

MRI SHIELDING

ARCHITECTURAL SITE PLANNING GUIDE



Abbott Northwestern Hospital,
Minneapolis, MN

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Section 1 Introduction

Magnetic Resonance Imaging (MRI) is a diagnostic imaging tool that uses magnetic fields and radio waves to generate an image of the patient. It is different from X-ray in that it does not expose the patient to anything harmful and is a much better tool for soft tissue imaging, whereas X-ray is ideal for hard tissue such as bone.

An MRI is primarily defined by its field strength. For clinical applications, low field magnets are generally less than 1.5 Tesla while 3.0 Tesla is considered high to very high. Research magnets often range from 0.2 Tesla to above 20 Tesla.

MRI shielding is also different than X-ray shielding. X-ray requires the use of lead and is more “line-of-sight” with respect to where the shielding must be positioned. MRI requires radio frequency shielding nearly 100% of the time with the exception being some small research MR systems. Some of these do not require RF shielding as they are usually too small to be used for imaging people. MRI can also require magnetic shielding; however, this is determined on a site-by-site basis.

RF shielding must create a complete box with all walls, ceiling, and flooring covered with an RF shield. The RF shield can be made of almost any metal, but the most common types of metals are copper, galvanized steel and aluminum.

What is the purpose of RF shielding? To block out specific radio waves that may distort images created by the MRI. The specific radio waves may vary based upon the type of MRI installed. As an example, the typical performance required of an MRI shield is to achieve 100 dB of RF signal attenuation at 100 MHz.

What is the purpose of magnetic shielding? To contain some amount of magnetic field generated by the MRI, so as not to interfere with surrounding areas. Each site is different as the layout and type of magnet varies. However, the single most common goal for each MRI site is to contain the 5-gauss field to controlled areas. 5 gauss should not exist in any area where a person may unknowingly walk through the field. Examples include a waiting room behind or next to an MRI, a service space in the ceiling below the MRI where maintenance workers may frequent, or an area used for another modality such as PET, where a magnetic field would not be anticipated.

It should be noted that the 5-gauss limit is a Federal Drug Administration (FDA) recommendation and not law. The end user must determine what levels of magnetic field are to be contained to which locations.



Philips Open Magnet

Section 2 MRI Systems

Clinical MRI systems are produced by companies such as General Electric Healthcare, Siemens Medical Solutions, Philips Medical Systems, Hitachi Medical Systems and Toshiba Medical Systems. Others produce specialized MRI systems such as ONI and Esaote. And, there are those that provide a unique system that utilizes the MRI produced by one of these companies, but augments it with special features or applications such as BrainLab or IMRIS.

Some research MRI system manufacturers include Magnex Scientific/Varian Medical, Bruker, and Oxford Instruments. There are also MRI systems designed specifically for animals. For our purposes, these will be categorized under research systems to distinguish them from discussions on clinical MRI.

All MRI systems are considered either a closed bore system or an open bore system. A closed bore system is much like a donut where the patient is moved into the donut hole to be scanned. An open bore system is like a C-clamp with a gap or slot between two magnet plates. The patient is slid between the plates to be scanned.

The benefit of a closed bore system is that you can typically generate higher field strengths for the magnet. High-field strength generally means clearer images and shorter scan times or more patients within the normal workday.

The benefit of an open bore system is that it can accommodate obese patients more easily and allows for a greater field of view for the patient, which helps alleviate a sense of claustrophobia. An open bore system also tends to be less costly than a closed bore system, but may not be greater than 1.0 Tesla in field strength and is often produced at 0.35 Tesla.

Specialty MRI systems are typically extremity scanners. They are designed to accommodate a patient's arm, leg, or head. The benefits of an extremity scanner include centrally focusing on a single area of the body and producing fast, clear images. They are also much less costly than a whole body MRI scanner, but are usually produced at less than 1.0 Tesla, with a few exceptions.

All MRI systems have their own requirements for shielding, space, acoustics, vibration, power, air conditioning, and so forth. You should be able to obtain the requirements of your system from your MRI manufacturer.

If you are obtaining a used or refurbished MRI system, you may have difficulty obtaining the same level of information and/or support from the original equipment manufacturer (OEM). Whoever is providing your equipment should also provide you with OEM documentation. You can also obtain support from your RF shielding vendor (see Section 8, Service).



Ferromagnetic Detection System

Section 3 Before the Shielding

Often overlooked are the things you need to do *before* RF shielding is installed. Every site should be evaluated for electromagnetic interference (EMI) and vibration prior to finalization of the site. If your site has excessive EMI and/or vibration, you may not be able to fully utilize your MRI scanner once it has been installed.

EMI is typically generated by nearby elevators, electrical distribution within the building, nearby car parking or roads and paths as well as electric trams, subways, etc. The level of EMI can be reduced with shielding; however, it is minimal. Types of shielding include galvanized steel and aluminum. Silicon steel or low carbon steel may be helpful, but may require welding or soldering to create the proper eddy current shielding effect required for EMI.

Shielding is a passive solution to EMI issues, but there are active solutions available such as magnetic active compensation systems (MACS). These systems measure EMI fluctuations and generate a balancing field, so the MRI does not notice the EMI. It should be noted that while 85% of all sites can benefit from an active solution, about 15% may not be solved due to the complex nature of the site. It is critical that an EMI test be conducted prior to finalizing the location of the MRI.

Vibration testing is often overlooked, but should be conducted on each and every site. New magnet technology has made magnets lighter and faster, but also more sensitive to vibration. To avoid finding out *after* you've installed your MRI that your slab needs a vibration pad, schedule a vibration test early to allow modification of the slab construction, if needed.

Planning for the magnetic field should be done as soon as you have determined what MRI system you will be acquiring. The 5-gauss zone is a good starting point. Examine where the 5-gauss zone will lie both in plan and elevation. If it lies outside controlled spaces, then you need to determine if you want to post a sign stating "you are now entering a magnetic field" or if you want to add magnetic shielding to move the 5-gauss field from the offending area.

You should also look at the 1-gauss field, again both in plan and elevation, to ensure that no sensitive equipment will lie within that field such as CT scanners, CRT monitors, and so forth. If you cannot move the affected equipment or reposition the MRI, then you will have to add magnetic shielding or accept the affects of the magnetic field on the equipment.

Finally, safety should be considered with respect to the MRI suite layout. Is it possible that someone such as a patient, non-MRI hospital personnel, or visitor could accidentally enter into the MRI scan room? Are there adequate screening procedures in place to ensure that no accidental magnetic materials will be brought into the MRI scan room? A Ferrous Metal Detector System (FMDS) can augment the safety and screening procedures at most MRI sites, but are often overlooked until the project is well underway. Consideration early in the project allows for planning, evaluation, and inclusion of these products. A single accident can cost significantly more than the price of an FMDS and is well worth the time and effort to consider it.

Section 4 RF Shielding

RF shielding is required for every clinical MRI system and most research systems. However, performance may vary based upon the particular MRI system. Always check with your MRI system manufacturer to confirm specific requirements. Following are general RF shielding sense frequencies:

9.8 MHz.....	0.23 T	63.9 MHz.....	1.5 T
12.7 MHz.....	0.3 T	127.8 MHz.....	3.0 T
15.0 MHz.....	0.35 T	200.2 MHz.....	4.7 T
21.3 MHz.....	0.5 T	300.0 MHz.....	7.0 T
42.6 MHz.....	1.0 T	400.0 MHz.....	9.4 T

While most MRI manufacturers will require 100 dB of RF attenuation at the sense frequency, the requirements may vary for any given manufacturer and for higher-frequency testing specifications.

RF shielding can be made of virtually any type of metal; however, the most prominent types used for MRI shielding are copper, galvanized steel, and aluminum. Other metals are not typically used due to drawbacks such as price, ease of handling or modifications, and corrosion.

ETS-Lindgren’s copper RF shield is made of copper sheeting wrapped around wood frames bolted together to form walls and a ceiling. This system is lightweight, easily modified to address field or site discrepancies, and provides a lasting RF enclosure.

An alternative RF shield system is the cell type, which has a plywood-like core and is laminated on both sides with galvanized steel, copper or aluminum. This system is heavier and can be modified on site, but with more effort. In addition, the clamping system, often called “hat and flat,” is ferrous and not recommended by some MRI systems as it may create shimming problems.

The third type of RF shield system is a pan-form shield constructed entirely of metal. No wood is utilized. This system is bolted together to form the walls, ceiling and floor. This system can utilize galvanized steel, stainless steel, or aluminum, depending upon the preference of the MRI system manufacturer. However, this system cannot be modified on site. Rather, panels must be engineered, manufactured, and shipped to the site.



Cell Type Shielding



Copper Shielding



Pan Form Shielding

Section 4.1 RF Flooring

There are three basic types of RF flooring: monolithic copper, modular cell type, and pan form.

Monolithic copper requires a normal 1" depression/buildup, is moisture-resistant, and has a cement-like underlayment as a finish. This is the recommended RF floor system for MRI applications.



*Monolithic Copper
Flooring*

The modular cell type floor is a panel system requiring a depression/buildup of 1 1/8" to 1 3/8" with identical construction to that of the cell wall and ceiling panels. It is a wood core with laminated metal on both sides of the core. A vapor barrier is placed on the floor to isolate the shield from the ground. Finished flooring may be installed directly on top of the cell floor panels with in-fill.



*Modular Cell Type
Flooring*

The pan-form floor is an all-metal construction with pan-shaped panels bolted together. In-fill of the panels is required by the customer and is usually done with a concrete underlayment. This system is not recommended if you have trenches within the MRI suite.



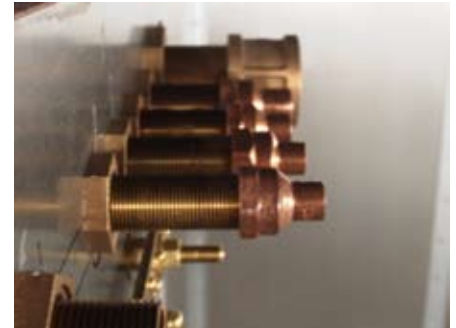
Section 4.2 RF Filters & Waveguides

The RF shield forms a complete box around the MRI system. Everything that is to come into the MRI room must pass through an RF filter or waveguide.



RF filters are mounted on the RF shield and create an penetration point for electrical power for lighting or powered outlets within the MRI room. RF filters also accommodate data cables.

Waveguides are penetrations in the RF shield that allow a fluid flow into the MRI room. Air conditioning, water and medical gases all provide a fluid flow and require a waveguide.



To confirm whether an RF filter or waveguide is required, just follow a simple rule of thumb:

- 1). If there are *electrical wires*, you will need a *filter*
- 2). If it is *fluid* (air or liquid), you will need a *waveguide*

Section 5 Magnetic Shielding

Magnetic shielding is not required for every site and is often overlooked in the early planning stages. Essentially, the goal of magnetic shielding is to protect the environment from the MRI magnetic field.

Magnetic shielding is not the same as lead shielding. Lead shielding is identified via “line of sight” whereas magnetic shielding must take into account the geometry of the magnetic field relative to the position of the magnetic shield.

Magnetic shielding is usually fabricated with silicon steel in sheet form, but it can also be done in steel plate. Steel plate is not as easy to work with and tends to be more expensive whereas silicon steel is easy to manipulate. The type of material you will need should be determined by your shield designer.

