

SECTION 13 49 23
INTEGRATED RFI/EMI SHIELDING ASSEMBLIES

PART 1 - GENERAL

1.01 SECTION INCLUDES

- A. Architecturally integrated shielding.
 - 1. The designing, furnishing, installing, and testing of a radio-frequency interference (RFI) and electromagnetic interference (EMI) shielded enclosure acceptable to the manufacturer of the Owner's new magnetic resonance imaging (MRI) equipment.
 - a. Fully shield the scan room, including – but not limited to – floor, walls, ceiling, doors, windows, and penetrations.
 - b. Isolate the finish inside the scan room from the shielding using a fire-retardant-treated wood stud wall.
 - c. Provide finished surfaces, electrical outlets, and electrical switches for the interior stud wall.
 - d. Provide mounting hardware for internal items requiring attachment to the shield walls.
 - e. Install attachments prior to performance testing.
 - 2. Coordinate the design of the shielded enclosure with current Architectural, Fire-Suppression, Plumbing, Heating, Ventilating, and Air-Conditioning (HVAC), Electrical, Communication, and Electronic Safety and Security Drawings and Drawings from manufacturer of MRI equipment. Conflicts between documents shall be communicated to – and will be resolved by – the Architect.
- B. Accessory components.

1.02 RELATED REQUIREMENTS

- A. Document 00 31 00 - Available Project Information: Shielding report.
- B. Section 01 23 00 - Alternates: Description of alternate(s) affecting the Work of this Section.
- C. Section 01 51 00 - Temporary Utilities: Heating of installation area to minimum of 68 degrees Fahrenheit for a period of 24 hours prior to, and during enclosure installation.
- D. Section 02 41 00 - Demolition: Preparation of surfaces to receive shielded enclosure.
- E. Section 03 30 00 - Cast-in-Place Concrete:
 - 1. Levelness of concrete slab substrate shall be within plus-or-minus 1/4 inch over entire space and no more than 3/16 inch below a high spot on a 10-foot-long straight edge.
- F. Section 03 54 00 - Cast Underlayment (if required to achieve levelness requirements above).
- G. Section 09 21 16 - Gypsum Board Assemblies: Gypsum board on metal studs shall be the interior finish of the shielding surfaces.
- H. Section 09 51 00 - Suspended Acoustical Ceilings: Aluminum lay-in ceiling grid.
- I. Section 09 91 23 - Interior Painting: Field-painting, either internal or external to the shielded enclosure.
- J. Section 13 49 26 - Modular RFI Shielding Rooms.

1.03 PRICE AND PAYMENT PROCEDURES

- A. See Section 01 23 00 - Alternates, for product alternatives affecting this Section.

1.04 ABBREVIATIONS AND ACRONYMS

- A. EMI - Electromagnetic interference.
- B. MRI - Magnetic resonance imaging.
- C. RFI - Radio-frequency interference.

1.05 REFERENCE STANDARDS

- A. Comply with applicable provisions of state/local building code. Comply with reference standards to the extent referenced in this Section.
 - 1. Exception: Where requirements that are more stringent are indicated on the Drawings or specified herein.
- B. ANSI/SDI A250.4 - Test Procedure and Acceptance Criteria for Physical Endurance for Steel Doors, Frames and Frame Anchors; 2024.
- C. ASCE 7 - Minimum Design Loads and Associated Criteria for Buildings and Other Structures; Most Recent Edition Cited by Referring Code or Reference Standard.
- D. ASTM A568/A568M - Standard Specification for Steel, Sheet, Carbon, Structural, and High-Strength, Low-Alloy, Hot-Rolled and Cold-Rolled, General Requirements for; 2019a.
- E. ASTM A1008/A1008M - Standard Specification for Steel, Sheet, Cold-Rolled, Carbon, Structural, High-Strength Low-Alloy, High-Strength Low-Alloy with Improved Formability, Required Hardness, Solution Hardened, and Bake Hardenable; 2023, with Editorial Revision.
- F. ASTM A1011/A1011M - Standard Specification for Steel, Sheet and Strip, Hot-Rolled, Carbon, Structural, High-Strength Low-Alloy, High-Strength Low-Alloy with Improved Formability, and Ultra-High Strength; 2023.
- G. ASTM C840 - Standard Specification for Application and Finishing of Gypsum Board; 2023.
- H. ASTM E84 - Standard Test Method for Surface Burning Characteristics of Building Materials; 2023d.
- I. ASTM E90 - Standard Test Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions and Elements; 2023.
- J. ASTM E413 - Classification for Rating Sound Insulation; 2022.
- K. ASTM F2170 - Standard Test Method for Determining Relative Humidity in Concrete Floor Slabs Using in situ Probes; 2019a.
- L. AWWA U1 - Use Category System: User Specification for Treated Wood; 2024.
- M. AWS A5.8M/A5.8 - Specification for Filler Metals for Brazing and Braze Welding; 2019.
- N. AWS B2.1/B2.1M - Specification for Welding Procedure and Performance Qualification; 2021, with Errata (2023).
- O. AWS D1.1/D1.1M - Structural Welding Code - Steel; 2020, with Errata (2023).
- P. AWS D9.1/D9.1M - Sheet Metal Welding Code; 2018.
- Q. FS MM-L-751 - Lumber; Softwood; Revision H, August 13, 1970.
- R. ICC (IBC) - International Building Code; Most Recent Edition Adopted by Authority Having Jurisdiction, Including All Applicable Amendments and Supplements.
- S. ICRI PC1-10 - Concrete Surface Profile Chip Set; 2013.
- T. IEEE 299 - IEEE Standard Method for Measuring the Effectiveness of Electromagnetic Shielding Enclosures; 2006 (Reaffirmed 2012).
- U. MIL-STD-220 - Method of Insertion Loss Measurement; 2009c (Validated 2024).
- V. NFPA 99C - Standard on Gas and Vacuum Systems; 2005.

