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Standard Guide for Dry Lead Glass and Oil-Filled Lead Glass Radiation Shielding Window Components for Remotely Operated Facilities[1]

This standard is issued under the fixed designation C1572/C1572M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 *Intent:*

1.1.1 The intent of this standard is to provide guidance for the design, fabrication, quality assurance, inspection, testing, packaging, shipping, installation, and maintenance of radiation shielding window components. These window components include wall liner embedments, dry lead glass radiation shielding window assemblies, oil-filled lead glass radiation shielding window assemblies, shielding wall plugs, barrier shields, view ports, and the installation/extraction table/device required for the installation and removal of the window components.

1.2 *Applicability:*

1.2.1 This standard is intended for those persons who are tasked with the planning, design, procurement, fabrication, installation, and operation of the radiation shielding window components that may be used in the operation of hot cells, high level caves, mini-cells, canyon facilities, and very high level radiation areas.

1.2.2 This standard applies to radiation shielding window assemblies used in normal concrete walls, high-density concrete walls, steel walls and lead walls.

1.2.3 The values stated in SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the standard. Common nomenclature for specifying some terms; specifically shielding, uses a combination of metric units and inch-pound units.

1.2.4 This standard identifies the special information required by the Manufacturer for the design of window components. Table A1.1 shows a sample list of the radiation source spectra and geometry information, typically required for shielding analysis. Table A2.1 shows a detailed sample list of specific data typically required to determine the physical size, glass types, and viewing characteristics of the shielding window, or view port. Annex A3 shows general window configuration sketches. Blank copies of Table A1.2 and Table A2.1 are found in the respective Annexes for the Owner–Operator's use.

1.2.5 This standard is intended to be generic and to apply to a wide range of configurations and types of lead glass radiation shielding window components used in hot cells. It does not address glovebox, water, X-ray glass, or zinc bromide windows.

1.2.6 Supplementary information on viewing systems in hot cells may be found in Guides C1533 and C1661.

1.3 *Caveats:*

1.3.1 Consideration shall be given when preparing the shielding window designs for the safety related issues discussed in the Hazard Sources and Failure Modes, Section 11; such as dielectric discharge, over-pressurization, radiation exposure, contamination, and overturning of the installation/extraction table/device.

1.3.2 In many cases, the use of the word "shall" has been purposely used in lieu of "should" to stress the importance of the statements that have been made in this standard.

1.3.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health and environmental practices and determine the applicability of regulatory requirements prior to use.*

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *Industry and National Consensus Standards*—Nationally recognized industry and consensus standards which may be applicable in whole or in part to the design, fabrication, quality assurance, inspection, testing, packaging, shipping,

[1] This guide is under the jurisdiction of ASTM Committee C26 on Nuclear Fuel Cycle and is the direct responsibility of Subcommittee C26.14 on Remote Systems.

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installation and maintenance of radiation shielding window components are referenced throughout this standard and include the following:

2.2 *ASTM Standards:*[2]

A27/A27M Specification for Steel Castings, Carbon, for General Application
A36/A36M Specification for Carbon Structural Steel
A48/A48M Specification for Gray Iron Castings
A240/A240M Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications
A747/A747M Specification for Steel Castings, Stainless, Precipitation Hardening
C859 Terminology Relating to Nuclear Materials
C1533 Guide for General Design Considerations for Hot Cell Equipment
C1661 Guide for Viewing Systems for Remotely Operated Facilities
D1533 Test Method for Water in Insulating Liquids by Coulometric Karl Fischer Titration
E165 Practice for Liquid Penetrant Examination for General Industry
E170 Terminology Relating to Radiation Measurements and Dosimetry
E2024 Test Methods for Atmospheric Leaks Using a Thermal Conductivity Leak Detector
ASTM/IEEE SI-10 Standard for Use of the International System of Units

2.3 *American Concrete Institute (ACI) Standards:*[3]

ACI C-31 Seismic Requirements

2.4 *American Institute of Steel Construction (AISC) Standard:*[4]

Manual of Steel Construction

2.5 *American National Standards Institute (ANSI) Standards:*[5]

ANSI Y 14 Engineering Drawing and Related Documentation Practices
ANSI/ASME NQA-1 Quality Assurance Requirements for Nuclear Facility Applications
ANSI/AWS A2.4 Standard Symbols for Welding, Brazing and Nondestructive Examination
ANSI/AWS B2.1 Specification for Welding Procedure and Performance Qualification
ANSI/AWS D1.1/D1.1M Structural Welding Code—Steel
ANSI/AWS D1.6/D1.6M Structural Welding Code—Stainless Steel
ANSI/ISO/ASQ 9001 Quality Management Standard Requirements

2.6 *American Society for Nondestructive Testing (ASNT) Standards:*[6]

ASNT-SNT-TC-1A Recommended Practice for Qualification and Certification of Nondestructive Testing

2.7 *Steel Structures Painting Council (SSPC):*[7]

SSPC-SP1 Solvent Cleaning
SSPC-SP5 White Metal Blast Cleaning
SSPC-PA1 Shop, Field, and Maintenance Painting of Steel

2.8 *Federal Standards (FS):*[8]

QQ-C-40 Caulking, Lead Wool, and F7 Lead Pig

2.9 *Federal Regulations (FR):*[8]

10 CFR20.1003 Definitions
10 CFR50, Appendix B Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants
CFR830.120 Subpart A Nuclear Safety Management, Quality Assurance Requirements

2.10 *International Building Code (IBC):*[8]

IBC Section 2314 Earthquake Regulations

2.11 *Other Standards:*

AESS (R) 44/70000/6 Atomic Energy Standard Specification for Shielding Glass[9]
NCRP Report No. 82 SI Units in Radiation Protection and Measurements[10]
ICRU Report 10b Physical Aspects of Irradiation[11]

3. Terminology

3.1 *General Considerations:*

3.1.1 The terminology employed in this guide conforms with industry practice insofar as practicable.

3.1.2 For definitions of general terms used to describe nuclear materials, hot cells, and hot cell equipment, refer to Terminology C859.

3.2 *Definitions:*

3.2.1 *air dryer cartridge, n*—a cloth bag containing moisture-absorbent crystals.

3.2.1.1 *Discussion*—The bag is inserted into the dryer assembly. The crystals are used to absorb moisture from the contained environment.

3.2.2 *anti-reflection treatment, n*—a process applied to the surface of the glass that reduces reflection and increases the light transmission through the glass.

3.2.2.1 *Discussion*—It is often called a low-reflection treatment.

3.2.3 *as-built drawings, n*—a set of drawings that reflect all of the changes that were incorporated into the components during the manufacturing process since the original design.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American Concrete Institute (ACI), P.O. Box 9094, Farmington Hills, MI 48333-9094, http://www.concrete.org.

[4] Available from American Institute of Steel Construction (AISC), One E. Wacker Dr., Suite 700, Chicago, IL 60601-2001, http://www.aisc.org.

[5] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

[6] Available from American Society for Nondestructive Testing (ASNT), P.O. Box 28518, 1711 Arlingate Ln., Columbus, OH 43228-0518, http://www.asnt.org.

[7] Available from Society for Protective Coatings (SSPC), 40 24th St., 6th Floor, Pittsburgh, PA 15222-4656, http://www.sspc.org.

[8] Available from U.S. Government Printing Office Superintendent of Documents, 732 N. Capitol St., NW, Mail Stop: SDE, Washington, DC 20401, http://www.access.gpo.gov.

[9] HMSO, St. Clements House, 2-16 Colegate, Norwich, NR3 1BQ. UK.

[10] Available from National Council of Radiation Protection and Measurements, 7910 Woodmont Avenue, Suite 400, Bethesda, MD 20814-3095.

[11] Available from International Commission on Radiation Units and Measurements, Inc., 7910 Woodmont Avenue, Suite 400, Bethesda, MD 20814-3095.

3.2.4 *barrier shield assembly, n*—consists of steel frames, gaskets, and a glass plate; typically cerium-stabilized, assembled together to form a see through barrier.

3.2.4.1 *Discussion*—The assembly is mechanically fastened to the hot side of the wall liner to provide a gas tight containment barrier, which protects the window assembly from any radioactive contamination within the hot cell (alpha particles and other contaminates).

3.2.5 *barrier shield glass, n*—a glass plate; typically cerium stabilized that is used as a cover glass to see through and isolate the window assembly from contamination.

3.2.5.1 *Discussion*—It is normally mounted in a barrier shield frame with gaskets to make up a barrier shield assembly.

3.2.6 *bellows, n*—a flexible enclosure generally made of a pliable gasket material, which expands and contracts with the temperature change of the inert gas and other components, maintaining a controlled atmosphere within the window assembly.

3.2.6.1 *Discussion*—When employed, the bellows is generally connected to the top of the expansion tank on an oil-filled window, and directly above the air dryer on the window housing of a dry window. The material of selection must be compatible with the environment, and with the window components.

3.2.7 *browning, n*—the discoloration and darkening of glass to a brownish color due to excessive radiation exposure.

3.2.8 *bubbler system, n*—a device used as a pressure relief, and constructed of an outer open top container or chamber that is filled with a liquid.

3.2.8.1 *Discussion*—It has a separate pressurized tube inserted into the liquid. When over-pressurization occurs in the tube, the gas bubbles out the bottom of the tube and up to the surface through the liquid.

3.2.9 *buffer seal, n*—a specially configured seal gasket used on a barrier shield.

3.2.10 *build-up factor, n*—for radiation passing through a medium, buildup factor is the ratio of the total value of a specific radiation quantity (direct and scattered) measured as absorbed dose at any point within that medium to the contribution to that quantity from the incident uncollided radiation reaching that point.

3.2.10.1 *Discussion*—The build-up factor increases with increased shielding thickness and is higher for low atomic number materials.

3.2.11 *cave, n—in the nuclear hot cell applications*, typically a small-scale hot cell facility.

3.2.11.1 *Discussion*—This term is sometimes used synonymously with hot cell.

3.2.12 *central viewing area, [L^2], n*—the central viewing area of a glass slab or glass plate is that viewing area, circular or elliptical, of which the diameter of axis is 80 % of the maximum usable viewing window dimensions.

3.2.13 *cerium-stabilized glass, n*—a glass type that contains a small percentage of cerium oxide to help stabilize the glass from discoloration due to radiation exposure.

3.2.13.1 *Discussion*—It is often called non-browning glass.

3.2.14 *CMTR, n*—the abbreviation for a Certified Material Test Report, which is a document that certifies the results of tests and analyses performed on the item provided.

3.2.15 *checks, n*—very small fractures, or breakouts, normally around the edge of a glass plate or glass slab.

3.2.16 *chip, n*—a fragment broken from an edge or surface.

3.2.17 *clear view, [L^2], n*—the physical size (length × width) of the smallest glass slab of all the glass components in a shielding window assembly.

3.2.17.1 *Discussion*—The actual clear view may be reduced by the method of retention of the glass in the window.

3.2.18 *cold side, n*—the surface on a radiation shielding window that is farthest from the radioactive source, and usually is not subject to contamination.

3.2.19 *cold side load, n*—a cold side load window assembly is an assembly that is inserted into a wall liner or removed from a wall liner from the operator (cold side) of the hot cell.

3.2.20 *cover glass (hot or cold side), n*—a glass plate positioned on the hot or cold side of the window.

3.2.20.1 *Discussion*—The cover glass is often held in place with a trim frame assembly and seal gaskets. This assembly achieves a seal, which isolates the inner glass slabs from the external atmosphere and may also hold or contain the mineral oil within the window assembly.

3.2.21 *density inch, n*—a term used to describe the specific gravity of a shielding material multiplied by the thickness of that material in inches. The units are g/cc × (in.).

3.2.22 *desiccant air dryer, n*—a device filled with crystals and is used to remove moisture from a contained environment.

3.2.23 *dielectric discharge, n*—an instantaneous flow of electrical current from an irradiated glass component to the ground, causing severe damage to the glass, usually in the form of a dendritic fracture (Lichtenberg Figure) or heavy cleavage.

3.2.24 *dose rate, [L^2 T^3], n*—a quantity of absorbed dose received in a given unit of time.

3.2.25 *dry lead glass window, n*—a radiation shielding window that is filled with slabs of lead glass with polished glass surfaces.

3.2.25.1 *Discussion*—The assembly may be continuously purged with an inert gas. The glass surfaces within the shielding window assembly are normally treated to minimize surface reflection.

3.2.26 *duty cycle, [T], n*—is a factor considered in the design of window life based on anticipated cell usage.

3.2.26.1 *Discussion*—It is dose rate versus time at a particular location.

3.2.27 *exposure, [M^1 TI], n—in X-ray and gamma radiation*, radiation exposure is a measure of the amount of ionization produced by X-ray or gamma rays as they travel through air.

3.2.27.1 *Discussion*—The special unit of radiation exposure is the roentgen (R). It is equivalent to 2.58×10^{-4} coulombs per kilogram of air.

3.2.28 *extreme view angle, n*—the maximum angle that an operator can see into the hot cell when looking through the shielding window from the extreme perimeter edge of the cold side trim frame.

3.2.29 *gas purge line, n*—a stainless steel tube supplying a pressurized gas to the window assembly.

3.2.30 *gas-tight seal, n*—a seal that meets the requirements of a leak rate test.

3.2.31 *gas vent line, n*—a stainless steel tube connected to the window assembly for the purpose of venting gas.

3.2.32 *glass plate, n*—typically used as cover glasses or barrier shields.

3.2.32.1 *Discussion*—The maximum thickness is typically 40 mm [1.5 in.] thick.

3.2.33 *glass slabs, n*—typically used for internal shielding in windows and view ports.

3.2.33.1 *Discussion*—The typical thickness ranges from a minimum of 40 mm [1.5 in.] up to a maximum of 400 mm [16 in.] thick.

3.2.34 *glass surface defects, n*—refer to those defects that are on the glass surface and can be removed by reprocessing or repolishing the glass surface.

3.2.34.1 *Discussion*—These defects are scratches, short finish, and stripping.

3.2.35 *high level caves, n*—a small-scale hot cell facility.

3.2.36 *hot side, n*—the surface on a radiation shielding window that, when installed, will be the closest to the radioactive sources.

3.2.37 *inclusions, n*—"small bubbles," "small black stones," and "seeds" that are visible in optical quality glass.

3.2.38 *inert gas, n*—a type of commercial-grade, moisture-free gas.

3.2.38.1 *Discussion*—The gas is usually argon or nitrogen that is purged into the internal window assembly to displace ambient air.

3.2.39 *installation/extraction table/device, n*—a heavy duty table or device capable of supporting one and one-half times the shielding window's weight that is used for extracting a shielding window, shielding plug, or view port from an embedment wall liner, or installing the shielding window, shielding plug, or view port into the wall liner.

3.2.40 *lead packing, n*—lead material in the form of a wool mesh or sheet material positioned inside a window assembly housing to fill the voids between the edges of the glass slabs and the window housing.

3.2.40.1 *Discussion*—The packing is required to provide shielding equivalence to the glass components within the window assembly and the hot cell wall, and to eliminate radiation "shine" paths.

3.2.41 *light transmission, n*—the measurement of light transmitted through a media and is specified as a ratio of light transmitted through the media as compared to the light transmitted through air.

3.2.42 *mini-cell, n*—a very small, hot cell.

3.2.43 *NCR, n*—the abbreviation for a Manufacturer's Non-Conformance Report.

3.2.43.1 *Discussion*—This quality assurance report is generated when an item does not meet specification and must state the manufacturer's proposed course of action and how the solution deviates from the contract.

3.2.44 *non-browning glass, n*—a glass type that resists discoloration due to high radiation exposure.

