ALUMINUM FOIL RF SHIELDING SYSTEMS

When designed and installed properly, foil rooms have consistently exceeded NSA 73-2A requirements.

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INTRODUCTION

For many years the aluminum foil enclosure system has received criticism as an unworkable system. Some engineers, both designers and users, have strong convictions that welded steel or demountable modular systems must be used for an RF shielded enclosure. These notions are based largely on misconceptions of aluminum shielding capabilities. In many applications the aluminum foil system has met customers' requirements and provided a low cost alternative to the steel enclosures. This article will discuss aluminum foil shielding — its performance, benefits, limitations, application and economic considerations.

A standard medium level shielding requirement is the NSA 73-2A specification. This specification, typically known as the *50 dB* specification, calls for the use of aluminum foil technology. Unfortunately, the recommended construction techniques shown in NSA 73-2A have become outdated. The systems built using these techniques had difficulty meeting the attenuation requirments. By utilizing new construction techniques and good shielding practices the foil system can provide 60 to 80 dB of electric field and plane wave attenuation from 10 kHz to 1 GHz. The attenuation achieved by this system can fulfill many shielding requirements at significant cost savings (20 to 30 percent) over modular and steel systems.

The dominance of steel over aluminum foil shielding materials has existed for decades. However, recent improvements in construction materials and methods, coupled with less stringent shielding requirements, have brought parity to the two shielding technologies.

SHIELDING PERFORMANCE

A popular misconception is that aluminum foil has no magnetic shielding properties. This is incorrect, since all metals provide a certain amount of magnetic shielding. The total amount of shielding provided is dependent on the permeability and relative conductivity of the metal. These factors determine the absorption and reflective properties of the shield. Table 1 shows the theoretical magnetic attenuation of a 6-mil sheet of aluminum foil as compared to a steel sheet of the same thickness. The following formulas were used to determine the attenuation factors shown in Table 1.

$$R = 20\text{Log}\left[\left(\frac{0.462}{r}\right)\left(\frac{\sqrt{\mu}}{Gf}\right) + \left(0.136r\right) x \left(\sqrt{\frac{Gf}{\mu}}\right) + 0.354\right] dB$$

Where:

R = Reflection loss in dB

r = Distance from source to shield (inches)

μ = Relative magnetic permeability referenced to freespace
Iron (1000) Aluminum (1)

G = Relative conductivity referenced to copper
Copper (1) Aluminum (0.61)
Iron (0.17)

f = Frequency in hertz

$$A = 3.338 \times 10^{-3} \times t \times \sqrt{Gf\mu}\ dB$$

Where:

A = Absorption loss in dB

t = Thickness of metal in mils

G = Relative conductivity

f = Frequency in hertz

μ = Relative magnetic permeability

These formulas show that aluminum foil offers little absorption attenuation to low frequency magnetic fields, but does provide a fair amount of reflective shielding. Note that the thickness of the shielding material affects only the absorption component of the overall attenuation.

Figure 1 is a comparison of the NSA 73-2A attenuation requirements and actual measurements performed on some aluminum foil systems. The results are average attenuation values measured over three entire shielding systems, including pipe penetrations, waveguide air vents, doors and seams. The data represented is the average attenuation measured at all test points on three accredited aluminum foil rooms. At 10 kHz, 100 kHz, and 1

Aluminum (6 mils)

Frequency	Absorption Loss (dB)	Reflection Loss (dB)	Total Shielding Effectiveness (dB)
60 Hz	.1	23	23
1 kHz	.5	35	35
10 kHz	1.5	45	47
100 kHz	5.0	55	60

Steel (6 mils)

Frequency	Absorption Loss (dB)	Reflection Loss (dB)	Total Shielding Effectiveness (dB)
60 Hz	2	N/A	2
1 kHz	8	3	11
10 kHz	26	11	37
100 kHz	82	20	102

*See advertisement on page 244.

