# THE TECHNICAL BASIS FOR SELECTING A SHIELDING ENCLOSURE

## Introduction

The purpose of this article is to provide the conceptual technical basis underlying the selection of shielding enclosures so that manufacturers' claims of performance can be evaluated intelligently. This need arises, not because of unfounded claims by manufacturers, but because there are many varieties of enclosures and a number of variations upon testing techniques (even to a given standard) to "prove" their performance. Testing methods will be covered by another article in ITEM; basic technical factors which determine performance will be treated here, but accessory items common to all types of enclosures, such as powerline filters, are not included.

Let us now lay the groundwork for understanding these factors. For this purpose, the commonly used, but often missapplied, transmission theory of shielding will be followed. It is commonly used because it is directly analogous to transmission line theory which is inherent in the formal training of most electronics engineers; hence, it is readily grasped. This theory correctly considers transmission of an electromagnetic (EM) wave through a shield to be like the transmission of current and voltage along a two-conductor line. It is misapplied because many people overlook the fact that this theory was derived for a uniform shield, i.e., one without metallic discontinuities, such as mechanically clamped seams between panels or finger-stock seams around doors, and without metallic irregularities, such as at welded, brazed or soldered seams. In reality, conventional theory represents the performance of the basic material, not an overall shielding structure. This performance can be, and in practice generally is, influenced by performance at seams (and at other points of RF leakage).

With this consideration in mind, let us review briefly EM shielding theory to highlight salient features, and to discuss the modification of theoretical shielding performance by actual leakage paths. This foundation prepares us to understand the performance characteristics of various types of shielding-enclosure construction and the considerations necessary to evaluate performance claims made by manufacturers. Let us later discuss and summarize the major technical considerations in the selection of a shielding enclosure.

## Shielding Theory - For Material Only

The transmission theory of shielding has been presented many times, for example (1-4). Rather than repeat it here, let us examine properties of the basic equation for a single-layer uniform shield, expressed in dB. The shielding effectiveness S in dB is

$$S = A + R + B, \qquad (1)$$

where

A = Penetration loss through the shield (microscale heat dissipation)
  $= 8.686 \sqrt{\pi\mu\sigma f}\ \ell$

P = Reflection loss at both sides of shield (air-metal interfaces)
  $= 20 \log |k+1|^2/4|k| \approx 20 \log |k|/4$ for $|k| >> 1$

B = Correction term due to re-reflections (negligible for A>15 dB)
  $\approx 10 \log (1-2\times10^{-0.1A}\cos 0.23A + 10^{-0.2A})$ for $|k| >> 1$

and

$k = Z_w/\eta$, $Z_w$ (wave impedance) = E/H, $\eta$ (intrinsic impedance) $= \sqrt{j\omega\mu/\sigma}$.

The notation is standard and units are MKS.

TABLE 1

CALCULATED PENETRATION LOSS AND REFLECTION LOSS OF METAL SHEET

| FREQUENCY | IRON (SAE 1045) $\mu_r$ | PENETRATION LOSS/MIL THICKNESS (dB/mil) COPPER $\sigma_r = 1, \mu_r = 1$ | IRON $\sigma_r = 0.17$ | PLANE-WAVE REFLECTION LOSS (dB) COPPER $\mu_r = 1$, $\sigma_r = 1$ | IRON $\sigma_r = 0.17$ |
|---|---|---|---|---|---|
| 60 Hz | 1000 | 0.026 | 0.334 | 150. | 112. |
| 1 kHz | 1000 | 0.106 | 1.37 | 138. | 110. |
| 10 kHz | 1000 | 0.334 | 4.35 | 128. | 90.5 |
| 150 kHz | 1000 | 1.29 | 16.9 | 117. | 78.8 |
| 1 MHz | 700 | 3.34 | 36.3 | 106. | 72.1 |
| 15 MHz | 400 | 12.9 | 106. | 96.4 | 62.7 |
| 100 MHz | 100 | 33.4 | 137. | 88.2 | 60.5 |
| 1.5 GHz | 10 | 129. | 168. | 76.4 | 58.8 |
| 10 GHz | 1 | 334. | 137. | 68.2 | 60.5 |

NOTE: Other values of $\mu_r$ for iron are 600 at 3 MHz, 500 at 10 MHz and 50 at 1 GHz.