3.2.45 *normal concrete, n*—a concrete mixture that has a weight of between 2250 and 2400 kg per m^3 [140 to 150 lb/ft^3].

3.2.46 *normal view angle, n*—the angle of view the operator can see into the hot cell when looking through the shielding window at the operator's eye level at a given distance from the cold side cover glass.

3.2.47 *oil expansion tank, n*—a stainless steel or glass tank attached to the cold side hot cell wall which allows for volumetric changes of the oil within the window due to temperature changes.

3.2.47.1 *Discussion*—Stainless steel is the preferred type. The oil supply in the window is connected to the expansion tank.

3.2.48 *oil-filled lead glass window, n*—a lead glass radiation shielding window filled with an optical grade shielding oil.

3.2.49 *polished glass surface, n*—a glass surface that has been polished and has minimal visual defects such as scratches and short finish.

3.2.50 *secondary gamma, n*—is radiation generated by reactions between primary gamma rays and the material through which it is traveling.

3.2.51 *shielding oil, n*—an optical grade mineral oil used to fill the voids between the glass slabs and couple the glass surfaces in an oil-filled lead glass shielding window assembly.

3.2.51.1 *Discussion*—The oil also provides minor gamma and neutron shielding.

3.2.52 *shielding wall plug, n*—a device constructed similar to that of a radiation shielding window, except that it has no visual capabilities for viewing into the hot cell.

3.2.52.1 *Discussion*—It is used only to plug the hole where a radiation shield window normally is installed. A shielding plug allows the Owner-Operator to move and interchange shielding windows to other locations. It is an effective tool in reducing operating and maintenance costs of a hot cell.

3.2.53 *shine, n—in the nuclear industry*, shine is direct, scattered, or reflected radiation.

3.2.54 *short finish, n*—the small microscopic pits normally found in the outer edges or corners on the surface of a polished plate or slab of glass. The pits do not affect the optical visibility through the glass.

3.2.55 *stepped window, n*—a stepped shielding window is one that has one or more steps at its perimeter and provides an interruption in the potential radiation shine path from the hot side to the cold side of the window.

3.2.56 *streaming, n*—see *radiation streaming*.

3.2.57 *striae, n*—transparent lines appearing as though threads of glass have been incorporated into the glass sheet.

3.2.58 *stripping, n*—a streaking appearance on a polished glass surface with no measurable depth indicating a loss of polish without glass removal.

3.2.59 *total integrated dose (tid), [L^2 T^{-2}], n*—is the total amount of radiation received by a component or location for the design life of the component.

3.2.59.1 *Discussion*—Total dose is computed by multiplying the dose rate(s) by the corresponding time(s) and summing the results over the time span. Another way to express this is as the area under the curve of a dose rate versus time diagram.

3.2.60 *trim frame, n*—a steel frame with a drilled hole pattern that functions to mechanically fasten a cover glass to a window housing.

3.2.61 *trim frame assembly, n*—consists of steel frames, gaskets and a glass plate (cover glass), assembled together to form a see-through cover glass.

3.2.61.1 *Discussion*—The assembly is mechanically fastened to the cold side or hot side of a window housing to provide a gas tight containment for the shielding window assembly.

3.2.62 *very high radiation area, n*—an area, accessible to individuals, in which radiation levels external to the body could result in an individual receiving an absorbed dose in excess of 500 rads [5 grays] in 1 h at 1 m from a radiation source or 1 m from any surface that the radiation penetrates. **(10 CFR20.1003)**

3.2.63 *viewing angle, n*—the term used to describe the widening view from the eyeball when looking through a shielding window into a hot cell.

3.2.64 *view port, n*—a small shielding window that is usually positioned in a cask, wall, or other shielded structure and is utilized for the express purpose of viewing a small area where a gauge, meter, valve, etc. might be located.

3.2.65 *WG, [ML^{-1} T^{-2}], n*—the abbreviation for *water gauge*.

3.2.65.1 *Discussion*—It is the pressure differential, equal to the pressure exerted by a column of water of the specified height.

3.2.66 *wall liner embedment, n*—a metal structure which is embedded in the hot cell wall.

3.2.66.1 *Discussion*—The radiation shielding window fits into the wall liner.

3.2.67 *window cavity, n*—the space inside the window housing that contains the glass slabs and lead packing.

3.2.68 *window housing, n*—the outer metal structure of the shielding window.

3.2.68.1 *Discussion*—It fits into the wall liner embedment.

3.2.69 *window interchangeability, n*—the ability to remove a shielding window of the same size from one embedment wall liner and move and install it into another embedment wall liner of the same size.

4. Significance and Use

4.1 *Radiation Shielding Window Components:*

4.1.1 Radiation shielding window components operability and long-term integrity are concerns that originate during the design and fabrication sequences. Such concerns can only be addressed, or are most efficiently addressed, during one or the other of these stages. The operability and integrity can be compromised during handling and installation sequences. For this reason, the subject equipment should be handled and installed under closely controlled and supervised conditions.

4.1.2 This standard is intended as a supplement to other standards and to federal and state regulations, codes, and criteria applicable to the design of radiation shielding window components.

5. Quality Assurance and Quality Requirements

5.1 *Quality Assurance (QA):*

5.1.1 The Manufacturer should administer a quality assurance program acceptable to the Owner-Operator. QA programs may be required to comply with 10 CFR50, Appendix B, 10 CFR830.120 Subpart A, ANSI/ASME NQA-1, or ANSI/ISO/ASQ 9001.

5.1.2 The Owner-Operator should require appropriate quality assurance of purchased radiation shielding window components to assure proper fit up, operation, and reliability of the components when they are installed in the hot cell.

6. Design Requirements

6.1 *General Requirements:*

6.1.1 *Application:*

6.1.1.1 The Owner-Operator shall specify whether the radiation shielding window shall be dry lead glass or oil filled lead glass, based on the application needs and preference. Considerations in making the determination should be based on viewing, seismic, neutron shielding, clarity, and maintenance requirements.

6.1.1.2 Materials of construction on the hot side shall be radiation resistant to the hot cell environment, easily decontaminated, and compatible with other materials with which they are in contact.

6.1.1.3 The radiation shielding components shall be designed to provide the required radiation shielding, hot side contamination containment, and viewing capability within the shielded hot cells.

6.1.2 *Configuration:*

6.1.2.1 The shielding window components shall be designed as cold side or hot side load with single or multiple steps. A cold side load window with a single step is the preferred method.

6.1.2.2 If the manufacturer elects to provide multiple stepped window components, he shall demonstrate to the Owner-Operator prior to fabrication release that the windows can be installed, extracted, and re-installed from the cold side with the barrier shield secured in place on the wall liner embedment.

6.1.3 *Radiation Environment and Shielding:*

6.1.3.1 *Attenuation:*

(1) Each radiation shielding window shall provide adequate radiation shielding for the radiation source in the respective cell.

(2) The Owner-Operator shall specify the source in terms of the specific isotopes, activity, its dose rate, its geometry, and its distance from the hot side of the window. Refer to Annex A1.

(3) The Owner-Operator shall specify the radiation level at the cold side of the window; for example, 2.5 µSv/h [0.25 mrem/h] at a distance of 150 mm [6 in.] from the surface of the cold side cover glass. It is recommended that the attenuation of the window match the attenuation of the hot cell wall.

6.1.3.2 *Build-Up Factor:*

(1) Unless otherwise specified by the Owner-Operator, the window shall be designed to accommodate the radiation build-up factor. Build-up Factor in shielding calculations takes account of scattered radiation. Most shielding calculations are based on highly collimated photon sources but normally, the source is only broadly collimated or uncollimated.

(2) Radiation scattered from elsewhere in the shield will reach a particular dose point under consideration. In general, build-up factor increases with shield thickness and is higher for low atomic number materials.

6.1.3.3 *Radiation Streaming:*

(1) Shielding shall be provided along any possible radiation path through the window penetration and the wall liner.

(2) Installation of shielding materials into the gaps between the window housing and the wall liner (with the exception of metal spacers) should not be permitted for new design and build windows to meet the dose rate requirement at the cold side of the window. This requirement is to eliminate the potential for mixed hazardous waste such as contaminated lead packing that may be removed from the opening between the window and wall liner.

6.1.4 *Light Transmission:*

6.1.4.1 The minimum initial light transmission specified by the Owner-Operator for each type window shall be measured at a wavelength of 589 nanometres. Refer to Table A2.1 Sample Data Sheet.

6.1.5 *Dimensions:*

6.1.5.1 The minimum dimensions of the clear view and the maximum dimensions of the barrier shield assemblies shall be as specified by the Owner-Operator on the data sheet for each type of window.

6.1.5.2 The centerline viewing height of clear view (eye position above cold side floor), the offset viewing height (eye position above cold side floor), the offset viewing distance from clear view centerline, and the viewing distance (distance from eyeball to glass) shall be specified by the Owner-Operator on the data sheet for each type of window.

6.1.5.3 The hot side of the barrier shield cover glass should be designed to eliminate master-slave manipulator interference. Refer to Annex A3, Fig. A3.8.

6.1.6 *Wall Thickness, Density and Material:*

6.1.6.1 The Owner-Operator shall specify the wall thickness, density, and material. Refer to Annex A2.

6.1.7 *Viewing Angles:*

6.1.7.1 The Owner-Operator shall specify the minimum viewing angles as described in Annex A3, Figs. A3.3-A3.5, and on the Annex A2 Data Sheet.

6.1.7.2 Annex A3, Figs. A3.3-A3.5 shows typical calculated centerline and offset viewing angle geometry in horizontal and vertical sections, respectively.

6.1.8 *Physical Conditions:*

6.1.8.1 The Owner-Operator shall provide the necessary information regarding the design and operating requirements for the cold side and hot side of the window. Refer to Annex A1 – Annex A3.

6.1.9 *Seismic Requirements:*

6.1.9.1 The Owner-Operator shall provide seismic requirements for designing the shielding window components as determined by the ACI C-31 Seismic Requirements, the IBC Section 2314—Earthquake Regulations, or other seismic codes specific to the Owner-Operator's facility.

6.1.9.2 The shielding window components shall withstand seismic and other concurrent loads while maintaining containment and shielding during the event. Viewing functionality of the shielding windows during and after the event is not required, but shielding and containment must be maintained.

6.1.9.3 Seismic qualification of the shielding window components shall be by analysis unless otherwise specified by the Owner-Operator.

6.1.9.4 Friction, where not purposely designed (AISC friction type connection), shall not be relied upon as a resisting force during seismic events. Shielding window assemblies must be mechanically restrained to the wall.

6.1.10 *Design Life:*

6.1.10.1 The design life and radiological duty cycle of the windows shall be specified by the Owner-Operator.

6.2 *Wall Liner Embedments:*

6.2.1 *Design:*

6.2.1.1 The wall liners shall be of a single or multi-step construction to prevent radiation streaming. The wall liners shall be designed to provide the necessary shielding to compensate for the gap between the window housing and the wall liner. Refer to Annex A3, Figs. A3.1 and A3.2, for sketches of the shielding window configurations.

6.2.2 *Structure:*

6.2.2.1 The wall liners shall be constructed of carbon steel or stainless steel weldments or iron or stainless steel castings. It is recommended that the hot side of the wall liners, especially where there are corrosive environments, be constructed of stainless steel weldments or stainless steel castings. Porous castings that may trap contamination shall not be permitted.

6.2.2.2 Castings shall be inspected for surface defects and porosity after machining. Castings shall also be inspected for internal voids by ultrasonic or X-ray testing. These inspections verify surface and internal casting quality, which assures structural soundness, radiological containment, and adequate shielding.

6.2.2.3 Materials used in the construction of wall liners shall be suitable for the specific application as recommended by the designer or manufacturer, and as approved by the Owner-Operator. Refer to 7.2 Steel/Castings.

6.2.2.4 When the wall liners are to be flared out to the hot side to accommodate extreme viewing angles, the designer must ensure that attenuation provided by the wall is not compromised.

6.2.3 *Sealing System:*

6.2.3.1 The wall liners shall be designed to have a primary and secondary containment seal.

(1) The primary containment seal shall be at the hot side of the wall liner and shall be accomplished by sealing the barrier shield assembly to a machined surface of the hot side face of the wall liner.

(2) The secondary containment seal shall be at the cold side, or at the most cold side step of the wall liner, and shall be accomplished by sealing the window assembly to a machined surface at the cold side, or most cold side step, of the wall liner.

(3) The design shall be such that a gas-tight seal is formed in the cavity between the barrier shield and the window assembly when the shielding window assembly is inserted into the wall liner. Refer to Annex A3, Fig. A3.6 and Fig. A3.8, for sketches of trim frame configurations and stepped wall liner configuration.

6.2.4 *Gas Purge:*

6.2.4.1 An inert gas purge line and a gas vent line should be provided at the cold side wall liner face to supply and exhaust inert gas to and from the cavity between the barrier shield and window assembly.

6.2.4.2 Consideration shall be given not to exhaust contamination to the cold side, should the primary barrier shield seal malfunction. All seal welds shall be continuous so that the liner and flanges will provide an inert gas tight seal.

6.2.5 *Gaps—Liner to Housing:*

6.2.5.1 The interface between the wall liner and the shielding window assembly shall be designed to provide a gap at the top and sides to allow centering the shielding window in the wall liner cavity. The gap is to provide for window interchangeability.

6.2.5.2 A gap shall be provided between the window and the wall liner at the bottom. The inside bottom surface of the wall liner shall be designed to mate with the skids or rollers on the shielding window assembly.

6.2.6 *Concrete Anchors:*

6.2.6.1 Where required, the embedded wall liners shall have concrete anchors secured to the assembly exterior where the wall liner surfaces are in contact with the concrete wall.

6.2.7 *Liner Handling:*

6.2.7.1 Each wall liner shall have suitable lifting points for handling purposes.

6.2.8 *Temporary Bracing:*

6.2.8.1 The embedded wall liner will also be utilized as a form for placing concrete when the shielding wall is poured.

6.2.8.2 The Manufacturer shall provide and install internal horizontal and vertical temporary bracing as necessary for the embedded wall liners such that the required tolerances are maintained during shipment and installation.

6.2.8.3 Any bracing shall be placed such that the vent holes shall be accessible during the concrete pour.

6.2.8.4 The temporary bracing shall be removed at the time when the concrete forms are removed.

6.2.9 *Vent Holes:*

6.2.9.1 Vent holes shall be cut into the bottom surface of the wall liners as required to accommodate the removal of trapped air pockets during the concrete pour.

6.2.9.2 The vent holes in the wall liners shall be seal welded closed and liquid dye penetrant examined before window installation.

6.3 *Shielding Window Assemblies:*

6.3.1 *Design:*

6.3.1.1 The window housings shall be of a single or multi-step construction to prevent radiation streaming.

6.3.1.2 The window housings shall be designed to provide the necessary shielding to compensate for the gap between the window housing and the wall liner.

6.3.1.3 Shielding window assemblies of the same size shall be interchangeable with wall liners of the same size. Window designs (components and sub-assemblies) should be toleranced accordingly for interchangeability. Refer to Annex A3, Figs. A3.1 and A3.2, for sketches of the shielding window configurations.

6.3.2 *Structure:*

6.3.2.1 The shielding windows shall be dry lead glass or oil-filled lead glass.

6.3.2.2 The shielding window housings shall be constructed of carbon steel or stainless steel weldments, or iron or stainless steel castings. It is recommended that the hot side of the windows, where exposed to corrosive environments, be constructed of stainless steel weldments or stainless steel castings.

6.3.2.3 Materials used in the construction of shielding windows shall be suitable for the specific application as recommended by the designer or manufacturer, and as approved by the Owner-Operator. Refer to Section 7.2 Steel/Castings.