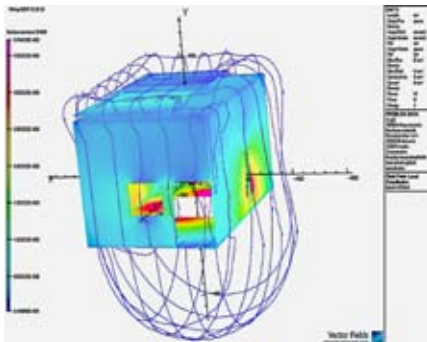


Silicon Steel Shielding



Steel Plate Shielding

In most cases, your MRI vendor should be able to provide you with magnetic shield design services. There are also independent companies who offer it. And, ETS-Lindgren offers magnetic shield design services as well. You should consider a company that is associated with your shielding vendor. If a design is poorly done, it is all too easy to finger point. An all-in-one solution is usually the best decision.



Section 6 Siting Considerations / Requirements

There are many facets to take into account when planning an MRI suite. The following are some key items to consider:

- Is the site suitable for the magnet from a vibration standpoint?
- Is the site suitable for the magnet from an EMI noise standpoint?

If not, have it tested before finalizing the location. Testing can be done by either the MRI or shielding vendor.



- What is the delivery path for the magnet?
- Are the halls wide enough? Are they tall enough?
- Is the floor strong enough?
- Who will rig the magnet?
- Have the riggers evaluated the site as well as the proposed path of delivery?
- If the magnet has to be removed in the future, will it significantly disrupt others with the intended exit path?

Consult the MRI vendor's Site Planning Specialist with respect to the following:

- Is the site large enough?
- Does it meet room size requirements (length, width, height)?
- Is there adequate air conditioning?
- Will it remain at least 65 degrees Fahrenheit in the MRI room for curing of floor epoxies?
- Does the magnetic field overlap with areas around, above, or below other equipment that may be disturbed by the MR magnetic field?



- Have you examined the proximity of moving metal (i.e., cars trucks, dumpsters, elevators) and electrical equipment (switchgear and transformers) to the MRI?
- Have you considered all possible routes of access for people to accidentally enter the MRI suite?
- Would a ferrous metal detection system serve as an effective supplement to your safety screening process?

You should consider the 1 gauss and 5 gauss lines for most interference concerns. Consider altering the layout first, then magnetic shielding second.

Consider where you will place it early in the layout design for optimal effectiveness.

- Have you considered the sound level of the MRI and will it impact surrounding offices or suites?

Sound can be carried structurally through ducts or vents and even the penetration panel of the MRI system. Acoustic options for RF shielding consist of sound absorption material within RF panels, acoustic doors, and an additional layer of glass on RF windows.



Consult your MRI vendor to obtain the acoustic levels of their equipment and then select a Sound Engineer who can evaluate your entire acoustic situation- not just RF shielding.

ETS-Lindgren has partnered with a professional acoustic engineering company that can conduct a complete analysis of your acoustic needs.

Acoustic installations take approximately 5-7 days based upon room size and options. Contact your ETS-Lindgren representative for more information.

RF Shield Considerations:

Typically, ETS-Lindgren installs the RF shield, closes all temporary openings to run an initial test of the shield, and, once acceptable, leaves the site. Upon delivery of the magnet, ETS-Lindgren returns to close the access opening in the RF shield and conducts a final RF test. Your situation may differ, so consult your ETS-Lindgren representative for your specific requirements.

- What is the proposed delivery path for the RF and/or magnetic installation shielding materials?
- Can these materials fit within the service elevator?
- What is the weight capacity of the service elevator?
- How far is the loading dock from the MRI suite?
- How large and where is the staging area for the shielding materials relative to the MRI suite?

Check with your RF shielding vendor to verify the size of the staging area required, which will vary depending upon the type and amount of shielding installed.

- Will the staging area be secure from vandalism?
- Will the storage area and MRI suite be protected from the elements (rain, wind, snow, sun)?
- Will the MRI suite be heated during installation?
- Will there be electrical power available for tools?

Section 7 Details

The Enclosure

The preferred RF enclosure for MRI application consists of wood panels wrapped with copper. This provides a lightweight system that offers the best longevity in RF integrity. The panels are bolted together and to the floor system.

The alternative consists of metal-wood-metal composite panels. Each panel is clamped to the adjacent panel to form the entire shield. It is heavier and introduces some amount of ferrous material around the MRI. Consult the MRI vendor for acceptance of this type of system.

The Floor

The RF floor should be moisture-resistant and consist of copper sheets covered with a cementitious underlayment ready to accept finished flooring materials (to be installed by another contractor). The RF floor is a nominal 1” in total depth. For a flush floor finish, a nominal 1” depression is required in the MRI suite. Alternatively, a 1” rise will require a ramp outside the MRI suite.

The alternative is a composite metal-wood panel system. This is covered with an underlayment material such as particleboard and ready to accept finished flooring materials.

The RF Door

Although there are many types of RF door systems available, including single swing, double swing, sliding, double sliding, acoustic, non-acoustic, automatic, and manual, typical doors used for MRI applications are:

ETS-Lindgren MRDS Door- Manual door system with friction seals that require periodic maintenance. Available in acoustic and non-acoustic.

ETS-Lindgren Auto-Seal II RF Door- Pneumatically-operated door system using hospital air or compressor air. Smooth edges are perfect for general cleaning and will not snag on clothing or break off. Popular security options on this door include an automatic opener/closer or keypad entry.



Auto-Seal II Door



MRDS Door

Windows

ETS-Lindgren offers the highest-visibility RF view window for the technician sitting at the control console to monitor and observe the patient. It is an aluminum extruded window with a double layer of mesh sandwiched between two layers of safety glass. The window can be sized from 2' x 2' up to 4' x 5'. For larger sizes, a mullion is required.

For skylights or exterior windows, the Clearshield[™] RF Window Wall System can be designed to cover an entire wall from floor to ceiling. With an attractive black matte finish, the window can be used as a future magnet access path without having to tear out finishes.

Waveguides and Filters

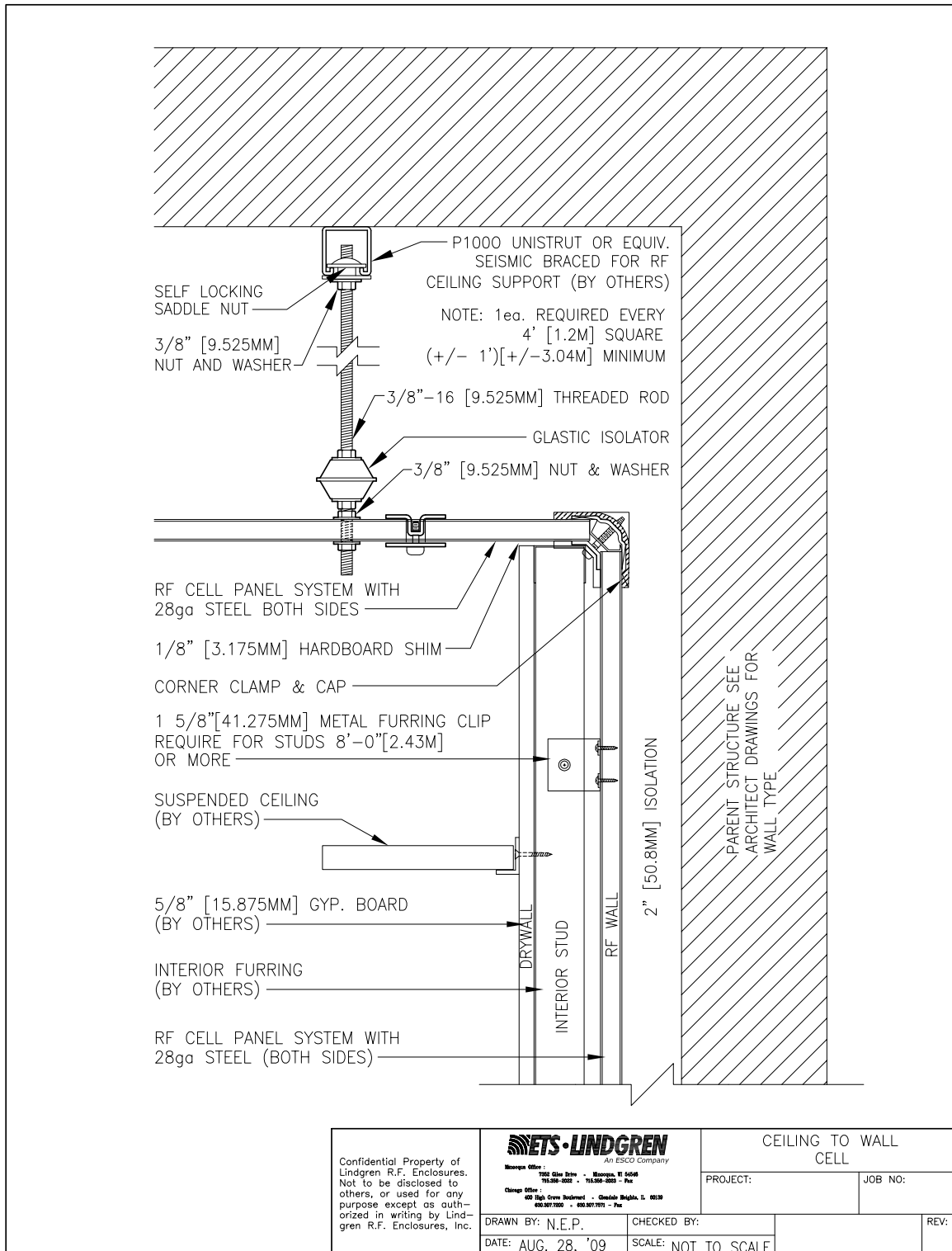
All services for the MRI suite must pass through either a filter or a waveguide. Waveguides used for air supply to and from the room are honeycomb and can be sized to match the duct running to the MRI suite. Additional waveguides include those for sinks, medical gas, sprinklers, fiber optics, and plastic or rubber tubing. Finally, the cryogen vent from superconducting magnets must pass through a cryogen waveguide. The size of the cryogen waveguide will vary based upon the MRI system. Typically, the MRI vendor will connect the magnet to the waveguide, but it is the customer or contractor's responsibility to run the pipe beyond the shield to the outside of the building.

Filters are primarily used to supply electrical power to the MRI suite. Power for outlets and lighting will require a separate RF filter for each separate circuit. Filters are also used for nurse call, code blue, telephone, and data. As each site has its own needs, please contact your ETS-Lindgren representative for the appropriate RF filter for your particular application.