1.06 ADMINISTRATIVE REQUIREMENTS

- A. Coordination: Prior to installation, verify performance criteria and coordinate installation with the following.
 - 1. Shielding report identified in Section 00 31 00 - Available Project Information.
 - 2. Manufacturer of MRI equipment.
 - 3. Plumbing installer.

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4. Heating, ventilating, and air-conditioning installer.
 5. Electrical installer.
 6. Low-voltage installer.
- B. Preinstallation Conference: Conduct conference at Project site to comply with requirements of Section 01 30 00 - Administrative Requirements. Review methods and procedures related to RFI/EMI shielding including – but not limited to – the following:
1. Required storage space prior to installation.
 2. Temporary lighting and electrical power.
 3. Sequence and schedule of RFI/EMI shielding work in relation to other work.
 4. Unimpeded delivery route for shielding materials from truck to the site of the Work.
 5. Supplementary RFI shielding and filters at penetrations of shielding by piping, ductwork, and conduit.
 6. Methods of attaching other construction and equipment to shielding enclosure.
 7. Notification procedures for work that requires modifying RFI/EMI shielding.
- C. Sequencing: The site of the Work shall be completed to the following extents.
1. Concrete work is complete, level to specifications, and with proper surface preparation.
 - a. Surface of concrete slab has been cured for a minimum of seven days.
 2. Structural systems are in place.
 3. Interior gypsum board has been installed with joints and fasteners taped and compounded to a Level-2 Finish per ASTM C840.
 4. Utility services are positioned and routed for proper connection to the shielded enclosure.

1.07 SUBMITTALS - GENERAL

- A. See Section 01 30 00 - Administrative Requirements for submittal procedures.

1.08 SUBMITTALS FOR REVIEW

- A. Product Data: Manufacturer's data sheets on each product to be used, marked-up and/or highlighted in sufficient detail to indicate what is included – and what is NOT included.
1. Preparation instructions and recommendations.
 2. Storage and handling requirements and recommendations.
 3. Installation methods.
- B. Shop Drawings: Obtain approval from manufacturer of MRI equipment before submitting to Architect.
1. Show accurate layout of shielded area based on field-verified site dimensions and conditions. Include:
 - a. Floor plans.
 - b. Enclosure elevations.
 - c. Wall sections.
 - d. Corner details.
 2. Show dimensioned details of:
 - a. Fabrication.
 - b. Connections.
 - c. RFI-shielded penetrations.
 - d. Related work.

1.09 SUBMITTALS FOR INFORMATION

- A. Certificates:
1. For waveguide products and fabrications, certify compliance with specified performance criteria.
 - a. Submit statement signed by responsible official of a manufacturer of a product, system, or material, attesting that the product, system or material meets specified requirements.

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- b. List the specific requirements which are being certified.
 - c. Include the name of the Project.
 - d. Date of certificate shall NOT precede award of this Contract.
 - 2. Furnish certificates of compliance specified in Part-3 article entitled "Field Quality Control."
- B. Deferred/Delegated Design Submittals: Submit seismic design details sealed by a professional engineer documenting that the components of the shielding enclosure have been designed to resist applicable earthquake motions.
- C. Field Quality Control Submittals:
 - 1. Quality Assurance Plan: Submit detailed procedures which define how and when the following requirements of the Contract Documents will be provided.
 - a. Material procurement records.
 - b. Inspection records.
 - c. System and material testing and certification records.
 - d. Written records and drawings indicating location of welds made by each welder or welding operator.
 - 2. Field Test Reports: Indicate frequencies at which tests were made, location of each test, and results.
 - a. Identify test methods used.
 - b. Include analysis and interpretation of test results.
 - c. Properly identify each report:
 - 1) RFI Qualification Test.
 - 2) RFI Acceptance Test.
 - 3) Ground Isolation Monitoring Test (before any utility connections).
- D. Installer Qualification Statements:
 - 1. Submit list of past installations identifying the following.
 - a. Purchaser.
 - b. Address of installation.
 - c. Organization servicing installation.
 - d. Date of installation.
- E. Designer Qualification Statements.
- F. Welders' Qualification Statement: Welders' certificates in accordance with AWS B2.1/B2.1M and dated no more than 12 months before start of scheduled welding work.
- G. Field Testing Agency Qualification Statements.