6.3.2.4 Shielding Windows designed with encased concrete or magnetite shall be provided with external vent holes near the cold side to relieve possible pressure buildup that may occur from the creation of hydrogen and oxygen gases caused by decomposition of the concrete or magnetite under long-term radiation exposure.

6.3.2.5 Porous castings that may trap contamination shall not be permitted. Castings shall be inspected for surface defects and porosity after machining. Castings shall also be inspected for internal voids by ultrasonic or X-ray testing. These inspections verify surface and internal casting quality, which assures structural soundness, radiological containment and adequate shielding.

6.3.3 *Sealing Systems:*

6.3.3.1 The window housing shall incorporate a gasket to provide a secondary containment seal at the cold side of the wall liner or at the most cold side step of the wall liner. This may be accomplished by machining a surface at the wall liner. The window manufacturer shall recommend a method to compress the seal at the wall liner. The purpose of the seal is to eliminate moisture between the hot side face of the window and barrier shield.

6.3.3.2 Carbon steel or stainless steel trim frame assemblies with cover glasses and sealing gaskets may be mounted at both the hot side and cold side faces of the shielding window assemblies, forming a gas tight chamber within the window cavities.

6.3.3.3 The Owner-Operator shall specify the requirement for a hot side trim frame assembly for a dry lead glass window.

6.3.3.4 The hot side and cold side surfaces of the window housings shall be designed to provide a sealing surface for the seal gaskets and a mounting surface for the trim frame assemblies as required.

6.3.3.5 The hot side seal gasket for the hot side cover glass where used shall be placed between the cold side face of the glass and the machined steel face at the hot side of the shielding window assembly.

6.3.3.6 The cold side seal gasket for the cold side cover glass shall be placed similarly.

6.3.3.7 The joints of the seal gaskets shall be vulcanized (not glued), or the gasket shall be cookie cut from a solid sheet of gasket material. Refer to Annex A3, Fig. A3.6 and Fig. A3.8, for sketches of trim frame configurations.

6.3.3.8 The compression gaskets shall be located between the trim frame clamping flange and the cover glass.

6.3.4 *Roller/Skids:*

6.3.4.1 A pair of skids shall be located on the underside of the shielding window assemblies. The purpose for the skids is to assist in the installation and removal of the windows and also to help properly align the window assemblies within the wall liners.

6.3.4.2 The skids shall be designed to match the internal bottom surfaces of the wall liners and to insure a perpendicular fit-up. Machining of matching surfaces is recommended.

6.3.4.3 An alternative method to using skids is to use rollers mounted in the external underside of the shielding window assemblies.

6.3.5 *Window Handling:*

6.3.5.1 The windows shall be provided with suitable lifting points.

6.3.5.2 A suitable attachment method for extracting and installing the windows shall be provided.

6.3.6 *Shielding Glass:*

6.3.6.1 Polished glass slabs shall be installed into the window housings and secured to the interior sides of the window housings with lead packing or other suitable shielding material.

6.3.6.2 The window assemblies shall provide the desired shielding while maintaining optical clarity.

6.3.6.3 The glass slabs shall be secured within the window housings in a manner as to prevent loss of shielding during a seismic event. Refer to paragraph 6.3.11.2.

6.3.7 *Cover Glasses:*

6.3.7.1 The hot side cover glass, where installed, shall provide as a minimum 25 % greater allowable surface pressure than the cold side cover glass. The purpose for this requirement is to assure the cold side cover glass ruptures first in the event of over-pressurization of the shielding window assembly.

6.3.7.2 During purging and oil changing, a polycarbonate panel should be installed over the external surface of the cold side cover glass and mounted to the trim frame. This panel shall serve as a safety shield in case the cold side cover glass ruptures.

6.3.8 *Purge Systems:*

6.3.8.1 *Design:*

(1) Where excessive temperature cycling may be present, it is important to keep ambient air and moisture from entering the internal window cavity to prevent filming on the internal glass surfaces.

(2) Provisions shall be made in the shielding window assemblies for the free flow of inert gas, or shielding oil beneath each internal glass slab, and for the venting of inert gas, or flow of shielding oil over the top of each internal glass slab during the purging or oil filling and oil draining processes.

(3) Passages for inert gas and oil flow shall be designed with offsets to prevent radiation streaming through the shielding window.

(4) The shielding window assemblies shall be designed such that they may be filled, drained, gas purged, and vented from the cold side, without removal of the shielding window assemblies from the wall liners.

(5) There shall be no residual oil trapped at the bottom of the shielding window assemblies when the oil is drained and there shall be no air pockets trapped at the top of the shielding window assemblies when the shielding windows are filled with oil.

(6) The oil fill and drain system should be designed such that the entire shielding window assembly can be filled or drained without interruption of flow in approximately one hour. This recommendation is to eliminate potential stain lines on the glass surfaces due to interruption of oil flow.

6.3.9 *Components:*

6.3.9.1 All fittings and valves shall be stainless steel. No fluoropolymer resin packing shall be allowed in the valves or used as a thread sealant on the threaded fittings.

6.3.9.2 A desiccant air dryer assembly shall be mounted above each shielding window and connected to the window ventilation system (both inside the window and between the window and wall liner cavity) and also to the inert gas purge system. On an oil window, the desiccant air dryer shall be located above the oil expansion tank.

6.3.9.3 The inert gas purge system shall have a pressure reduction valve and a pressure relief valve or bubbler system to reduce the inert gas pressure on the windows to a maximum of 1.7 kPa [0.25 psi].

6.3.9.4 There shall be a valve in line above the desiccant air dryer assembly to shut off the supply of the inert gas when changing out the air dryer crystal cartridge.

6.3.9.5 The air dryer shall be easily accessible for change out of the air dryer cartridge.

6.3.9.6 There shall also be a valve mounted on the lower cold side face of the shielding window assembly for draining oil from the window or for purging and venting the window.

6.3.9.7 Where an inert gas system is unavailable or impractical, the top of the air dryer shall be sealed with an expandable bellows of neoprene or other suitable material to seal the window cavity from the ambient air and still allow for expansion of the inert gas or shielding oil. Bellows manufactured of latex material are not recommended.

6.3.10 *Oil Expansion Tank:*

6.3.10.1 An oil expansion tank shall be provided for each oil-filled shielding window assembly. The oil expansion tank shall be mounted at the Manufacturer's recommended height above the top of the cold side cover glass, and shall be free from all interference from other equipment. A recommended practice is to mount the oil expansion tank no more than 2 ft. above the window assembly to prevent over-pressurization of the window.

6.3.10.2 The expansion tank shall be constructed of stainless steel (preferred) or glass and shall provide adequate expansion for the shielding oil in the window assembly.

6.3.10.3 The expansion tank shall be designed and mounted in a manner so that no residual oil remains in the tank when the tank is drained.

6.3.10.4 It shall have a bottom connection for feeding oil to the window, a top connection for connecting to the inert gas purge line, and a replaceable sight gauge for visually checking the oil level in the expansion tank.

6.3.10.5 The expansion tank shall be leak tested to the same pressure requirements as the window housing.

6.3.11 *Seismic Restraints:*

6.3.11.1 Seismic restraints shall be bolted to the cold side face of each wall liner to secure each shielding window assembly in position.

6.3.11.2 Stainless steel seismic restraints shall be positioned inside of the window assembly to secure the glass components from movement. Carbon steel should not be used.

6.3.12 *Installation/Removal:*

6.3.12.1 The shielding window assemblies are typically moved with the use of a lift truck, bridge crane, or boom crane.

6.3.12.2 The window assemblies shall be installed with the use of an installation/extraction table or other suitable device.

6.3.12.3 The insulated multi-strand copper grounding strap must be fastened to the cold side face of the window assembly and connected to the building ground system during installation. A continuity check shall be made between the shielding window and the building ground upon completion of the installation to ensure proper grounding.

6.4 *Shielding Wall Plugs:*

6.4.1 *Design:*

6.4.1.1 The shielding plugs shall have the same external configuration as the shielding windows and shall be of a single or multi-step construction to prevent radiation streaming.

6.4.1.2 The shielding plugs shall be designed to provide the necessary shielding to compensate for the gap between the shielding plug and the wall liner.

6.4.1.3 Shielding plugs of the same size shall be interchangeable as though they were shielding windows fitting into wall liners of the same size. Shielding plug designs (components and sub-assemblies) should be toleranced accordingly for interchangeability. Refer to Annex A3, Figs. A3.1 and A3.2, for sketches of the shielding window configurations.

6.4.2 *Structure:*

6.4.2.1 The shielding plugs shall be constructed of carbon steel or stainless steel weldments, or iron or stainless steel castings. It is recommended that the hot side of the plugs, where exposed to corrosive environments, be constructed of stainless steel weldments or stainless steel castings.

6.4.2.2 Porous castings that may trap contamination shall not be permitted. Castings shall be inspected for surface defects and porosity after machining. Castings shall also be inspected for internal voids by ultrasonic or X-ray testing. These inspections verify surface and internal casting quality, which assures structural soundness, radiological containment, and adequate shielding.

6.4.2.3 Materials used in the construction of shielding plugs shall be suitable for the specific application as recommended by the designer or manufacturer, and as approved by the Owner-Operator. Refer to 7.2, Steel/Castings.

6.4.2.4 Shielded Wall Plugs designed with encased concrete or magnetite shall be provided with external vent holes near the cold side to relieve possible pressure buildup that may occur from the creation of hydrogen and oxygen gases caused by decomposition of the concrete or magnetite under long-term radiation exposure.

6.4.3 *Sealing System:*

6.4.3.1 The shielding plug shall incorporate a gasket to provide a secondary containment seal at the cold side of the wall liner or at the most cold side step of the wall liner. This may be accomplished by machining a surface at the wall liner. The manufacturer shall recommend a method to compress the seal at the wall liner. The purpose of the seal is to eliminate moisture between the hot side face of the plug and barrier shield.

6.4.4 *Rollers/Skids:*

6.4.4.1 A pair of skids shall be located on the underside of the shielding plugs. The purpose of the skids is to assist in the installation and removal of the shielding plugs and also to help properly align the shield plugs within the wall liners.

6.4.4.2 The skids shall be designed to match the internal bottom surfaces of the wall liners and to ensure a perpendicular fit-up. Machining of matching surfaces is recommended.

6.4.4.3 An alternative method to using skids is to use rollers mounted in the external underside of the shielding plugs.

6.4.5 *Shielding Wall Plug Handling:*

6.4.5.1 The shielding plugs shall be provided with suitable lifting points. A suitable attachment method for extracting and installing the shielding plug shall be provided.

6.4.6 *Seismic Restraints:*

6.4.6.1 Seismic restraints shall be bolted to the cold side face of each wall liner to secure each shielding plug in position.

6.4.7 *Installation/Removal:*

6.4.7.1 The shielding plugs are typically moved with the use of a lift truck, bridge crane, or boom crane.

6.4.7.2 The shielding plugs shall be installed with the use of an installation/extraction table or other suitable device.

6.4.7.3 The insulated multi-strand copper grounding strap must be fastened to the cold side face of the shielding plug and connected to the building ground system during installation. A continuity check shall be made between the shielding plug and the building ground upon completion of the installation to ensure proper grounding.

6.5 *Barrier Shield Assemblies:*

6.5.1 *Design:*

6.5.1.1 The barrier shield frame shall be of a size sufficient to carry the weights of itself, the barrier shield glass, and the other components that make up the barrier shield, with minimal deformation. Refer to Annex A3, Figs. A3.7 and A3.8, for sketches of the barrier shield configurations.

6.5.2 *Structure:*

6.5.2.1 Consideration shall be given to the hot cell environment, ability to decontaminate, and compatibility with other materials in which they are in contact, when selecting materials of construction.

6.5.2.2 The barrier shield frames shall be constructed of fabricated carbon steel or stainless steel weldments, or iron or stainless steel castings. It is recommended the barrier shield frames, where exposed to corrosive environments be constructed of stainless steel weldments or stainless steel castings.

6.5.2.3 Porous castings that may trap contamination shall not be permitted. Castings shall be inspected for surface defects and porosity after machining. Castings shall also be inspected for internal voids by ultrasonic or X-ray testing. These inspections verify surface and internal casting quality, which assures structural soundness, radiological containment, and adequate shielding.

6.5.2.4 Materials used in the construction of barrier shield frames shall be suitable for the specific application as recommended by the designer or manufacturer, and as approved by the Owner-Operator. Refer to 7.2, Steel/Castings.

6.5.3 *Barrier Shield Glass and Assemblies:*

6.5.3.1 The barrier shield glass shall provide as a minimum 25 % greater allowable surface pressure than the cold side cover glass.

6.5.3.2 The barrier shield assembly shall provide mechanical protection for the shielding window assembly and shall provide a gas tight buffer seal so that the shielding window assembly can be removed from the wall liner without breaching the containment boundary.

6.5.4 *Hot Side Window Guard:*

6.5.4.1 Where appropriate for safety protection from glass breakage or dielectric discharging due to manipulator arms impacting the hot side glass surface; consideration should be given to the installation of a removable metal grid, polycarbonate sheet, or other suitable guard at the very hot side of the barrier shield.

6.5.5 *Sealing System:*

6.5.5.1 The barrier shield assembly shall have a buffer seal gasket, which seals the barrier shield assembly to the wall liner flange.

6.5.6 *Installation/Removal:*

6.5.6.1 For remote operations, the barrier shield shall be capable of being removed and replaced remotely from the hot side of the window assembly.

6.6 *View Ports:*

6.6.1 *Design:*

6.6.1.1 The view port housings shall be of a single or multi-step construction to prevent radiation streaming.

6.6.1.2 The view port housings shall be designed to provide the necessary shielding to compensate for the gap between the view port housing and the wall liner.

6.6.1.3 View port assemblies of the same size shall be interchangeable with wall liners of the same size. View port designs (components and sub-assemblies) should be toleranced accordingly for interchangeability.

6.6.2 *Structure:*

6.6.2.1 The view ports shall be dry lead glass.

6.6.2.2 The view port housings shall be constructed of carbon steel or stainless steel weldments or iron or stainless steel castings. It is recommended that the hot side of the view ports, where exposed to corrosive environments, be constructed of stainless steel weldments or stainless steel castings.

6.6.2.3 Porous castings that may trap contamination shall not be permitted. Castings shall be inspected for surface defects and porosity after machining. Castings shall also be inspected for internal voids by ultrasonic or X-ray testing. These inspections verify surface and internal casting quality, which assures structural soundness, radiological containment, and adequate shielding.

6.6.2.4 Materials used in the construction of view ports shall be suitable for the specific application as recommended by the designer or manufacturer, and as approved by the Owner-Operator. Refer to 7.2 Steel/Castings.

6.6.2.5 View Ports designed with encased concrete or magnetite shall be provided with external vent holes near the cold side to relieve possible pressure buildup that may occur from the creation of hydrogen and oxygen gases caused by decomposition of the concrete or magnetite under long-term radiation exposure.

6.6.3 *Sealing System:*

6.6.3.1 The view port shall incorporate a gasket to provide a secondary containment seal at the cold side of the wall liner or at the most cold side step of the wall liner. This may be accomplished by machining a surface at the wall liner. The manufacturer shall recommend a method to compress the seal at the wall liner. The purpose of the seal is to eliminate moisture between the hot side face of the view port and barrier shield.

6.6.3.2 Carbon steel or stainless steel trim frame assemblies or corner clips may be used to secure cover glasses and sealing gaskets at both the hot side and cold side faces of the view port assemblies.

6.6.4 *View Port Handling:*

6.6.4.1 The view ports shall be provided with suitable lifting points.

6.6.4.2 A suitable attachment method for extracting and installing the view ports shall be provided.

6.6.5 *Cover Glasses:*

6.6.5.1 Cover glasses may be bonded or laminated to the shielding glass in a view port assembly.

6.6.6 *Seismic Restraints:*

6.6.6.1 Seismic restraints shall be bolted to the cold side face of each wall liner to secure each view port assembly in position.

