which provides biological shielding essentially equal to that of the concrete radiation shield.

3.37 Window Liner. A metal covering attached to the concrete which lines the window penetration (see 3.16, liner).

3.38 Other terms relating to concrete and concrete construction shall be as defined in ASTM C 125, *Terms Relating to Concrete and Concrete Aggregates*, and in ACI SP-19, *Cement and Concrete Terminology*.

4. General

4.1 Purpose. This section outlines various aspects of shield design and theory which provide the basis for relating functional shielding design to facility design and which also provide the basis for effective use of the information presented in later sections. It covers requirements, recommendations, and precautions not covered in later sections and summarizes the special features of design and construction of concrete radiation shields not applicable to more conventional concrete construction. To ensure that the intent of this standard is met, it is essential that a comprehensive quality assurance program, as outlined in Section 11, Quality Assurance, be developed and adhered to during all phases of the project.

4.2 Application. This standard is intended for use by architect-engineers, facility planners, designers, and operators in the design and construction of concrete radiation shields; it is also intended to be a reference and source of basic information in the preparation of specifications for such facilities. The standard is to be used in conjunction with the other documents listed in Section 2, Applicable Documents. Where these latter documents differ from project drawings and specifications, the project documents shall govern.

4.3 Shield Design. The establishment of shield configuration is an interactive process among a number of technical disciplines and must take into consideration the radiation attenuation, structural, and thermal requirements in consonance with operational needs of the facility. The first step in design is to develop preliminary layouts based on user needs and preliminary estimates of the shield thickness required to attenuate the expected radiation levels in the cell; these should be sufficiently detailed to identify major design problems and conflicts. Upon completion of preliminary shielding layouts, work can be started on the detailed shield design. During this stage, nuclear, structural, thermal, and functional analyses are made and changes in shield configuration indicated by the results of these analyses are incorporated in the final facility design.

4.3.1 Shielding Analysis. Analyze the proposed shield design for radiation attenuation and for streaming through ducts and voids. Recognized methods for shielding analysis are described in the references listed in Appendix A.

Gamma Shielding. Gamma rays of importance usually have photon energies ranging from 0.5 to 10 MeV (million electron volts). In this energy range, shield thickness can be reduced by using materials having constituents of high atomic number to increase the average density of the shield material. Heavy aggregates are sometimes used for this purpose. Both shield density and composition are important factors in gamma-ray attenuation and are subject to the economic considerations discussed in 4.4.

Neutron Shielding. Neutron attenuation is generally more difficult than gamma-ray attenuation because the neutrons must be slowed down (thermalized) in order to achieve significant capture by the shielding material. Hydrogen is more effective in slowing neutrons than any other element. Because it is also one of the constituents of water, hydrogen is present in all concretes to some extent. Loss of excess water under service conditions leads to loss of capability to attenuate neutrons; in some cases this loss is due to high service temperatures. Good practice, therefore, requires that the maximum concrete temperature should not exceed 150°F. A mineral aggregate containing water of crystallization can be used in concrete to compensate for loss of water at concrete service temperatures above 150°F or to provide more neutron attenuation than would otherwise be provided by concrete containing the normal amount of water. Thermal neutron capture can also be enhanced by the use of aggregates containing boron; boron-containing aggregates also suppress the high capture energy gamma rays produced by neutron capture in the usual shield materials.

Alpha and Beta Shielding. Protection against alpha and beta radiation is primarily a matter of preventing the release of airborne particulate matter and fission-product gases. When alpha or beta radiation is present in addition to neutron or gamma radiation, it is necessary to (a) provide a leak-tight liner within the concrete radiation shield, (b) seal all openings of the shield, and (c) provide an exhaust system of suf-

ficient capacity to maintain a negative pressure within the cell, fitted with HEPA filters (see AACC CS-1, *Standard for HEPA Filters*) and, if radioiodine may also be present, adsorber cells (see AACC CS-8, *Standard for High-Efficiency Gas-Phase Adsorber Cells*). Cell air may be recirculated back into the cell after filtration, but should not be released to occupied areas of the facility.

4.3.2 Thermal Analysis. Check the proposed design for thermal gradients that may be imposed both during normal operation and under design basis accident (DBA) conditions, using recognized techniques for analysis of heat conduction problems. In the event of high nuclear radiation fluxes incident on the inner surfaces of the shield, consider additional effects of internal heat-generation within the mass of the concrete due to the attenuation of neutrons and gamma rays. Also check for thermal gradients which may exist during construction due to the exothermic chemical reaction which occurs during curing of the concrete. Where curing stresses could be excessive, the hot weather concreting techniques described in ACI 305, *Recommended Practice for Hot Weather Concreting*, should be specified. Where temperature gradients cannot be controlled by ventilation or other methods of surface cooling, and where excessive cracking cannot be controlled by reinforcement, water-cooling lines may be provided within the concrete to offset the effects of operational and internal heat generation.

4.3.3 Applied Loads. Consider the effects of all combinations of applied loads that can be anticipated during the life of the facility. These may include, but are not limited to,

- (1) loads transmitted from the structural members of the shield
- (2) dead weight of the shield and its components
- (3) live loads
- (4) steady-state and transient pressure loads
- (5) loads due to shielded carriers, handling equipment, and other items used during operation, located or operated within the radiation shield or on the roof of the shield
- (6) loads from utilities and services (for example, thrusts due to thermal expansion of piping)
- (7) vibration
- (8) loads resulting from a DBA
- (9) snow, wind, and tornado loads (for shields exposed to the weather)
- (10) earthquake (seismic) loads.

4.3.4 Structural Analysis. Structural analysis may be based on either the working stress method or the ultimate strength method of ACI 318, *Building Code Requirements for Reinforced Concrete*. When using the working stress method, credit for temporary loads may be taken from the same increase in allowable stresses that is allowed for wind and earthquake forces. When using the ultimate strength method, establish design loads by summing the products obtained by multiplying each of the loads by an appropriate load factor; select load factors to account for the uncertainty in determining the correct magnitude of the load. Structural analysis may also have to take into consideration seismic forces and the possibility of an explosion in the cell.

4.3.5 Accident Condition Analysis. If a DBA must be considered in design, use the procedures and factors given in ACI SP-349, *Criteria for Reinforced Concrete — Nuclear Containment and Reactor Structures*, for analyzing the accident conditions and effects.

4.3.6 Operational Analysis. A detailed analysis of all foreseeable operations and maintenance procedures that will be conducted in the cell shall be made. Consider all equipment and handling-device motions and requirements, both inside and at the operating face of the cell, and viewing angles and area of view of shielding windows and optical devices (for example, periscopes). Establish the interfaces that may exist between engineering disciplines and between crafts that will be involved in design and construction. A full-size or large-scale mock-up, in which the operations can be simulated, is recommended for complex installations. The operational analysis should include, but not be limited to, the following factors:

- (1) clearances between manipulators and other through-wall or wall-mounted equipment, both on the interior of the cell and the operating face
- (2) interferences and infringing locations of equipment, handling and viewing devices, penetrations, and access openings
- (3) overhead clearances, freedom from obstructions, and location of roof blocks