



SECTION 134000
RADIO FREQUENCY FOR MRI SHIELDING – SOLDERED COPPER SYSTEM

PART 1 – GENERAL

1.1 DESCRIPTION

The purpose of RF shield construction is to create an enclosure in which radio frequency (RF) is contained and/or prevented from entering. This environment is necessary to ensure proper performance of Magnetic Resonance Imaging (MRI) equipment.

1.2 WORK INCLUDED

This section includes furnishing all labor, materials, equipment, tools, and related items to engineer, pre-fabricate, deliver, install and test a modular RF shield for an MRI scan room.

1.3 WORK NOT INCLUDED

The following work is excluded, but shall be coordinated with the Shielding Vendor:

- A. Construction or preparation of the parent structure to receive the shield assembly.
- B. Weatherproofing and climate control of the parent structure prior to the installation of the shield assembly.
- C. Connections of other work to the RF shield.
- D. Delivery and installation of the MRI equipment.
- E. Field painting and/or any other final finishes.
- F. All work as required in Related Sections below.

1.4 RELATED SECTIONS

- A. Division 08 Doors
- B. Division 08 Glazing
- C. Division 09 Gypsum Board Systems
- D. Division 09 Finishes
- E. Division 13 Magnetic Shielding
- F. Division 22 Plumbing-Piping
- G. Division 23 Air Conditioning-Ductwork
- H. Division 26 Electrical

1.5 REFERENCES

Comply with applicable requirements of the following standards and those others references in this Section.

- A. Military Standards
 - 1. MIL-STD-220A, Method of Insertion Loss for Radio Frequency Filters
 - 2. MIL-STD-285, Method of Attenuation Measurements for Electromagnetic Shielding Enclosures for Electronic Test Purposes.
- B. Underwriters Laboratories, Inc.

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1. UL-1283, Standard for Safety – Electromagnetic Interference Filters.
- C. American Standards for Testing and Materials
 1. ASTM F1869, Standard Test Method for Measuring Moisture Vapor Emission Rate of Concrete Subfloor Using Anhydrous Calcium Chloride.
- D. International Standards
 1. IEEE 299, Standard Method for Measuring the Effectiveness of Electromagnetic Shielding Enclosures (Supersedes MIL-STD 285)

1.6 PERFORMANCE REQUIREMENTS

- A. Attenuation: The shield must meet the following performance criteria according to specifications supplied by the MRI equipment manufacturer:
 1. Attenuation of magnetic field
 2. Attenuation of Electric field
 3. Attenuation of Plane wave
 4. Attenuation of Sound
- B. Ground: The shield structure must be electrically grounded at a single point, with a minimum resistance to alternate ground of 1,000 ohms.

1.7 SUBMITTALS

- A. Procedure: Submit under provisions of Section 013300
- B. Product Data: Include manufacturer's complete information on system.
- C. Shop drawings: Show full layout of system, including all dimensions and required points of coordination with work of other sections. Demonstrate full compliance with contract documents. Shield Vendor's shop drawings will be approved in writing by the General Contractor, or other appropriate responsible party prior to fabrication of the RF shield.
- D. Test Reports: Upon completion, provide the following:
 1. RF Qualification Test
 2. RF Acceptance Test
 3. Ground Isolation Monitoring Test

1.8 QUALITY ASSURANCE

- A. Standards: Perform work of this section in accordance with provisions of the following:
 1. IEEE 299 (Supersedes MIL-STD-285)
 2. MIL-STD-220A
- B. Qualifications: Shield vendor shall have been engaged in continuous business for at least fifteen (15) years in the manufacturing and installation of shielded products and a minimum of five (5) years in manufacturing and installation of RF shielding.
- C. Shield vendor shall be ISO 9000 compliant, or shall be currently and actively engaged in a structured program seeking ISO 9000 compliance.
- D. Shall have within his direct employ experienced and properly equipped engineering, drafting, architectural design and project management departments.
- E. Have in-house capabilities to fabricate and erect the RF shielded enclosure.
- F. Warranties
 1. Warrant the RF shield to be free of defects in materials and workmanship as evidenced by retention of the specified RF shielding characteristics

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for periods as noted below and in accordance with the Shielding Manufacturer's standard warranty. Assumes no physical modifications are made to the RF shield by anyone other than the original shield vendor.