6.6.6.2 Stainless steel seismic restraints shall be positioned to secure the glass components within the view port assembly. Carbon steel shall not be used.

6.6.7 *Installation/Removal:*

6.6.7.1 The view port assemblies are typically moved with the use of a lift truck, bridge crane, or boom crane.

6.6.7.2 The view port assemblies shall be installed with the use of an installation/extraction table or other suitable device.

6.6.7.3 The insulated multi-strand copper grounding strap must be fastened to the cold side face of the view port assembly and connected to the building ground system during installation. A continuity check shall be made between the view port and the building ground upon completion of the installation to ensure proper grounding.

6.7 *Installation/Extraction Table/Device:*

6.7.1 *Design:*

6.7.1.1 The installation/extraction table/device or other suitable equipment shall be designed to perform installation and removal of the shielding windows, shielding plugs, and view ports into or out of the wall liner openings from the cold side of the hot cell.

6.7.2 *Structure:*

6.7.2.1 The table/device shall be constructed of fabricated carbon steel or stainless steel for ease of decontamination. Cast iron or cast stainless steel shall not be used in any weight bearing member.

6.7.2.2 The table/device shall be designed to safely raise a load of 1.25 times the actual load being raised to the desired height for installation or removal.

6.7.2.3 Materials used in the construction of table/device shall be suitable for the specific application as recommended by the designer or manufacturer, and as approved by the Owner-Operator. Refer to 7.2, Steel/Castings.

6.7.3 *Overturning:*

6.7.3.1 The design shall include features that permit attaching the table/devise to the wall liner to eliminate movement and overturning during the installation or removal process of the shielding windows, shielding plugs, or view ports. The design should also include a provision to prevent the hydraulic table from moving or lowering during use.

6.7.4 *Special Tools:*

6.7.4.1 The table/device shall include all special tools such as come-a-longs, chains, steel cables, grounding cables, jacks, levels, shackles, threaded rods, special fasteners, etc., to perform the installation or removal of the shielding windows, shielding plugs, or view ports.

6.7.5 *Testing:*

6.7.5.1 The load testing of the table/device provides reasonable assurance that the table/device will function properly when installing the window components.

6.7.5.2 The table/device shall be tested for performance to demonstrate satisfactory operation, and functional design under operating conditions. Refer to 10.8.

6.7.6 *Table/Device Handling:*

6.7.6.1 The table/device shall have suitable lifting points for handling purposes.

6.7.6.2 The Owner-Operator shall specify the requirement for wheels, rollers, and special equipment required to move the table/device under load. The designer shall confer with the Owner-Operator regarding proper floor loading.

7. Material Requirements

7.1 *Glass:*

7.1.1 Shielding glass shall comply with the requirements as set out in Atomic Energy Standard Specification AESS (R) 44/70000/6. It is important that the glass slabs and cover glasses are of the best quality and that there are no visual defects in the central viewing area that are detrimental to the operator performing his work through the window or view port.

7.1.1.1 *Inclusions (Bubbles, Stones, Seeds):*

(1) The glass provided shall be free of significant defects.

(2) Any inclusion which is within the size limitation specified will individually not be considered to be a significant defect, but where more than an allowable number of inclusions are present and they collectively will represent a significant defect.

(3) Permissible inclusions are specified in Table 1.

7.1.1.2 *Striae:*

(1) All glass shall meet AESS (R) 44/70000/6 specifications for optical glass with respect to striae.

7.1.1.3 *Surface Finish:*

(1) The surface finish in the central area of the optical faces shall be free of defects other than light short finish. Optical faces of glass plates or slabs that are for gasket sealing surfaces shall be flat to accommodate a seal. The edge surfaces of glass slabs shall be dull and nonreflecting, equivalent to a surface produced by acid etching, sawing, or sand blasting.

7.1.1.4 *Surface Defects:*

(1) Chips and checks which do not extend into the glass more than 2 % of the nominal width or length dimensions shall be permitted on edge surfaces which will not be gasketed, provided they do not exceed 25 mm [1 in.] and are neatly ground so that no cracks can originate at such defects.

(2) For gasketed glass slabs, edge chips and cracks that are neatly ground out and do not extend into the polished area used for gasket seating shall be permitted.

7.1.1.5 *Dielectric Discharge Resistance:*

(1) Hot side cover glasses and barrier shield glasses subjected to very high radiation shall be constructed of a glass composition which, when irradiated to 1×10^7 Gy [1×10^9 rads] (accumulated dose) shall not electrically discharge.

7.1.1.6 *Browning:*

TABLE 1 Permissible Inclusions

Inclusion Size		Number of Inclusions Allowed	
mm	in.	Central Viewing Area	Outer Viewing Area
<0.25	[<0.01]	Allow up to 5 in any one 25 mm [1 in.] dia. area only	Ignore
0.25–0.75	[0.01–0.03]	100 (min separation 25 mm) [1 in.]	Ignore
0.75–1.0	[0.03–0.04]	10 (min separation 100 mm) [4 in.]	20
1.0–1.5	[0.04–0.06]	2	5
>1.5	[>0.06]	None	None

(1) The shielding windows shall be designed so that the glass components shall not prematurely brown when exposed to the accumulated design life dosage at that location.

(2) Cerium-stabilized glass shall be utilized in an appropriate manner to eliminate browning.

(3) Internal glass shielding slabs shall not be bonded or laminated where exposed to radiation in excess of 1 kGy [1 × 10^5 rads] (accumulated dose).

7.1.1.7 *Glass Compatibility:*

(1) Bonded or laminated glass slabs shall not be used in windows filled with shielding oil.

7.1.1.8 *Dimensional and Geometrical Tolerance:*

(1) The dimensional and geometrical tolerances for plates and glass slabs shall be as specified in Tables 2-4.

7.1.1.9 *Traceability:*

(1) Each glass slab or glass plate shall have a unique identification number. The number shall be permanently marked on the glass as agreed with the Owner-Operator, typically on the lower right-hand edge. The Manufacturer shall maintain full traceability.

7.1.1.10 *Anti-Reflection Treatment:*

(1) Glass surfaces on a dry lead glass window may be anti-reflective treated to meet light transmission requirements. On an oil-filled lead glass window, no internal glass surfaces need be treated. Only the hot side surface of the hot side cover glass and the cold side surface of the barrier glass may be treated. The general surface appearance of each slab or cover glass so treated shall be uniform when viewed along a line of sight perpendicular to the optical surfaces. The light transmission of each slab or cover glass so treated shall be recorded after the treatment. The method of anti-reflective treatment and the results of the treatment shall be noted on the inspection certificate.

7.2 *Steel/Castings:*

7.2.1 All metal materials in the wall liner embedments, window housings, shielding plugs, barrier shield assemblies, and view ports shall comply with applicable standards referenced in Section 2, Referenced Documents, and Other References. Materials used in the construction shall be suitable for the specific application as recommended by the designer or manufacturer, and as approved by the Owner-Operator. Suggested materials, but not limited to, are as follows: Specification A36/A36M for carbon steel, Specification A240/A240M for stainless steel, Specifications A27/A27M and A48/A48M for iron castings, and Specification A747/A747M for stainless steel castings.

TABLE 2 Plate and Slab Thickness Tolerances

Maximum Side Dimensions	Thickness	
	mm	in.
Plates	+0, -1.5	[+0, -0.06]
Slabs up to 400 mm [16 in.] in length	+0, -2	[+0, -0.08]
Slabs up to 600 mm [24 in.] in length	+0, -3	[+0, -0.12]
Slabs over 600 mm [24 in.] in length	+0, -4	[+0, -0.16]

NOTE 1—The combined amount of wedge and flatness deviation shall not exceed the thickness tolerance.

TABLE 3 Plate and Slab Side Length or Diameter Dimensional Tolerances

Maximum Side Length or Diameter Dimension	Length, Width, and Diameter	
	mm	in.
Up to 400 mm [16 in.] dimension	+0, -4	[+0, -0.16]
400 mm [16 in.] to 600 mm [24 in.] dimension	+0, -5	[+0, -0.20]
Over 600 mm [24 in.] dimension	+0, -6	[+0, -0.24]

NOTE 1—The faces of all slabs and plates shall be parallel within the limits defined by the geometrical tolerances.

TABLE 4 Bevel Dimensional Tolerances

Bevels	Beveled Width	
	mm	in.
The edges of all glass shall be beveled at 45° to reduce the risk of edge damage	3.0 ± 1.0	[0.12 ± 0.04]

7.3 *Gasket Material:*

7.3.1 The gasket material for the shielding window and view port assemblies shall be suitable for the designed high radiation environment, and shall have proven compatibility with internal window materials.

7.3.2 The gaskets shall be designed to meet the design life and duty cycle of the window, as specified by the Owner-Operator.

7.4 *Shielding Oil:*

7.4.1 The shielding oil shall be an optically clear mineral oil; modified, purged, and tested. Failure to properly test the shielding oil may allow unwanted moisture to enter the window cavity. Moisture may deposit on the glass surfaces and cause the glass surfaces to fog and allow the window to become opaque. The shielding oil shall meet the following specifications.

7.4.1.1 Peroxide number (H_2O_2 content) for new oil shall be <1.0 parts per million (ppm). The test method shall be as specified by the Owner-Operator.

7.4.1.2 Water content as determined by Test Method D1533 for new oil shall be <10 parts per million (ppm).

7.4.1.3 Safety Data Sheets (SDS) for the shielding oil shall be submitted to the Owner-Operator.

7.5 *Paints and Coatings of Metal Surfaces:*

7.5.1 The carbon steel or cast iron surfaces of the wall liner embedments, window housings (including any glass band frames contained within the window), shielding plugs, barrier shield assemblies, and view ports shall be cleaned and sandblasted of rust and scale and coated with an epoxy compatible with shielding oil, lead glass, lead metal, and the sealing gaskets.

7.5.1.1 The epoxy shall be suitable for the design dose.

7.5.1.2 Solvent cleaned, sandblasted, and painted surfaces shall comply with the requirements of the Steel Structures Painting Council; Solvent cleaning SSPC-SP1, Commercial Sandblast Cleaning SSPC-SP5, and Paint Application Specification SSPC-PA1.

7.5.1.3 The surfaces to be embedded in the concrete shall be cleaned and sandblasted, but not coated.

7.5.1.4 Stainless steel surfaces shall not be sandblasted and must be protected during the sandblasting and coating process. The stainless steel surfaces shall not be coated.

7.6 *Lead:*

7.6.1 Lead sheet or lead wool used within the window assemblies and view ports shall be to Federal Standard QQ-C-40. The material shall be cleaned as necessary for satisfactory long-term compatibility with the glass, epoxy coating, and oil used in the window assemblies and view ports.

8. Fabrication

8.1 *Welding Qualification:*

8.1.1 The Manufacturer's drawings shall specify all welds. Gas-tight seal welds shall be multiple-pass and clearly indicated. Welding and welder qualifications shall be performed in accordance with ANSI/AWS B2.1, ANSI/AWS D1.1/D1.1M, and ANSI/AWS D1.6/D1.6M.

8.1.2 Visual Weld Inspectors shall be certified as AWS/CWI. Certified Welding Inspectors (CWIs) shall comply with ANSI/AWS D1.1/D1.1M, or ANSI/AWS D1.6/D1.6M, as applicable, except that eye examinations shall be performed yearly to comply with NDE requirements.

8.1.3 Nondestructive Test Personnel performing weld examinations shall be certified in accordance with ASNT-SNT-TC-1A with a Level II, or Level III certification for each NDE method used, or a similar document recommended by the Manufacturer. The practice or standard used shall be mutually acceptable to the Manufacturer and the Owner-Operator.

8.2 *Acceptance Criteria:*

8.2.1 Structural welding shall be inspected and accepted using the criteria specified in ANSI/AWS D1.1/D1.1M and ANSI/AWS D1.6/D1.6M.

8.3 *Identification:*

8.3.1 Each wall liner embedment, shielding window housing, view port housing, shielding plug, barrier shield assembly, and extraction/installation table/device shall be stamped or etched with an individual serial number. These numbers shall be used by the Manufacturer on all records requiring identification of the components.

9. Assembly and Workmanship

9.1 *Housing Assembly:*

9.1.1 A segregated area, isolated from metal working machinery dust or glass processing dust, shall be used for assembly of the window components.

9.2 *Oil Expansion Tanks:*

9.2.1 The oil expansion tanks shall be flushed with a cleaning agent that shall leave no residue and then blown dry.

9.3 *Glass Surfaces:*

9.3.1 It is extremely important that the glass surfaces be properly cleaned prior to being installed in the window components. Smudges, fingerprints, suction-cup prints, rough deposits, water-marks, polishing compound, film, stains, and wiping marks that are left on the glass surfaces could become enhanced under radiation exposure and may eventually be the cause of poor visibility through the shielding window or view port.

9.3.2 The method for cleaning glass slabs (edge surface preparation, as well as optical viewing surfaces) shall be detailed in the Manufacturer's procedures and listed on the Manufacturer's manufacturing, inspection, and test plan.

9.3.3 The glass surfaces shall be cleaned with glass cleaning materials that will leave no residue on the glass surfaces.

9.3.4 Each glass slab or cover glass shall be carefully inspected prior to insertion into the window housing or view port by a window technician and by a quality assurance glass inspector. There shall be no smudges, fingerprints, suction cup prints, rough deposits, watermarks, polishing compound, film, stains, and wiping marks on the viewing surfaces.

10. Testing and Inspection

10.1 *Testing, Inspection and Reporting:*

10.1.1 All testing, inspection certification and reporting performed in the Manufacturer's facility and the Owner-Operator's facility will be the responsibility of the Manufacturer per an agreed-upon leak test requirement between the Manufacturer and the Owner-Operator. It is recommended that the Manufacturer submit a manufacturing, inspection, and test plan, which includes leak testing steps at phases of the fabrication and assembly process, to the Owner-Operator prior to start of fabrication.

10.2 *Wall Liner Embedments:*

10.2.1 All relevant joints, seals, and surfaces shall be checked for leakage.

10.2.2 The wall liner embedment shall pass a leak test to establish that the liner is gas tight within the limits herein specified.

10.2.3 The wall liner openings should be blanked off and sealed. The wall liner cavity shall be filled with helium to a differential pressure of between 300 and 450 mm [12 and 18 in.] WG, and held for a one-hour period of time at a controlled temperature, with less than 0.5 % measurable decay in the WG column. After the one-hour period, all gaskets, joints, and seams shall be checked for leaks with a calibrated helium leak detector to a recommended rate of less than 1×10^{-4} cc/s [6.1×10^{-6} in.^{3}/s]. Leak testing should be performed per Test Methods E2024 or an agreed upon applicable procedure between the Manufacturer and the Owner-Operator. Test pressures may differ depending on the wall liner embedment design.

10.2.4 Some testing applications may require a longer probe to gain access to the joint or seam being tested. If a probe extension of 300 mm [12 in.] or longer is used on the tip of the leak rate testing instrument, a reduced sensitivity leak rate of 1×10^{-3} cc/s [6.1×10^{-5} in.^{3}/s] is acceptable.

10.2.5 The requirement for leak testing the window housing or view port housing and window assembly cavities and the cavities between the wall liner and shielding window, shielding plug, or view port insures that the window cavities remain filled with inert gas, as moisture from the atmosphere may collect and fog the glass surfaces if leakage occurs.

10.2.6 The liner shall be tested with a pseudo or real barrier shield assembly and pseudo or real window housing. The results of the leak test shall be recorded. An inspection certificate shall be prepared for each assembly.