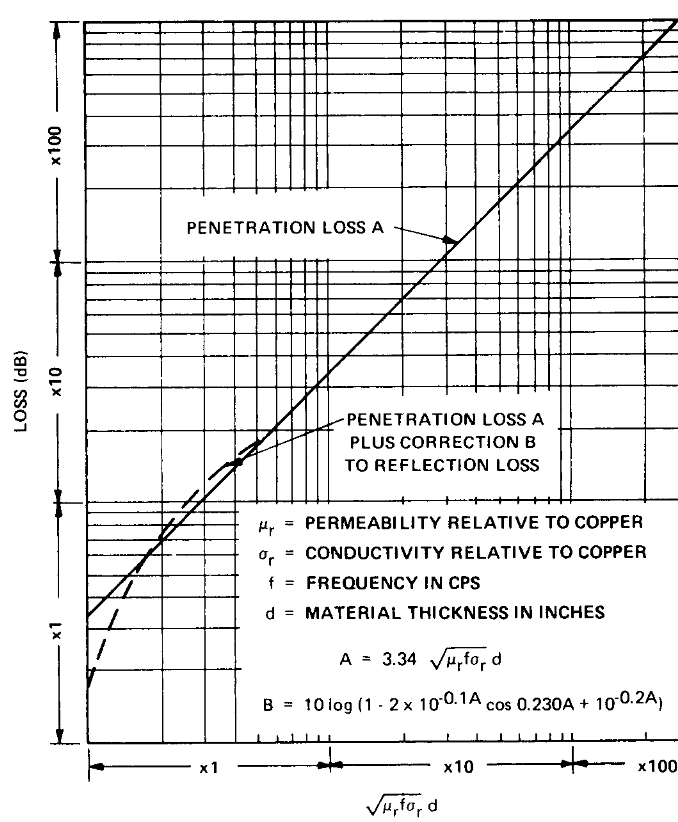



Figure 1. Penetration Loss (Plus Correction to Reflection Loss)

See LectroMagnetics on the back cover.

Consider now the separate shielding-effectiveness terms. The penetration loss A depends upon only two basic factors: the material (electrical characteristics of incremental magnetic permeability $\mu$ and electrical conductivity $\sigma$, and physical thickness ) and the frequency (f). Note that this term is independent of impedance of the incident EM wave and, thus, does not depend on the specific application of the shield. The term is expressed graphically in Figure 1. Typical calculated values for copper and iron are given in Table 1.

The reflection-loss term R is a function only of the ratio k of wave impedance $Z_w$ (=E/H) of the incident wave to the intrinsic impedance $\eta$ of the shielding material. The user of a shielding enclosure seldom has control over the impedance $Z_w$ of the incident wave, but he does have some control over the intrinsic impedance of the shielding material by proper selection of an enclosure. A typical value of intrinsic impedance for copper ($\mu = 4\pi \times 10^{-7}$ h/m, $\sigma = 5.8 \times 10^{7}$ mhos/m) is

$$|\eta_{cu}| = 4.52 \times 10^{-7} \sqrt{f(Hz)} \text{ ohms} \quad (2)$$

Obviously, $|\eta_{cu}|$ is extremely small at low frequencies where low-impedance waves may exist, and is much less than a plane-wave impedance (377 ohms) at the higher frequencies where enclosures encounter primarily plane waves. (Even at 10 GHz, $|\eta_{cu}|$ = 0.0453 ohm). Thus, the ratio $|k|$ is, in almost all cases, much greater than one well into the gigahertz range due to the values of electrical parameters for metals. Even though $|k|$ is much greater than unity, note that the magnitude does depend upon the wave impedance. For a high-impedance wave, $|k|$, and therefore R, will be greater than for a low-impedance wave. Thus, the reflection-loss term R depends upon the specific application of the shield. It is expressed graphically for a plane-wave source in Figure 2.