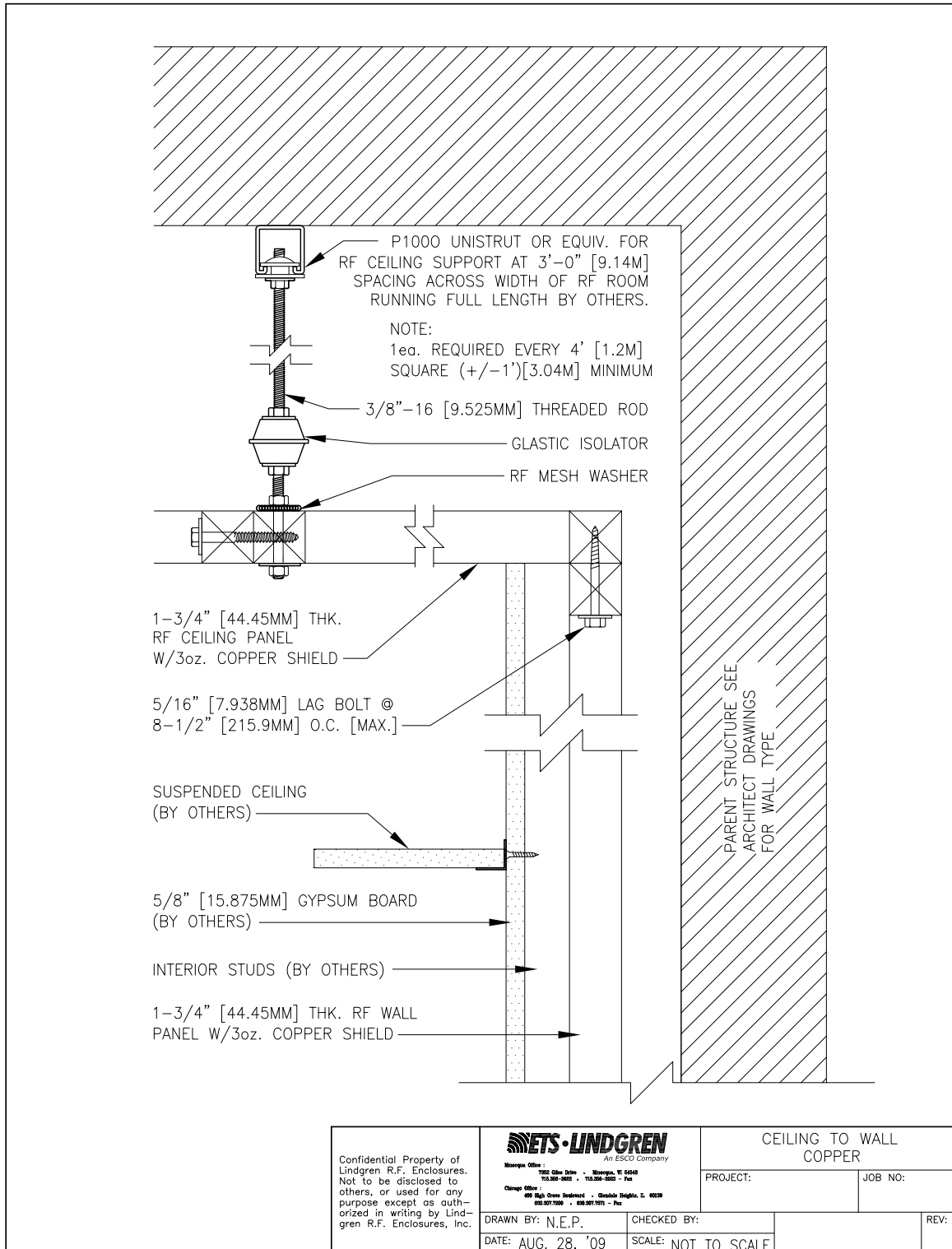
Architectural Details

The following are standard details that may be obtained from ETS-Lindgren in either AutoCAD format or PDF for use in the architectural drawing package. Site-specific details will be included in the RF shielding drawing package. Contact your ETS-Lindgren representative for more information. (Please note the plans reflecting pages are attached to this Site Planning Guide).