10.3 *Window and View Port Housings:*

10.3.1 Prior to coating, all relevant joints, seals, and surfaces shall be checked for leakage.

10.3.2 The window housing, view port housing, and expansion tank shall pass a leak test identical to that of the wall liner embedment. The results of the leak test shall be recorded. An inspection certificate shall be prepared for each assembly.

10.4 *Glass Slabs and Glass Plates:*

10.4.1 Each finished glass slab and glass plate shall be inspected and an individual inspection record shall be prepared with an identification number of the slab or glass plate. The record shall indicate the condition of any checks, chips, striae, inclusions, dimensions, and density of the glass.

10.4.2 The light transmission of each slab shall also be recorded. If the glass slab or cover glass is to receive low-reflective treatment or etching, the light transmission shall be recorded again after treatment.

10.5 *Shielding Window and View Port Assemblies:*

10.5.1 After installing the glass, prior to purging or filling with oil, or both, the window assembly or view port assembly shall be filled with helium to a differential pressure of between 300 and 450 mm [12 and 18 in.] WG and held for a 1-h period of time at a controlled temperature, with less than 0.5 % measurable decay in the WG column. After the 1-h period, all gaskets, joints, and seams shall be checked for leaks with a calibrated helium leak detector to a recommended rate of less than 1×10^{-4} cc/s [6.1×10^{-6} in.^{3}/s]. Leak testing should be performed per Test Methods E2024 or an agreed upon applicable procedure between the Manufacturer and the Owner-Operator. Test pressures may differ depending on the window assembly or view port assembly design. In practice, the smaller helium molecule is able to find leak paths that denser materials (air, nitrogen, or oil) cannot exploit.

10.5.2 Some testing applications may require a longer probe to gain access to the gasket, joint or seam being tested. If a probe extension of 300 mm [12 in.] or longer is used on the tip of the leak rate testing instrument, a reduced sensitivity leak rate of 1×10^{-3} cc/s [6.1×10^{-5} in.^{3}/s] is acceptable. The results of the leak test shall be recorded. An inspection certificate shall be prepared for each assembly.

10.5.3 Check for stain lines on the glass due to interpretation of oil flow into the window assembly. Refer to 6.3.8.1 (**1**). If there are stain lines, the window assembly must be disassembled, cleaned, re-tested, and refilled.

10.5.4 After the window or view port has been completely assembled, viewing angles shall be tested for compliance to the Owner-Operator requirements.

10.5.5 After the window or view port has been completely assembled, the overall light transmission shall be tested for compliance to the Owner-Operator requirements.

10.5.6 The light transmission, viewing angles and visual appearance of the complete window or view port assembly shall be recorded. A certificate shall be prepared for the window or view port assembly recording the measured light transmission, viewing angles, and the serial numbers of the window or view port housing and all glass components; any additional glass defects (new chips, etc.); and the results of the leak test. The window or view port assembly transmission multiplied by the transmission of the barrier shield glass shall be used to determine the overall window or view port transmission.

10.6 *Barrier Shield Assemblies:*

10.6.1 All relevant joints, seals, and surfaces shall be checked for leakage.

10.6.2 The barrier shield frame assembly shall be tested on the hot side wall liner flange embedment with a pseudo or shielding window assembly, or view port assembly secured within the wall liner. The test shall verify the barrier shield to liner fit-up and the leak-tightness of the production-type primary gas-sealing gasket on the barrier shield.

10.6.3 The cavity between the barrier shield frame assembly and the pseudo or shielding window assembly, or view port assembly shall be filled with helium to a differential pressure of between 300 and 450 mm [12 and 18 in.] WG, and held for a 1-h period of time at a controlled temperature, with less than 0.5 % measurable decay in the WG column. After the 1-h period, all gaskets, joints, and seams shall be checked for leaks with a calibrated helium leak detector to a recommended rate of less than 1×10^{-4} cc/s [6.1×10^{-6} in.^{3}/s]. Leak testing should be performed per Test Methods E2024 or an agreed upon applicable procedure between the Manufacturer and the Owner-Operator, or both. Test pressures may differ depending on the barrier shield assembly, window assembly, or view port assembly design. In practice, the smaller helium molecule is able to find leak paths that denser materials (air, nitrogen, or oil) cannot exploit.

10.6.4 Some testing applications may require a longer probe to gain access to the gasket, joint or seam being tested. If a probe extension of 300 mm [12 in.] or longer is used on the tip of the leak rate testing instrument, a reduced sensitivity leak rate of 1×10^{-3} cc/s [6.1×10^{-5} in.^{3}/s] is acceptable. The results of the leak test shall be recorded.

10.6.5 If glass is not available at this time, a suitable polycarbonate or metallic plate may be substituted in lieu of the glass. An inspection certificate shall be prepared for the barrier shield assembly.

10.7 *Shielding Window/Shielding Plug/View Port to Wall Liner Fit-Up:*

10.7.1 The shielding window, shielding plug, or view port shall be fit-up tested in the wall liner. The cavity between the shielding window assembly, shield plug, or view port assembly and the pseudo or barrier shield frame assembly shall be filled with helium to a differential pressure of between 300 and 450 mm [12 and 18 in.] WG and held for a 1-h period of time at a controlled temperature, with less than 0.5 % measurable decay in the WG column. After the 1-h period, all gaskets, joints, and seams shall be checked for leaks with a calibrated helium leak detector to a recommended rate of less than 1×10^{-4} cc/s [6.1×10^{-6} in.^{3}/s]. Leak testing should be performed per Test Methods E2024 or an agreed upon applicable procedure between the Manufacturer and the Owner-Operator. Test pressures may differ depending on the barrier shield, window assembly, shield plug, or view port assembly design. In practice, the smaller helium molecule is able to find leak paths that denser materials (air, nitrogen, or oil) cannot exploit. The test shall verify the leak-tightness and window, shielding plug, view port to wall liner embedment fit-up. The results of the leak test shall be recorded. An inspection certificate shall be prepared for each assembly.

10.8 *Installation/Extraction Table/Device:*

10.8.1 The table/device shall be tested for performance by the Manufacturer to demonstrate satisfactory operation and functional design under operating conditions. A load of 1.5 times the weight of the shielding window or shielding plug (whichever is heavier) shall be used for testing the installation/extraction table/device. Typical test criteria of the table shall be agreed upon by the Manufacturer and Owner Operator.

10.9 *Shielding Oil:*

10.9.1 The shielding oil shall be tested and certified for use in oil-filled lead glass shielding windows per the requirements set out in 7.4. Results of the test shall be recorded.

10.10 *Radiation Integrity Testing:*

10.10.1 The Owner-Operator, after installation of the window components should perform a radiation integrity test on each shielding window, view port, and each shielding plug to verify that the window components provide adequate shielding.

11. Hazard Sources and Failure Modes

11.1 **Warning:**

11.1.1 *Dielectric Discharge:*

11.1.1.1 Dielectric discharge of a glass component on a shielding window is a very serious hazard. The discharge can occur spontaneously due to dielectric breakdown in the dielectric strength of the material or it can be initiated by pressure or impact.

11.1.1.2 When a discharge occurs, a bright flash of light is emitted and a loud audible report is produced (sounding like a shotgun blast). A release of electrical energy of approximately 300 000 volts and 30 000 amps is not uncommon. It can cause death or serious injury. It is recommended that all necessary precautions be made in the design of the shielding window to eliminate the risk of a dielectric discharge.

11.1.1.3 It is extremely important that the proper glass components be selected and located in the correct positions within the shielding window assembly. Grounding the master-slave manipulators and the window assembly will allow the discharge to dissipate to ground if one should occur.

11.1.1.4 A 20 mm [0.75 in.] thick rubber mat placed on the floor at the cold side front of the window should be adequate to insulate the window technician from ground.

11.1.1.5 Strict compliance with procedures is recommended when operating hot cell equipment.

11.2 **Warning:**

11.2.1 *Over-pressurization:*

11.2.1.1 During installation and servicing, extreme care should be taken to avoid over-pressurizing the window cavity or the cavity between the wall liner and the window housing. Over-pressurization can cause the cover glass or barrier shield to rupture and shatter.

11.2.1.2 Strict compliance with procedures is recommended when purging the window cavities during installation or when servicing the shielding windows.

11.2.1.3 Care should be provided in the design of radiation shielding windows, shielded wall plugs, and view ports to ensure that when encased concrete or magnetite is used as internal shielding, that vent holes are provided near the cold side to relieve possible pressure to the atmosphere. Hydrogen and oxygen gas can be created from water hydration as the concrete or the magnetite mixture decomposes from exposure to high radiation, resulting in over pressurization.

11.3 **Warning:**

11.3.1 *Radiation Exposure:*

11.3.1.1 Radiation exposure to the window operator is a safety concern.

11.3.1.2 The shielding window components shall be designed to properly maintain containment during a seismic event and to attenuate the specified radiation in the hot cell.

11.3.1.3 Seismic, structural, and streaming calculations shall be made by the Manufacturer to ascertain proper attenuation and shielding.

11.4 **Warning:**

11.4.1 *Contamination:*

11.4.1.1 Contamination containment should be considered in the window design. The shielding window components shall be designed to properly contain radioactive materials within the hot cell.

11.4.1.2 Ease of decontamination should be considered in the window component design. This will reduce risk of exposure during maintenance/decommissioning.

11.5 **Warning:**

11.5.1 *Overturning of Installation/Extraction Table/Device:*

11.5.1.1 For personal safety, extreme care should be taken during the installation and removal of shielding windows, shielding plugs, or view ports to avoid overturning the installation/extraction table/device.

11.5.1.2 Strict compliance with procedures is recommended when installing or extracting radiation shielding windows, shielding plugs, or view ports.

11.5.1.3 The installation/extraction table/device shall be tested and certified to safely handle the load of the window components.

11.5.1.4 The installation/extraction table/device shall be secured with bolts to the wall embedment liner to restrict movement or overturning.

11.5.1.5 Bracing, or tie downs, shall be installed at the rear of the table/device to prevent it from backward and upward movement.

11.5.1.6 The installation/extraction table/device should include a provision to prevent the hydraulic table from lowering during use.

12. Procedures and Special Requirements

12.1 *Drawings:*

12.1.1 The Owner-Operator shall specify the fabrication, assembly and detail drawings, installation instructions, and associated drawings to be provided by the Manufacturer.

12.1.2 Drawings shall be prepared in accordance with ANSI Y 14 or other standards as specified by the Owner-Operator.

12.1.3 Weld symbols shall be prepared in accordance with ANSI/AWS A2.4 or other standards specified by the Owner-Operator.

12.2 *Reports and Documentation:*

12.2.1 The Manufacturer shall prepare and submit documentation according to the requirements of the Owner-Operator. Quality assurance requirements pertaining to documentation are specified in Section 5.

12.2.2 As a minimum, the Manufacturer shall prepare a manufacturing, inspection, and test plan; an acceptance test procedure, a quality assurance procedure, a shipping procedure, and an installation procedure.

12.3 *Document Submittals:*

12.3.1 Table 5 contains a list of recommended document submittals to be specified by the Owner-Operator.

13. Packaging, Handling, and Shipping

13.1 *Responsibility for Delivery:*

13.1.1 Responsibility for delivery of the window components to the Owner-Operator's facility shall be specified in the contract.

13.2 *Preparation for Shipment:*

13.2.1 Before crating, all exposed glass surfaces shall be covered to protect the glass from weathering and to reduce the possibility of scratching. The exposed glass surfaces shall be further protected from mechanical damage.

13.2.2 Provisions shall be made for expansion of the window components so they are not over-pressurized during transport and storage.

13.2.3 Each window assembly or window component shall be suitably packaged.

13.2.3.1 A vapor barrier with an enclosed desiccant package shall be wrapped around the window component.

TABLE 5 Recommended List of Document Submittals

Item	Description	Action by Owner-Operator
1.	Viewing Analysis	Approval
2.	Shielding Analysis	Approval
3.	Weld Procedures	Approval
4.	Welder Qualification Record	Approval
5.	Filler Material Control Program	Approval
6.	Weld Inspector Qualification Certification	Approval
7.	CMTR's for filler material	Approval
8.	Assembly Drawings	Approval
9.	As-Built Drawings	Approval
10.	Acceptance Test Procedures	Approval
11.	Quality Assurance Procedures	Approval
12.	Shipping Procedures	Approval
13.	Storage, Installation, and Maintenance Manuals	Approval
14.	Acceptance Test Reports	Reference
15.	Glass Data	Reference
16.	Catalog Cuts	Reference
17.	Material Information	Reference
18.	Material Samples	Approval
19.	Relevant NCR's	Approval
20.	Manufacturing, Inspection and Test Plan	Approval
21.	Material Safety Data Sheets (MSDS)	Reference

13.2.3.2 The window component shall be secured to the inside of the shipping crate and, where necessary, insulation shall be added to assure temperature changes to the window component of less than 3°C/h [5°F/h] for applicable shipment and indoor storage for a period to be specified by the Owner-Operator.

13.2.3.3 It is recommended that a temperature range of 4 to 27°C [40 to 80°F] be maintained on all glass bearing window components during transport and storage.

13.3 *Wall Liner Embedments, Window Assemblies, and Shielding Plugs:*

13.3.1 The components shall be crated as appropriate and shipped in the same attitude in which they will be installed.

13.4 *Barrier Shield:*

13.4.1 The barrier shield assemblies shall be crated and shipped on edge.

13.5 *Installation/Extraction Table/Device:*

13.5.1 The installation/extraction table/device and miscellaneous tools shall be crated as appropriate and separate from the window components.

13.6 *Handling and Hoisting:*

13.6.1 Shipping crates/skids shall be designed for lifting by a lift truck or with an overhead hoist. Each crate/skid shall have lift points clearly identified.

13.7 *Transport and Storage:*

13.7.1 All containers or packages shall be clearly labeled to show the purchase order number, weight, part number or name of the part or assembly, the Manufacturer, and the address to which shipped. The shielding window and barrier shield containers shall be marked "Fragile—Glass—Handle with Care."

13.7.2 It is recommended that all glass-bearing assemblies be shipped in an enclosed vehicle equipped with air suspension ride, with shock recorders (range 2 to 10 g, dependent on window design) mounted on the outside and within the glass-bearing crates. This recommendation is made to minimize breakage of the glass, which is the most expensive item in the shielding window assembly.

14. Installation and Maintenance

14.1 *Installation and Maintenance Services:*

14.1.1 It is recommended that the Owner-Operator specify that the following installation and maintenance services be provided by the Manufacturer:

14.1.1.1 Provision shall be made for installation supervision of the wall liner embedments.

14.1.1.2 Provision shall be made for a crew of shielding window technicians to install the shielding windows, shielding plugs, or view ports. They shall use the installation/extraction table/device and miscellaneous tools provided to perform the work. The Manufacturer shall identify on the detailed delivery schedule the estimated time required to install the shielding windows, wall plugs, or view ports.

14.1.1.3 Provision shall be made for a crew of shielding window technicians and a qualified quality assurance inspector to install the barrier shield and leak test the cavity between the shielding window, the wall liners, and the barrier shields.

14.1.1.4 Provision shall be made for specialized routine maintenance training on the window components at the Owner-Operator's facility for the hot cell engineers and operators.

14.1.1.5 Provision shall be made for necessary maintenance on the window components at the Owner-Operator's facility after the window components are installed. Recommended maintenance items may include re-torquing bolts, changing gaskets, taking oil test samples, performing analysis on oil samples, changing oil in the oil filled lead glass window assemblies, changing dryer cartridges in the window purge systems, cleaning glass components, and purging windows.