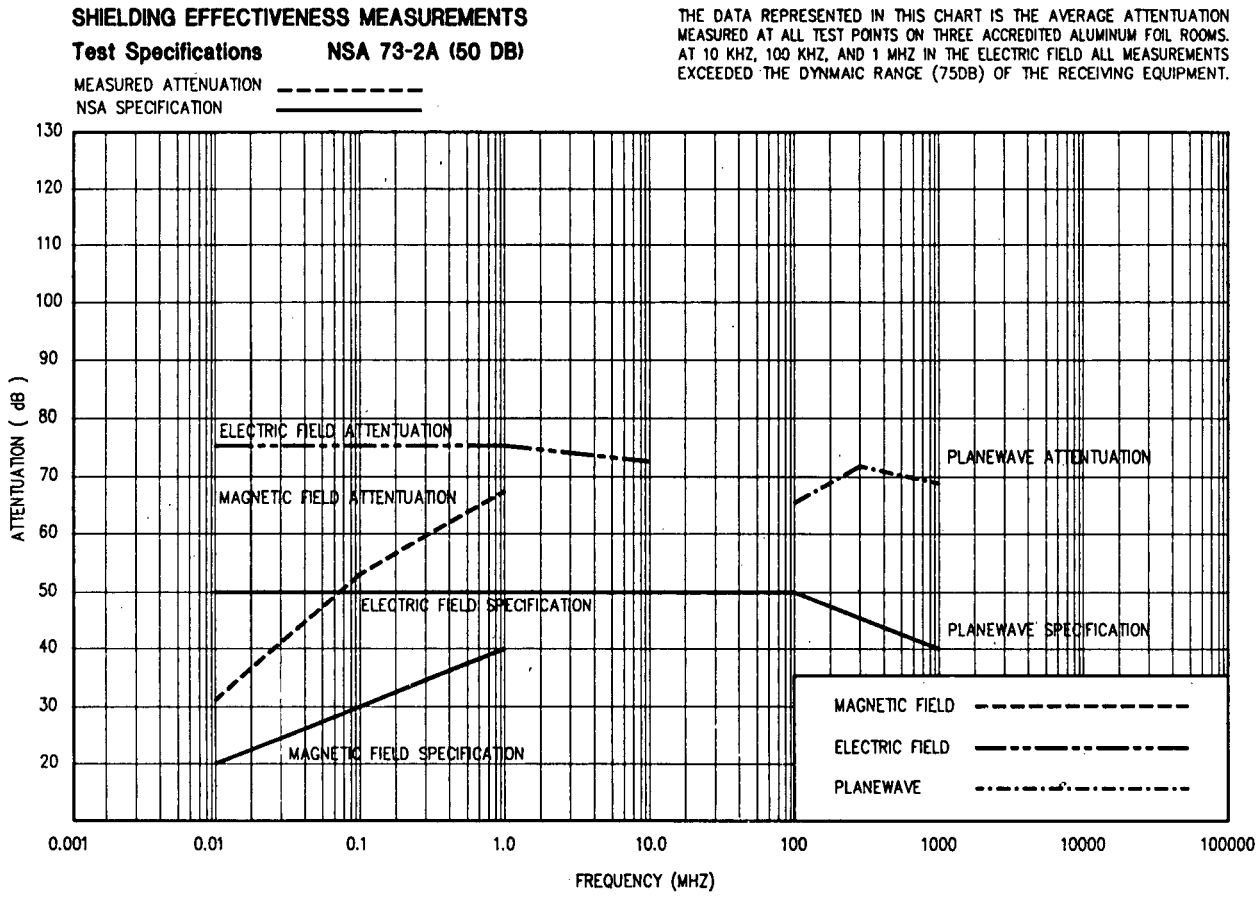

Figure 1.Shielding Effectiveness Measurements. Test Specifications NSA 73-2A (50 dB).

MHz in the electric field all measurements exceeded the dynamic range (75 dB) of the receiving equipment. The disparity between measured data and calculated data can be attributed to many factors which would affect the overall shielding characteristics of the foil system, such as pipe penetrations and air vents.

LIMITATIONS AND BENEFITS

General Comparisons

The benefits and limitations of foil enclosures are more easily observed when compared to shielding systems made with other materials. Steel and copper are the most common shielding materials used today.

Steel RF shielding systems (demountable, welded or seam sprayed) are typically designed for NSA 65-6 specifications. This specification calls for 100 dB of attenuation and is more expensive to implement. Demountable steel panel rooms provide transportability of the enclosure at the expense of periodic bolt retorquing.

Copper foil rooms can be built to meet NSA 73-2A specifications. However, the material cost for this type of shielding is higher than that for aluminum foil systems, and copper is more corrosive than aluminum.

Conductive coatings have gained some attention lately as an alternate shielding material. Unfortunately, many of these are difficult or hazardous to apply. Most of the lower cost coatings do not meet NSA 73-2A, and the higher quality coatings are more expensive then comparable shielding technologies. Finally, mating conductive composites with door frames, vents or filters is not easily accomplished. Further advances in composite technology are needed to make conductive coatings a viable alternative.

Benefits Of Aluminum Foil

Aluminum foil RF enclosures provide many benefits to the appropriate user. Some of the benefits are described here.

Performance. Aluminum foil systems can be constructed which exceed NSA 73-2A and which can be guaranteed for 5 years.