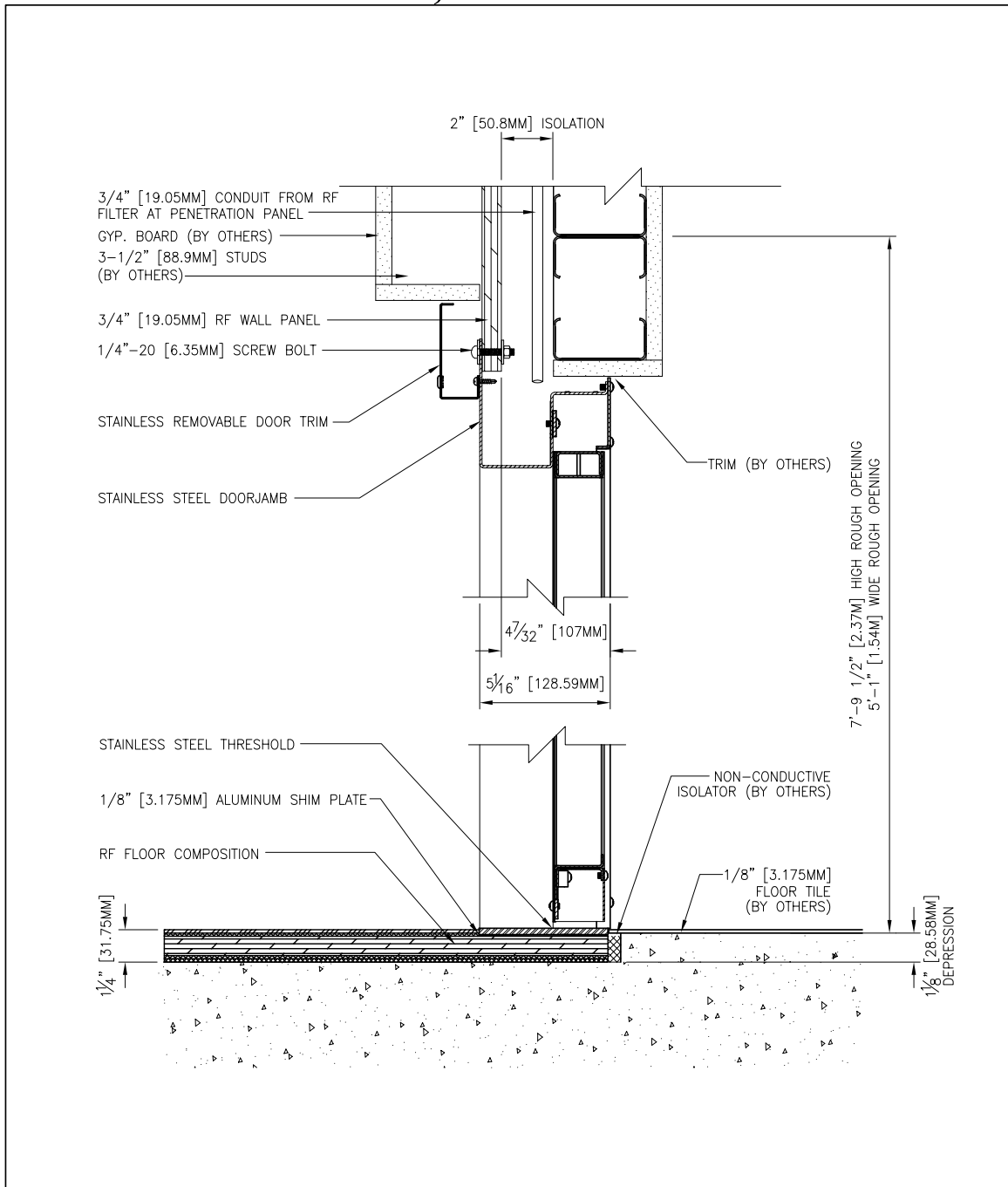
CELL TYPE SHIELD CEILING TO WALL




COPPER SHIELD CEILING TO WALL

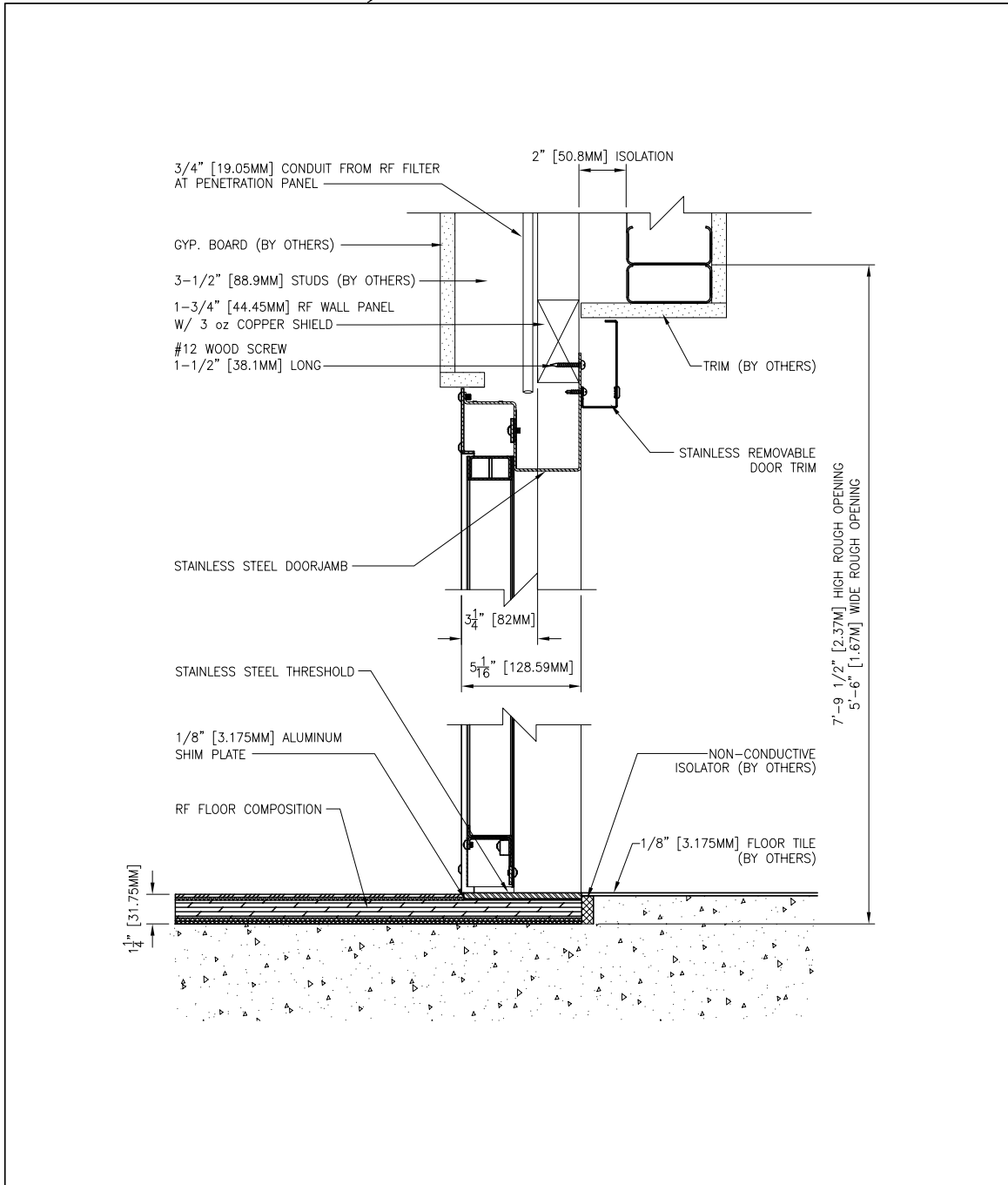



AUTO-SEAL II DOOR ELEVATION- INSWING, CELL TYPE SHIELD, CELL TYPE FLOOR



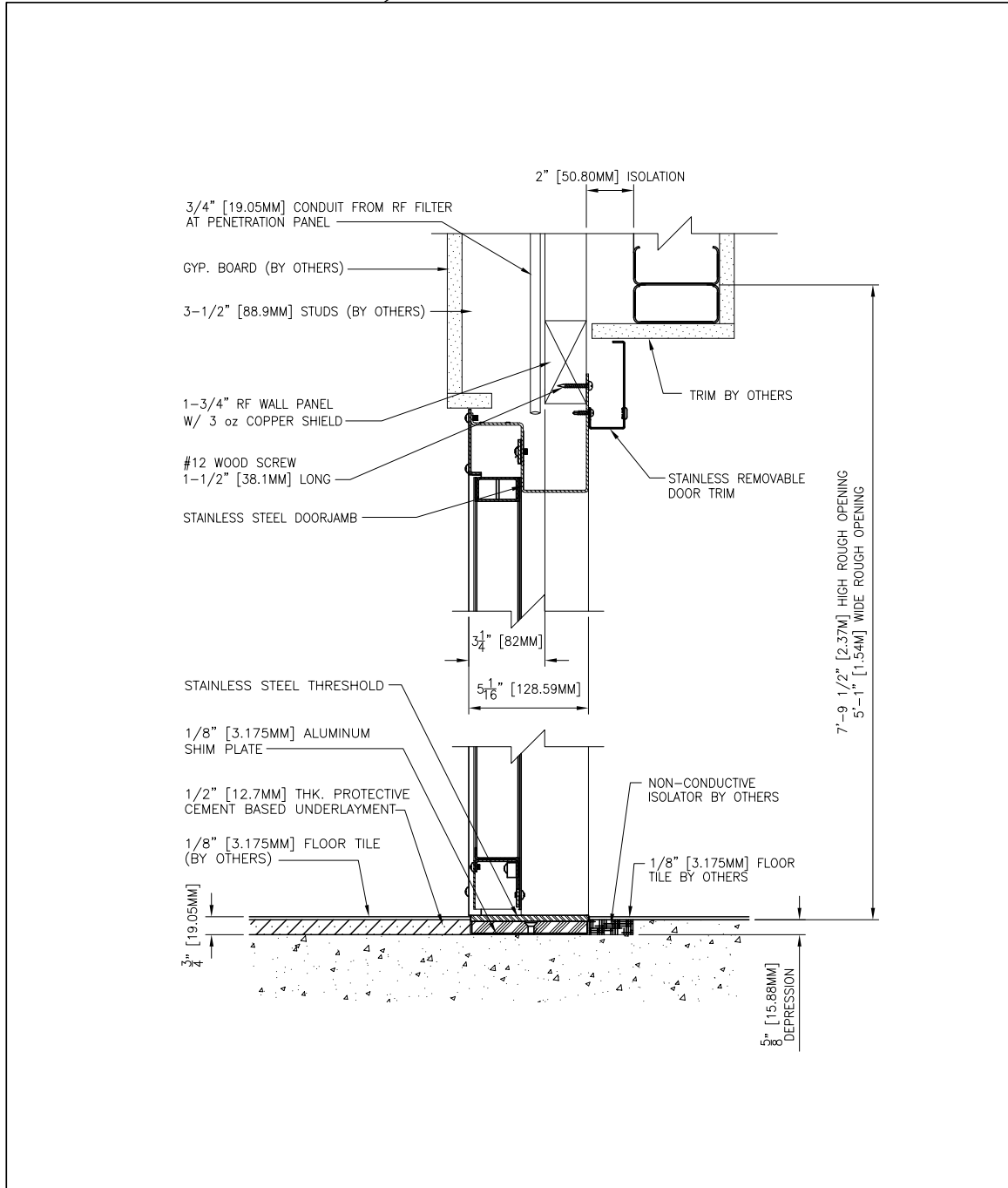
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AUTO-SEAL II DOOR ELEVATION- INSWING, COPPER SHIELD, CELL TYPE FLOOR



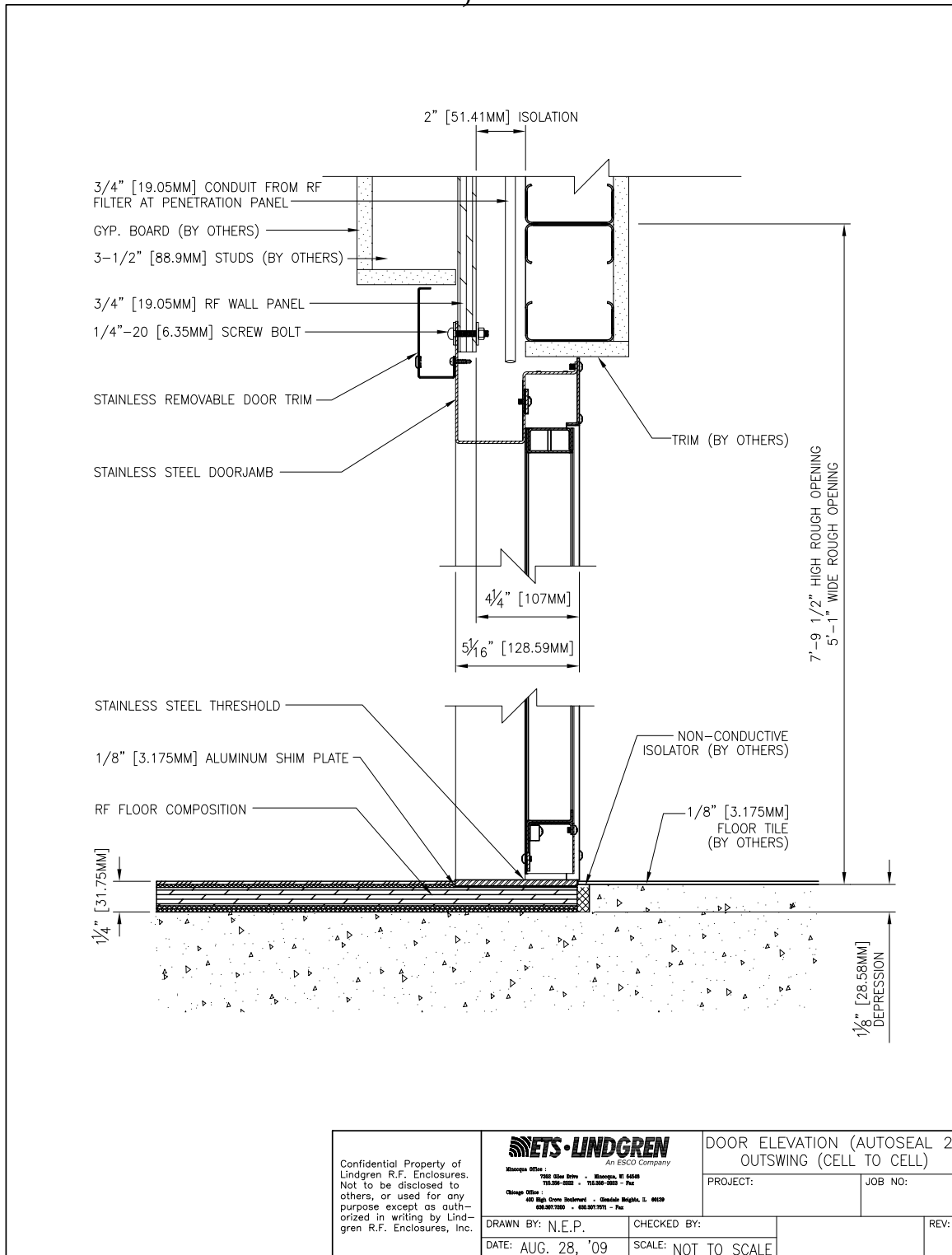
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AUTO-SEAL II DOOR ELEVATION- INSWING, COPPER SHIELD, MONOLITHIC FLOOR