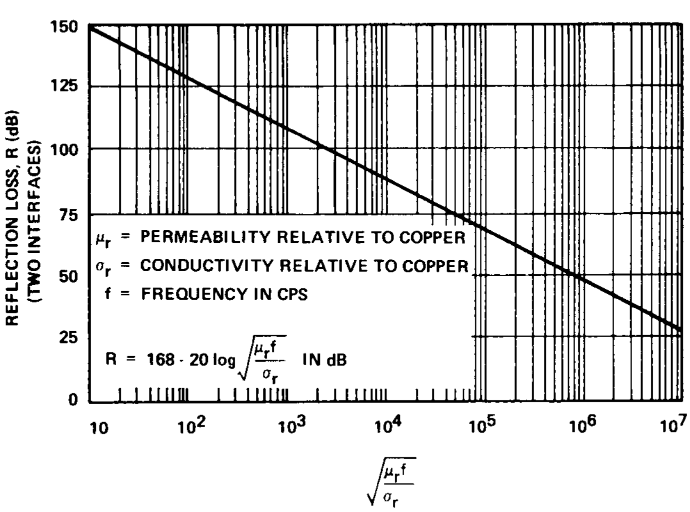


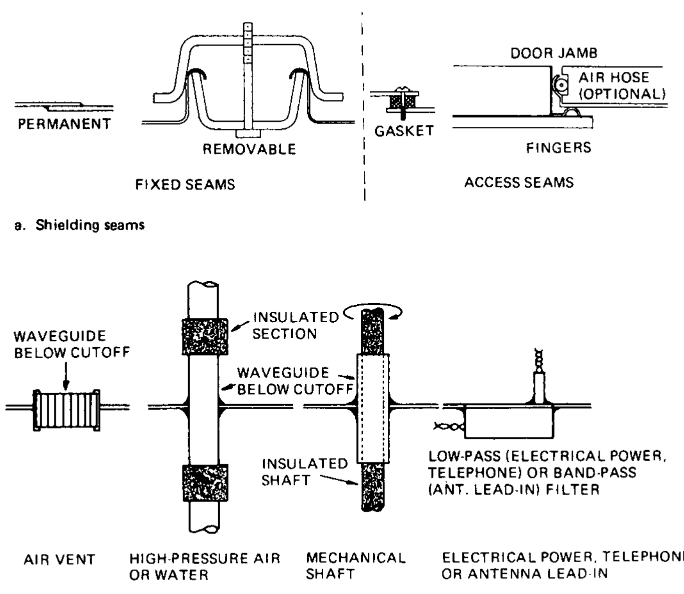

Figure 2. Reflection Loss for Plane-Wave Source

The correction term B depends only on the penetration loss A (for practical cases where $|k| >> 1$) and is thus independent of the specific application of the shield. It becomes negligible whenever the penetration loss exceeds 15 dB. This condition holds over the useful frequency range of commonly used enclosures; the correction term need not normally be considered further (unless an enclosure is to be used at extremely low frequencies where A may be under 15 dB). If required, it can be used to modify the penetration loss term as shown in Figure 1.

The shielding expression (1) indicates an increasing degree of performance with frequency. At the lower frequencies, calculated and measured values of shielding effectiveness are in good agreement; here, performance is material-limited.

## Leakage

As the frequency is increased, the theoretical performance of the shielding material becomes better; however, the shielding enclosure is no longer able to achieve its theoretical potential. The reason is that shielding joints or seams, even if fused, permit small portions of electromagnetic energy to bypass the highly effective shielding material. (The better the material performance, the less leakage is required to cause degradation.) In addition, other paths of leakage exist, examples of which are shown in Figure 3. The sum of all leakage signals has both amplitude and phase effects, which are dramatically illustrated by results of tests on two small shield cans, Figure 4. At the lower frequencies, shielding performance is basically that of the material itself, but at the higher frequencies performance is determined by leakage. In between, a resonance-type effect is observed when the magnitudes of leakage and material penetration paths are similar, but the phases are substantially different (due to widely different phase velocities between EM waves in metal and air). High-frequency shielding effectiveness, depending upon seam quality and existence of bypasses, typically ranges from 30 dB (for poor seams) to 100 dB or greater, depending upon control of all leakage paths.

