Designation: C1572 – 04

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; 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 This 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 system of units employed in this standard is the metric unit, also known as SI Units, which are commonly used for International Systems, and defined, by ASTM/IEEE SI-10ASTM/IEEE SI-10 Standard for Use of International System of Units. 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. A1.1 shows a sample list of the radiation source spectra and geometry information, typically required for shielding analysis. 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. A3 shows general window configuration sketches. Blank copies of A1.2 and A2.2 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.

1.3 *Caveats*:

1.3.1 Consideration shall be given when preparing the shielding window designs for the safety related issues discussed in the Hazards Sources and Failure Modes, Section 11; such as dielectric discharge, over-pressurization, radiation exposure, contamination, and overturning of the 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 and health practices and determine the applicability of regulatory requirements prior to use.*

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

2.2 *ASTM Standards:*[2]

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

[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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[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.

ASTM/IEEE SI-10 Standard for Use of the International System of Units

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

C-31 Seismic Requirements

2.4 *American National Standards Institute (ANSI) Standards:*[4]

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 Structural Welding Code—Stainless Steel

ANSI/ISO/ASQ Q9001 Quality Management Standard Requirements

2.5 *American Society for Nondestructive Testing (ASNT) Standards:*[5]

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

2.6 *Steel Structures Painting Council (SSPC):*[6]

SSPC-SP1 Solvent Cleaning

SSPC-SP6 Commercial Blast Cleaning

SSPC-P1 Paint Application Specification

2.7 *Federal Standards (FS):*[7]

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

2.8 *Federal Regulations (FR):*[7]

10 CFR830.120 Subpart A, Nuclear Safety Management, Quality Assurance Requirements

2.9 *International Building Code (IBC):*[7]

IBC Section 2314 Earthquake Regulations

2.10 *Other Standards:*

AESS (R) 44/70000/6 Atomic Energy Standard Specification for Shielding Glass[8]

NCRP Report No. 82 SI Units in Radiation Protection and Measurements[9]

ICRU Report 10b Physical Aspects of Irradiation[10]

3. Terminology

3.1 *Definitions:*

3.1.1 *absorbed dose*—the quotient of the mean energy (E) imparted by ionizing radiation to matter of mass (M). The SI unit for absorbed dose is the gray, defined as 1 joule/kg and is equivalent to 100 rads. **NCRP-82**

3.1.2 *activity*—the measure of the rate of spontaneous nuclear transformations of a radioactive material. The SI unit for activity is the becquerel, defined as 1 transformation per second. The original unit for activity was the curie (Ci), defined as 3.7×10^{10} transformations per second. **NCRP-82**

3.1.3 *air dryer cartridge*—a cloth bag containing moisture absorbent crystals. The bag is inserted into the dryer assembly. The crystals are used to absorb moisture from the contained environment.

3.1.4 *alpha*—see *radiation*.

3.1.5 *anti-reflection treatment*—a process applied to the surface of the glass that reduces reflection, and increases the light transmission through the glass. It is often called a low-reflection treatment.

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

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

3.1.8 *barrier shield glass*—a glass plate; typically cerium stabilized that is used as a cover glass to see through and isolate the window assembly from contamination. It is normally mounted in a barrier shield frame with gaskets to make up a barrier shield assembly.

3.1.9 *becquerel (Bq)*—see *activity*.

3.1.10 *bellows*—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. 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.

3.1.11 *beta*—see *radiation*.

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

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

3.1.14 *buffer seal*—a specially configured seal gasket used on a barrier shield.

3.1.15 *build-up factor*—term used for radiation passing through a medium, which is the ratio of the total value of a specific radiation quantity (such as absorbed dose) at any point in that medium to the contribution to that quantity from the incident uncollided radiation reaching that point. **E170**

3.1.16 *central viewing area*—the central viewing area of a glass slab or glass plate is that viewing area, circular or

[3] American Concrete Institute (ACI) Standards, 38800 Country Club Drive, Farmington Hills, MI 48331.

[4] American National Standards Institute (ANSI) Standards, 1819 L St. NW Washington D.C., 20036.

