ARCHITECTURAL SHIELDING: INTRODUCTION AND APPLICATION

Water-based copper conductive coatings offer a new approach to architectural shielding.

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INTRODUCTION

As the automation of military command, control, communications and intelligence systems continues to expand, the need for shielding facilities to house these systems becomes increasingly important. In addition to military considerations, the increasing numbers of sophisticated sensitive electronic equipment in government facilities, hospitals, radio stations, television stations, and testing chambers has brought the subject of electromagnetic interference/radio frequency interference (EMI/RFI) shielding to the forefront of the architectural design community. Electromagnetic shielding of a facility involves the complete enclosing of an area within a continuous metal enclosure. The metal enclosure may be freestanding, attached to structural walls, integrated into existing walls, or sprayed onto structural walls.

The basic purpose of EMI/RFI shielding is to attenuate electromagnetic waves, which consist of two oscillating fields at right angles. One of these fields is the electric (E) field, while the other is the magnetic (H) field. In many cases, shielding a facility from electromagnetic waves is necessary to:

- Protect electronic equipment from destructive outside interference sources, such as high power transmitters (Radar, FM), nuclear effects - electromagnetic pulse (EMP), and lightning.
- Prevent the interception of classified military or industrial information through espionage.
- Protect electronic circuitry from electromagnetic energy that may cause temporary equipment malfunctions.
- Protect humans from hazardous radiation environments.

The goal of architectural shielding is to incorporate building materials within a structure that will protect the contents against the harmful effects of EMI/RFI.

CONSIDERATIONS

Over the last five years a great deal has been written covering the broad topic of architectural shielding. Numerous military handbooks, application notes and technical articles have been written. The main thrust of these specifications and papers has been aimed at military applications. Many application notes and technical papers are based on the development of new products and materials for use in architectural shielding considerations. New conductive fabrics, wallpapers, aluminum/copper foils, plastics with conductive coatings, and paints have been developed.

These represent numerous approaches to possible design techniques, each of which presents its own set of questions. The following general questions should be answered for each approach.

- What is the inherent shielding effectiveness of various standard building designs and structures?
- What are their relative costs?
- How can standard designs be modified to improve shielding effectiveness? What are the additional materials and costs?
- What materials are available for magnetic field, electric field, and plane wave shielding? What are the relative costs for the materials?
- What are the various methods of installing shielding materials? How can penetrations be best implemented without undue compromise to the shielding? What are the relative costs?
- How should vents (heat and air conditioning), plumbing, and other openings be treated? What shielding method should be used? What are the relative costs?
- How should power and signal cabling be accomplished? Where should filtering be used and how much? What are the cost reducing factors?
- How should joints between wall panels, wall-to-ceiling/ceiling-to-roof, wall-to-floor be treated? How does this vary depending upon shielding effectiveness, frequency range and cost?
- What environmental conditions (i.e., humidity, temperature) affect

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the life cycle of the shielding design?

- How can life cycle be estimated, and what are the cost trade-offs?
- How effective are new shielding materials, such as conductive coatings and wire/fabric meshes, and what are their applications? Are they cost-effective?
- How should doors be designed to obtain shielding effectiveness goals?
- How should windows be designed to obtain shielding effectiveness goals? Will these windows provide actual inside/outside visibility or only light transmissivity?
- Can conductive caulking be used to seal window and wall seams? Can conductive epoxies be used? If so, where?
- What materials providing both magnetic and electric field shielding (i.e., joints, corners, seams) are easiest to work with?
- Can wire mesh (copper, aluminum, steel) be used for wall shielding in place of foil sheets and yield required shielding effectiveness figures? What characteristics (percent open, weave contact, etc.) should the mesh have?
- Will mesh material be too difficult to work with (i.e., joints, corners, seams)?
- On straight wall areas, where foils might be used, is there a minimum of foil thickness that must be used for "workability"?
- How are seams to be jointed? How much overlap must be used for seams where foils are used? How much overlap for mesh?
- What level of shielding effectiveness is possible using each listed approach? What are the relative costs and related reliability?
- In the event that adhesives are used to attach foils or meshes to wallboard or concrete, what are the characteristics of the adhesives with respect to adhesion strength, tensile strength, dielectric strength, electrolytic corrosion factors, and temperature characteristics? What are their longevity and relative costs?

Judicious consideration of the questions can result in tabulated results showing:

- Shielding effectiveness of various materials and methods;
- Cost (labor and material) of various methods; and the
- Life cycle of various materials and methods.

APPLICATIONS

The actual proof of just how effectively a material shields against magnetic, electric and plane wave fields is its ability to attenuate these waves. Statements that a particular material has an attenuation characteristic of "100 dB or more" are not uncommon. However, unless the attenuation characteristics are expressed as *attenuation versus frequency* the 100 dB number has no meaning. An understanding of what type of measurement is being described -- magnetic, electric, plane wave -- is also necessary. Actually when either an entire building or an area within a building is to be shielded, the necessary level of attenuation, the frequency range and the necessity of magnetic shielding must be determined. Once these factors have been specified, the material to be used for the actual shield can be selected.

