SAE Aerospace
An SAE International Group

AEROSPACE RECOMMENDED PRACTICE

ARP1705	REV A

Issued 1981-06
Revised 2006-04

Superseding ARP1705

(R) Coaxial Test Procedure to Measure the RF Shielding Characteristics of EMI Gasket Materials

RATIONALE

This revision of ARP1705 was performed to increase the frequency range of the test fixture and to add valuable information pertaining to the use of transfer impedance as applicable to the shielding of electromagnetic waves.

TABLE OF CONTENTS

1. SCOPE

1.1 Purpose

The purpose of this procedure is to establish a technique for reliably and repeatedly measuring the RF shielding characteristics of EMI gasket materials and EMI gaskets against various joint surfaces. The procedure is also used to test the reliability of the gasketed joint combinations after being subjected to hostile environments.

1.2 Background

ARP1173 is the existing method for accomplishing the goals expressed in 1.1. This method consists of a small enclosure with a plate mounted on a metallic wall and gasket around the periphery of the plate. A source is placed within the enclosure and a receiving antenna located outside the enclosure.

The utility of data from measurements made using this technique is limited, since the results depend upon the dimensions and construction of the enclosure, the details of the antennae used for the source and receiver, and the dimensions of the shielded room in which the measurements are made, as well as upon the performance of the gasket under test. Since the data is so dependent upon the test setup it cannot be accurately used in equipment design analyses. The advantages of the transfer impedance method are discussed in References 2 and 3.

The transfer impedance method presented in this document offers an attractive alternative to any of the radiated field methods for evaluating gasket materials, since it yields data which is independent of the test method and test apparatus and can be used in design analysis.

The tests as described herein are designed to achieve the following: (1) test the relative value of the gasket; (2) test the relative value of joint surfaces as related to the gasket under test; and (3) test the ability of gaskets and gasketed joint surfaces to survive hostile environmental conditions.

2. REFERENCES

1. ARP1173, Test Procedure to Measure the RF, Shielding Characteristics of EMI Gaskets, July 1975.

2. “Radiated Field Strength Method for Measurement of the RF Shielding Characteristics of EMI Gaskets”, by D.R. Awerkamp, IEEE International Symposium on EMC, October 1975.

3. “Test Procedure to Measure the Transfer Impedance of Gasketed Joints for Shielded Enclosures”, by P.J. Madle, IEEE International Symposium on EMC, October 1979.

3. DEFINITIONS

3.1 TRANSFER IMPEDANCE

“Electromagnetic leakage via seams (and gasketed joints)” in shielded enclosures occurs primarily as a result of currents which cross the seam.

- Such crossing causes a voltage to be developed on the far side of the seam.

- Electromagnetic leakage through the seam is directly proportional to the (transfer) voltage developed across the seam.

In shielding theory the seam is characterized in terms of its transfer impedance as follows:

$Z_T = V/J_S$
Z_T = Transfer impedance of seam (Ω-m)
V = Transfer voltage (voltage across seam)
J_S = Density of current which crosses the seam (A/m)

3.2 Shielding Effectiveness (EMC)

For a given external source, the ratio of the electric or magnetic field strength at a point before and after the placement of the shield in question.

(IEEE Standard Dictionary of Electrical and Electronic Terms, P. 528. 1972.)

It is noted that this definition must be used with great caution and not in the literal sense of actually placing and removing a shield. The actual shielding effectiveness of a barrier is a function of many variables which are not accounted for in the definition above or within the contents of this document.

3.3 Shielding Quality

The shielding effectiveness of a shield is approximately equal to the impedance of the wave divided by the transfer impedance of the gasketed joint. For the purpose of this document, the definition of shielding quality is:

$SQ = 377/ Z_T$
$SQ (dB) = 20 \log 377 - Z_T (dB)$

4. BASIS FOR TEST METHOD

4.1 Electromagnetic (EM) Wave

An EM wave is composed of an electric (E) field and a magnetic (H) field. The value of the E field is measured in volts/meter and the H field in amperes/meter.