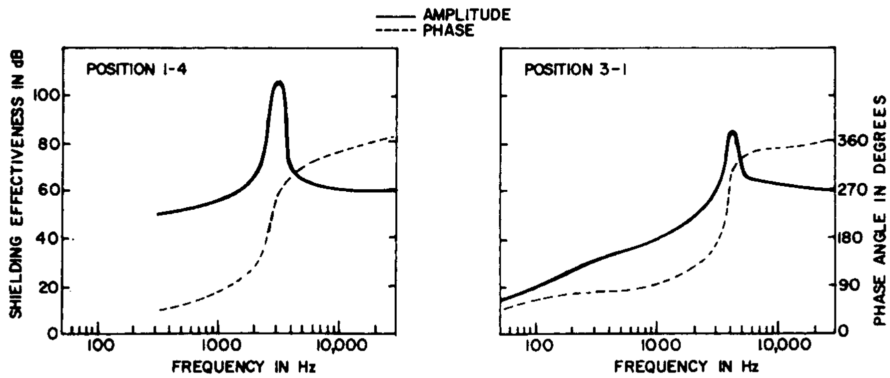



Courtesy Microwave Journal

Figure 3. Typical RF Leakage Paths

To date, there has been no satisfactory analytical study of seam leakage. Experimental data to derive equivalent transmission-line values for seam leakage, postulated as a second transmission line in parallel with the shield material transmission line, resulted from an incompleted study (5, 6).

Other investigations related to this problem include an early empirical study of holes in shielding (7) and several more recent studies of apertures (such as Reference 8) related to electromagnetic pulse (EMP) problems. Such evidence of progress gives rise to hope that a serious attack upon the seam-leakage problem lies in the near future.




a. Annealed Co-Netic can, 1/32 in thickness, with ¼ in hole

b. Annealed Co-Netic can, 1/32 in thickness, with two ¼ in notches in bottom lip

Courtesy Microwave Journal

Figure 4. Relationship of Amplitude and Phase for Shield-Can Penetration

Non-seam leakage is not nearly so significant since it normally yields to conventional design. Let us, however, call attention to a common design error affecting the EM performance of ventilation ducts. Air flow between the inside and the outside of enclosures generally occurs through waveguides below cutoff, often in a grouping of the order of 1000. These represent, in the worst case, 1000 or so parallel paths, but design is frequently based upon below-cutoff attenuation of just one. The resulting error could be as much as 30 dB. This difficulty may be overcome by overdesigning single waveguides by an amount as great as the degradation.

## Types of Enclosures: Performance Characteristics

Standard manufactured shielding enclosures may be classified in many different ways. From the viewpoint of shielding performance, let us consider these primary characteristics: shielding material, single or double wall, panel seams, door seams, microwave absorber.

**Shielding material.** From shielding theory, it is obvious that high penetration-loss performance requires a shielding material with a high permeability-conductivity ($\mu\sigma$) product and substantial thickness ( ). Using electrical parameters relative to copper, a figure of merit for shielding material can be taken as

$$F = \sqrt{\mu_r \sigma_r}\,(10^3\,\ell) \qquad (\text{or } F_d = \sqrt{\mu_r \sigma_r}\,(10^3 d)), \qquad (3)$$

where $\ell$ is in meters; d, inches. With this as a measure, the anticipated relative performance of different materials can be assessed (see Table 2 for values of $\sqrt{\mu_r \sigma_r}$). Most-commonly-used materials include copper screening, zinc-clad sheet steel, and steel plate. Other materials such as sheet copper and sheet aluminum are used less frequently. Since copper screening is not a sheet material, the figure-of-merit expression is usable only with a thickness value equivalent to that for sheet material. An easy way to determine this is to compare copper screening with the same surface area and weight of sheet copper and use the sheet thickness in the figure-of-merit expression. When equation (3) is used with zinc-clad steel, it results in a somewhat understated figure of merit, since cladding results in a laminated sheet which provides performance superior to a plain sheet.

**Single or Double Wall.** The theoretical equation (1) was presented for a single metal thickness. However, the shielding performance of a double wall is simply that of single wall of double thickness for frequencies where the spacing between walls is small compared with a quarter-wavelength. For example, consider a double wall with 3.8 cm (1.5in) spacing. Then the maximum frequency for which equivalence holds is