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

[6] Steel Structures Painting Council (SSPC), 40 24th Street 6th Floor, Pittsburgh, PA 15222.

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

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

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

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

elliptical, of which the diameter of axis is 80 percent of the maximum usable viewing window dimensions.

3.1.17 *cerium-stabilized glass*—often called non-browning glass is a glass type that contains a small percentage of cerium oxide to help stabilize the glass from discoloration due to radiation exposure.

3.1.18 *certified material test report (CMTR)*—a document that certifies the results of tests and analyses performed on the item provided.

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

3.1.20 *chip*—a fragment broken from an edge or surface.

3.1.21 *clear view*—the physical size (length × width), of the smallest glass slab of all the glass components in a shielding window assembly. (The actual clear view may be reduced by the method of retention of the glass in the window.)

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

3.1.23 *cold side load*—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.

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

3.1.25 *curie*—see *activity*.

3.1.26 *density inch*—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) × inch.

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

3.1.28 *dielectric discharge*—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.

3.1.29 *dose equivalent*—represents a quantity used for radiation protection purposes that expresses on a common scale, the dose from all types of radiation. Dose equivalent is the product of absorbed dose (D), a quality factor that normalizes the effects between different radiation types (Q) and other modifying factors (N). The specialized unit for dose equivalent is the rem. The quality factors are specified by the International Commission on Radiological Units and Measurements for different types of radiation and organ exposures. The SI unit for dose equivalent is the sievert (Sv), which is equal to 100 rem. Human exposure is often expressed in terms of microsieverts (µSv), 1×10^{-6} sieverts, or in terms of millirem (mrem), 1×10^{-3}. 10 µSv is equal to 1 mrem. **NCRP-82, ICRU-10b**

3.1.30 *dose rate*—a quantity of absorbed dose received in a given unit of time.

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

3.1.32 *exposure*—the quotient of the total charge of ions of one sign produced in air when all electrons are liberated by photons in a volume element of air mass sufficient to completely stop the electrons (charged particle equilibrium). Radiation exposure is a measure of the amount of ionization produced by x-ray or gamma rays as they travel through air. The special unit of exposure is the roentgen (R). It is equivalent to 2.58×10^4 coulombs per kilograms of air. **NCRP-82**

3.1.33 *extraction/installation table/device*—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.

3.1.34 *extreme view angle*—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.

3.1.35 *gamma*—see *radiation*.

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

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

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

3.1.39 *glass plate*—typically used as cover glasses or barrier shields. The maximum thickness is typically 40 mm (1.5 in.) thick.

3.1.40 *glass slabs*—typically used for internal shielding in windows and view ports. The typical thickness ranges from a minimum of 40 mm (1.5 in.) up to a maximum of 400 mm (16 in.) thick.

3.1.41 *glass surface defects*—refer to those defects that are on the glass surface, and can be removed by reprocessing or repolishing the glass surface. These defects are scratches, short finish, and stripping.

3.1.42 *gray (Gy)*—see *absorbed dose*.

3.1.43 *high density concrete*—a concrete having a weight of greater than 2400 kg per cubic meter (150 lb per cubic foot).

3.1.44 *hot cell*—an isolated shielded room that provides a controlled environment for containing radioactive material and equipment. The radiation levels within a hot cell are typically 1 Gy/h (100 rads per hour) or higher.

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

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

3.1.47 *inert gas*—a type of commercial grade moisture free gas, usually argon or nitrogen that is purged into the internal window assembly to displace ambient air.

3.1.48 *lead packing*—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. 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.

3.1.49 *light transmission*—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.

3.1.50 *master-slave manipulator*—a device used to remotely handle radioactively contaminated items, or nuclear material in a hot cell. The uncontaminated or "clean" portion of the manipulator is called the "master" and the contaminated portion of the manipulator or follower is called the "slave." Mechanical master-slave manipulators are mounted through the wall of the hot cell or pass through the ceiling. Powered manipulators can be electric or hydraulic. The extensions and fingers of the slave components inside the hot cell duplicate the manipulations of the arms and fingers of the operator at the cold side face of the cell.

3.1.51 *millirem (mrem)*—see *dose equivalent*.