As previously stated, the majority of architectural shielding programs relate to the military; but the commercial world must not be ignored. During the period when electronic equipment destined for military usage was undergoing vast changes in technology and complexity, which in many cases necessitated placing equipment within shielded enclosures/rooms, the same changes were taking place in the commercial world. Electronic computers, word processing equipment, receivers, multiplexers, security systems, etc. have been brought into non-military facilities. The electronic equipment "residing" in the non-military facilities act as receptors for electromagnetic emissions that make up what is commonly referred to as the electromagnetic environment. The electromagnetic environment can cause equipment malfunctions and may in many cases necessitate placing sensitive equipment within a shielded room/area/building. For example:

- hospitals
- hospital laboratories
- banks
- stock exchanges
- insurance companies
- communication centers (AT&T, MCI, Sprint)
- radio stations
- aircraft control towers
- commercial test laboratories
- manufacturing companies (automated equipment)
- cable television transmission centers

In these commercial areas where shielding is found to be necessary, 100 dB of attenuation between 10 kHz and 1 GHz will probably not be necessary. The usual design goal in most commercial applications is 60 dB between 50 kHz and 1 GHz. The basic objective in the commercial world is to achieve the shielding necessary at minimum costs and labor.

COPPER PAINT

Table 1 illustrates five methods commonly used for architectural shielding purposes. Notably, only the last three columns illustrate attenuation levels of 50 dB or less. The use of copper paint is indeed a practical and inexpensive way to achieve shielding effectiveness levels of 60 dB (or more) between 10 kHz and 1 GHz. The paint referenced by Table 1 (column 5) was developed for use as an EMI/RFI shield for rooms/enclosures/structures and

Characteristic	Method: Solid Metal Structure	Manufactured Modular Panels	Foil/Wallpaper	Mesh/Screen*	Copper Paint*
Construction	Sheet Metal (10 to 14 Gauge) On Structural Frame—Steel/Concrete	Sheet Metal (24 to 26 Gauge On A Wood/Fiber Board Or Rigid Foam Core	Copper/Aluminum/Fibre/Steel (0.5 to 5+ Mil Thick) On Wallboard Or Equiv.	Copper/Aluminum/Steel Mesh (.015 In To 2.0 In. Spacing) On Wood Or Structural Frame	Copper Paint On Standard Wallboard, Plywood, Built On Structural Frame (1-3 Mil) Thick On Surface. Can Be Used On Plastic, Fiberboard Or Masonry
Joining Methods	Welded/Brazed	Bolted	Turned & Bent, Taped, Soldered, Stapled, Pasted, Conductive Adhesive/Epoxy	Bolted, Taped, Soldered, Stapled, Conductive. Epoxy	Standard Wallboard Tape, Ducttape (Paint Over Tape) Copper Tape
Typical Attenuation (Nominal)	120 dB (10 kHz-1 GHz) 'E' 20 dB-60 dB (10 kHz-1 MHz) 'H'	100 dB (10 kHz-1 GHz) 'E' 20 dB-60 db (10 kHz-1 MHz) 'H'	60 dB 10 kHz-1 GHz 'E' (0 dB Mag. 'H')	> 60 dB (10 kHz-1 GHz) For Fine Mesh (150 Wires) < 60 dB Above 100 MHz For Coarse Mesh. No Magnetic Attenuation	> 60 dB (10 kHz-1 GHz) 'E' (2-3 Mil Thickness)
Technical Advantages	Very High Attenuation, Durable, Low Degradation Rate & Low Maintenance (If Welded)	High Attenuation, Durable, Moderate Weight, Demountable	Lightweight	Lightweight	Lightweight, Easy To Apply, Durable, Easy To Maintain/Repair Can Be Covered By Wallpaper/Paint
Disadvantages	Weight-Installation Costs	Uncertain Life Cycle Performance, Susceptible To Water Damage, Difficult To Maintain	Fragility, Uncertain Life Cycle Performance. Very Difficult To Maintain. Difficult To Attach To Walls/Surfaces. Must Be Protected	Fragility, Uncertain Life Cycle Performance. Difficult To Attach Must Be Protected	Can Be Scratched Or Abraided
Installation Cost	Highest	High	Moderate	Moderate To Low	Lowest
Life Cycle Cost (Predicted)	Low	Moderate To High	Moderate	Low To Moderate	Low
Repairability	Difficult—Cracked Welds Likely Problem—Could Require Wall Removal For Repair.	Difficult—Rust And/Or Corrosion—Must Disassemble—Clean—Reassemble	Likely Problem—Tears. Repair Easy If Tear(s). Can Be Found—Walls Must Be Opened	Likely Problem, Tears. Must Patch Where Tears Are Found. Must Attach 'Patch' Securely (Solder, Alum Solder, etc.) If Covered Walls Must Be Opened	Where RF Leakage Is Found Area Can Be Repainted (Brush, Roller Or Spray). Scratches Or Abrasions Can Be Repainted Without Repair. Holes Must Be Filled Prior To Paint. (Spackle)

*Mesh/Screen/Wallpaper/Copper Paint Not Recommended For Tempest Shielding.