15. Keywords

15.1 barrier shield; dielectric discharge; dry lead glass window; hot cell; installation/extraction table/device; installation and maintenance; oil-filled lead glass window; shielding glass; shielding oil; shielding plug; shielding window; view port; wall liner embedment

ANNEXES

(Mandatory Information)

A1. RADIATION SOURCE SPECTRA AND GEOMETRY

TABLE A1.1 Sample Data

Isotope	Activity		Distance		Source Geometry
	GBq	Ci	mm	[in.]	
Co-60	370,000	10,000	914	[36]	Single Cylinder Source having a radius of 602 mm [23.7 in.], a length of 2408 mm [94.8 in.], and a Source Density of 2.7g/cc [0.097 lbs/in.^{3}]
Cs-137	37,000	1,000	914	[36]	
MIXED FISSION PRODUCTS	18,500	500	914	[36]	
					The Cylinder Source is vertical with the midpoint of the cylinder source located opposite the center of window.

TABLE A1.2 Blank

Isotope	Activity		Distance		Source Geometry
	GBq	Ci	mm	[in.]	

A2. SHIELDING WINDOW REQUIREMENT DATA SHEET

TABLE A2.1 Sample Data

Shielding Window Requirements	Units	Shielding Window Example	Shielding Window Example
Identification No.		1	2
Window Type—Dry Lead Glass or Oil Filled Lead Glass		Oil Filled Lead Glass	Dry Lead Glass
Hot Side Trim Frame Assembly Required		Yes	Yes
Initial Light Transmission, Min.		30 %	65 %
Radiation Source Spectra and Geometry		Annex A1	Annex A1
Average Distance from Source to Hot Side of Window	mm [in.]	914 [36]	914 [36]
Yearly Dose, Hot Side	Sv [rem]	1.0E+5 [1.0E+7]	5.0 [5.0E+2]
Max Beta Dose to Hot Side	Sv/h [rem/h]	10 [1000]	0.0001 [0.01]
Max Allowable Cold Side Dose	μSv/h [mrem/h]	2.5 [0.25]	2.5 [0.25]
Minimum Density Inch (density multiplied by inch)	g/cc × (in.)	110	55
Cell Atmosphere		Air	Air
Temperature Range Hot Side/Cold Side	°C [°F]	15 to 57 [60 to 135]	40 [104]
Pressure Differential Hot Side< Cold Side	Pa [in-WG]	250 to 625 [1.0 to 2.5]	250 to 625 [1.0 to 2.5]
Max Force Required to Open Barrier Shield Assembly	N [lbf]	90 [20]	90 [20]
Maximum Weight Barrier Shield	kg [lbm]	226.8 [500]	226.8 [500]
Design Life	yr	20	20
Duty Cycle		100 Sv/h [1.0E + 4 rem/h] two days/week	Continuous
Hot Cell Wall Material	kg/m^3 [lb ⁄cu ft]	High Density Concrete 3200 [200]	Normal Density Concrete 2340 [146]
Dimensions	Ref. Sketches[A]	mm [in.]—Typical	mm [in.]—Typical
Hot Cell Wall Thickness	Fig. A3.1 (J), Fig. A3.2 (J)	1219 [48]	305 [12]
Window Clear View, Minimum			
Horizontal		1016 [40]	559 [22]
Vertical		559 [22]	1016 [40]
Barrier Shield Clear View, Maximum			
Horizontal		1626 [64]	1118 [44]
Vertical		1118 [44]	1626 [64]
Centerline Viewing Height of Clear View Above Floor	Fig. A3.4 (K)	1702 [67]	1702 [67]
Offset Viewing Height Above Floor	Fig. A3.5 (M)	1804 [71]	1804 [71]
Offset Viewing Distance from Clear View Centerline	Fig. A3.5 (N)	102 [4]	102 [4]
Viewing Distance (Eyeball to Glass)	Fig. A3.3 (L), Fig. A3.4 (L), Fig. A3.5 (L)	305 [12]	305 [12]
Viewing Angles		Degrees—Typical	Degrees—Typical
Horizontal			
Normal—Left and Right	Fig. A3.3 (A)	36°	30°
Extreme—Left and Right	Fig. A3.3 (B)	82°	62°
Centerline Vertical			
Normal—Up	Fig. A3.4 (C)	24°	40°
Normal—Down	Fig. A3.4 (D)	24°	40°
Extreme—Up	Fig. A3.4 (E)	56°	82°
Extreme—Down	Fig. A3.4 (F)	62°	82°
Offset Vertical			
Normal—Up	Fig. A3.5 (G)	20°	36°
Normal—Down	Fig. A3.5 (H)	28°	44°

[A] Letters in parenthesis may be found on the Sketches in Figs. A3.1-A3.5 of Annex A3.

TABLE A2.2 Blank

Shielding Window Requirements	Units	Shielding Window Number	Shielding Window Number
Identification No.		1	2
Window Type—Dry Lead Glass or Oil Filled Lead Glass			
Hot Side Trim Frame Assembly Required			
Initial Light Transmission, Min.			
Radiation Source Spectra and Geometry			
Average Distance from Source to Hot Side of Window	mm [in.]		
Yearly Dose, Hot Side	Sv [rem]		
Max Beta Dose to Hot Side	Sv/h [rem/h]		
Max Allowable Cold Side Dose	μSv/h [mrem/h]		
Minimum Density Inch (density multiplied by inch)	g/cc × (in.)		
Cell Atmosphere			
Temperature Range Hot Side/Cold Side	°C [°F]		
Pressure Differential Hot Side< Cold Side	Pa [in-WG]		
Max Force Required to Open Barrier Shield Assembly	N [lbf]		
Maximum Weight Barrier Shield	kg [lbm]		
Design Life	yr		
Duty Cycle			
Hot Cell Wall Material	kg/m^3 [lb ⁄cu ft]		
Dimensions	Ref. Sketches[A]	mm [in.]—Typical	mm [in.]—Typical
Hot Cell Wall Thickness	Fig. A3.1 (J), Fig. A3.2 (J)		
Window Clear View, Minimum			
Horizontal			
Vertical			
Barrier Shield Clear View, Maximum			
Horizontal			
Vertical			
Centerline Viewing Height of Clear View Above Floor	Fig. A3.4 (K)		
Offset Viewing Height Above Floor	Fig. A3.5 (M)		
Offset Viewing Distance from Clear View Centerline	Fig. A3.5 (N)		
Viewing Distance (Eyeball to Glass)	Fig. A3.3 (L), Fig. A3.4 (L), Fig. A3.5 (L)		
Viewing Angles		Degrees—Typical	Degrees—Typical
Horizontal			
Normal—Left and Right	Fig. A3.3 (A)		
Extreme—Left and Right	Fig. A3.3 (B)		
Centerline Vertical			
Normal—Up	Fig. A3.4 (C)		
Normal—Down	Fig. A3.4 (D)		
Extreme—Up	Fig. A3.4 (E)		
Extreme—Down	Fig. A3.4 (F)		
Offset Vertical			
Normal—Up	Fig. A3.5 (G)		
Normal—Down	Fig. A3.5 (H)		

[A] Letters in parenthesis may be found on the Sketches in Figs. A3.1-A3.5 of Annex A3.