4.2 Induced Currents in Barrier (Surface Current Density)

When the wave is impinged on a metal (conductive) barrier, the current as measured by the value of the H field induced into the barrier. The induced current is called surface current density (Js) and is measured in amperes/meter, i.e.,

$$J_S = H_I \text{ (A/m)} \qquad \text{(Eq. 1)}$$

where:

H_I = Value of H field incident on the barrier

4.3 Seams and Gasketed Joints

The surface current density will produce a voltage across a seam (or gasketed joint) which it crosses. This voltage will penetrate the seam and appear across it on the “shielded side” surface, where the voltage will generate fringing fields (a secondary EM wave) in the shielded zone. The magnitude of the EM wave (fringing field) is directly proportional to this voltage.

The function of an EMI gasket is to reduce the impedance of any such aperture, slot or joint and thereby reduce the local voltage across the imperfection.

4.4 Transfer Impedance of a Joint

The transfer impedance of a joint, with or without a gasket, normalized to a one meter length, is defined by:

$$Z_T = V/J_S \ (\Omega\text{-m}) \qquad \text{(Eq. 2)}$$

where:

V = Voltage across joint (V)

J_S = Current crossing Joint (A/m)

4.5 Measurement of Transfer Impedance

Transfer impedance may be measured by forcing a current to flow from one surface to another through a gasket across a seam while measuring the voltage developed across the seam.

Because this test method measures the current in one surface and the voltage across the seam (from one surface to the other), the measured gasket performance is independent of the test setup.

4.6 Use of Transfer Impedance in Equipment Design

Virtually every design project involves some unique feature which is known only by the designers. These unique features include the sources of interfering signals, the dimensions and shapes of equipment enclosures, the routing of cables, etc. Design teams must analyze their own system to determine the magnitude of the induced surface currents on the irradiated surfaces and the maximum local voltages which may be allowed at the shielded surface of each joint, seam or other penetration. The allowable “worst-case” transfer impedance for each such application can only be determined from these current and voltage values. Material and component manufacturers can greatly assist designers by providing information on the performance of each catalog item, such as gaskets, finger-stock, etc., in terms of its transfer impedance against the selected joint surface.

In simple cases, the magnitude of the transfer impedance is sufficient; however when more than one penetration, leak or gasketed joint is of concern in a given local region, then the phase of the transfer impedance of each becomes significant so that the individual leakages may be combined to determine the severity of the total leakage.

4.7 Penetration of an EM Wave Through an EMI Gasketed Joint

When a radiated EM wave is impinged on a metallic shielding barrier, a current (surface current density in amperes per meter) is generated in the material. When the current flows across a gasketed maintenance cover as illustrated in Figure 1, a voltage *e* is generated across the gasket. The value of *e* is equal to the current in amperes/meter times the impedance of the joint (transfer impedance in ohm-meters).

The transmitted EM fields (E_T and H_T) illustrated in Figure 1 are generated by the voltage across the gap and have the characteristics of a low impedance slot antenna.

The radiated power can be estimated from the example of Figure 1 as follows:

$$E_T \approx 2e / 2\pi R = J_S Z_T / \pi R \qquad \text{(Eq. 3)}$$

$$H_T \approx E_T \lambda / 2\pi R(377) \quad R < \lambda/2\pi$$
$$= E_T / 377 \quad R \geq \lambda/2\pi$$

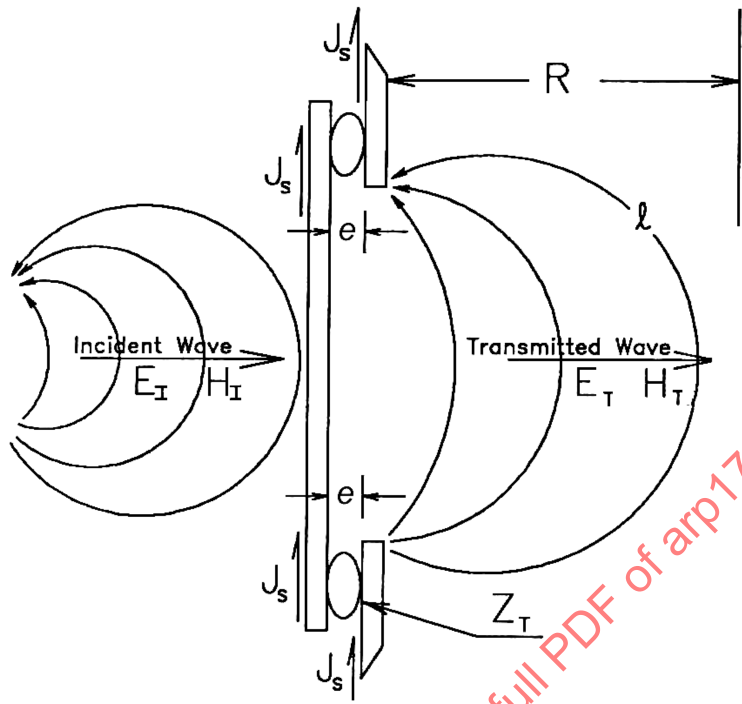


FIGURE 1

where:

J_S = J_I current due to field striking barrier

e = Voltage across gasket

= $J_S Z_T$

Z_T = Transfer impedance of gasketed joint (ohm-m)

5. TEST FIXTURE

Figures B1 through B12 illustrate the construction of the test fixture. The frame members are made from 6061-T6 aluminum. For quality control purposes the “shielding quality of the gasket” under test is performed with the base and contact plate made from 6161-T6 aluminum with contact surfaces gold plated. For shielding quality testing of gasketed joint surfaces and for testing the effects of the various hostile environments illustrated in the Appendix A and B the plates are to be manufactured from the materials to be used in actual application and plated with the proposed surface coating.

5.1 Fixture Assembly

Figure B1 illustrates the gasket assembly under test (consisting of a base plate, a gasket and contact plate). The spacing between the two plates is controlled with non-conductive spacers where the compression of the gasket is to be that recommended by the gasket manufacturer (or as dictated by the design of the equipment). The contact plate is fastened to the base plate with 3-1/4 - 20 nylon (non-conductive) cap screws. This assembly is EM bonded to the receiver plate with an EMI gasket imbedded in the edge of the receiver plate and held in place with two toggle clamps. Current is brought into the fixture via the input connector assembly consisting of a modifier type N connector and 50 ohm resistor assembly. The voltage measured across the gasket is performed using the output connector assembly consisting of a modified type N connector and an output pin assembly.

The description of the 50 ohm resistor is contained in the notes of Figure B5.

The frame assembly (including the toggle clamps) is illustrated on the Figure B8 and contained in the notes.

5.2 Maximum Gasket Dimensions

Figure B13 illustrates a contact plate which has the maximum gasket dimensions outlined on it. These maximum outside dimensions are as follows:

Square Gasket - 3.40 inches
Circular Gasket - 4.0 inches
Thickness - 0.50 inches

5.3 Test Set-Up

Figure B14 illustrates the setup to be used in the performance of the testing. This consists of the following:

1. The current to be delivered to the transfer impedance test fixture is obtained by connecting the output of the signal source to the receiver input port, measuring the voltage and dividing by 50.

2. The voltage across the gasket is measured by connecting the signal source to the transfer impedance input connector and the output connector of the fixture to the receiver. As noted, to obtain the required dynamic range to accurately measure the transfer impedance of the gasket under test it may be required to add an amplifier to the output of the signal generator. A pre-amplifier may also be required to be added to the output of the test fixture.

5.4 Dynamic Range

For many good gasket materials, the transfer impedance may be as low as a few micro-ohms-meters - that is, a few micro-ohms per meter length. Therefore, the receiver should be capable of measuring signal levels as low as 140 dB, below the output of the signal generator. This typically requires the use of a 1 watt broadband power amplifier driven by the swept frequency signal generator, a low-noise broadband preamplifier in front of the receiver may also be required.

6. NOTES

6.1 The change bar (l) located in the left margin is for the convenience of the user in locating areas where technical revisions, not editorial changes, have been made to the previous issue of this document. An (R) symbol to the left of the document title indicates a complete revision of the document.

PREPARED BY SAE COMMITTEE AE-4, ELECTROMAGNETIC COMPATIBILITY

APPENDIX A - TEST PROCEDURE

A.1 SCOPE

This procedure establishes an accurate method of grading the EM shielding quality of the EMI/RFI gasket materials and EMI/RFI gasketed joints. The frequency range is 10 kHz to 1.0 GHz.

1. Obtaining the current delivered to the Zt fixture is required for all testing and is obtained as follows:

    a. Attach the output of the signal generator (with 50 ohm output) to the input to the receiver.

    b. Record the current delivered to the test fixture (i.e., divide the recorded voltage obtained above by 50 ohms or subtract 34 dB if recording is expressed in dB).