Table 1. Comparative Shielding Methods.

has been tested several times during the past two years utilizing conventional shielding effectiveness methods (according to MIL-STD-285 methods, and as a wall paint for a 7' x 7' x 7' room constructed exclusively for shielding effectiveness tests).

The paint tested is a metallic paint utilizing a specially formulated non-oxidizing copper as a conductive agent. A water-based system permits application by brush, roller or spray. The paint is not harmful or noxious when applied in enclosed areas with limited ventilation. One gallon covers over 650 square feet with a thickness of one mil. With a 2 mil (dry film) thickness, surface resistivity is less than 0.1 ohm square.

Copper paint is widely known as a shielding medium for electronic equipment enclosures. However, the

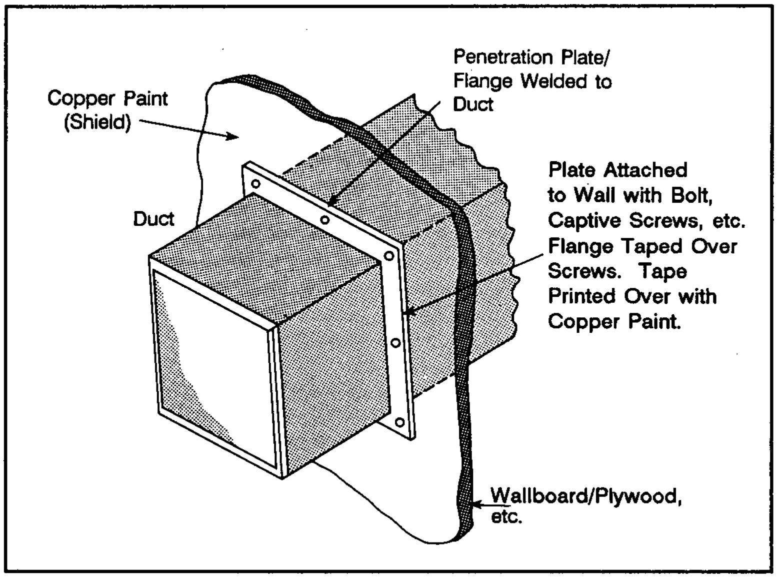

Figure 1. Air Conditioning/Heating Duct Penetration.

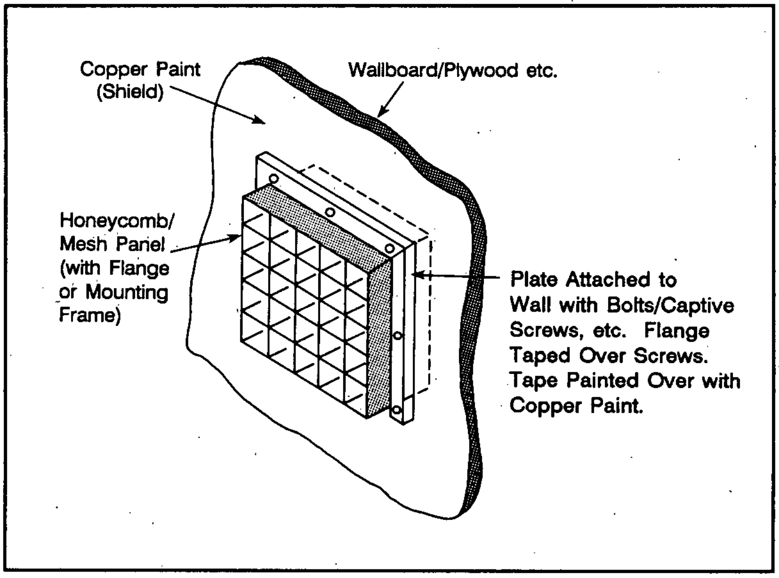

Figure 2. Ventilation Penetration.