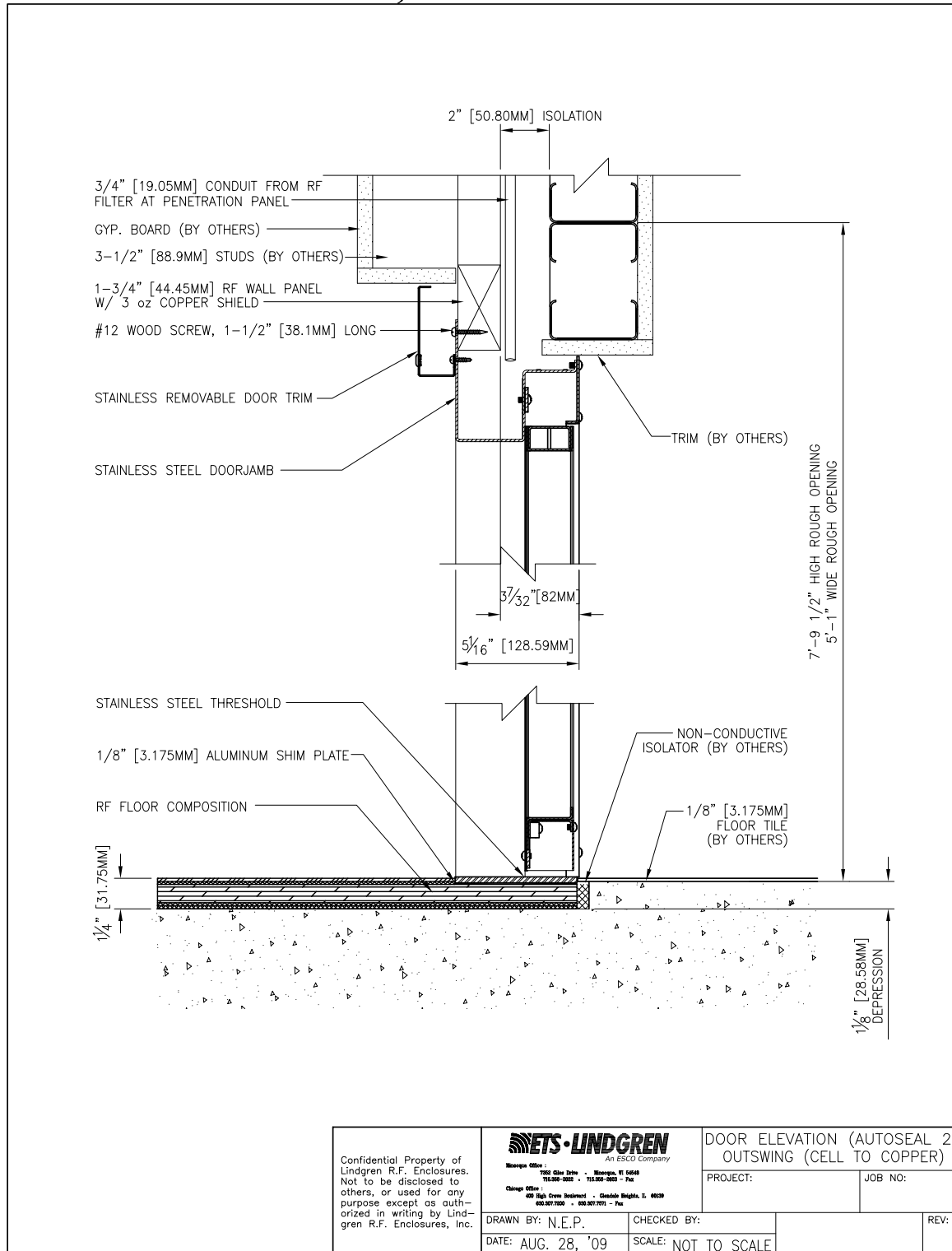


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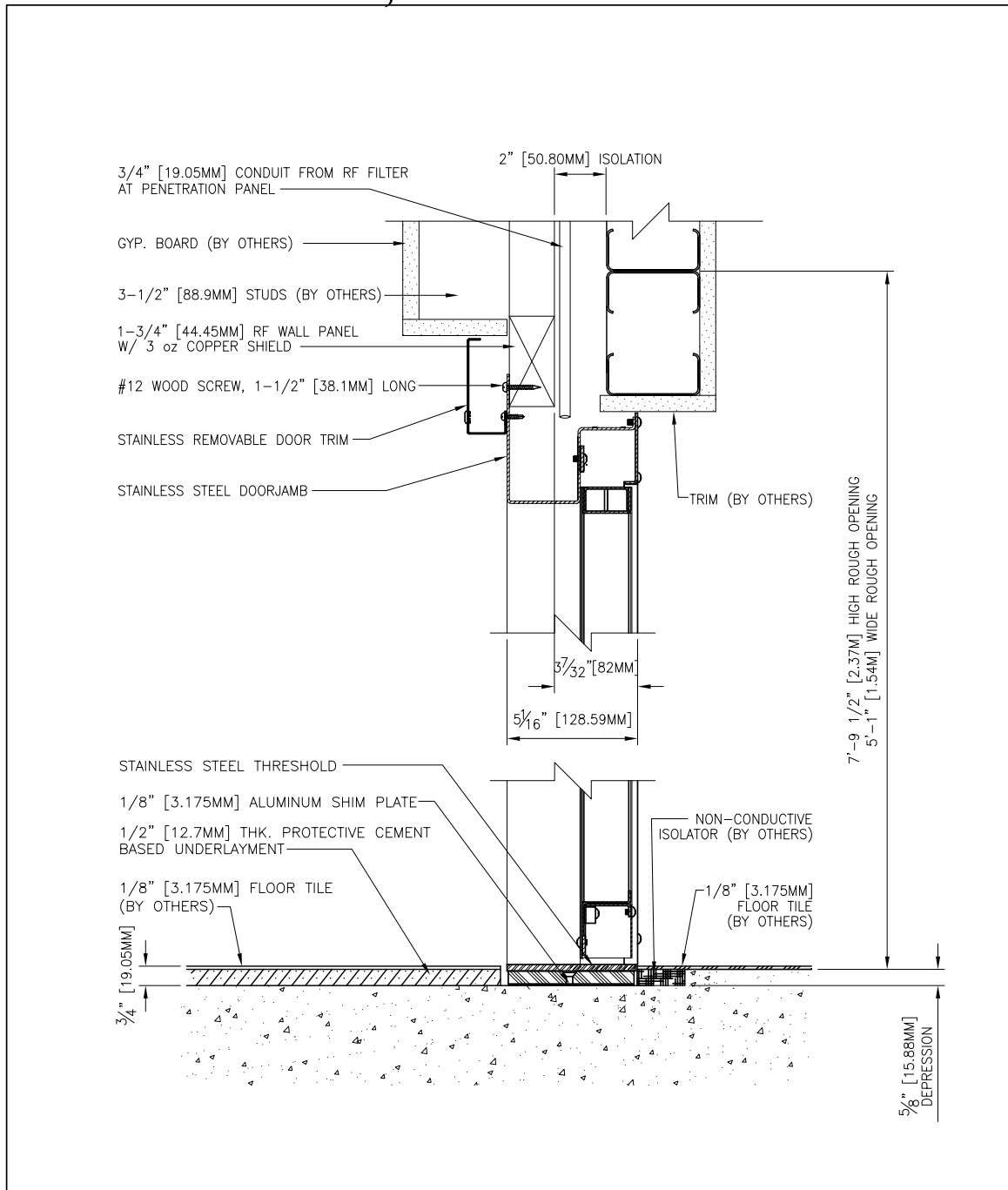
AUTO-SEAL II DOOR ELEVATION- OUTSWING, CELL TYPE SHIELD, CELL TYPE FLOOR




AUTO-SEAL II DOOR ELEVATION- OUTSWING, COPPER SHIELD, CELL TYPE FLOOR

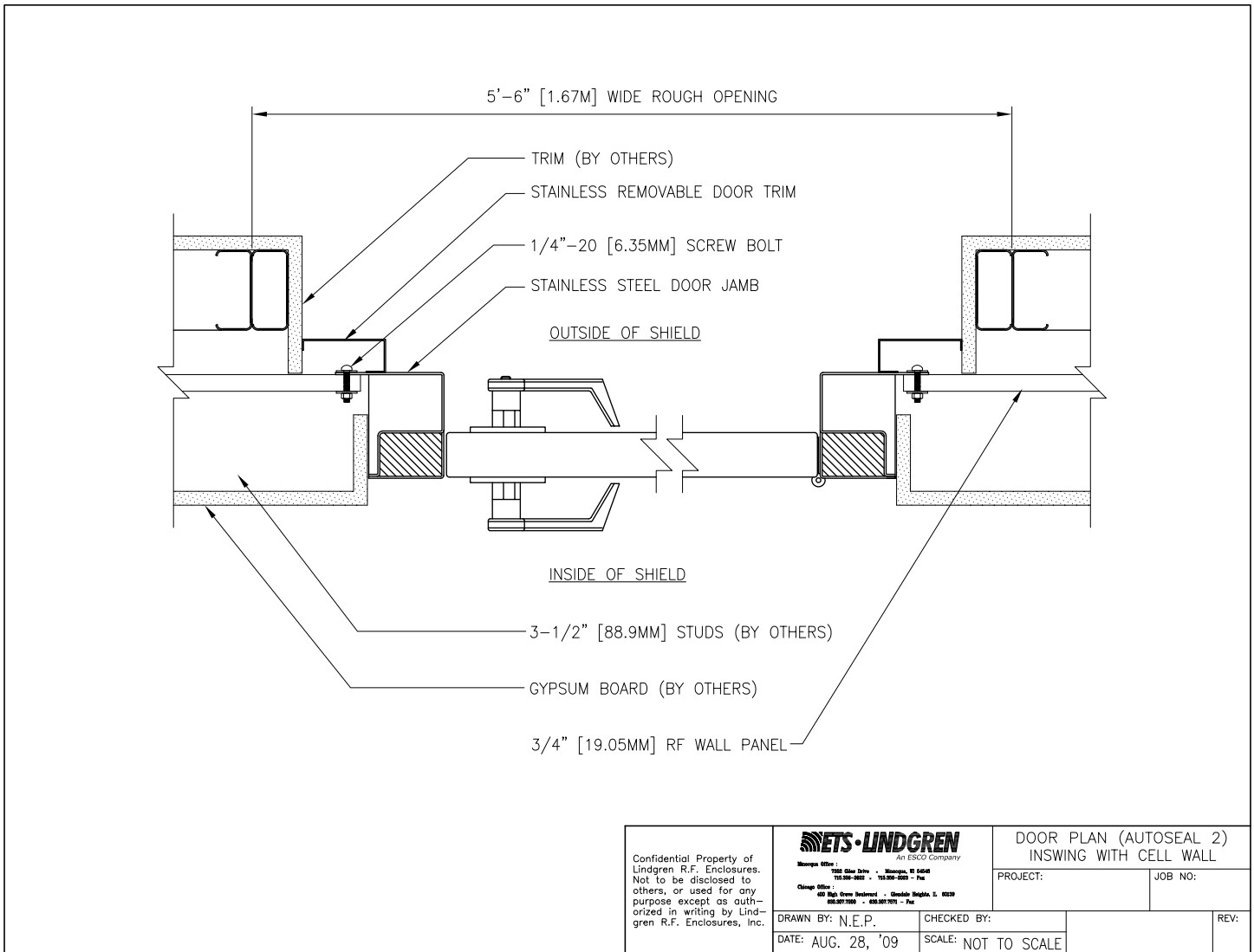



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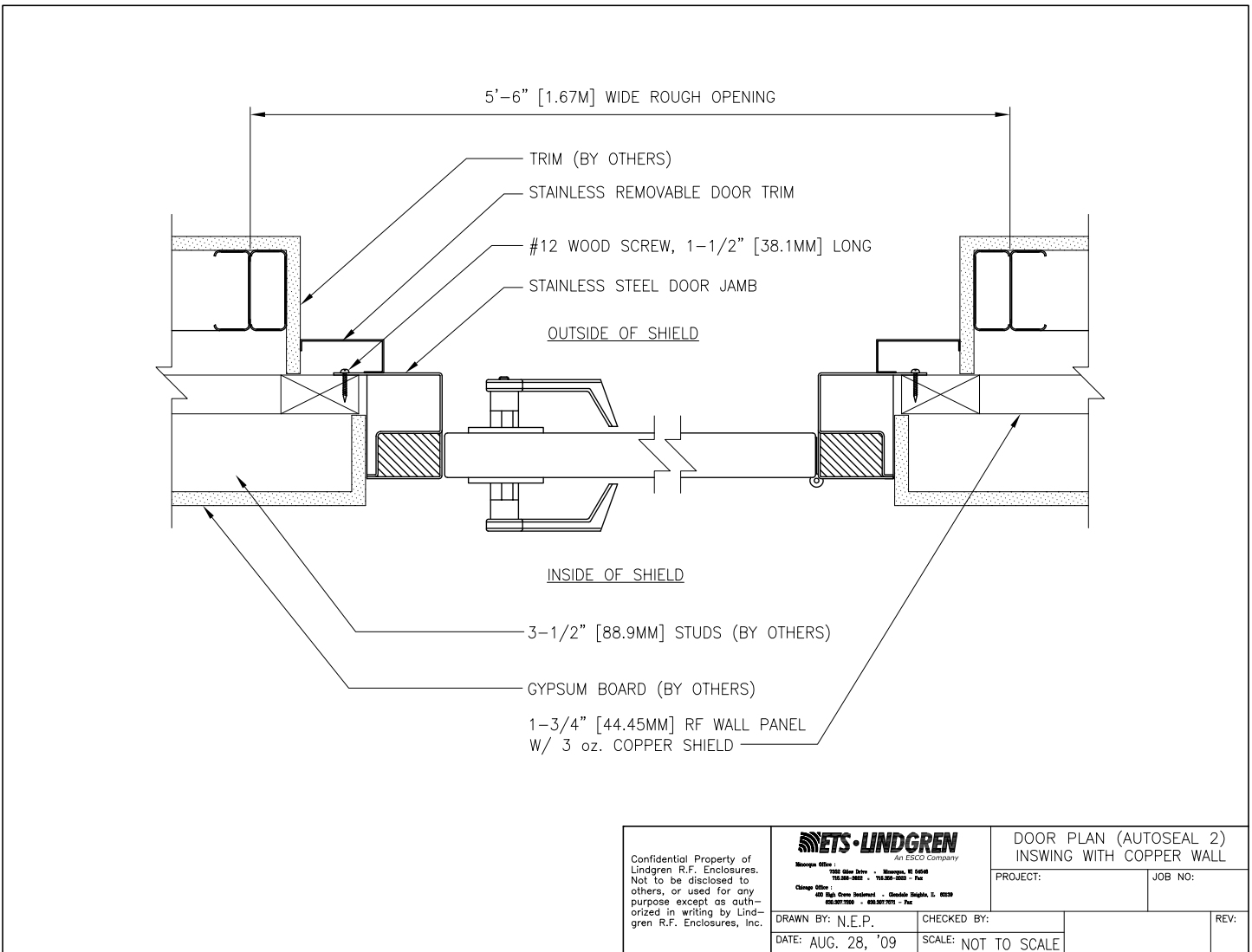
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AUTO-SEAL II DOOR PLAN- INSWING, CELL TYPE SHIELD