- a. Enclosure: Five (5) years from date of completion of acceptance test.
 - b. RF Filters: One (1) year from date of completion of acceptance test.
 - c. RF Door: One (1) year without annual maintenance contract. Five (5) years from date of completion of acceptance test and with annual maintenance provided by the shield vendor.
2. The warranties specified in this article shall not deprive the owner of other rights the Owner may have under other provisions of the contract documents and shall be in addition to, and run concurrent with, other warranties made by the Shield Vendor under requirements of the contract documents.

PART 2 – PRODUCTS

2.1 MANUFACTURERS

- A. To establish the quality level and design requirements for the project, the design shielding is based on products as manufactured by:

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- B. Alternative products (substitutions): Contractor must furnish appropriate and complete product data, proof of ISO 9001:2008 certification, worker OSHA certifications, environmental characteristics, and sample warranty with bid for the Architect to consider the substitutions as "equal" to the manufacturer, product specified and quality assurance requirements.

- 1. Further additional information may be requested by the Architect for determination that the proposed product substitution is fully equal to the specified products. There is no guarantee that proposed substitutions will be approved and the Contractor is hereby directed not to order any materials until said approval(s) are received in writing.
- 2. Requesting substitutions is at the Contractor's own risk, including uncompensated delays of the Project. Time may be required for sufficient review and for additional requests of information. Delays of work which result from substitution reviews and re-submissions are not grounds for additional time or cost change orders, and will not be considered by the Owner.

2.2 MATERIALS & COMPONENTS

- A. RF Wall & Ceiling Shield: Consist of 3/4" fire rated plywood with 5-ounce minimum copper sheet with all joints and seams soldered. Plywood shall be

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supported by a wood frame, provided by the general contractor. Frame shall be designed to support the full ceiling loads for drop ceiling, lighting, cable trays, ductwork, etc ...

1. **Wall supports:** a fire rated wood 2x4 frame structure to be erected by others prior to the start of the RF shield installation.
 2. **Ceiling supports:** a fire rated wood 2x4 frame structure to be erected by others prior to the start of the RF shield installation.
 3. **Attachment points:** Shall be installed by the Shield Vendor for support of other work and materials to be installed by others. Load, location and quantity of attachment points shall be specified prior to shield fabrication.
 4. **Penetration Panel:** The penetration panel opening location will be field verified. An opening will be cut thru the copper and plywood. The opening will be framed with copper wrapped fire rated wood 2x4 to accept the MRI vendors supplied penetration panel at the time of magnet delivery.
 - a. **Test plate:** A blank test plate shall be incorporated into the panel dimensioned to the same size as the MRI vendor's penetration panel. The test plate shall serve as a temporary seal of the penetration panel for RF testing of the shield prior to magnet delivery.
 - b. **Grounding Bus Bar:** A ½" diameter solid brass threaded rod with a solid brass attachment bar shall be mounted through the RF panel adjacent to the power line filters. This structure shall serve as a single point grounding point for the RF shield. Intended for subsequent attachment of a dedicated wire to the electrical ground point of the building.
- B. RF Shielded Floor System:** Shall consist of 5 oz or greater copper sheeting that is soldered at all seams with the following elements:
1. **Floor Underlayment**
 - a. Vapor retardant shall be a polyethylene sheet, 6 mils minimum thickness.
 - b. **Support material:** Plywood or MDF board adhered to copper sheets so that the finish flooring materials can be applied.
 2. **Magnet supports/anchors:** shall be installed according to Equipment Vendor's specifications
 3. **Wiring trenches/raceways:** shall be lined with formed 12-ounce copper and made electrically contiguous with the floor panels.
- C. Components:**
1. **Penetration Panel-** a standard RF panel that is provided by the MRI vendor and integrated into the RF wall panel.
 2. **Magnet delivery access panel-** A removable section will be provided in the shield to allow entry or exit of the MRI magnet. The location shall be specified at the drawing approval milestone and prior to shield fabrication.
 3. **Heating ventilation and Air conditioning waveguides-** Vent Type Wave guide below cutoff type, 3/16" hex cell, 1 inch in thickness. Design of the waveguide to permit air flow as per MRI system manufacturer specifications while maintaining the require shielding effectiveness equal to the RF enclosure.