Economy. Aluminum foil enclosures cost substantially less than comparable *50 dB type* RF systems. If physical and sound security requirements exist, they can be met economically. Aluminum foil enclosures are most economical in large installations where shielding material costs outweigh expenses for doors, filters, and other penetrations.

Reliability. Unlike demountables, there are no mechanical fasteners at panel connections. Therefore, loss of shielding effectiveness due to loosening of joints is eliminated. Use of water-resistant adhesives minimizes problems associated with excessive moisture.

Aesthetics. Standard architectural finishes may be used in the interior as there are no panel connections which must be accessed for maintenance.

Flexibility. Site fabrication techniques easily accommodate duct chases, beams, columns, and unusual corners or angles. Field changes

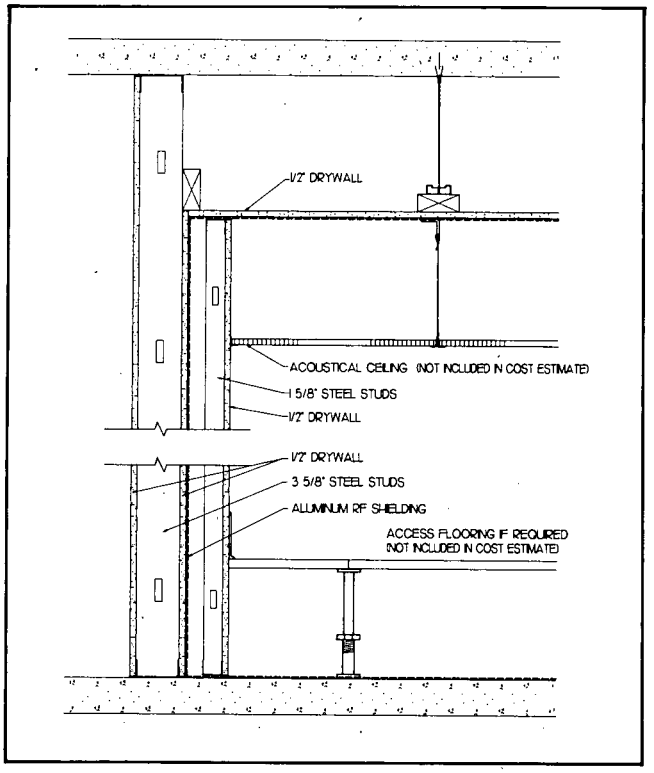

Figure 2. Aluminum Foil System.

and site irregularities have no impact on the shielding installation.

These inherent benefits create a good argument for the lightweight, flexible, foil technology. The use of foil in 60 to 80 dB shielding applications should increase as users become more aware of these benefits.

Limitations Of Aluminum Foil

Foil rooms cannot be used for every application. Situations in which foil rooms should not be used are summarized below.

100 dB Requirements. Most steel systems are designed for 100 dB and should be used for these installations.

Low Frequency Magnetic Shielding. The low frequency magnetic field attenuation for aluminum foil is less than that for steel systems. Magnetic shielding is required when protection from high current devices (MRI equipment, some large electromechanical machinery, high power conversion devices, etc.) is needed.

Transportable Rooms. Demountable rooms are designed to be moved and should be specified if mobility is required.

CONSTRUCTION CONSIDERATIONS AND TECHNOLOGIES

Proper design of RF shielded facilities must take into consideraton many factors. This section will address construction materials and methods used to install aluminum foil shields.

One of the major benefits of an aluminum foil system is its compatibility with standard construction designs and techniques. The base substrate for applying the foil can be a standard wall, easily installed by local general contractors. Figure 2 shows a typical foil installation. The aluminum foil is applied to the interior side of the perimeter wall with a moisture resistant adhesive. After application of the foil, a low cost cover wall is installed to provide protection for the foil and serves as an aesthetic wall covering inside the facility. An overhead framing system with drywall is required for the application of the ceiling foil. The framing system also provides structural support for hanging electrical and mechanical systems inside the facility.

Even though the installation of the foil system uses conventional construction methods, the foil application itself requires considerable experience in shielding techniques. For this reason, the application of the foil and the installation of all shield-related penetrations is best left to firms experienced in the technology.

Materials

Proper material selection is important in designing an aluminum foil system that will provide the required attenuation and long-term durability. Aluminum foil is available in alloys that are formulated to prevent corrosion while tempered to allow for easy installation.

In choosing an adhesive system, consideration must be given to the moisture resistant properties of the adhesive as well as to the toxicity level of the solvents. A proper selection will guarantee long-term reliability and provide a safe working environment for the personnel applying the foil.