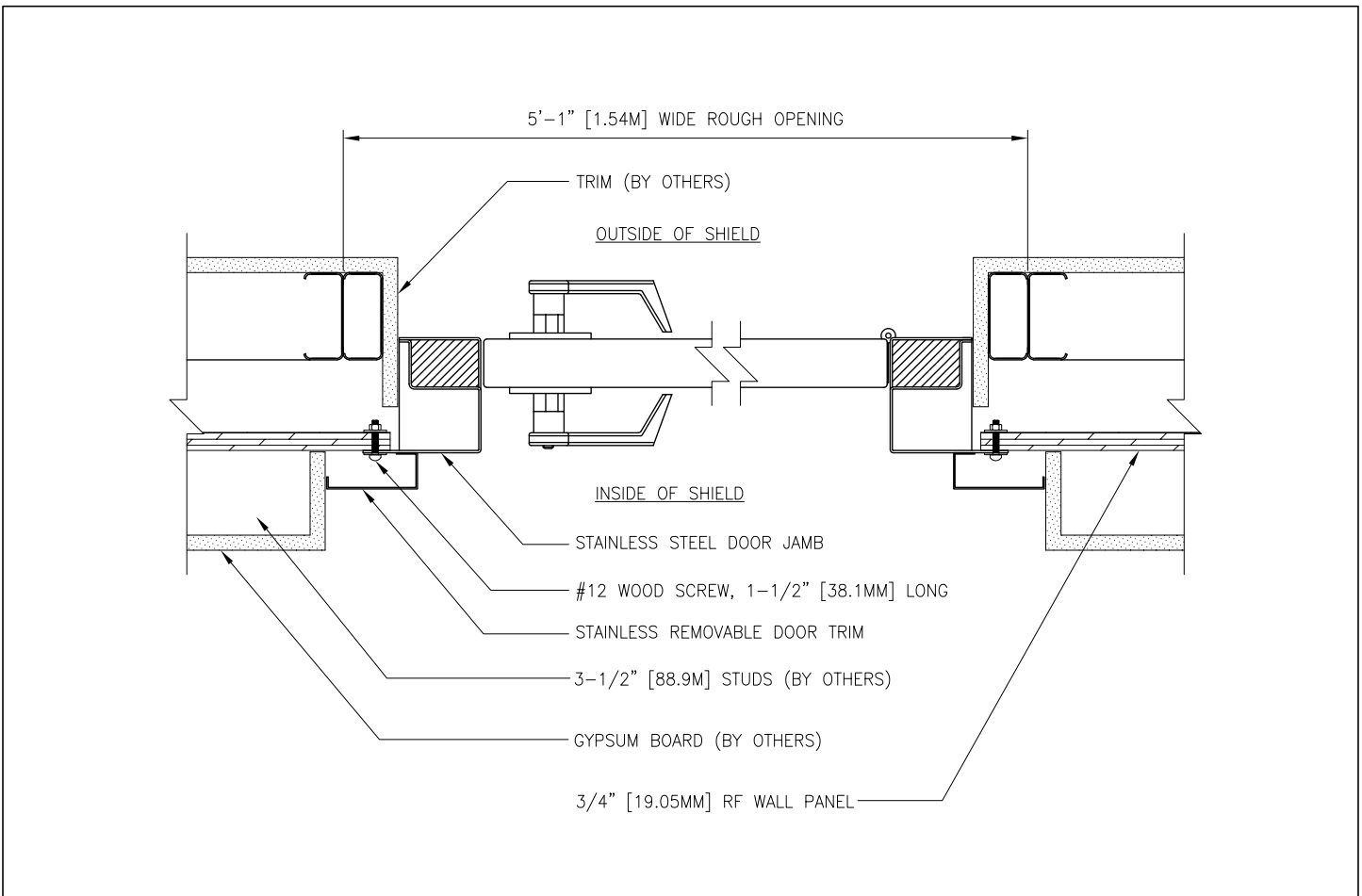



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AUTO-SEAL II DOOR ELEVATION- INSWING, COPPER SHIELD

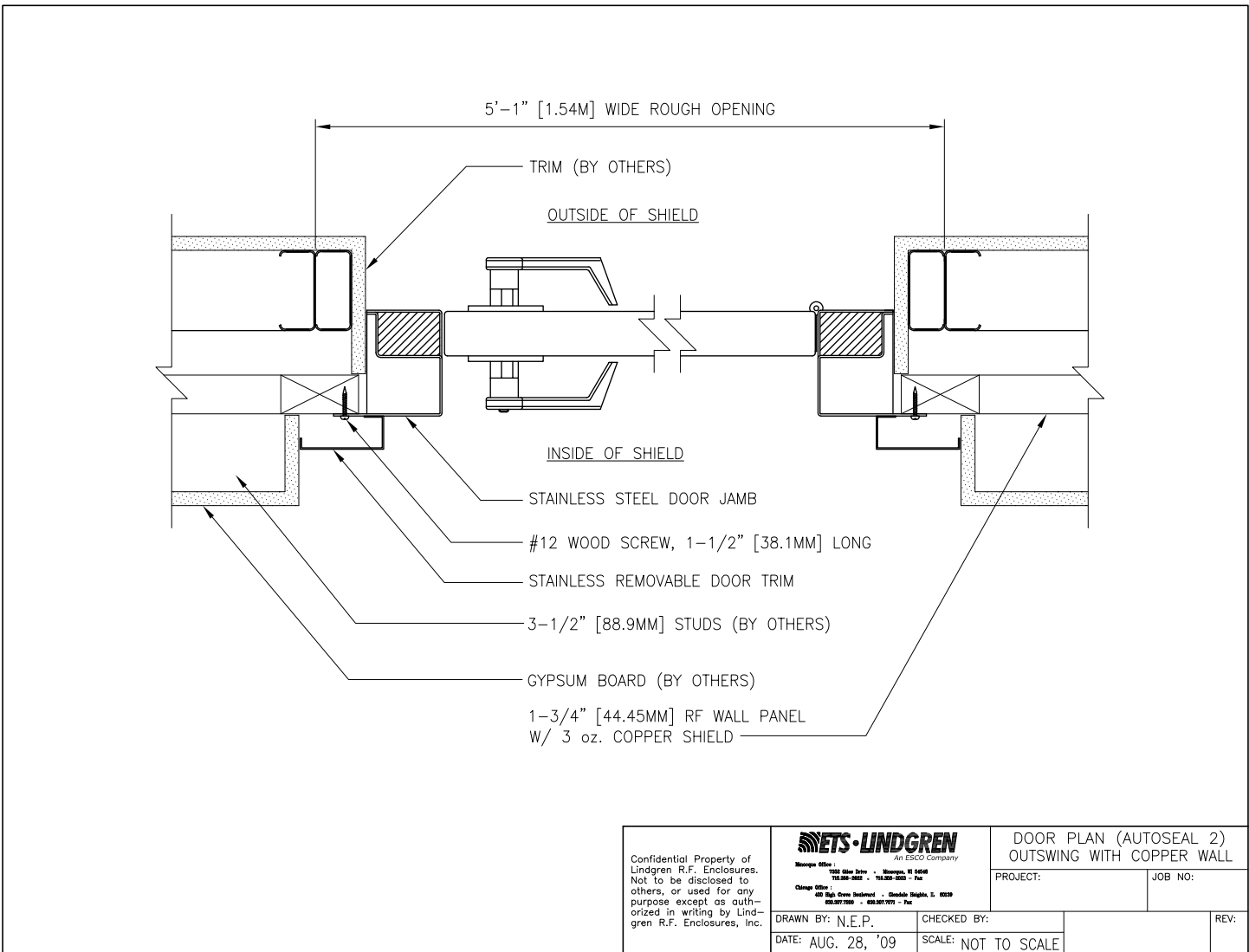


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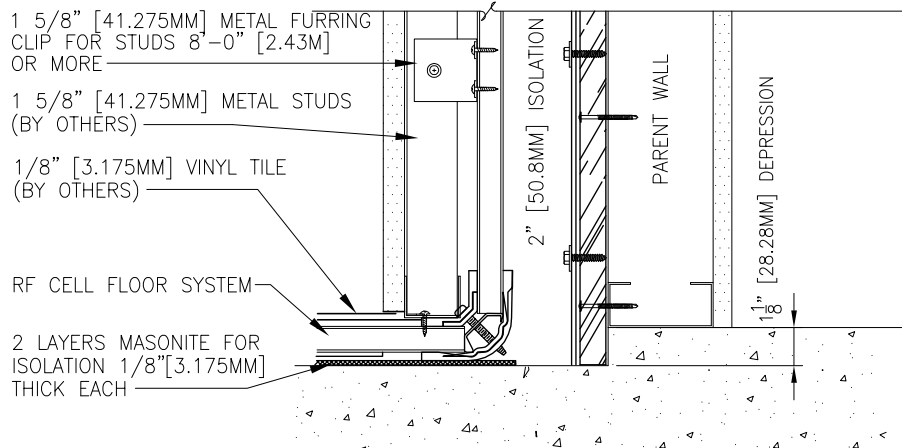