4. **Cryogenic Gas Exhaust Wave Guide- Wave Guide below cutoff type, size as required by MRI system manufacturer. Construct cryogenic wave guide vent of suitable material to maintain a shielding effectiveness equal to that of the RF shielded enclosure.**
 - a. The mechanical contractor shall provide a dielectric connection to the exterior side of the cryogenic vent of a suitable material to maintain a minimum of 1000 ohms DC resistance to earth ground and resist structural failure during a magnet quench event.
5. **EMI Rated Power Line and Signal Electrical Filters: RF shielded electrical filters shall provide an insertion loss as specified within MIL-STD 220-A and maintain the shielding effectiveness equal to that of the shielded enclosure. Provide an EMI filter for each electrical conductor that penetrates the enclosure, including neutral conductors. UL ratings will be required for power line conductors. Design filters to attenuate RF energy on incoming conductor at 10 dB from 150kHz to 10 GHz. Power line and DC lighting EMI filters shall exhibit no greater than 3 milli-amps of leakage current at rated capacity. Filters required for, but not limited to:**
 - a. Non-Invasive monitoring
 - b. MRI stereo
 - c. Telephone & intercom
 - d. Feed-thru apertures as required
 - e. Power outlets
 - f. Room lighting
 - g. Note that the RF shield supplier is responsible to provide and install the EMI filter assembly. Connection, wiring, switches, controls, etc... to the filter is by others.
6. **Mechanical Pipe Penetrations: Wave guide below cutoff type. Construct pipe penetrations of a material suitable to conditions of service for which it is installed, and to maintain shielding effectiveness equal to that of the shielded enclosure.**
7. **Medical Gas Piping Systems: Provide medical gas panel that complies with NFPA chapter 99C – 42. The use of threaded fittings with dielectric connectors shall be prohibited.**
- D. **Door Assembly: Guardian™ RF Shielded door: The door and frame assembly shall provide RF integrity while presenting the overall appearance of a conventional medical facility door. Door and frame assembly will be fit and hung at the factory. RF attenuation shall be accomplished by means of a continuous RF door seal around the entire perimeter of the door.**
 1. **Door Frame:** Shall consist of stainless steel or extruded aluminum at manufacturers option and shall be polished before installation. The frame shall be formed in such a way as to assure proper mating with the RF door seals.
 2. **Door Leaf:** To consist of a solid core wood or aluminum at manufacturers option. 4'0" x 7'0" shall be considered the standard size.
 3. **Door Hinges:** The door assembly shall be factory mounted with hospital grade radial thrust stainless steel ball-bearing hinges.
 4. **Threshold:** Shall consist of a stainless steel or extruded aluminum, tapered ramp directly fastened to the jambs. This will serve as an