$$f << 3(10)^{10}/4x3.8 = 2(10)^9. \qquad (4)$$

TABLE 2

ELECTRICAL PROPERTIES OF VARIOUS SHIELDING MATERIALS

| METAL | RELATIVE CONDUCTIVITY $\sigma_r$ | LOW-FREQUENCY RELATIVE PERMEABILITY $\mu_r$ | LOW-FREQUENCY/ HIGH FREQUENCY $\sqrt{\mu_r \sigma_r}$ |
|---|---|---|---|
| Silver | 1.05 | 1 | 1.03 |
| Copper, Annealed | 1.00 | 1 | 1.00 |
| Copper, Hard-Drawn | 0.97 | 1 | 0.99 |
| Gold | 0.70 | 1 | 0.84 |
| Aluminum | 0.61 | 1 | 0.78 |
| Magnesium | 0.38 | 1 | 0.62 |
| Zinc | 0.29 | 1 | 0.54 |
| Brass | 0.26 | 1 | 0.51 |
| Cadmium | 0.23 | 1 | 0.48 |
| Nickel | 0.20 | 1 | 0.45 |
| Phosphor-Bronze | 0.18 | 1 | 0.42 |
| Iron | 0.17 | 1000 | 13/0.41 |
| Tin | 0.15 | 1 | 0.39 |
| Steel, SAE 1045 | 0.10 | 1000 | 10/0.32 |
| Beryllium | 0.10 | 1 | 0.32 |
| Lead | 0.08 | 1 | 0.28 |
| Hypernik | 0.06 | 80,000 | 69/0.25 |
| Monel | 0.04 | 1 | 0.20 |
| Mu-Metal | 0.03 | 80,000 | 49/0.17 |
| Permalloy | 0.03 | 80,000 | 49/0.17 |
| Steel, Stainless | 0.02 | 1000 | 4.5/0.14 |

With the usual engineering interpretation of "much less than" as "at least one order of magnitude less" (one tenth), the maximum frequency becomes

$$f_{max} = 200 \text{ MHz}. \qquad (5)$$

Above this frequency, resonance-type effects occur which theoretically permit the enclosure to exceed the single-shield type performance at many frequencies, but likewise cause it to be degraded at some others. In practice, these effects are generally not experienced in good enclosures because the high shielding performance of wall materials, far in excess of enclosure performance, is degraded by overriding leakage effects at seams (even good ones) and elsewhere.

**Panel Seams.** Panels are electrically joined by two basic methods: mechanical clamping and fusion. A wide variety of mechanical clamping methods are available, but these will not be reviewed in detail. Instead, let us just consider the requirements of a good system. The overall objective is to provide an electrical contact continuous along a seam, without interruption or variation in contact resistance, and of at least as high electrical conductivity as the shielding material itself. This objective appears impractical to meet with mechanical clamping. The practical approach is to use mechanical clamping at frequent intervals along a seam and tolerate the degradation between clamps. Even at clamps, the objective of electrical conductivity as high as the shielding material itself is generally not met. Despite these problems, shielding manufacturers generally provide seams of high-enough performance to meet a large range of application requirements. (Seams are usually the downfall of the do-it-yourselfer.) To maintain performance, such seams may require retightening over long intervals, or even disassembly and recleaning in corrosive environments.

With respect to the placement of seams, let us first consider a dihedral corner of a rectalinear enclosure. Current flow around a corner tends to crowd the interior angle as in Figure 5. Since the current uses less of the metal thickness here than along a flat surface, resulting effective lower conductivity means poorer shielding performance at the corners (the effect is enhanced at a trihedral corner). If, in addition, a seam were to be placed along a corner, the difficulty would be compounded due to even decreased conductivity. For this reason, some modern shielding enclosures utilize formed corners and have seams only on flat surfaces, as in Figure 6.

Fused seams will, generally speaking, achieve higher performance than mechanical seams since the electrical conductivity can usually be made higher. Even with fused seams, ideal objectives have not been achievable, even under laboratory experimental conditions. (The best known seam results from electron-beam welding, whereby the parent metal pieces are joined in a vacuum without the use of any foreign binder material.) Even so, welded steel and brazed (or soldered) copper seams, capable of providing over 100-dB enclosures, are commercially available. **Door Seams.**

**Door Seams.** Door seams for frequent entry generally do not utilize gasket material since frequent use causes the gasket to lose its compressibility and, with that, its shielding performance. In order to achieve low leakage, most door seams for frequent use utilize high-conductivity spring-contact fingers, usually around at least a double periphery. Spring fingers are made of beryllium-copper or phosphor-bronze stock, often silver-plated. Any such material is a compromise between high electrical conductivity, good contacting surfaces, and adequate spring retention for many thousands of operations. In normally encountered environments, the contacting surfaces are kept clean automatically by means of a wiping action between the fingers and a door jamb; good contact can be assisted by means of an inlaid compressed-air hose to provide high contact presure. One difficulty with contact fingers is that they are exposed to passing objects and are easily broken. At least one manufacturer provides a construction where fingers are well protected.