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AUTO-SEAL II DOOR PLAN- OUTSWING, COPPER TYPE SHIELD

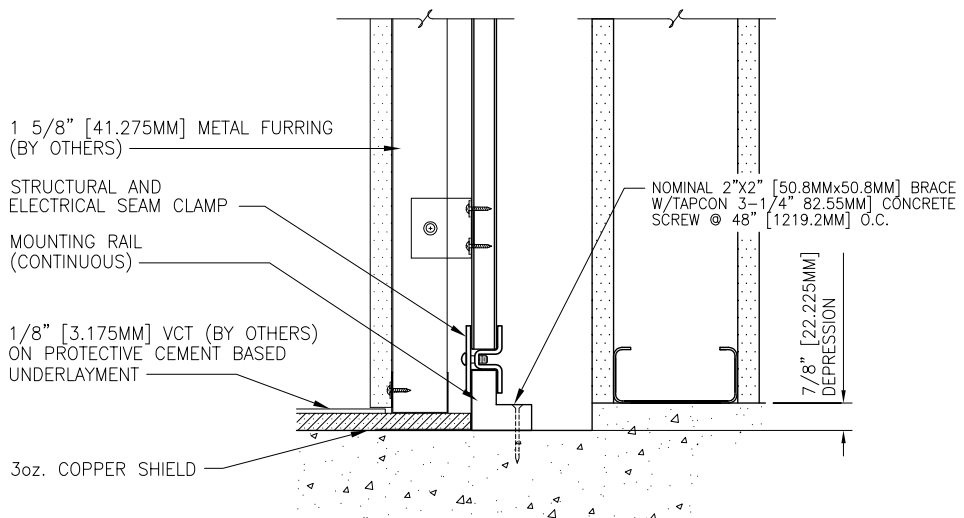



FLOOR TO WALL- CELL TYPE SHIELD, CELL TYPE FLOOR



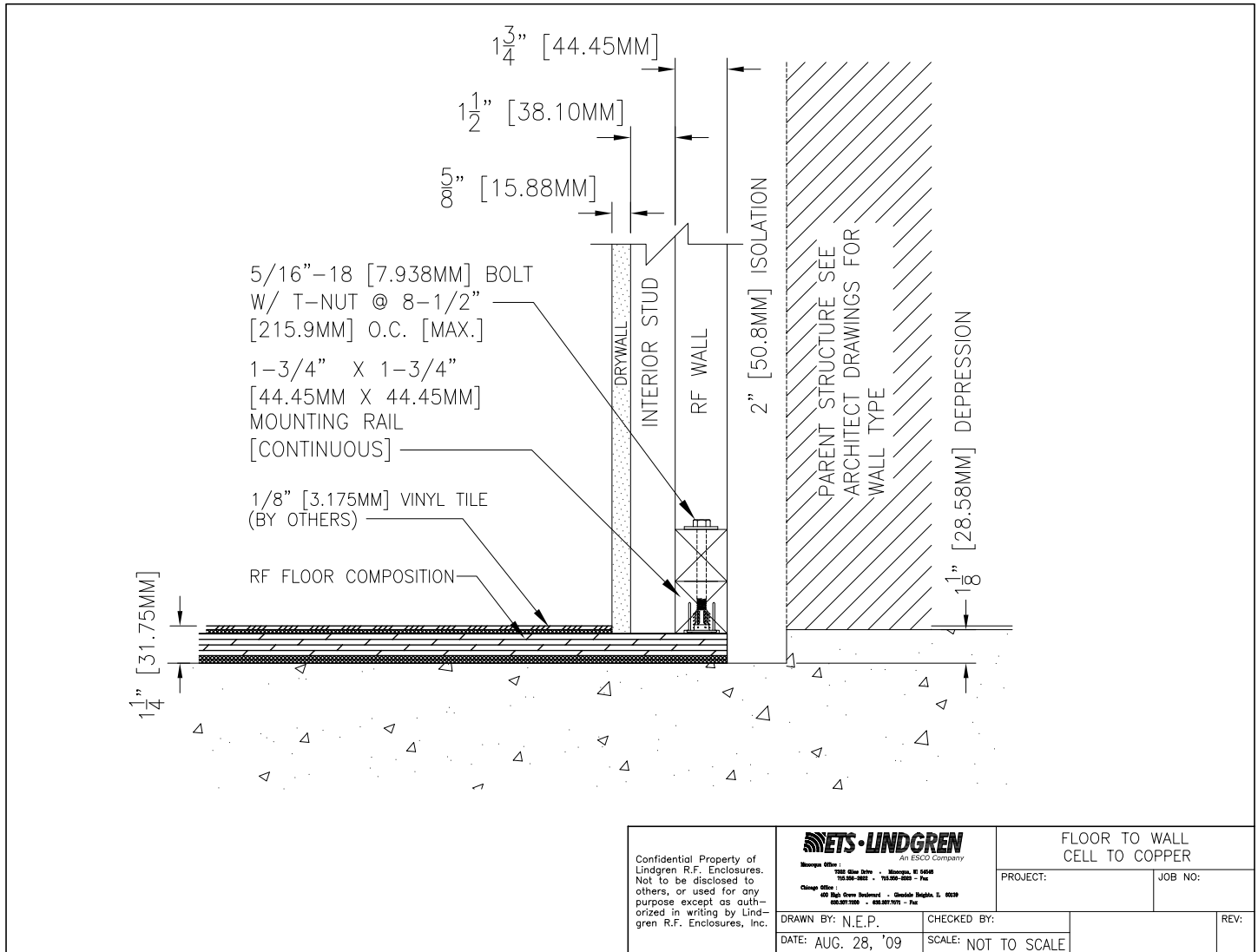
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FLOOR TO WALL- COPPER SHIELD, CELL TYPE FLOOR

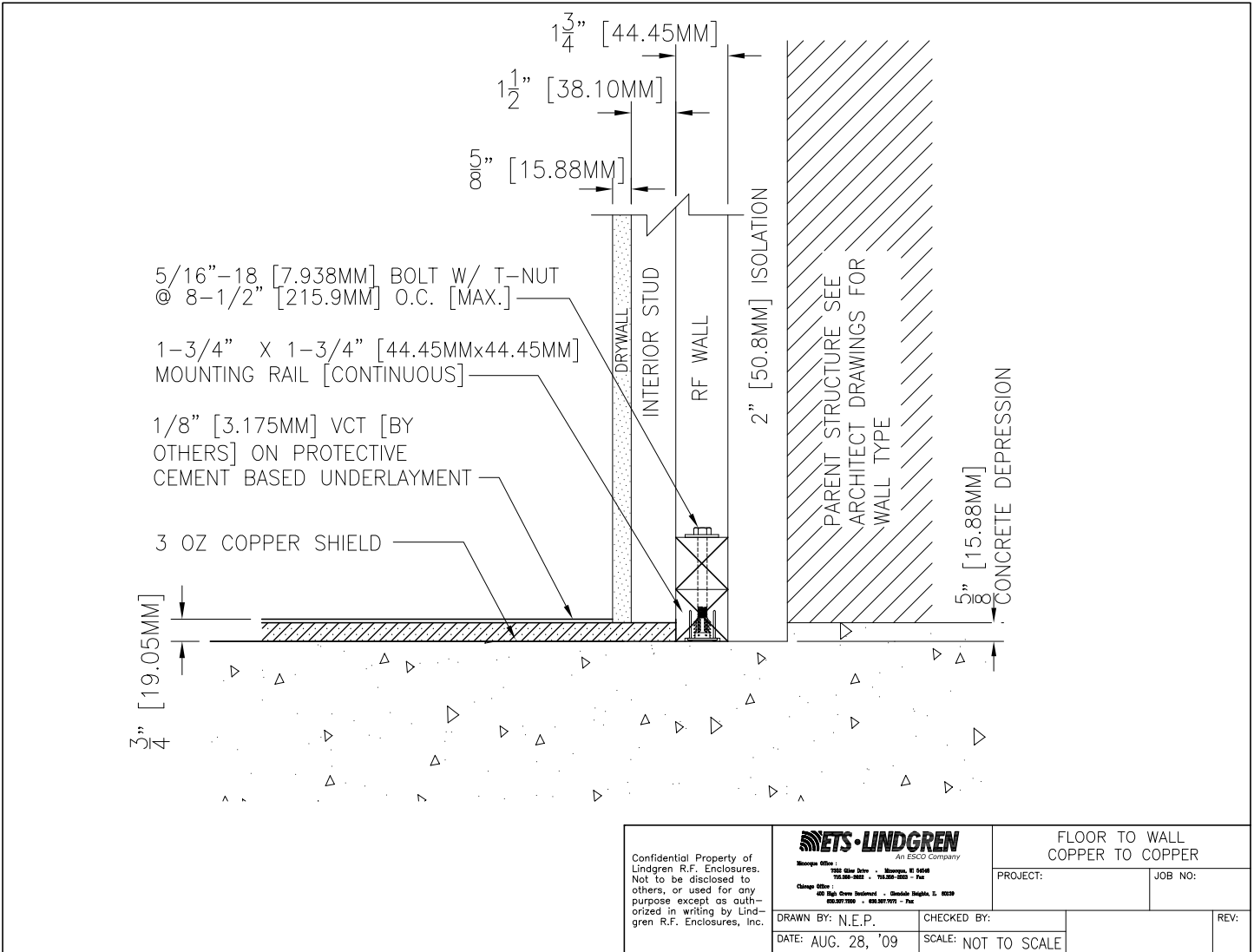


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	PROJECT:		JOB NO:	
DRAWN BY: N.E.P.	CHECKED BY:		REV:	
DATE: AUG. 28, '09	SCALE: NOT TO SCALE			