3.1.52 *NCR*—the abbreviation for a Manufacturer's Non-Conformance Report (NCR). 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.

3.1.53 *neutron*—see *radiation*.

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

3.1.55 *normal concrete*—a concrete mixture that has a weight of between 2250 and 2400 kg per cubic meter (140 to 150 lb per cubic foot).

3.1.56 *normal view angle*—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.

3.1.57 *oil expansion tank*—a stainless steel (preferred), 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. The oil supply in the window is connected to the expansion tank.

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

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

3.1.60 *roentgen (R)*—see *exposure*.

3.1.61 *radiation absorbed dose (rad)*—see *absorbed dose*.

3.1.62 *radiation—for purposes of this standard*, is defined as the emission that occurs when a nucleus undergoes radioactive decay. The emitted radiations may include alpha and beta particles, gamma rays, and neutrons. **E170**

3.1.62.1 *alpha*—alpha radiation is an alpha particle composed of two protons and two neutrons with a positive charge of plus two. (It is the same as a helium atom with no electrons.)

3.1.62.2 *beta*—beta radiation is an electron that was generated in the atomic nucleus during decay and has a negative charge of one.

3.1.62.3 *gamma*—gamma radiation is high energy, short wavelength electromagnetic radiation and normally accompanies the other forms of particle emissions during radioactive decay. Gamma radiation has no electrical charge.

3.1.62.4 *neutron*—neutron radiation results from instability in the atomic nucleus that may be the result of either radioactive instability of the nucleus, interaction of the nucleus with another particle or energy source. Neutrons have an atomic mass slightly heavier than a proton, but have no electrical charge.

3.1.63 *radiation shielding window—for purposes of this standard*, is an optically transparent instrument that provides a means for viewing into a hot cell, and shields the operator while performing work. A shielding window is generally constructed of an outer metal frame, called a housing and is filled with optically polished lead glass slabs that are secured within the housing with lead packing. Most shielding windows have cover glasses and trim frames on both viewing ends to seal the window cavity. The shielding windows can be either dry or oil-filled.

3.1.64 *radiation streaming*—a term used to describe unshielded beams of radiation.

3.1.65 *roentgen equivalent man (rem)*—see *dose equivalent*.

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

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

3.1.68 *shine*—see *radiation streaming*.

3.1.69 *short finish*—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.

3.1.70 *sievert*—see *dose equivalent*.

3.1.71 *stepped window*—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.

3.1.72 *source*—the radioactive material inside the hot cell. The source emits radiation energy, which requires shielding to protect personnel.

3.1.73 *streaming*—see *radiation streaming*.

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

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

3.1.76 *trim frame*—a steel frame with a drilled hole pattern. Its function is to mechanically fasten a cover glass to a window housing.

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

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

3.1.79 *view port*—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.

3.1.80 *WG*—the abbreviation for "water gauge." It is the pressure differential, equal to the pressure exerted by a column of water of the specified height.

3.1.81 *wall liner embedment*—a metal structure, which is embedded in the hot cell wall. The radiation shielding window fits into the wall liner.

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

3.1.83 *window housing*—the outer metal structure of the shielding window. It fits into the wall liner embedment.

3.1.84 *window interchangeability*—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 CFR830 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 his 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, 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 load, 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 nanometers. Refer to 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 American Concrete Institute C-31 Seismic Requirements, the International Building Code 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 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 and/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 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 be designed with a machined surface 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.

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.

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, and/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 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 to seal the window cavity from the ambient air and still allow for expansion of the inert gas or shielding oil.

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.

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.

6.3.12 *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 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.

6.4.3 *Sealing System*:

6.4.3.1 The shielding plug shall be designed with a machined surface to provide a secondary containment seal at the cold side of the wall liner, or the most cold side step of the wall liner.

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

6.5.3 *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, 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.

6.6.3 *Sealing System*:

6.6.3.1 The view port housing shall be designed with a machined surface 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.

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.

6.6.7 *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 1.5 times the actual load being raised to the desired height for installation or removal.

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 or overturning during the installation or removal process of the shielding windows, shielding plugs, or view ports.

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 then collectively they 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 two percent 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.

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