- integral mating part of the seal assembly affixed to bottom of the door. Threshold is to be made electrically contiguous with the door frame.
5. **Door Latching Device:** Shall consist of hospital grade heavy duty lever lockset classroom function. The device is to be configured with a construction core cylinder lock in such a way as to allow controlled access into the room, but allow exit at any time.
 6. **RF door seals:** Conventional Copper/Beryllium 'fingerstock' material shall not be used. The RF door seal shall consist of a continuous brass seal strip with exposed outer edge of the seal hemmed 1/4" or fabric -over-foam RF gasket at manufacturer's option
 7. **Door Finish:** Plastic laminate or standard unfinished paint-grade white birch or red oak wood veneer shall be applied to both sides. Anodized aluminum trim shall be applied to both sides.
- E. Optional Up-grades:** Shield vendor shall provide pricing and availability for the following items:
1. **Automatic door:** To consist of a standard door described above, modified to receive a pneumatic latching system that when engaged will automatically seal the door to the frame. The door shall open and close via wall mounted push plates that when activated will engage an electromechanical operator. The operator shall be integrated in to the pneumatic latch system to provide simple push button activation. Free egress from the room shall be maintained always.
 2. **Acoustic Dampening Package** consisting of:
 - a. Installation of acoustic material within the door core, frame and bottom.
 - b. Glazing the operator window with 3/16" tempered glass on one side and 1/4" tempered glass on the other side
- F. RF Windows:** To consist of two (2) internal layers of 304 stainless steel screen material, mounted in a hardwood frame in such a way as to become electrically contiguous with the shield, and painted flat black to minimize reflection. The two layers of screen material must be laid at opposing angles to minimize 'moiré' patterns. The window frames shall conform to hat and flat attachment system described above. Oversized RF windows may require mullions.
1. **Interior (Control Room Window)** shall be glazed with 1/4" tempered glass on both sides. 4'0" x 4'0" shall be considered standard size.
 2. **Exterior (View Window):** View windows are typically located to match exterior windows on the parent structure. View windows shall be glazed with 1/4" tempered glass on one side only.
 3. **Skylight:** Skylight RF windows are typically located to match exterior skylights of the parent structure. Skylight RF windows shall not require glass, and consist of window framing and screen only. Because the RF shielded skylight assembly does not have glass applied, the space above the assembly will be open to the conditioned space below the assembly, and therefore the walls of the skylight assembly should be sealed by others to prevent dust and debris from falling on the RF screen.
- G. Finishes**
1. Installation of finishes within the MRI room shall be by others and shall be installed such that no penetrations are made through the RF shielding.

H. Magnetic Shielding

1. For shield installations where attenuation of the MRI magnetic field is required, magnetic shielding will be installed according to precise specifications as to the thickness, location relative to magnet isocenter, and type of material. These specifications are to be supplied to the MRI equipment vendor.

PART 3 – EXECUTION

3.1 DESIGN

- A. Architectural Drawings shall be supplied to the Shield Vendor as complete, accurate and approved for construction to ensure accurate preparation of Shield Vendor's shop drawings.
- B. MRI Equipment Vendor's Drawings shall be supplied complete and approved to the Shield Vendor before fabrication. Shield vendor will combine information contained therein with the architectural data to provide a comprehensive set of shop drawings. In cases where a discrepancy exists between Architectural and MRI Equipment Vendor's drawings, Shield Vendor shall notify both parties, along with the General Contractor, and any other appropriate responsible party and proceed as directed.
- C. Field Measurements: Shield Vendor may elect, at its discretion, to gather field measurements as necessary to complete timely and accurate shop drawings. In cases where a discrepancy exists between written and actual dimensions, Shield Vendor shall notify the parties involved and proceed as directed.
- D. Shop Drawings: Shield Vendor shall use its best efforts to gather information and provide timely and accurate shop drawings prior to fabrication. Shop drawings will be approved in writing before fabrication takes place. Approval of shop drawings shall constitute 20% completion of the project.

3.2 FABRICATION

- A. Shield Vendor shall use its best means and methods to substantially pre-fabricate all necessary components for the shield, based upon the approved shop drawings.
- B. All raw materials and components used in the manufacturing process will be new, unused material and will conform to local and NEC codes.
- C. Shield Vendor shall use established means and methods for quality control assurance during the fabrication process.

3.3 EXAMINATION

- A. Verify that substrates are ready to receive work of this section and openings correspond to locations and dimensions indicated on approved shop drawings.
 1. Verify that floors are level to within 1/8 inch in 10 feet.
 2. Verify that required utilities are available.
- B. Do not begin work of this section until unacceptable conditions have been corrected.
- C. Site Conditions: General Contractor shall examine the areas and conditions under which the RF shielded enclosure is to be installed and notify the Shield Vendor of conditions detrimental to the proper and timely completion of work. Work shall not proceed until unsatisfactory conditions have been corrected.

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- D. Dimensions:** Upon arrival for installation, Shield Vendor shall verify that the job site is ready to receive work of this section and openings correspond to locations and dimensions indicated on approved shop drawings.