1.10 SUBMITTALS FOR PROJECT CLOSEOUT

- A. Maintenance Contracts:
 - 1. Submit a proposal from Installer to Owner for continuing service, in the form of a standard annual service agreement, starting on date warranty service is concluded.
 - a. Exception: Systems that include a warranty for life of installation.
 - 2. State services, obligations, conditions, and terms for agreement period – and for future renewal options.
- B. Operation and Maintenance Data: For shielding and accessories, to include in operation and maintenance manuals.
- C. Warranty Documentation: Ensure that forms have been completed in Owner's name.
- D. Project Record Documents: Record actual locations of penetrations through shielding.

1.11 QUALITY ASSURANCE

- A. Manufacturer/Installer Qualifications:
 - 1. Firm regularly and presently manufacturing RFI shielding of type specified as one of its principal products.

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2. Firm recognized and/or approved by the Owner and the Architect and the manufacturer of the MRI equipment.
3. Firm having within its direct employ experienced and properly equipped engineering, drafting, and project management departments.
4. Firm with at least five years of documented experience designing and manufacturing shielding of type specified.
 - a. Product proposed for use shall have been in successful service on at least five installations similar and equivalent to this Project for a minimum period of five years.
- B. Designer Qualifications: The individual that seals the seismic design details shall be a professional engineer, experienced in the structural design of this Work, and licensed, registered, or otherwise legally qualified to practice in the State of North Carolina.
- C. Welding Qualifications: Welding processes and welding operators qualified in accordance with AWS A5.8M/A5.8, AWS D1.1/D1.1M, AWS D9.1/D9.1M for the type of material(s) being welded, and no more than 12 months before start of scheduled welding work.
- D. Field Testing Agency Qualifications: Independent testing agency having staff experienced in field testing of shielding that conduct such testing as a normal service and maintain equipment required for testing.
 1. Approved by Owner.
 2. Able to provide data showing at least five successfully tested installations.

1.12 DELIVERY, STORAGE, AND HANDLING

- A. Store products in manufacturer's unopened packaging until ready for installation.

1.13 FIELD CONDITIONS

- A. Field Measurements: Verify dimensions of MRI area by field measurements before fabrication, Indicate measurements on Shop Drawings.
- B. Heat installation area to a minimum temperature of 68 degrees Fahrenheit for a period of 24 hours prior to – and during – installation.

1.14 WARRANTY

- A. Special Warranty: Manufacturer of enclosure system shall warrant the installed assemblies to be free of defects in materials and workmanship as evidenced by the retention of specific RFI-shielding characteristics for the specified warranty period. Manufacturer of enclosure system agrees to repair or replace shielding and assembly components that fail in materials or workmanship within specified warranty period.
 1. Failure shall include – but not be limited to – ceasing to meet performance requirements indicated whether due to:
 - a. Building movement.
 - b. Thermal expansion and contraction.
 - c. Vibration.
 - d. Other factors.
 2. Warranty shall also include installation and finishing that may be required due to repair or replacement of shielding.
 3. Enclosure Warranty Period: Five years from date of Substantial Completion.
 - a. Exception: The following components will be covered by the Contractor's general building guarantee (if installed).
 - 1) Electromagnetic filters.
 - 2) RFI-shielded doors.
 - 3) RFI-shielded windows.
 - 4) Pipe penetrations.
 - 5) Air vent RFI filters.

- B. Pass-through warranties provided by subcontractors to manufacturer of enclosure system will NOT be acceptable.