FLOOR TO WALL- CELL TYPE SHIELD, MONOLITHIC FLOOR

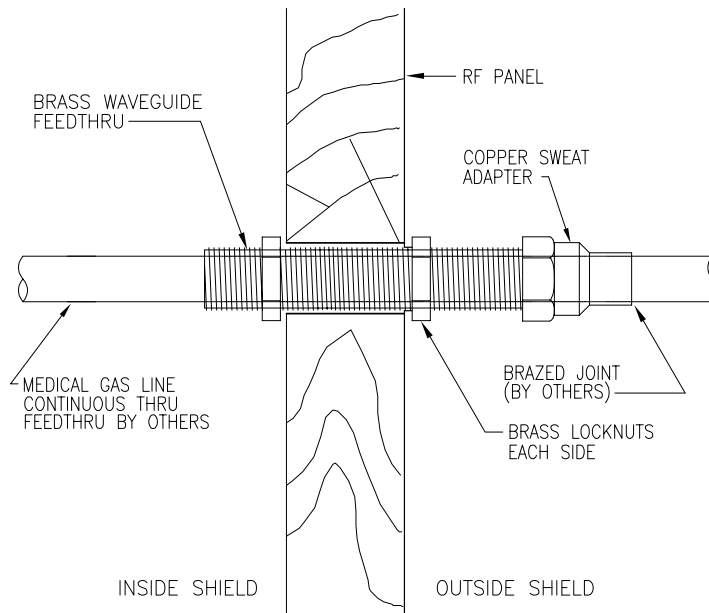



FLOOR TO WALL- COPPER SHIELD, MONOLITHIC FLOOR



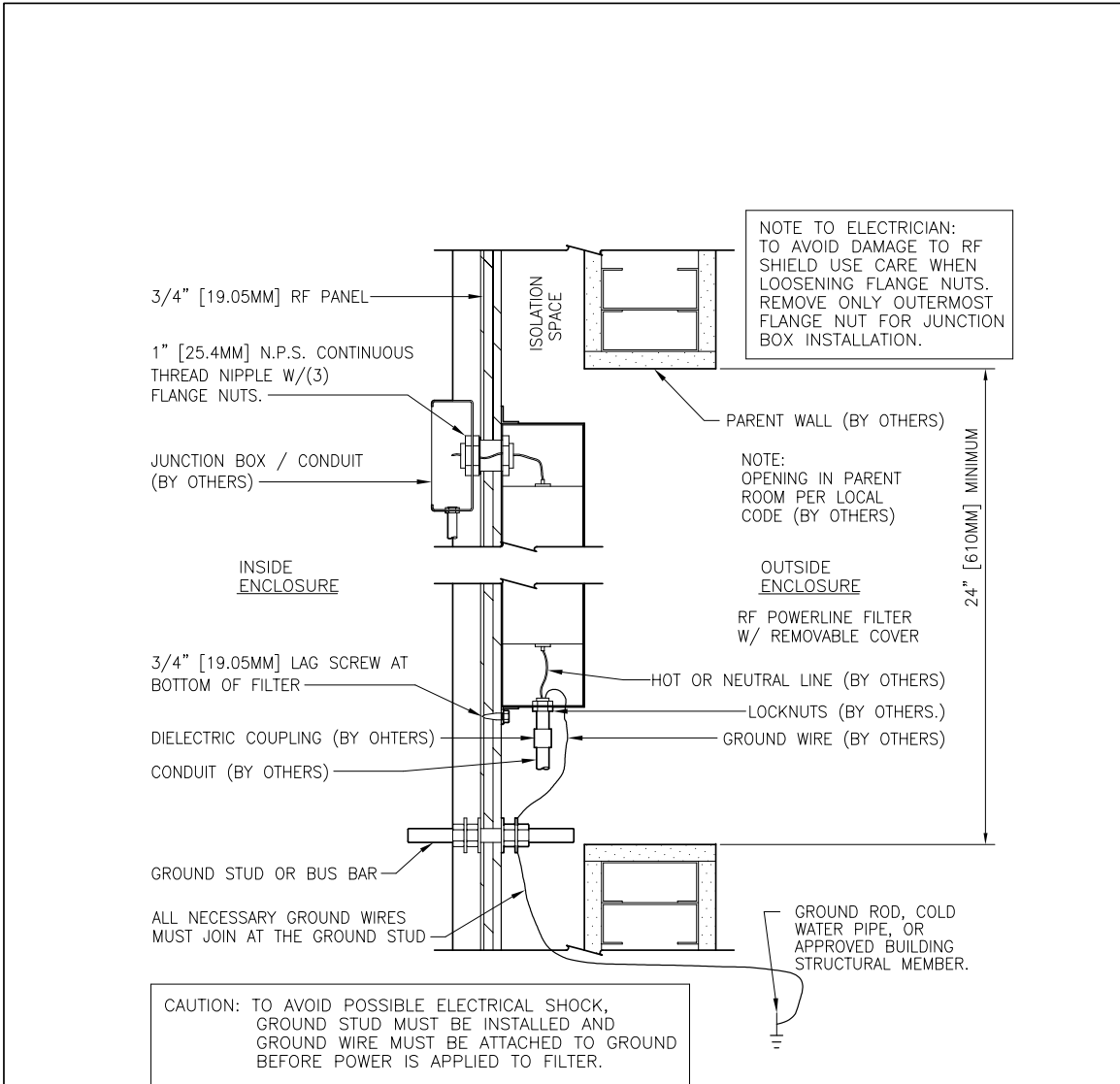
MEDICAL GAS WAVEGUIDE

NOTE: FINAL MEDGAS CONNECTION TO WAVEGUIDE CANNOT BE MADE UNTIL GROUND ISOLATION MONITORING IS COMPLETE



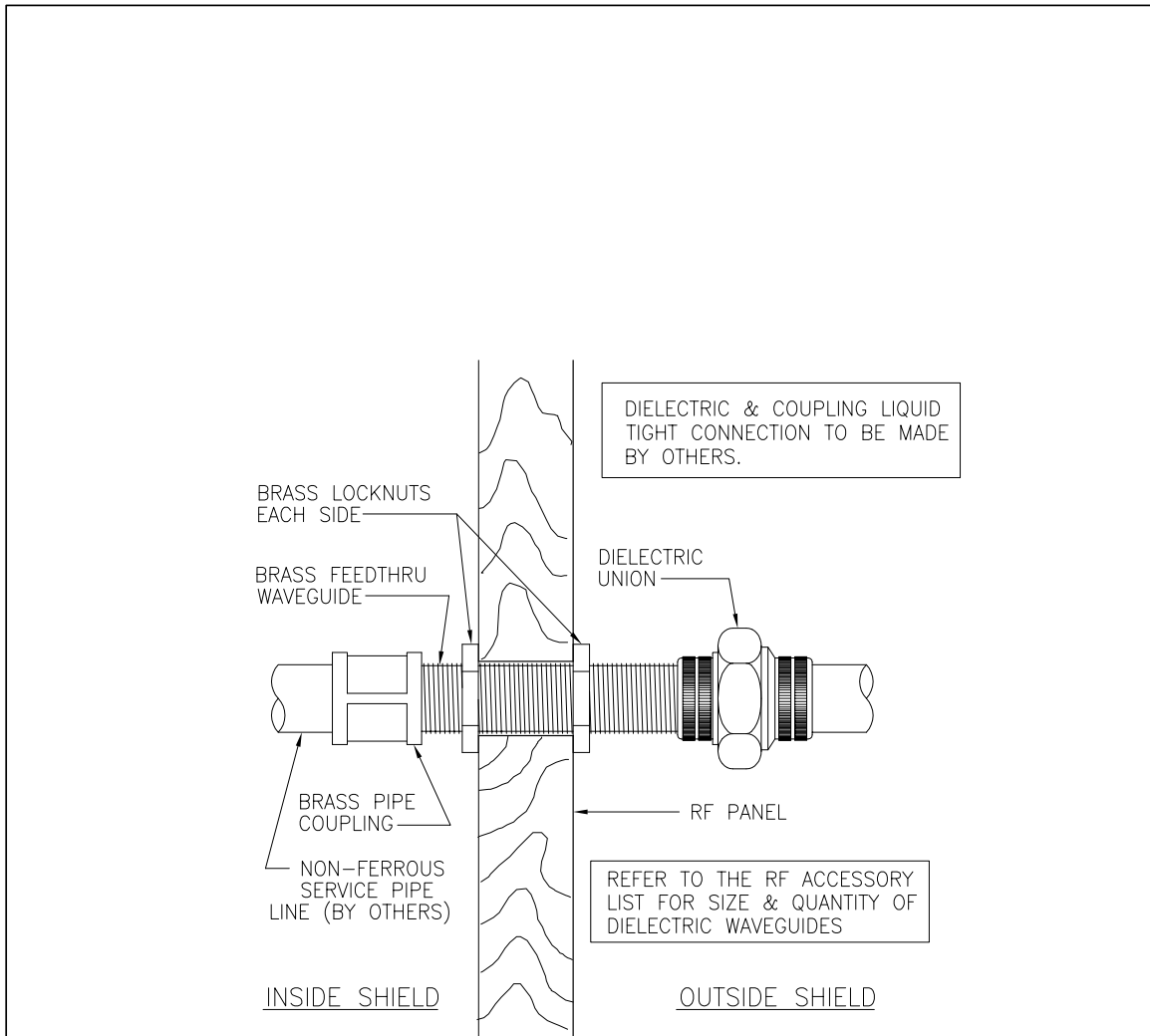
<p>Confidential Property of Lindgren R.F. Enclosures. Not to be disclosed to others, or used for any purpose except as authorized in writing by Lindgren R.F. Enclosures, Inc.</p>	 <small>An ESCO Company</small>		MEDGAS WITH GENERIC WALL	
	<small> Chicago Office: 400 High Green Boulevard • Glen Dale Heights, IL 60139 (708) 937-3300 • (708) 937-7271 • Fax </small>		PROJECT:	JOB NO:
	DRAWN BY: N.E.P.	CHECKED BY:		REV:
	DATE: AUG. 28, '09	SCALE: NOT TO SCALE		


RF ELECTRICAL POWER FILTER



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	Missouri Office: 7500 Olive Drive - Missouri, MO 64566 763.288-0202 • 763.288-8223 - Fax		PROJECT: _____ JOB NO: _____	
Chicago Office: 400 High Grove Boulevard - Glenview Heights, IL 60139 848.987.7000 • 848.987.7075 - Fax		DRAWN BY: N.E.P. CHECKED BY: _____		REV: _____
DATE: AUG. 28, '09		SCALE: NOT TO SCALE		

SPRINKLER WAVEGUIDE



Confidential Property of Lindgren R.F. Enclosures. Not to be disclosed to others, or used for any purpose except as authorized in writing by Lindgren R.F. Enclosures, Inc.	 An ESCO Company <small> Message Office: 7500 Glen Drive • Milwaukee, WI 53248 755.500-2022 • 755.500-2023 • Fax Chicago Office: 400 High Creek Road • Glenview Heights, IL 60039 848.507-3200 • 848.507-7070 • Fax </small>		SPRINKLER WITH GENERIC WALL	
	PROJECT:	JOB NO:	DRAWN BY: N.E.P.	CHECKED BY:
DATE: AUG. 28, '09	SCALE: NOT TO SCALE			

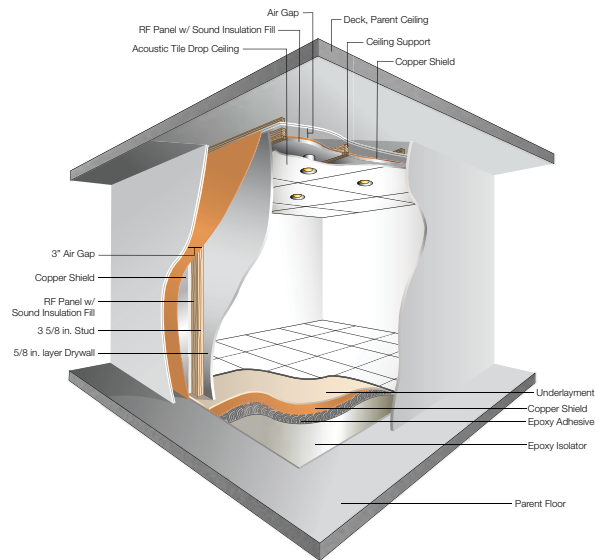
Section 8 Service

The number of used MRIs being sold and the number of sites replacing or upgrading old MRIs is growing dramatically. In addition, hospitals are striving to make their existing MRIs function longer, thereby delaying replacement. All of these actions necessitate the need for service.

ETS-Lindgren offers service contracts ranging from 1 to 5 years and also responds to as-needed service calls as well. With a dedicated Service Department consisting of 10 experienced and skilled personnel, ETS-Lindgren can respond to any problem on any RF shielding, including **non-ETS-Lindgren shields**.

Services include, but are not limited to:

- RF Testing / Troubleshooting
- EMI (moving metal) Testing
- Vibration Testing
- Design Assistance
- RF Shield Repair
- RF Shield Upgrade and/or Modification
- Engineering & Consultation
 - *Magnetic Shield Design
 - *Acoustic & Vibration consulting
 - *RF consulting



Acoustic Design Assistance

Contact your ETS-Lindgren representative or call our

Service Department at

(630) 912-1900

Section 9 Accessories

ETS-Lindgren is more than an RF shielding company. By offering a comprehensive line of accessories for the MRI suite, we can be your single source for a number of products and services.

LED Lighting

LED downlights serve as an excellent light source in the MRI suite and never have to be replaced. This eliminates the need for maintenance workers to replace bulbs within the MRI suite, which reduces the risk of ferrous tools being introduced into the suite and accidentally pulled into the MRI.

LED Graphic Panel Display

Envision any image you would like to display in your MRI suite and then backlight it with LEDs. This type of presentation helps create a soothing, relaxed environment for the patient. Whether you desire a ceiling or wall-mount, ETS-Lindgren offers a system and size to suit your needs.

Magnetic Active Compensation System (MACS)

MACS is designed to protect the MRI from environmental disturbances caused by trains, cars, elevators, etc. and resolves EMI disturbance in 90% of cases. It can be installed in conjunction with the RF shield or after. Evaluate your need for a MACS by arranging for EMI testing.

Closed Circuit TV (CCTV) Intercom System

CCTV is an affordable audio and/or video communication system for the MRI suite that is also easy to install. It increases your monitoring ability as well as communication with the patient.

Ferromagnetic Detection System (FMDS)

FMDS is an additional safety precaution that helps screen patients and hospital staff for ferrous objects prior to entering the MRI suite. Equipped with color-coded lighting and an auditory alert, you are made aware both before and as you pass the FMDS that you are at risk for causing an accident. Recommended by the American College of Radiology, ferromagnetic detectors are a tremendous addition to your existing safety and screening program.