**Microwave Absorber.** Although not strictly a shielding application, microwave absorber material placed within an enclosure not only reduces internal reflections but also generally aids the shielding property by providing additional reduction of microwave energy which penetrates the shield itself. Desired energy loss which occurs in both reflection and penetration requires a considerable volume of RF-lossy material, and substantially reduces working volume within the enclosure.

(Since internal reflections cause undesirable standing waves, another approach has been devised to destroy their effects within an enclosure by use of a mode stirrer, commonly used in microwave ovens, but not yet common in shielding enclosures.)

## Performance Claims

To evaluate performance claims of manufacturers, consider the following actions, in whole or in part:

- Check for reasonableness of claims using the preceding material as a guide.
- Request a report of tests previously done by independent testing organization.
- Request the identity of other purchasers of similar enclosures and ask about their experience.

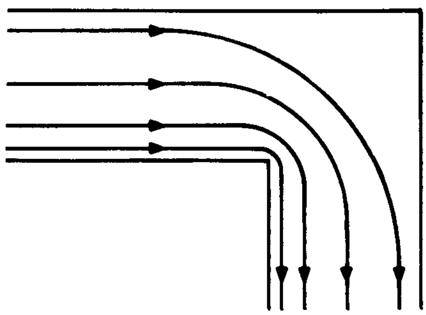
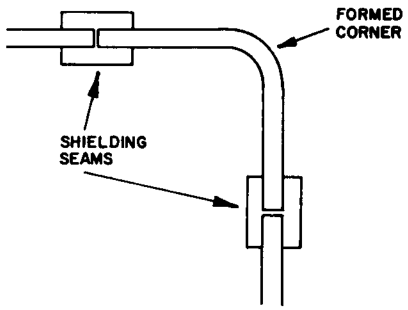


Figure 5. Current Flow Around Corner




Courtesy Microwave Journal

Figure 6. Corner Arrangement for Shielding Enclosure

- Review reports of tests on enclosures after installation, if available.
- Check conformance of test methods with applicable standard, such as IEEE standard 299 or MIL-STD-285, and determine if these satisfy specific requirements.

## Major Technical Considerations

In selecting a shielding enclosure for a given frequency range, check the following points:

- Material performance must exceed requirements at the lowest operating frequency (Equation 1).
- Weakest seam performance must exceed requirements at the highest operating frequency. (Use test data.) For screening type enclosures, screen leakage may be the overriding factor; screening performance generally deteriorates above 400 MHz (9).
- Type of seams should be adequate for the physical and atmospheric environment at the place of installation.

## References


1. S. A. SCHELKUNOFF, Electromagnetic Waves, D. Van Nostrand, 1943.
2. C. S. Vasaka, "Theory, Design and Engineering Evaluation of Radio Frequency Shielded Rooms", NADC, Johnsville, Pa. report NADC-EL-54129, August 1956.
3. R. B. Schulz, et al, "Shielding Theory and Practice", 9th Tri-Service Conference on EMC Record, October 1963.
4. Special Issue on Shielding, IEEE Transactions on Electromagnetic Compatibility, Vol. EMC-10, No. 1, March 1968.
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*The above article was prepared by Richard B. Schulz, IIT Research Institute, Electromagnetic Compatibility Analysis Center, Annapolis, Md.*

# TESTING SHIELDED ENCLOSURES

## INTRODUCTION

Testing of radio frequency shielded enclosures should be considered as a part of the installation and acceptance procedure associated with any procurement contract or end use requirement. Since all products purchased are subject to incoming inspection, it is important that the RF shielded enclosure be subjected to a qualified type of testing which will not only assure compliance with the bidding specifications but point out any weak areas that may appear at a later date as deficiencies which could reduce the overall performance level of the enclosure.