A3. GENERAL WINDOW CONFIGURATION SKETCHES

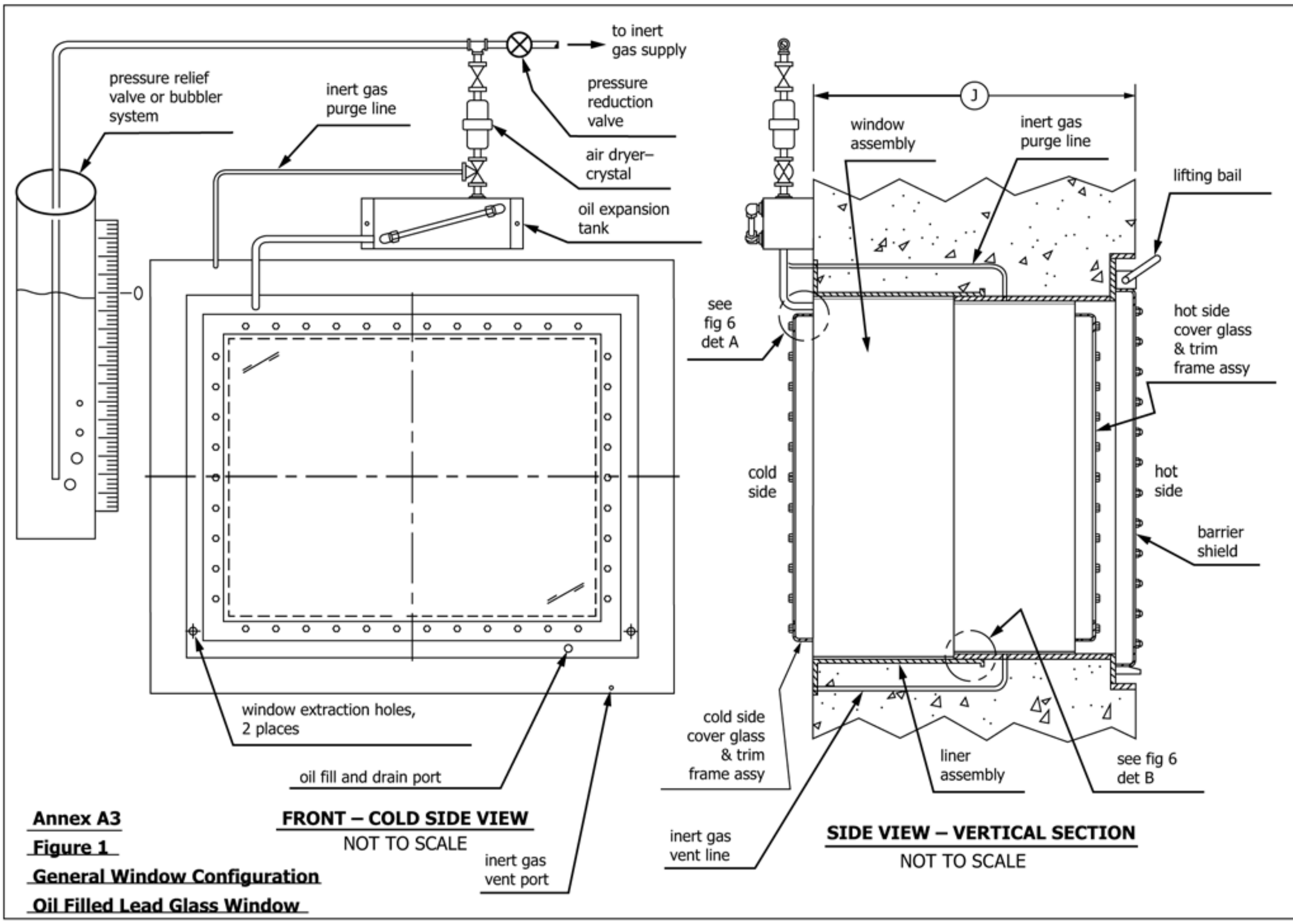

FIG. A3.1 General Window Configuration—Oil-filled Lead Glass Window

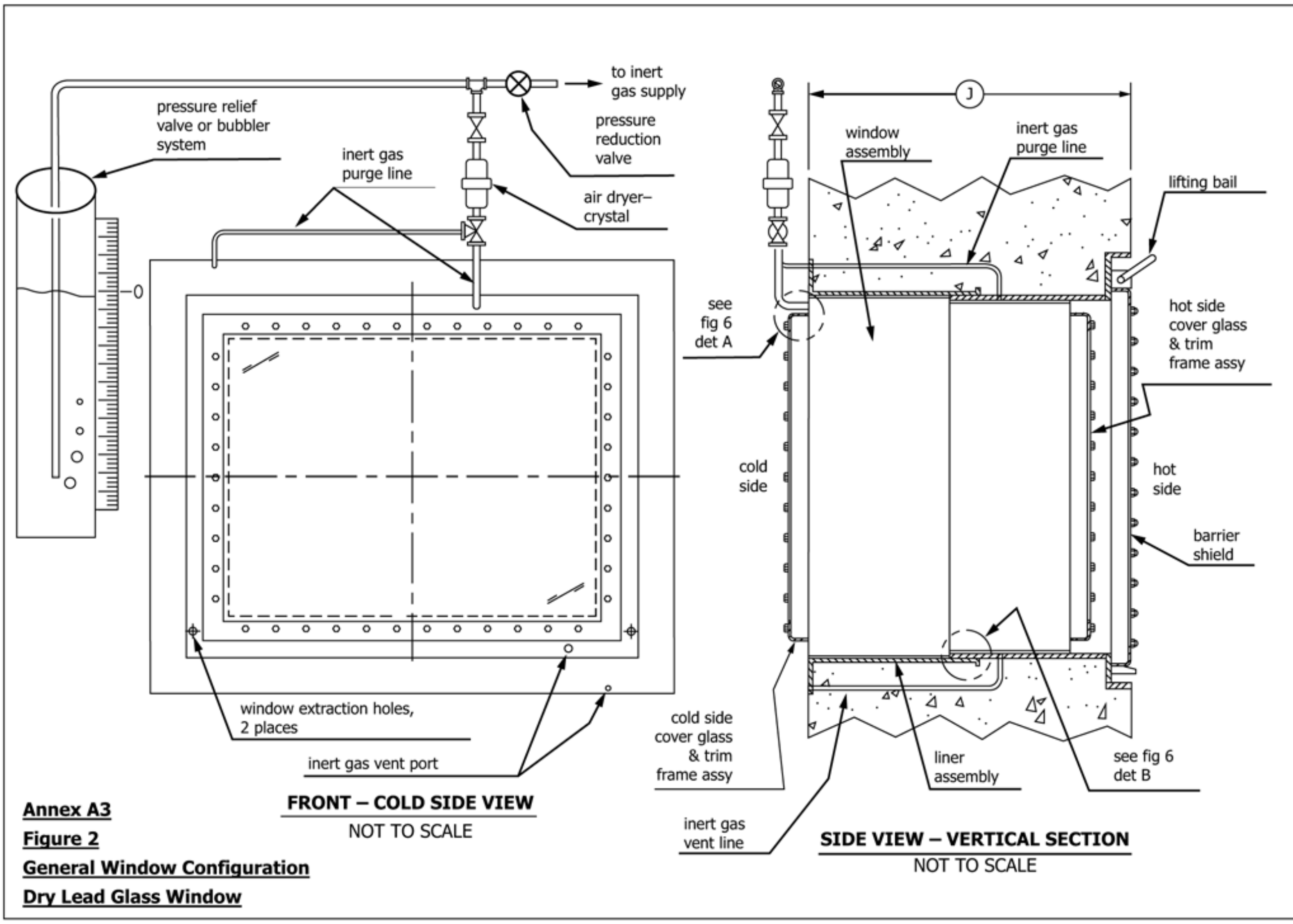

FIG. A3.2 General Window Configuration—Dry Lead Glass Window

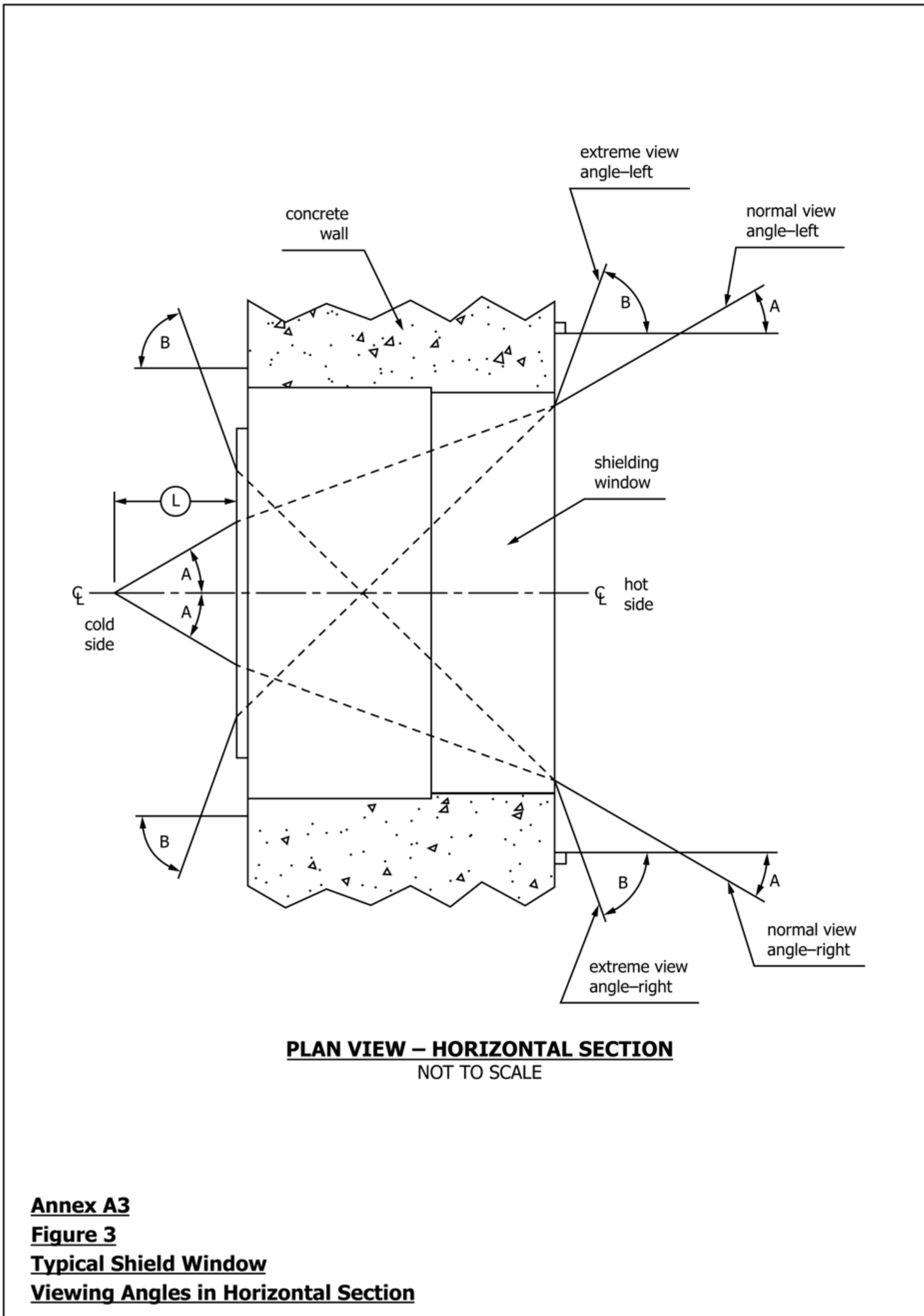

FIG. A3.3 Typical Shield Window—Viewing Angles in Horizontal Section

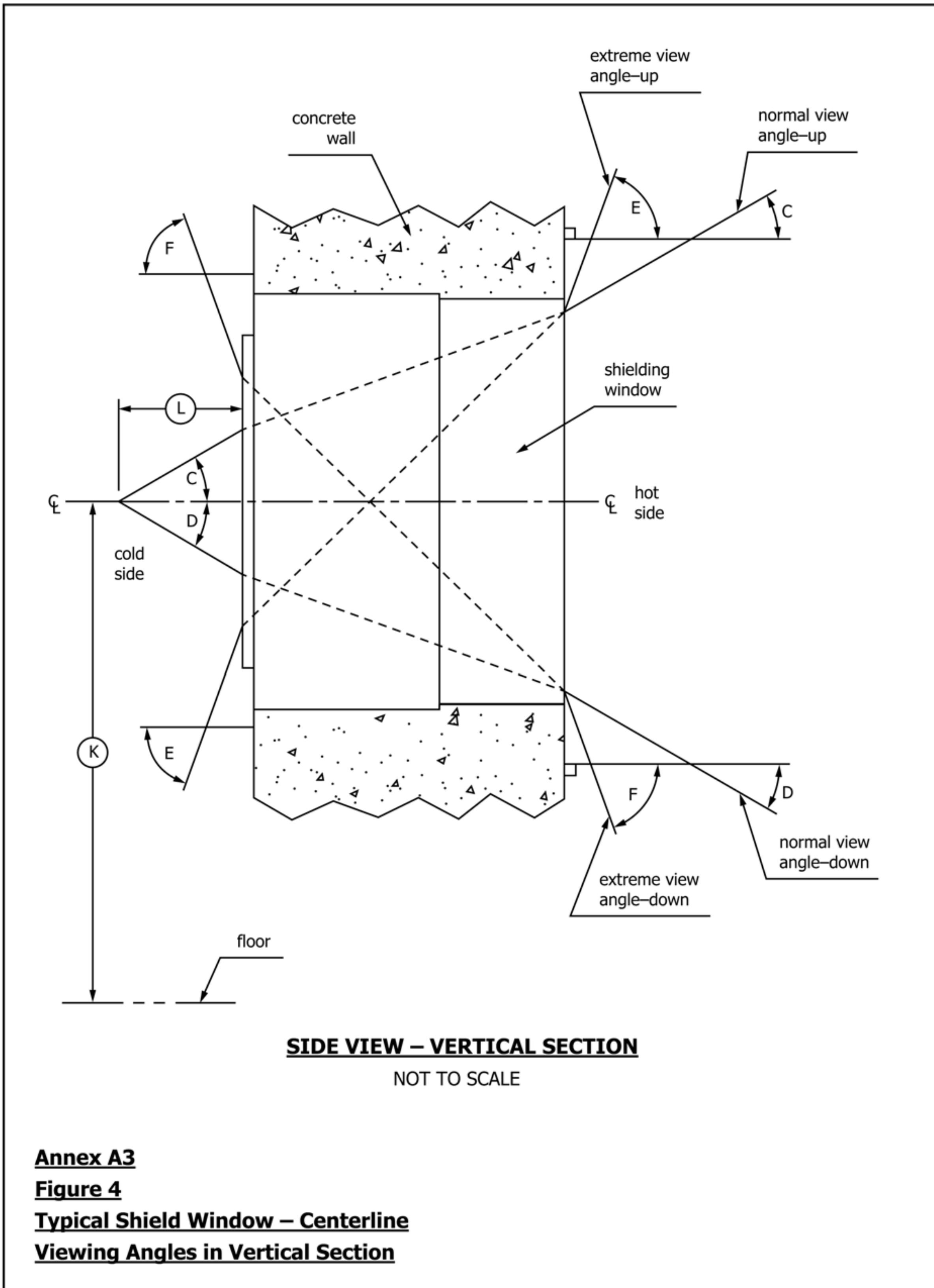

FIG. A3.4 Typical Shield Window—Centerline Viewing Angles in Vertical Section

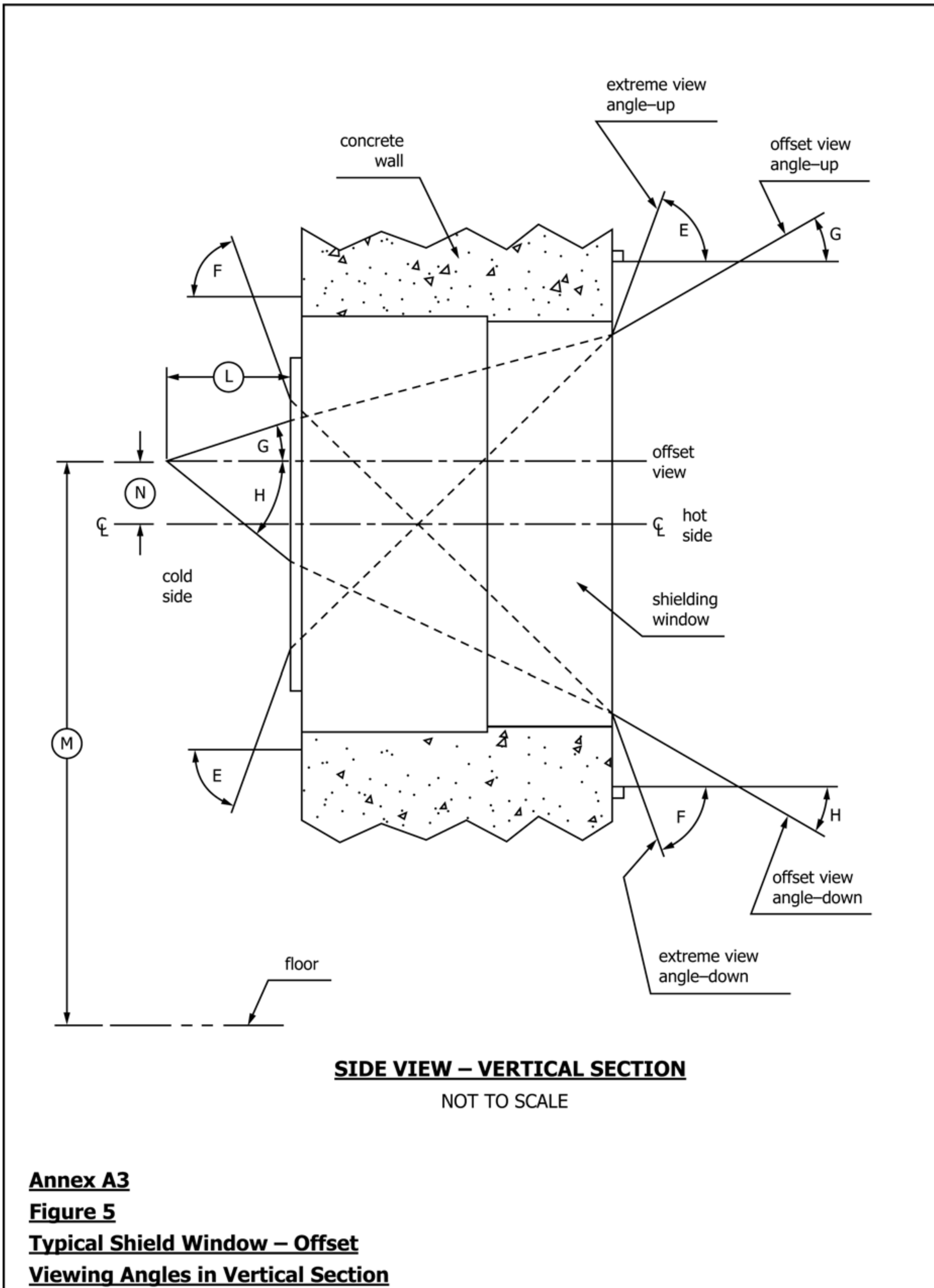

FIG. A3.5 Typical Shield Window—Offset Viewing Angles in Vertical Section

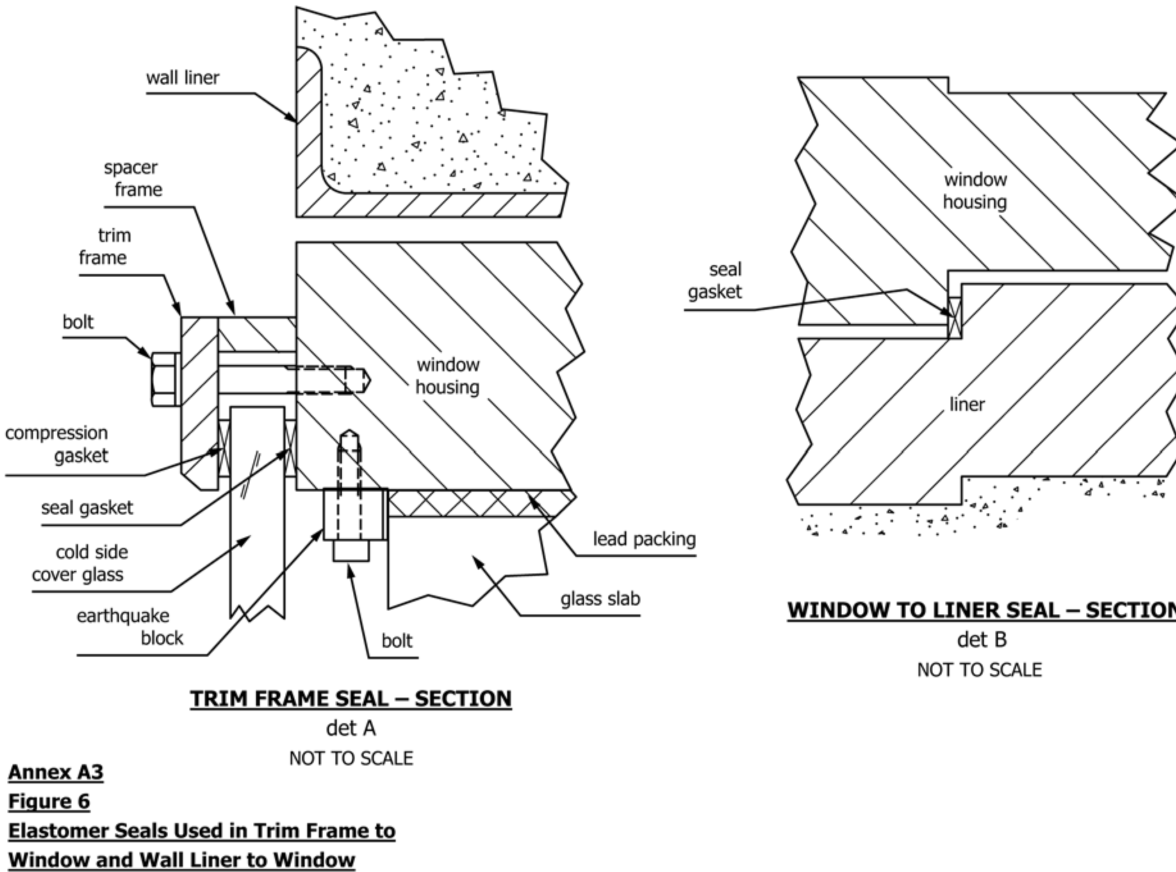

FIG. A3.6 Elastomer Seals Used in Trim Frame to Window and Wall Liner to Window

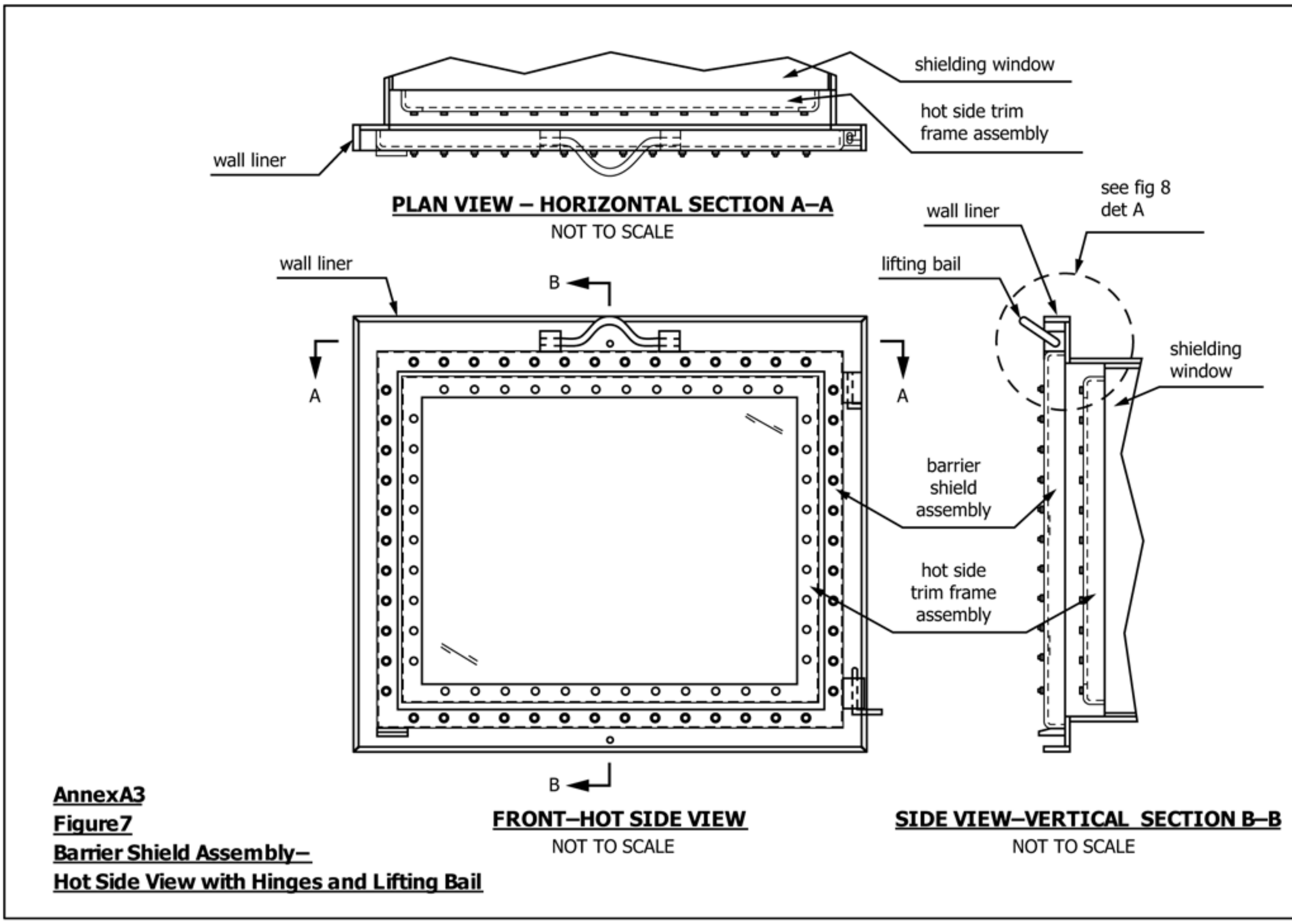

FIG. A3.7 Barrier Shield Assembly—Hot Side View with Hinges and Lifting Bail

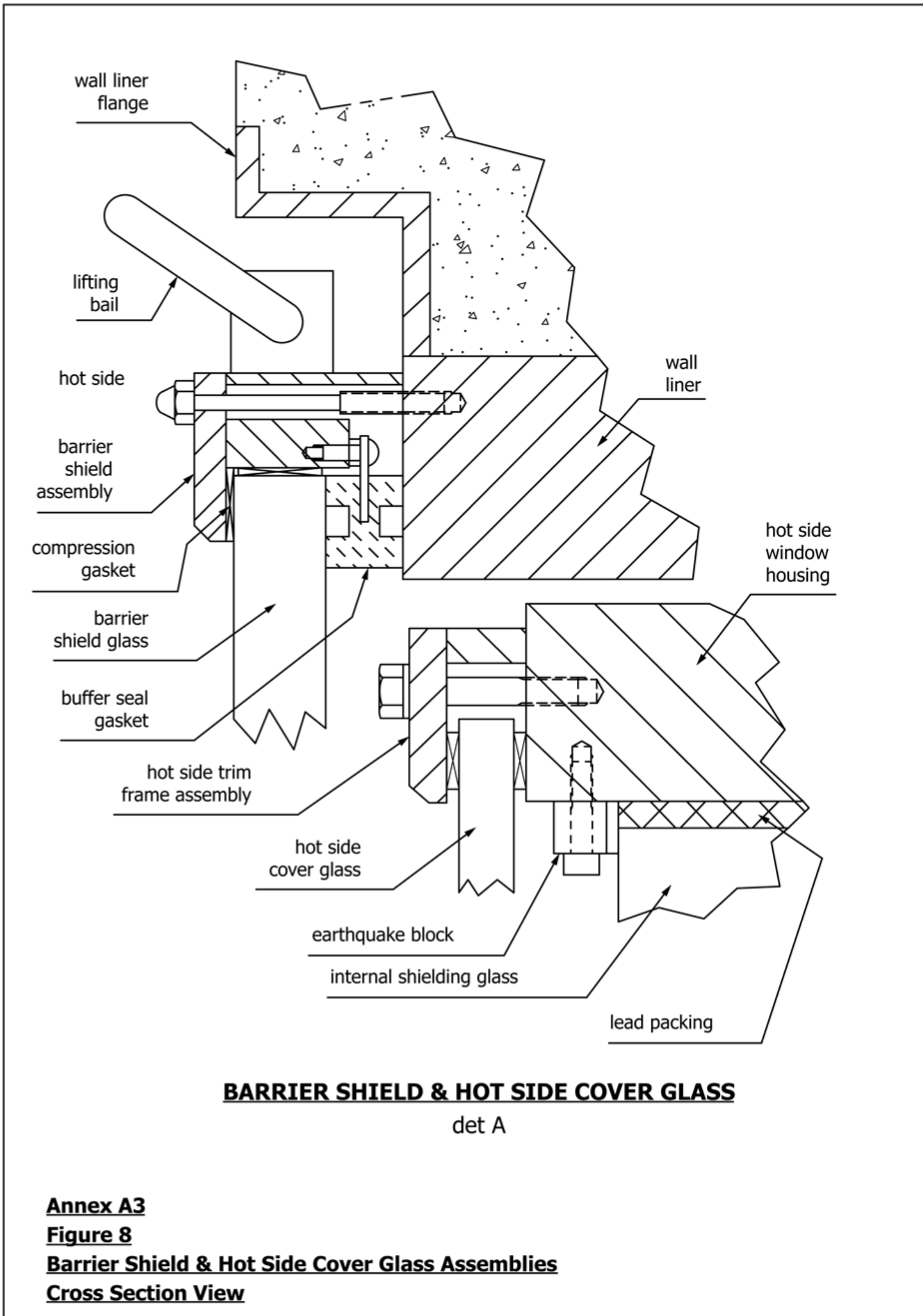

FIG. A3.8 Barrier Shield and Hot Side Cover Glass Assemblies—Cross Section View

REFERENCES

Documents having applicability to the design, fabrication, inspection, testing, installation and maintenance of dry lead glass and oil-filled lead windows include the following:

(1) Tobias, D. A. (Argonne),"Field Maintenance of Radiation Shield Windows at HFEF," *Proceedings 31st Conference on RSTD*, November, 1983.

(2) Kalkwarf, C. D. (Hot Cell Services Corp.), Tobias, D. A. (Argonne), "Dielectric Discharge Seminars," Sponsored by E. I. Dupont de Nemours, and Co., November, 1982.

(3) Kalkwarf, C. D.(Chem Nuclear Services, Inc.), "Maintenance and Refurbishment of Oil-Filled Lead Glass Shielding Windows," *Proceedings 27th Conference RSTD*, November, 1979.

(4) Kalkwarf, C. D.(Hot Cell Services Corp.), "Modification and Refurbishment of Lead Glass Shielding Windows," *Proceedings 31st Conference on RSTD*, November, 1983.

(5) Hardke, C. F. and Ferguson, K. R. (Argonne), "The Fracture by Electrical Discharge of Gamma-Irradiated Shielded Window Glass," *Proceedings 11th Hot Lab Conference 369*, 1963.

(6) "Maintenance Instructions for Oil-Filled Radiation Shielding Windows," *Products Engineering Department, Bulletin T-22*, Corning Glass Works, June 10, 1996.

(7) Eckels, T. W. and Smaardyk, A. (Argonne), "Design of a Shielding Window for a Nuclear Reactor Containment Cell," *Proceedings, 14th Conference on RSTD*, November, 1966.

(8) Bogar, G. F. (Viox),"Guide No. 3—Direct Viewing Windows," *Design Guides for Radioactive Material Handling Facilities and Equipment*, RSTD, 1988.

(9) Bogar, G. F. (Viox),"Cost Effective Design of Radiation Shielding Windows," *Proceedings 31st Conference on RSTD*, November 1983.

(10) Hoffman, H. E. and Wash, W. G. (Schott), "Criteria for Proper Selection of Shielding Glasses in Direct Viewing Windows," *Proceedings 31st Conference on RSTD*, 1983.

(11) Kalkwarf, C. D., Tobias, D. A., Carlston, H., Crowley R., and Lutz, M. (Hot Cell Services Corp.), "Seminar on Maintenance of Dry and Oil-Filled Lead Glass Radiation Shielding Windows," September, 2000.

(12) Eckels, T. W. and Mingean, D. P. (Argonne), "Further Data on Gamma-Induced Electrical Charge and Coloration of Shielded Glasses," *Proceedings of 18th Conference on RSTD*, 1970.

(13) Rockwell III, T.,"Reactor Shielding Design Manual," McGraw-Hill Book Company, Inc., 1956.

(14) Shand, E. B., "Glass Engineering Handbook," 2nd Edition, McGraw-Hill Book Company, 1958, p. 140.

(15) Gross, B. J., "Compton Current and Polarization in Gamma-Irradiated Dielectrics," *Applied Physics*, Vol 36, No. 5, May 1965, p. 1635.

(16) Cropper, W. H.,"Radiation-Induced Coloration in Glass," *Symposium on Radiation Effects*, American Ceramic Society, Glass Division, October, 1959.

(17) Jaeger, R. G., Blizard, E. P., Chilton, A. B., Grothenbuis, M., Honig, A., Jaeger, T. A., and Eisenlohr, H. H., "Engineering Compendium on Radiation Shielding," Volumes I, II, and III, Editions Springer-Verlag, New York, NY, 1968.

(18) Ernsberger and McGary, T. E. (Pittsburg Plate Glass Inc.), "Gamma-Radiation-Induced Conductivity in Nuclear Shielding Glasses as Determined by Space Charge Decay," *Proceedings 11th Hot Lab Conference*, 1963.

(19) Rizzo, F. X., Muller, A. C., and Zucker, M. S., "Electrical Discharge in Gamma-Irradiated Lead Shielding Glass," *Proceedings 11th Hot Lab Conference*, 1963.

(20) Kalkwarf, C. D., Campbell, R. A., and Crowley, R. W. (Hot Cell Services Corp), "Seminar on the Design of Lead Glass Radiation Shielding Windows," 1994.

(21) Van Voorde, M. H. and Pluym, G., "Radiation Damage of Materials Engineering Handbook," European Organization for Nuclear Research, Geneva, Switzerland, 1966.