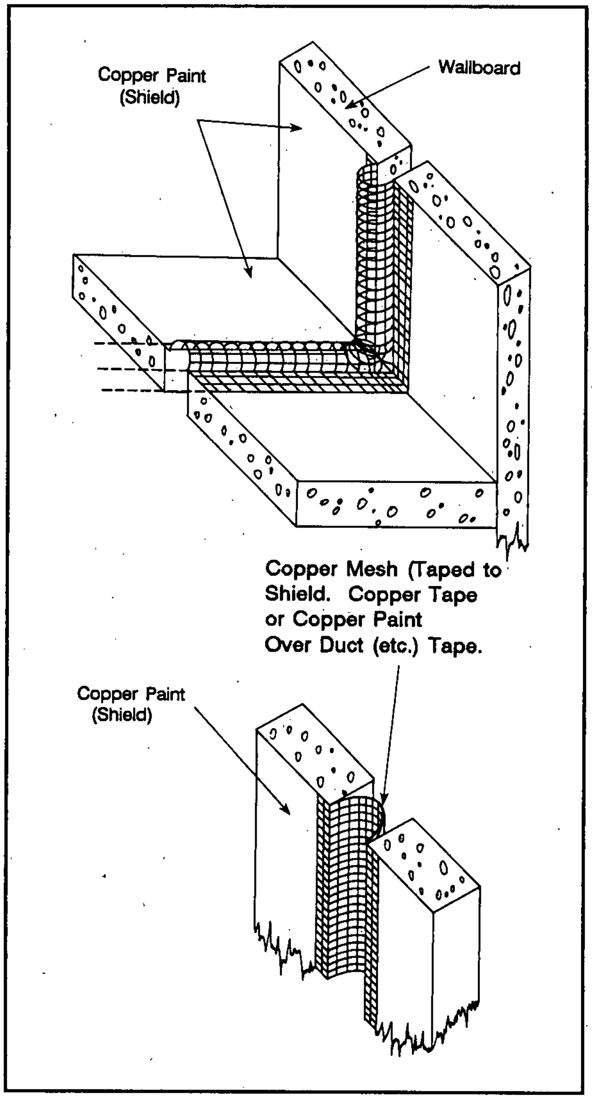

Figure 3. Expansion Joint in Edge Angle; External/Internal Joint.

use of copper paint as a means to achieve shielding for rooms/areas/buildings is not widely known. Copper paints sold for equipment shielding are solvent-based and incompatible with a wide variety of building materials. The water-based conductive copper coating maintains all of the mechanical and electrical characteristics of solvent-based paints and is compatible with typical materials found in rooms and structures, such as masonry, wallboard, wood, plastic and concrete. In addition, the paint is compatible with wallpaper, decorative paint and carpeting. The cost-effectiveness and flexibility of this system for architectural applications (where shielding requirements permit) is unparalleled.

SHIELD INTEGRITY

Penetrations through the painted walls, ceilings, etc. are handled according to the same *basic* procedures and techniques that are used for foils and meshes. Figures 1 and 2 illustrate an air conditioning/heating duct and a ventilation penetration. The basic shielding integrity must be maintained through the use of frames secured around the duct, and

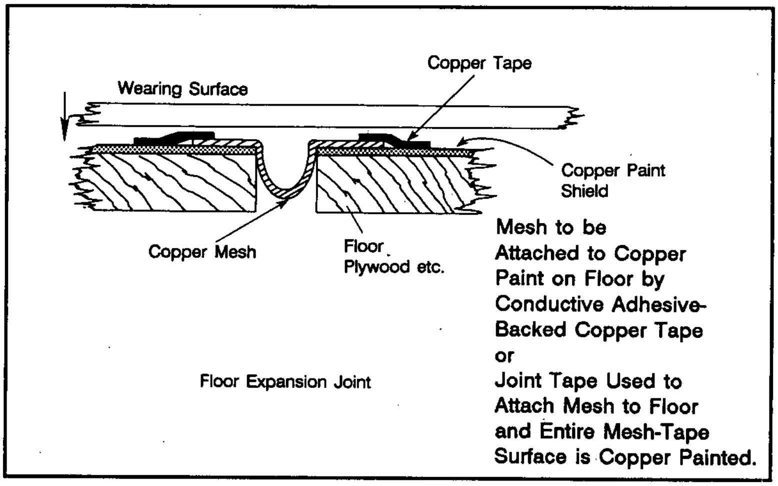

Figure 4. Floor Expansion Joint.

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held tightly to the wall with screws/bolts and the use of EMI gaskets (when necessary). Figures 3 and 4 illustrate methods to achieve expansion joint shield integrity. Many other penetrations need to be addressed as well, but with established procedures and new innovative methods, structure penetrations can be achieved that are "RF tight."

CONCLUSION

In summary, the use of the newly formulated water-based copper conductive paint as an alternative to costly, labor intensive, architectural shielding methods can be considered where shielding requirements permit. Cost analyses comparing currently used "conventional shielding methods" versus the use of copper paint favor copper paint in cost per square foot for any room or building. Already, copper paint is being used with great success in several installations in the United States and is being evaluated in other installations abroad. ■

ACKNOWLEDGEMENT

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