The investment in shielded rooms is a high one and the cost of instrumentation to complete the end use requirement for a laboratory is sufficient to substantiate the additional cost of maintaining this equipment and room at its maximum performance level. Shielded room testing provides the mechanism required to insure this high reliability.

Regardless of the competence of the installation crew, it is impossible to verify defects in installation procedure visually or through any other means than a qualified RF test of a shielded enclosure. Visual inspection has certain values but due to minute differences in elements of the construction as well as the possibility of failure of mechanical devices, the final RF test becomes the means of verifying the quality of the installed product. When defects are found it is imperative that action be taken while the test equipment is available to verify that such correction was adequate to meet the performance required.

## TEST SPECIFICATIONS

There are many specifications generated to cover adequate testing procedures. Some follow the standards of the military specifications which are good with certain limitations. Military specifications in all cases are outdated and need to be upgraded to suit the specific and current frequency requirements. Some specifications are written as original documents and may be presented without regard to the standard techniques of the industry. This procedure ends up in costly testing processes with very little value.

Sniffer testing is currently gaining more interest but has the overall deficiency of not presenting the results in absolute values but merely relative to some assumed performance and has little or no value unless compared to a true radiated type of test.

The use of AM or FM radios for quick checkout has the same deficiency as sniffer testing that its usefulness is limited and can only be compared after a true test and attenuation of the room has been obtained.

MIL-STD-285 has the largest degree of popularity for shielded room testing but needs upgrading in the frequencies of test to take care of areas below 150 KHz and above 400 MHz before it can be considered a practical document.

Table 1 indicates the current applicable mil specs and the date of issuance. It becomes apparent from this listing that no current specifications have been issued for the past 8 years.

Table 2 gives the overall range of test frequencies for each mil spec and observation indicates that NSA65-6 is the only specification covering a broad range of frequencies up to and including 10 GHz.

## TEST FREQUENCIES

Testing frequencies should be selected with more consideration to the areas of particular interest to the user. For example, there is little value in recording magnetic and electric field measurements at 1 KHz and 10 KHz if the equipment to be tested in the room will be operating in the range of 200 MHz to 10 GHz. A much better procedure would be to increase the frequency points in the area of interest or to scan all frequencies and observe the results on a spectrum analyzer so that discrete frequency leakage could be detected.

It is not uncommon to find a room that has been tested to MIL-STD-285 showing extreme leakage points at 18 MHz, 2 GHz, 5 GHz or any other specific discrete frequency. Room defects commonly found reflecting this type of condition are cracks in penetrations associated with electrical filters and wave guide type air vents. The results of this type of failure may not be apparent when checking at discrete frequencies unless you are lucky enough to find the one causing the failure. Increasing the density of discrete frequencies or scanning continuous frequency shifts would produce a better overall evaluation of the enclosure and insure that the supplier has furnished a room of the quality specificed.

Once it has been ascertained that the RF shielded enclosure is of the highest quality consistent with the design and procurement requirement, future checks need not cover all frequencies but can be of the spot discrete frequency type used only to verify that the overall performance has not degraded.

## TEST POINTS

The physical location of test points varies with the specifications stated. MIL-STD-285 and several others merely require one test point in each wall without specifically scanning around areas of known and expected problems. Testing should be performed at known weak points, namely around all entrances, doors, penetrations, filters and wave guide vents since it is relatively uncommon to have failures of the shielding effectiveness at ordinary panel joints. Spot checking at the center of door areas leaves much to be desired since the center area of door which is large may be several feet from the joint door to frame which is the weakest link in the shielded enclosure system. Proper testing requires a continual search at the periphery of the door area at all frequencies selected with particular attention to the frequencies of 1 GHz and 10 GHz where leakage, if it is existing is most apparent. In addition, movement of the antenna must be done with extreme care and knowledge of the way fields are deflected through door cracks, etc. to detect with accuracy the leakage.

## PERSONNEL

The test personnel should evidence full capabilities and background consistent with the testing job to be performed. As performance of the shielded enclosure is increased or the room size becomes large, the testing process will become more complex. The test personnel should be fully capable to cope with all such situations in an orderly manner to solve problems of deficiencies quickly and instruct the installation personnel in the proper technique for corrective action before resuming testing.