(22) Stoller, R. E., Kumar, A. S., and Gellis, D. S., "STF 1125—Effects of Radiation on Materials," *International Symposium*, ASTM, West Conshohocken, PA, 1989.

(23) Gould, J. and Wu, P. (Factory Mutual) "Fire Endurance Testing of Oil-filled Radiation Shielding Windows," prepared for U.S. D.O.E. Office of Environment, Safety, and Health, November, 1993.

(24) Campbell, R. A.(Hot Cell Sercices Corp) and Malbert, A. F. (Sovis), "Maintenance as a Factor in Shield Window Design," *Proceedings 31st Conference on RSTD*, November, 1983.

OTHER REFERENCES
Industry and National Consensus Standards

Nationally recognized industry and consensus standards which may be applicable in whole or in part to the design, fabrication, installation and maintenance of radiation shielding window components that are not referenced in this standard, but may be applicable include the following:

ASTM Standards:[2]

(1) A167 Specification for Stainless and Heat-Resisting Chromium-Nickel Steel Plate, Sheet, and Strip
(2) A193/A193M Specification for Alloy-Steel and Stainless Steel Bolting Materials for High Temperature or High Pressure Service and Other Special Purpose Applications
(3) A269/A269M Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service
(4) A276/A276M Specification for Stainless Steel Bars and Shapes
(5) A320/A320M Specification for Alloy-Steel and Stainless Steel Bolting Materials for Low-Temperature Service
(6) A479/A479M Specification for Stainless Steel Bars and Shapes for Use in Boilers and Other Pressure Vessels
(7) A489 Specification for Carbon Steel Lifting Eyes
(8) A490 Specification for Structural Bolts, Alloy Steel, Heat Treated, 150 ksi Minimum Tensile Strength
(9) A511/A511M Specification for Stainless Steel Mechanical Tubing
(10) C1036 Specification for Flat Glass
(11) C1554 Guide for Materials Handling Equipment for Hot Cells
(12) D676 Method for Test of Identification of Rubber by Means of a Durometer
(13) D974-58T Neutralization Value
(14) D1056 Specification for Flexible Cellular Materials—Sponge or Expanded Rubber
(15) D1831 Peroxide Number in Petroleum Wax
(16) D2000 Classification System for Rubber Products in Automotive Applications
(17) E299 Test Method for Trace Amounts of Peroxides in Organic Solvents
(18) F593 Specification for Stainless Steel Bolts, Hex Cap Screws, and Studs
(19) F594 Specification for Stainless Steel Nuts and Washers

American Society of Mechanical Engineers (ASME) Standard:[12]

(20) Boiler and Pressure Vessel Code

American Society for Nondestructive Testing (ASNT) Standard:[13]

(21) CP 189 Standard for Qualification and Certification of Nondestructive Test Personnel

American Welding Society (AWS) Standards:[14]

(22) AWS A2.1 DC Welding Symbols Chart: Desk
(23) AWS A3.0 Standard Welding Terms and Definitions
(24) AWS B5.17 Specification for the Qualification of Welding Fabricators
(25) AWS D11.2 Guide for Welding Castings
(26) QC-1-88 Standard for AWS Certification of Welding Inspectors

Military (MIL) Standards:[15]

(27) MIL-STD-410, NAS-410 Standard for Qualification and Certification of Nondestructive Test Personnel
(28) MIL-E-12397B Coating of Optical Glass Surfaces (Anti-Reflection)

Federal Standards (FS):[15]

(29) CCC-C440E Coating of Glass Optical Surfaces (Anti-Reflection)

Federal Regulations (FR):[15]

(30) 29 CFR1910 Occupational Safety and Health Standards
(31) 10 CFR Part 835 Occupational Radiation Protection

National Fire Protection Association (NFPA):[16]

(32) NFPA 801 Facilities Handling Radioactive Materials

American Nuclear Society (ANS):[17]

(33) ANS Design Guides for Radioactive Material Handling Facilities and Equipment
(34) ANS Glossary of Terms in Nuclear Science and Technology (ANS Glossary)
(35) ANSI/ANS 6.4.2-85 Specification for Radiation Shielding Materials

Other Standard:

(36) BS EN Lead and Lead Alloys[18]
(37) AFNOR A55E Lead Ingots

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[12] American Society of Mechanical Engineers, Two Park Ave., New York, NY 10016.

[13] American Society of Nondestructive Testing (ASNT) Standards, PO Box 28518, 1711 Arlingate Lane, Columbus, OH 43228-0518.

[14] American Welding Society (AWS) Standards, 550 NW LeJeune Road, Miami, FL 33126.

[15] Available from U.S. Government Printing Office, Superintendent of Documents, Mail Stop SSOP, Washington DC 20402-9328.

[16] Available from National Fire Protection Association (NFPA), 1 Batterymarch Park, Quincy, MA 02169-7471, http://www.nfpa.org.

[17] American Nuclear Society, 555 North Kensington Ave., La Grange Park, IL 60525.

[18] HIS Engineering / HIS International, 15 Inverness Way East, Englewood, CO, 80112.