3.4 INSTALLATION

- A. Job Site Readiness:** The following conditions are necessary to have the status of a "Ready Site". The General Contractor shall verify these conditions before the Shield Vendor arrives at the job site to begin installation:

1. Work Area

- a. There is a designated area adjacent to the MRI exam room for staging of the RF shield components and materials.
- b. There is a clean, clear, pathway for wheeled transport of materials and equipment from the delivery truck to the staging area.
- c. The MRI exam room and staging area is free of other work, workmen, clutter, and/or debris and the floor has been broom swept.
- d. The MRI exam room and staging area is weatherproofed, dry (non-condensing), and temperature controlled between 60°F and 90°F
- e. The General Contractor will provide a secure area for storage of Shield Vendor's tools and equipment.
- f. The General Contractor will provide proper work lighting in the area where the RF shield will be installed.
- g. The General Contractor will provide two (2) 120 VAC, 20 AMP service connections at the installation location. These services must be grounded and comply with any and all applicable local and N.E.C. codes.
- h. The General Contractor will provide containers for the disposal of refuse materials from the RF shield installation site. The General Contractor shall be responsible for the removal of containers after completion.

2. Parent Structure

a. Concrete Slab

- i. **Depression:** A level, non-ramped, threshold-to-floor junction is required, the slab within the shield footprint will be provided to the Shield Vendor as a depressed section measuring 1 ½" below the surrounding slab for an inward-opening or an outward opening door. These measurements assume a finished floor thickness of 1/8". In addition to these measurements, the slab depression may need to increase to allow for any specified floor magnetic shielding.
- ii. **Leveling:** Slab is to be made level by others to within 1/8" in 10 feet with maximum difference of ¼" between the highest and lowest point across the entire footprint of the shield.
- iii. **Curing:** Slab shall be cured to less than or equal to 3 lbs moisture vapor transmission per 1000 sq. ft. per 24 hours prior to installation (per ASTM F1869).

- iv. **Positioning:** The intended location of the MRI shield shall be established and marked on the slab by others prior to installation of the RF shield.
 - b. **Structural Clearance.** To ensure against grounding of the RF shield, a clearance to the building structure is required. The required clearance between the parent room wall and the RF shield walls is 2", and the required clearance between the parent room ceiling and the RF shield ceiling is 4". All external RF shield surfaces must have no electrical contact with existing building construction. Therefore, all metallic surfaces such as conduit, duct work, metal framing studs and piping that may contact the RF shield must be (electrically) isolated or removed.
 - c. **Overhead Support.** The RF shield ceiling panels are typically supported by the parent room construction. The RF shield ceiling system load is approximately 2 pounds per square foot. This weight does not include any magnetic shielding or interior structures, such as lights, duct work, wiring, plumbing, suspended ceilings or other construction. It is the responsibility of the Customer (or other appropriate responsible party) to ensure that the parent room overhead construction will adequately support the RF shield ceiling system and any other additional weight.
- 3. Assembly**
- a. Assemble all components of the RF and magnetic shielding system in strict conformance with Shield Vendor's methods, MRI equipment vendors specifications with manufacturer's employees and under direct supervision of a factory representative.
 - i. Install all materials to be straight, level, true and plumb.
 - ii. Verify integrity of RF shielding before covering shield material with other finish materials.
 - iii. Coordinate locations of penetrations with installation of RF shielding and approved shop drawings.
 - iv. Upon completion of the assembly, Shielding Vendor shall provide identification of magnet isocenter location.
 - 4. Upon completion of the assembly, Shielding Vendor shall dispose of all debris, trash, containers, residue, remnants and scraps which result from the work of this section. Refuse container shall be supplied by the General Contractor.
 - 5. **Soldered Copper System:**
 - a. Install dielectric barrier over floor slab.
 - b. Adhere copper sheeting with construction adhesive onto the dielectric barrier.
 - c. **Floor Underlayment:**
 - I. Install (2) layers of cement board over copper sheeting
 - II. Install a leveling compound
 - III. Apply finish flooring
 - d. **Copper sheeting:** Install as described in section 2.2.C
 - e. **Magnet Access Removable Panels:** Install as indicated on drawings.