PART 2 - PRODUCTS

2.01 INTEGRATED RFI/EMI SHIELDING ASSEMBLIES

- A. Architect has designed certain aspects of the shielding. Contractor is responsible for completing the design and furnishing and installing a continuous shielding enclosure meeting requirements of Contract Documents.
 - 1. See Section 13 49 26 - Modular RFI Shielding Rooms for modular shielded rooms.
- B. Design Requirements: Building volume to be shielded is indicated on Drawings; provide continuous shielding without holes, gaps, or unshielded penetrations.
 - 1. Certain aspects of design are shown on Drawings.
 - 2. Design to comply with ICC (IBC).
 - 3. Overhead Shielding: Suspended from structure above.
 - 4. Modifications necessary to achieve required performance may be made to components that are not exposed to view without prior approval; obtain approval of any modifications to components exposed to view in finished work.
- C. Shielding Performance: Provide attenuation in accordance with requirements of manufacturer of MRI equipment. Refer to shielding requirements, layout drawings, and details.
 - 1. RFI Shielding: Reduction of Radio Frequency Waves Emanating from External Transmitters: Attenuation shall be 90dB in the frequency range of between 15MHz and 128MHz.
 - 2. Construct installed shielded enclosure in such a way that, without connections to earthing terminal, ohmic value of shielded enclosure relative to earth ground shall be equal to or greater than 1,000 ohms or as required by manufacturer of MRI equipment.
 - 3. EMI Shielding: Contain gauss fields of five or greater within MRI room, as indicated in layout drawings of manufacturer of MRI equipment.
 - 4. Sound Rating:
 - a. Provide sound-control door and window assemblies identical to those of assemblies tested as sound-retardant units by a recognized acoustical testing agency, and having the following minimum STC as calculated by ASTM E413 when tested in an operable condition according to ASTM E90:
 - 1) Doors in MRI Suites: Not less than 32.
 - 2) Windows in MRI Suites: Not less than 40.
 - 3) Wall assembly of MRI enclosure (including interior finishes): Not less than 46.
 - b. Manufacturer's or prior field-test certifications will NOT be acceptable.
 - c. Owner may perform NIC field-testing to verify STC performance, as specified in the Part-3 article entitled "Field Quality Control."
 - 5. Surface-Burning Characteristics (per ASTM E84):
 - a. Flame-Spread Index: 25.
 - b. Smoke-Developed Index: 50.
 - 6. Shielding Material Conductivity: Not less than a conductivity rating of 1.
 - 7. Galvanic Corrosion Resistance:
 - a. Use of the following in the manufacture and installation of the shielded enclosure will NOT be acceptable:
 - 1) Dissimilar metals that exhibit an anodic voltage differential greater than 0.25 volts.
 - 2) Copper or aluminum in direct contact with bare concrete.
 - 3) Zinc-plated RFI framing in direct contact with copper RFI medium.
 - 4) Copper-plated steel or brass RFI framing in direct contact with galvanized steel.

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- b. Use of the following in the manufacture and installation of the shielded enclosure WILL be acceptable:
 - 1) Bronze or brass flame spray treatment of steel or aluminum RFI contact surfaces.
- c. Design RFI-shielding medium to display an anodic voltage differential index of less than 0.40 volts and a cathodic group number of 1 (0.00 volts) to 9 (0.40 volts).
- d. Provide RFI seam and joint construction methods to provide the maximum in shield conductivity, low impedance, radio-frequency attenuation, and reduction of eddy current generation at RFI seams and joints.
 - 1) Construct shielding system with proper materials so that ionic conduction across joints and RFI seams is less than 0.10 volts.
- D. Components of shielding enclosure, including supports and attachments, permanently attached to building structure shall resist the effects of earthquake motions in accordance with ASCE 7.
- E. Acceptable Manufacturer of Enclosure System:
 - 1. Basis-of-Design: ETS-Lindgren, Inc.: www.ets-lindgren.com/#sle.
 - a. Physical Address: 1301 Arrow Point Drive, Cedar Park, Texas 78613-6936.
 - b. Telephone: (512) 531 - 6400.
 - c. Facsimile: (512) 531 - 6500.
 - 2. Substitutions: Equivalent enclosure systems from other manufacturers can be proposed during the bidding phase until ten (10) days prior to the receipt of bids using Document 00 26 00 - Procurement Substitution Procedures.

2.02 COMPONENTS

- A. Shielding Material:
 - 1. RFI-Shielding and Radio-Frequency-Attenuating Material: Annealed pure copper.
 - a. Manufacturer of enclosure system shall provide a copper RFI-shielded enclosure unless otherwise stipulated by performance specifications from manufacturer of MRI equipment.
 - b. Use of Dissimilar Metals: NOT acceptable.
 - 1) RFI-shielding medium shall display an anodic voltage differential index of less than 0.40 volts and a cathodic group number of 1 (0.00 volts) to 9 (0.40 volts).
 - 2) Construct shielding system with proper materials so that ionic conduction across joints and RFI seams shall be less than 0.10 volts.
 - 3) Use of bronze or brass flame-sprayed treatment of steel or aluminum RFI contact surfaces in manufacturing and installation of shielded enclosure will be acceptable.
 - c. Material Substitutions: Not permitted.
 - 2. EMI Shielding Material: Silicon steel, steel plate, or other material complying with EMI shielding specified in Performance Requirements.
 - a. Steel Sheet: ASTM A568/A568M, ASTM A1008/A1008M, or ASTM A1011/A1011M.
 - 1) Minimum Metal Thickness: 0.0747 inch (fka 14 gage); thicker members may be used at Contractor's option if approved by Architect.
 - 2) Finish: Free of oil, dents, rust, and other defects; suitable for painting.
 - 3) Welding Materials: Comply with applicable requirements of AWS D1.1/D1.1M and AWS D9.1/D9.1M; use MIG welding and AWS A5.8M/A5.8 weld filler metal.
 - 3. Fasteners: Except where bolting is specifically permitted, provide welded connections.
 - a. Do NOT use self-tapping screws for attachment of shielding.
 - b. Powder-actuated drive pins may be used to attach to concrete.
 - c. Bolted Connections: Accurately drill or punch holes.
 - d. Use materials that are galvanically similar to the material being fastened.