## THE TEST PROGRAM

A well organized test program consists of many elements. A test plan should be submitted for approval prior to proceeding with any actual tests. This plan should indicate frequencies, fields and attenuation as specified, but in addition should locate precisely the location of the various tests to be performed. This process minimizes the time required for the tests and assures the lowest cost for the overall program.

Prior to the start of the physical measurements a visual inspection should be made of the entire enclosure to determine any obvious type of deficiency such as broken or missing contact fingers at door areas. It is useless to proceed with tests when the obvious faults are visible. These must be repaired to the complete satisfaction of the test engineer before proceeding.

During the actual test program, deficiencies must be reported immediately to the installation supervisor present and corrective steps taken before any additional frequencies or test points are recorded. Depending on the type of failure noted, it may be required to repeat all frequencies and test points before proceeding on.

A final test report is issued at the completion of the test to serve as a document which will verify the attenuation frequency and test points checked as of the date of test. In order to maintain the effectiveness of the shielded enclosure, it is extremely important that retesting at spot frequencies be performed on a semi-annual or annual basis. These checks can be performed at one or two elevated frequencies in the 400 MHz range and will alert the using personnel to deficiencies which may not be apparent to him. The presence of additional wires into the enclosure through unfiltered entranceways will reduce the attenuation of a 120 dB enclosure to 20 dB, missing contact fingers at door areas can provide an average 60 dB reduction. Corrective measures can be scheduled at the user's covenience to maintain the shielded enclosure at its maximum specified performance level.

## WHO SHOULD PERFORM THE TESTS

Testing is performed either by independent testing companies or by the shielded room manufacturer's testing department. Independent testing companies are of great value in determining the overall results of a shielded room installation but some independent test engineers have little experience with the minute details of individual room construction and are not thoroughly familiar with the various types of corrective measures which may be taken when deficiencies are found. Some independent test reports are issued several weeks after the actual test has been performed and all installation personnel are off the job. At this time it is difficult as well as expensive to call back the installation crew to take corrective action which may be simply tightening one screw.

All RF shielding enclosure manufacturers provide testing services as part of their contractual obligations if requested. These test teams are well experienced in all of the areas of potential failure of their particular product and can accomplish repairs in a most expeditious manner. Additionally, the same personnel who do the testing are authorized and qualified to make the repairs or adjustments on the spot. No time is lost and testing can proceed in an organized manner. When deficiencies are reported by an independent test laboratory after the repairs are made an additional visit must be made to verify the end results, resulting in a considerable additional expense which is unjustified.

An alternate procedure would be to have the shielded room manufacturer perform what tests he feels are required and then have these verified or witnessed by an independent testing agency.

The reputation of the shielded room manufacturer stands behind his ability to furnish and install a shielded room which complies with the specifications. It is to his advantage to demonstrate without any chance of criticism a bona fide and effective test program. His interest is always in providing the highest quality product that is available.

All professional testing agencies are qualified to run test equipment but only experienced room testers can define the problem areas and relate this to a fast and permanent fix. Probably the best qualified is the manufacturer's own staff engineers. He knows the product best. The maintenance of this high performance over a long period of time can be justified by the expense of spot checking at six-month intervals to maintain the room at peak performance. The investment in time and money for a shielded facility is small compared to the use it is put to and proper maintenance of the room is as important as calibration of the test equipment.

*The above article "Testing Shielded Enclosures" was written by Edwin S. Kesney, Vice President, Ray Proof Corporation, Norwalk, CT.*

**TABLE I**

| SPECIFICATION | DATE |
|---|---|
| MIL-E-4957A | 17 Nov. 1954 |
| MIL-STD-285 | 25 June 1956 |
| MIL-E-18639A | 26 Nov. 1957 |
| MIL-E-8881A | 31 Jan. 1964 |
| NSA 65-6 | 30 Oct. 1964 |
| RM-10A-751 | 1 Mar. 1968 |

**TABLE II**

| | 1 KHz | 150 KHz | 400 MHz | 10 GHz |
|---|---|---|---|---|
| MIL-E-4957 | | | | |
| MIL-E-8881 | | | | |
| MIL-STD-285 | | | | |
| MIL-E-18639A | | | | |
| NSA-65-6 | | | | |
| RM 10A-751 | +Fixed frequency | | | |