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6. **Wave Guides:** Attach securely to RF shielded enclosure with frames or attachment collars as detailed.
7. **Mechanical Sleeves:** Attach securely to RF shielding with dielectrics, as required to allow penetration of shield without degradation of RF shield attenuation characteristics.
8. **Filters:** Attach securely to RF shielding at all power line and communication wire penetrations, as required to prevent degradation of RF shield attenuation characteristics.
9. **Ground Stud:** Install a ground stud on the RF shield adjacent to power line filters inside the shield, as shown on shop drawings, for subsequent attachment of a dedicated wire to the electrical ground point of the building under Section 262100
10. **Finishes:** Installation of room finishes is specified in sections references in RELATED SECTIONS Article 1.4, and is performed by others.

3.5 FIELD QUALITY CONTROL

- A. Shield Vendor shall exercise care in handling and protecting materials and finishes during fabrication, shipment, erection and finishing, as necessary to prevent damage to finished surfaces and shielding linings.
- B. Shield Vendor shall field verify specs and dimensions of all components during installation of RF shielding. If non-critical discrepancies exist, he will notate the approved shop drawings and make field corrections if possible. As build drawings will be provided after completion of the project.
- C. Shield Vendor shall coordinate with other trades on site to ensure compliance with schedules, proper progression of work, and proper connections of other work to shield.
- D. Upon completion of the RF shield enclosure installation, it shall become the responsibility of the Owner, General Contractor, or other responsible party to maintain the integrity of the RF enclosure. In addition to the testing procedures outlined below in section 3.5.E.1-2, this responsibility shall also include:
 1. Ensure that the parent room and the RF shielded enclosure remain free of moisture.
 2. Prevent unauthorized attachments, penetrations or connections to the RF shielded enclosure.
- E. Testing
 1. Ground Isolation Testing
 - a. During installation, the Shield Vendor shall test the enclosure daily for electrical isolation from ground by a minimum of 1,000 OHMS. Upon completion of the shield assembly, the Shield Vendor will confirm that the RF shield remains isolated from electrical ground.
 - b. After installation of the shield, but before MRI equipment delivery, the General Contractor or other appropriate responsible party will assume responsibility that the RF shield remains isolated from electrical ground. The General Contractor or other appropriate responsible party on site will confirm ground isolation at least four (4) times daily. If a ground condition should be created by others during this period, they will be notified to immediately take measures to correct the situation. If ground condition persists after corrective measures, the General

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Contractor shall promptly notify the Shield Vendor so that appropriate action may be taken to correct the situation.

- c. Prior to his departure, Shield Vendor shall provide a battery-operated audible ground alarm system as a convenience to others. During Shield Vendor's absence, the monitoring and maintenance of the alarm shall be the responsibility of the General Contractor, or other appropriate responsible party on site.

2. Attenuation Testing

- a. Upon completion of the shield assembly, and prior to the application of finishes, the Shield Vendor shall seal the delivery access point and test the enclosure in accordance with IEEE 299, MIL-STD-285, MIL-STD-220-A, and the MRI equipment vendor requirements for magnetic field, and/or electric field, and/or plane wave attenuation. This test shall be witnessed by the General Contractor or other appropriate responsible party. If shield fails to conform to specifications, Shield Vendor shall immediately make such modifications as necessary to the shield to correct any non-compliance, and shall then re-test. Upon completion of a successful test, the Shield Vendor will then remove the magnet access panel and store it on-site in a designated area until the time of magnet delivery.
- b. Upon delivery of the MRI equipment, the Shield Vendor shall return to the site to seal the delivery access point and test the enclosure in accordance with IEEE 299, MIL-STD-285, MIL-STD-220-A, and MRI equipment vendor requirements, for magnetic field, and/or electric field, and/or plane wave attenuation. This final testing shall be performed in the presence of the General Contractor, or other appropriate responsible parties, to verify compliance with specified attenuation versus frequency characteristics.

3. Completion: Upon completion of successful final testing, the Shield Vendor shall provide the following:

- a. A formal report detailing the test results and certifying the shield for its intended use.
- b. A written warranty documentation as specified.
- c. As-build drawings.
- d. Instructions for care and maintenance of shield.