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- B. Dimension Lumber Framing: 1-1/2-inch-thick D Select or Better kiln-dried pine per FS MM-L-751, pressure-impregnated with fire-retardant chemical treatment.
1. Manufacturers:
 - a. Basis-of-Design: Hoover Treated Wood Products, Inc.; Pyro-Guard Interior Fire Treated Wood: www.frtw.com.
 - b. Substitutions: See Section 01 60 00 - Product Requirements.
 2. General:
 - a. Fire-retardant treatment shall not promote corrosion of metal fasteners.
 - b. Mark each piece of wood with treatment facility's stamp indicating compliance with specified requirements.
 - c. Provide stainless steel or other fasteners that are noncorrosive when in contact with wood treatment as recommended by manufacturer of fire-retardant treatment.
 3. Interior Type A: Comply with requirements of AWPA U1, Use Category UCFA, Commodity Specification H, low-temperature (low-hygroscopic) type.
 - a. Surface-Burning Characteristics (per ASTM E84):
 - 1) Flame Spread Index: Not more than 5.
 - 2) Smoke-Development Index: Not more than 30.
 - 3) Samples shall show no evidence of significant combustion when test is extended for an additional 20 minutes.
 - b. Kiln-dry wood after treatment to a maximum moisture content of:
 - 1) Lumber: 19 percent.
 - 2) Plywood: 15 percent.
 - c. Do NOT use material that is twisted, warped, or bowed, does not comply with requirements for untreated material, or is otherwise damaged or defective.
- C. Doors and Frames:
1. Door System:
 - a. Visually similar to standard, hospital-grade interior doors.
 - b. Having a documented to have a life-cycle test rating of at least 10,000 operational cycles without requiring adjustment or loss of radio-frequency attenuation.
 2. Factory-assembled shielded door unit that includes continuous seal around the entire perimeter of the door, with total assembly having shielding equal to that of shielded enclosure, complete with door leaf, door frame, threshold, and other hardware.
 3. Shielding Effectiveness: Equal to that specified for primary shielding, when closed.
 - a. Provide pneumatic doors that automatically seal against RFI using compressed air.
 - 1) Basis-of-Design Pneumatic Radio-Frequency Door System: ETS-Lindgren, Inc.; EVO Air: www.ets-lindgren.com/#sle.
 - 2) Radio-frequency seal design shall be easy to maintain and service.
 4. Door Construction: As specified in Section 08 14 16 - Flush Wood Doors.
 5. Door Facing: Wood veneer to match the doors specified in 08 14 16 - Flush Wood Doors.
 6. Frame shall be pre-finished, non-ferrous aluminum.
 7. Door Hardware:
 - a. General:
 - 1) Door shall employ fail-safe unlatching; upon loss of power the door shall revert to an unsealed condition.
 - 2) Remote activation/deactivation capable
 - 3) Any ferromagnetic parts or items are forbidden.
 - b. Lockset: Stainless steel (non-magnetic) mortise type with classroom function and conventional lever trim.
 - 1) Basis-of-Design Manufacturer: Allegion Plc.; Schlage: <https://commercial.schlage.com>.
 - (a) Exception: Requirement for remote activation/deactivation (under subparagraph entitled "General" above) shall govern.

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- c. MRI Interlock: Provide two normally open RFI-shielded door mechanical switches.
 - 1) Exposed, frame-mounted, micro-switches will NOT be acceptable.
 - 2) Electrical interconnections and mounting by electrical trade subcontractor.
 - d. Hinges:
 - 1) Minimum 4-1/2- by 4-1/2-inch brass or stainless steel, fully mortised, with minimum of two ball-bearing swing joints per hinge.
 - 2) Provide minimum of three hinges per leaf -- or continuous pin-and-barrel hinge.
 - 3) Documented to have a life-cycle test rating of at least 10,000 operational cycles without requiring adjustment.
 - e. Door Threshold: Flat without taper with a maximum height from the MRI room's parent slab of 5/8 inch, but not more than 1/2-inch above adjacent flooring materials for ADA-compliance, with 1/4-inch beveled edges if higher than 1/4 inch above adjacent flooring materials for ADA-compliance.
8. Width: As indicated on Drawings.
- D. RFI-Shielded Patient View Window(s): High-visibility stainless-steel screen on an aluminum frame.
- 1. Glass and Glazing: Clear laminated safety glass, 6 mm (1/4 inch) thick, as specified in Section 08 80 00 - Glazing.
 - 2. Construct window assembly utilizing an aluminum extrusion of an engineered shape to affix radio-frequency-attenuating screens and provide a means of securing double-sided glass.
 - a. Treat contact surface of aluminum extrusion with brass or bronze flame spray where attaching to copper shielding.
 - b. Join mesh electrically and mechanically to frame.
 - c. Weld frame to primary shielding.
 - d. RFI Performance: Provide a proven RFI seal design that is easily maintained and serviced. RFI-shielded window frame and seal assembly shall maintain a shielding effectiveness equal to that of the shielded enclosure.
 - e. Construct RFI-shielding screen of a double layer of Type 304 stainless steel and place layers in orientation to each other so that the resultant distortion of viewed image through the RFI-shielded window approaches zero.
 - f. Stain, not paint, the visible area of RFI-shielding screens black in color for optimum image visibility.