Foil tape utilized in sealing the joints between foil sheets must be designed to guarantee long-term adhesion and resistance to excess moisture. Various styles of RF shielding tape are available which meet these requirements. One manufacturer has documented the continued performance of their product over the 19-year life span of an installation on the West Coast.

Sound and Physical Security

Quite often the perimeter wall of a RF shielded facility must meet DIAM 50 requirements for sound and physical security. These requirements may be implemented with minimum cost and without modifications to the existing design. The wall section illustrated in Figure 2 can be upgraded to meet DIAM 50 requirements by the addition of one layer of drywall and sound blankets in the exterior wall. As in all SCIF wall construction, consideration must be given to sound flanking and conduit placement. If required, expanded metal may be added to this wall to provide physical security.

ECONOMIC CONSIDERATIONS

In the past many designers have installed the more expensive 100 dB

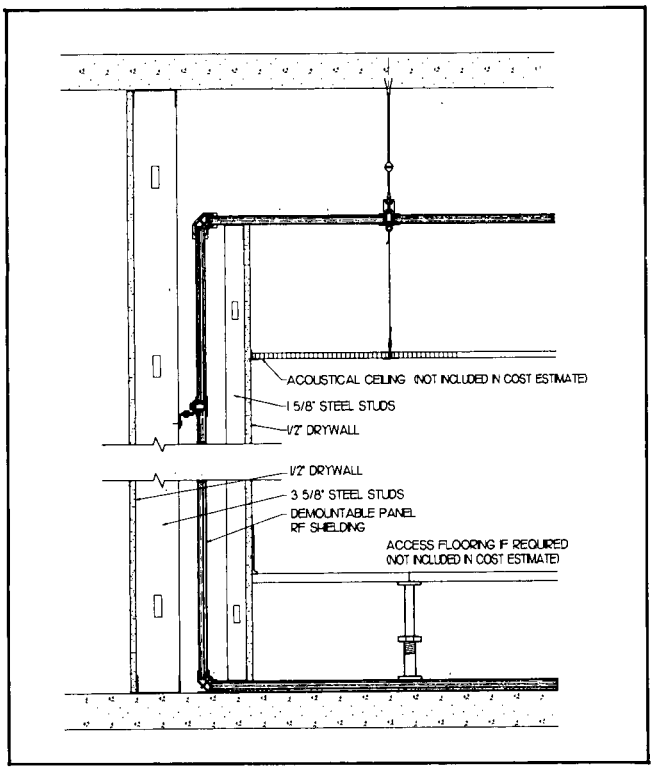

Figure 3. Demountable Panel System.

enclosures to meet NSA 73-2A. Their lack of awareness or confidence in alternative systems made this the only logical choice. The availability of a guaranteed NSA 73-2A foil system offers these designers a more cost-effective solution.

To summarize the cost difference between foil and steel enclosure systems, the following comparison is provided. Two bids were obtained from a qualified shielding contractor to install a 48-foot x 50-foot x 12-foot RF room. One bid was based on an aluminum foil system and the other on a demountable panel system. Both bids were prepared based on the following criteria:

- The RF room is rectangular in shape, 48 feet wide and 50 feet long with a height of 12 feet.
- Four RF doors were included along with two 5-foot x 7-foot vestibules. Two RF doors were interlocked at each vestibule.
- Three 2-foot x 2-foot interior columns were shielded.
- Ten 2-inch pipe penetrations and six 2-foot x 2-foot waveguides were included.
- RF filters for one 400 amp, 480 volt, 3 phase service were included.

The aluminum foil room was designed as shown in Figure 2, while the demountable design is shown in Figure 3. Both designs met the common criteria of providing an outside perimeter wall and an interior cover wall. To clarify the difference in cost between the two shielding systems, common components of both systems were excluded from the cost estimates, (i.e. outside cover walls, interior walls, access flooring and acoustical ceiling). Costs were included in the aluminum foil system to install the extra layer of drywall on the wall and ceiling and a drywall support system above the ceiling. Costs for the demountable room were 26 percent higher than the cost for a comparable aluminum foil system.

As the size of the room increases, the cost advantage of foil over steel systems increases. This is due to the reduced material and labor costs (per square foot) for the installation of foil.

SUMMARY

Aluminum foil RF shielding systems have proven to be a cost effective alternative to steel systems. Furthermore, aluminum foil offers more flexibility in facility design and system fabrication than other types of enclosures.

When designed and installed by firms experienced in the technology, foil rooms have consistently exceeded NSA 73-2A requirements. Increased awareness and confidence in aluminum foil systems should lead to continued growth of this shielding technology. ■

ACKNOWLEDGEMENTS

The author wishes to thank Antonio L. Cardenas and William B. Lentz for their technical contributions in preparing this article.