2.03 FABRICATION

- A. Fabricate as needed to meet Performance Requirements indicated.
 - 1. Clamp-together and taped systems will NOT be acceptable.
 - 2. Isolation: Provide isolation around structural supports and building steel as required for installation of shielded system, to comply with performance requirement for isolation between RFI shield and ground.
- B. RFI-Shielded Wall Assembly: The shielding system wall panels shall be vertically self-supported and structurally independent from the parent building. The wall assembly shall allow for the addition of Owner-provided interior finishes without penetration of the attenuating materials.
- C. RFI-Shielded Ceiling Assembly: The RFI-shielded ceiling assembly shall be supported from Owner-provided structural assemblies and provide interior surfaces that allow for Owner connections of interior finishes and utilities without penetration of the attenuating materials. RFI-shielded ceiling supports shall employ RFI-competent fasteners.

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- D. RFI-Shielded Floor Assembly: The RFI-shielding supplier shall provide a water-resistant RFI-shielded flooring system within the entire area of the RFI-shielded enclosure (inclusive of any depicted cable trenching designed flush with finished floor).
1. NO porous materials shall be used in the flooring system. For the purposes of this requirement, the term "porous" includes - but is not limited to - the following:
 - a. Wood particleboard.
 - b. Plywood.
 - c. Wafer board.
 - d. Hardboard ("Masonite").
 - e. Pressed paper products.
 2. RFI-shielded floor assembly must resist fluid ingestion from any fluid source within the RFI-shielded enclosure and any fluid source originating outside of the RFI-shielded enclosure.
 3. Basic System: Provide an all-copper, monolithic, RFI-shielded floor membrane. RFI solder-weld all-copper membrane seams.
 4. Electrical Isolation: Provide electrical isolation of shielded enclosure and RFI-shielded floor system by use of a two-part, thermosetting resin applied directly to concrete floor substrate.
 - a. Use of hardboard, other pressed wood materials, plastic sheet, or other sheet goods for electrical isolation – or as a moisture barrier – will NOT be acceptable.
 5. Substrates in contact with soil must have a properly engineered and installed, effective vapor-barrier system that prohibits hydrostatic, capillary, or moisture-vapor pressure.
 - a. Moisture Barrier: Thermosetting resin acceptable to manufacturer of enclosure system.
 6. Membrane Adhesive: Bond monolithic copper membrane to dielectric/moisture barrier with a two-part adhesive resin compatible with both the copper and dielectric/moisture barrier.
 7. Epoxy Grout Coating: Over-coat copper membrane with an epoxy grout chemically cured to a minimum bearing capacity of 5,000 psi.
 - a. Verify compatibility of floor and grout coating with finish flooring specified in Section 09 65 00 - Resilient Flooring.
 - b. Install grout overcoat to minimum 1/2-inch thickness over entire exam room surface.
 - c. Grout coating shall not delaminate and shall withstand the direct loading of the magnet cryostat and patient table.
- E. EMI Shielding:
1. The need for EMI shielding shall be as determined by EMI-shield design report from manufacturer of MRI equipment.
 2. When and if EMI shielding is required, provide EMI materials that conform to the specifications from manufacturer of MRI equipment with respect to:
 - a. Chemistry of the EMI materials.
 - b. Annealing processes if any.
 - 1) Any annealing of the EMI materials shall occur after the final fabrication of the material.
 - c. Orientation about the magnetic iso-center.
 - 1) Orient the inherent grain structure of the magnetic plates installed within the side walls, top, and bottom sides in the same direction as the resultant flux path.
 3. Fabricate magnet plate material true with no deviation in width or length greater than 0.03 inch.
 4. Structural Supports: Unless otherwise stated, structural supports for the application of the EMI materials shall be designed, provided, and installed by structural-steel subcontractor, not the EMI-shielding supplier.

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5. The EMI-shielding supplier shall be responsible for the application of the EMI materials to the structural supports.
 - a. Magnetic plates may be bolted or welded to the supporting structure.

2.04 ACCESSORIES

- A. All services must pass through either a filter or a sealed waveguide as follows:
- B. Service Entrance Plates: Steel sheet or plate; mounted in plane of primary shielding, continuously electrically bonded to shielding; for mounting of conductor penetrations.
 1. Thickness: At least as thick as primary shielding.
 2. Size: Providing at least a 6-inch space between penetrations and edge of plate.
 3. Frame for Welding: Steel or extruded brass, 1/4 inch thick, minimum.
 4. Location: As indicated on Drawings.
- C. Heating, Ventilating, and Air-Conditioning (HVAC): Design the waveguide type air vent filters to provide proper air passage for cooling and ventilation while also maintaining a shielding effectiveness equal to that of the shielded enclosure.
 1. Honeycomb waveguide-below-cutoff type, 3/16-inch brass hex cell, and 1-inch in thickness, with all components continuously electrically and mechanically bonded to each other and to shielding.
 - a. Provide interior and exterior dielectric collars and non-conducting boots to connect to the ductwork.
 - b. Provide suitable collars and boots, where required, for connection to diffusers or grilles located in suspended ceilings or in light and air valance.
 2. Shielding Effectiveness: Equal to that specified for primary shielding, with cutoff frequencies not less than one-and-one-half times that specified for primary shielding.
 3. Static Pressure Drop: Not more than 0.02 inch water gauge at air velocity of 600 feet per minute.
 4. Sound Attenuation: Provide supplemental RFI-shielded sound-reduction systems.
 5. Frame for Welding: Steel or extruded brass, 1/4 inch thick, minimum.
 6. HVAC services entering RFI-shielded enclosure shall be installed by HVAC trade subcontractor using techniques approved by manufacturers of RFI shielding and MRI equipment.
- D. Grounding Stud: Provide a permanently installed, single-point ground conductor terminal using a brass stud and an external and internal tapped and threaded copper buss bar.
 1. The grounding stud shall be common to both interior and exterior of shielded enclosure.
 2. Locate grounding buss bar terminal as directed by manufacturer of MRI equipment in relation to both MRI penetration panel and electromagnetic power line filters.
 3. Provide washers and nuts for attachment of grounding cables.
 4. Ground conductors entering and routing within RFI-shielded enclosure shall be installed by electrical trade subcontractor using techniques approved by manufacturers of RFI shielding and MRI equipment.
 5. RFI-shielding shall be properly grounded by the electrical trade subcontractor prior to the connection of electrical services to any electromagnetic power and/or signal filter.
- E. Conductor Penetrations: Rigid steel conduit from filter to shielding.
 1. Filters: Provide for each electrical conductor that passes through the shielded assembly, including neutral conductors.
 - a. RFI-shielded electrical filters shall maintain the shielding effectiveness equal to that of the shielded enclosure.
 - b. Obtain from the Owner the specific electrical characteristics of -- and the total number of conductors required for -- the following elements that will be utilized within the RFI-shielded enclosure:
 - 1) Lighting and power circuits.

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- 2) Communication devices.
- 3) Environmental control devices.
- 4) Data transmission devices.
- 5) Fire alarm devices.
- c. Provide conduit feeding the filter boxes with isolation coupling at the box for ground isolation.
- d. Electrical services entering and routing within RFI-shielded enclosure shall be installed by electrical trade subcontractor using techniques approved by manufacturers of RFI shielding and MRI equipment.
- 2. Power Line Filters:
 - a. Incoming Electrical Power and Lighting Lines: Provide with radio frequency filters, one for each electrical conductor, including grounds and neutrals, with integral waveguide penetrations, designed to attenuate radio-frequency energy on the incoming power feeders a minimum of 100 dB of insertion loss from 150 kHz to 1 GHz as measured by MIL-STD-220.
 - 1) UL certification will be required for all power line filters.
- 3. Voice and Data Line Filters:
 - a. Incoming Communication Lines Provide with radio frequency filters, one for each electrical conductor, including grounds and neutrals, with integral waveguide penetrations, designed to attenuate radio-frequency energy on the communication lines a stop band of 100 dB of insertion loss from 150 kHz to 1 GHz and pass band of 1 dB from 0 to 3000 Hz, as measured by MIL-STD-220.
- F. Pipe Penetrations: Fabricate of steel plate or sheet, configured to achieve cutoff frequencies not less than one-and-one-half times that specified for primary shielding; continuously welded or brazed to primary shielding.
 - 1. Mechanical Pipe Penetrations: Wave-guide-below-cut-off type.
 - a. Construct pipe penetrations of a material suitable to the conditions of service in which it is installed, and to maintain shielding effectiveness equal to that of the shielded enclosure.
 - b. Mechanical pipe penetration services entering and routing within RFI-shielded enclosure shall be installed by plumbing trade subcontractor using techniques approved by manufacturers of RFI shielding and MRI equipment.
 - 2. Medical Gas Piping Systems:
 - a. Provide a medical gas panel of the wave-guide-below-cutoff type that complies with Chapter 5 of NFPA 99C.
 - b. Each individual medical gas line shall be medically clean Type-K copper and pass, without seams, through the provided pipe wave-guides.
 - c. Provide a brass or copper mechanical coupling between the exterior end of the threaded gas line wave-guide that passes through copper pipe.
 - d. RFI-seal the exterior end of each pipe wave-guide to the respective gas pipe using approved methods.
 - 1) The use of threaded fittings with dielectric connectors will NOT be acceptable.
 - 2) The plumbing trade subcontractor shall provide and install medical gas lines using techniques approved by manufacturers of RFI shielding and MRI equipment.
 - 3. Cryogenic Gas Exhaust Wave Guide Vent: Provide waveguide-below-cutoff type; size as required by manufacturer of MRI equipment. Construct cryogenic wave-guide vent of suitable material to maintain a shielding effectiveness equal to that of the shielded enclosure and to prevent structural failure of the wave-guide tube during a magnet quench event.
 - a. The HVAC trade subcontractor shall provide dielectric connections at both the interior and exterior side of the cryogenic RFI vent of a suitable material to maintain a

minimum of 1,000 ohms direct-current-resistance to earth ground and prevent structural failure during a magnet quench event.

- b. Cryogenic gas exhaust piping systems both below and above the cryogenic wave-guide tube assembly shall be installed by HVAC trade subcontractor using approved techniques from manufacturers of RFI -shielding and MRI equipment.

PART 3 - EXECUTION

3.01 EXAMINATION

- A. The site of the Work shall be free and clear of materials not directly related to the installation of the shielded enclosure.
- B. Do not begin installation until substrates have been properly prepared.
- C. Moisture Barrier:
 - 1. Allowable relative humidity with the substrate: Less than 98 percent per ASTM F2170.
 - 2. If test results show unacceptable moisture levels, prepare substrate in accordance with moisture-barrier manufacturer's requirements.
 - a. If mechanical cleaning (bead-blasting) is required, use an apparatus that abrades concrete surface, contains dispensed shot within apparatus, and recirculates shot by vacuum pickup.
 - 1) Provide a concrete surface profile (CSP) of CSP 3 per ICRI PC1-10.
- D. Notify Architect of unsatisfactory preparation before proceeding.

3.02 PREPARATION

- A. Clean surfaces thoroughly prior to installation.
- B. Prepare surfaces as required by approved Shop Drawings using the methods recommended by manufacturer of enclosure system for achieving the best result for the substrate under the Project conditions.

3.03 INSTALLATION

- A. Work shall be performed by manufacturer of enclosure system, or under its direct supervision.
- B. Install in accordance with manufacturer's instructions.
- C. Install moisture barrier on concrete floor substrate according to resin manufacturer's instructions.
- D. Assemble shielded enclosure wall and ceiling RFI-shielding panels into straight, level, and plumb surfaces.
- E. Use specified wood studs at 16-inch spacing for application of wall finishes and to recess mechanical and electrical utility boxes.
- F. Align and secure RFI-shielded joints.

3.04 FIELD QUALITY CONTROL

- A. Perform preliminary inspections and tests as required to ensure that completed shielding will achieve specified performance requirements when field tested as specified; retesting due to failures will be at Contractor's expense.
- B. Field Testing: Comply with requirements of Section 01 40 00 - Quality Requirements.
- C. Test shielded enclosure in accordance with IEEE 299 , as modified for MR system installation. Demonstrate the required attenuation as detailed in paragraph entitled "Shielding Performance" in Part-2 article entitled "Integrated RFI/EMI Shielding Assemblies."
 - 1. Attenuation Testing: Engage the services of a qualified independent testing agency to perform tests specified by IEEE 299; conduct tests with doors closed and filters under normal load conditions.
 - a. In addition to IEEE 299 test points, test full perimeter of doors and each penetration.

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- b. Notify Owner at least two weeks in advance of tests to allow attendance by Owner's representative.
 - c. Perform tests after shielding has been completed, including each penetration and connection.
- D. Qualification Testing: Perform immediately after completion of the shielded enclosure and prior to installation of architectural surfaces within or outside the shielded enclosure. Make no trade connections to shielded enclosure until successful completion of test process.
 - 1. An observer of the Owner, or the Contractor, or the manufacturer of the MRI equipment will witness test procedure. Provide Owner with 72-hour notice of when test is to occur.
 - 2. Furnish a certificate of compliance to the Owner.
- E. Acceptance Testing: Perform immediately after installation of the selected MRI assembly and closure of the RFI-shielded entrance panel.
 - 1. An observer of the Owner, or the Contractor, or the manufacturer of the MRI equipment will witness test procedure. Provide Owner with 72-hour notice of when test is to occur.
 - 2. Furnish a certificate of compliance to the Owner.
- F. Ground Isolation Monitoring: Monitor ground isolation during entire phase of construction for a minimum of 1,000 ohms above earth potential.
 - 1. Immediately correct deficiencies found that are the result of a fault condition caused by the shielded enclosure supplier.
 - 2. Immediately report deficiencies found to be caused by other trades.
 - 3. Provide an adjustable audio and visual ground isolation device for continuous monitoring of the RFI-shielded enclosures ground isolation. Device shall remain with the shielded enclosure for follow-up monitoring by the Contractor.
 - 4. Furnish a certification of compliance to the Owner.
- G. Repair, modify, or replace defective components and portions of shielding at no extra cost to Owner. Retest at Contractor's expense.

END OF SECTION