2. Quality assurance testing of EMI gaskets. This consists of measuring the shielding quality of the gaskets under test using flat, low contact resistance, gold plated aluminum joint surfaces, and sufficient force to compress the gaskets to the manufacturers' specified deflection. The conditions under which the gaskets are to be tested are:

    a. Production quality gaskets.

    b. Production quality gaskets subjected to appropriate transportation and storage environmental conditions as applicable to system requirements (see Table A1).

3. Obtain the shielding quality of EMI gasketed joints. This consists of measuring the shielding quality of gasketed joints using the gasket material under test and flat joint surfaces, where the material and surface finish is that which is to be used during normal operation. The conditions under which gasketed joints are to be tested are:

    a. Production quality gaskets using joint materials and surfaces of concern.

    b. Production quality gaskets using joint materials and surface finishes of concern where the gaskets and joints are subjected to hostile appropriate environmental conditions as applicable to system requirements (see Table A2).

A.2 REQUIREMENTS

1. The gasket materials under test are to be placed between a set of test plates. The maximum size of the sample and sample placement is illustrated in Figure B13.

2. The testing is to be performed using receivers, spectrum analyzers or network analyzers in a sweep mode. If at all possible, a tracking generator is to be used to obtain a continuous sweep of data over the frequency range of interest. If a continuous sweep is not possible, then the data is to be obtained at randomly selected frequencies with a minimum of 8 frequencies per decade.

3. In testing for the shielding quality of the gasketed joints, the test plates are to be manufactured and plated from the materials identical to that to be used during actual application of the system concern.

A.3 TEST PROCEDURE

A.3.1 General

The testing is to be performed on sample coupons. During the performance of the test, the following considerations are to be observed.

1. In performing the quality control testing on the gaskets, the joint test surfaces are to be gold plated 6061-T6 aluminum.

2. In performing the shielding quality testing on gasketed joints, the joint surfaces are to be of the same material and finish as to be used during normal operation.

3. Prior to beginning the testing, the joint surfaces are to be cleaned of all contaminants with denatured alcohol or equivalent solvent.

A.3.2 Specific Testing

A.3.2.1 Obtain amplitude of current spectrum (required for all testing).

1. Attach the output of the signal generator to the input to the receiver and obtain the amplitude of the current (divide the received voltage by 50, or in dB subtract 34 dB from the dB voltage received).

2. If the signal source is not a tracking generator then set the signal source and receiver at different sweep frequencies and record a minimum of 8 reading per decade.

A.3.2.2 Shielding Quality testing of EMI Gaskets

1. Place the gasket coupon under test between gold plated joint surface plates and compress the gasket material to the deflection amount specified by the manufacturer of the gasket under test (this is performed by using non-conductive washers or spacers between the base and contact plates).

2. Set up the test fixture with the signal generator connected to the input port and the receiver connected to the output port.

3. Set the output power level of the signal source to the same level as used in A.3.2.1, and scan over the frequency range of interest. Observe the voltage amplitude spectrum obtained by the receiver, and record a minimum of 8 readings per decade where the frequencies are to be same as recorded in A.3.2.1.

4. Convert the reading to ohm-meters using the methodology of Section A.4.

A.3.2.3 Transfer Impedance Testing of EMI Gasketed Joints

1. Place the gasket coupon under test between the joint surface plates.

2. Set up the test fixture with the signal generator connected to the input port, and the receiver connected to the output port.

3. Set the output power level of the signal source to the same level as used in A.3.2.1, and scan over the frequency range of interest. Observe the voltage amplitude spectrum obtained by the receiver, and record a minimum of 8 readings per decade where the frequencies are to be the same as recorded in A.3.2.1.

4. Convert the reading to ohm-meters using the methodology of Section A.4.

A.4 CALCULATING TRANSFER IMPEDANCE OF EMI GASKETS AND GASKETED JOINTS

The transfer impedance (Z_T) of a gasket is the voltage across the joint surfaces divided by the current in amperes per meter flowing across the joint, i.e.,

$$Z_T = \frac{E\ (\text{Volts})}{I\ (\text{Amps/meter})} \quad (\Omega - m) \qquad \text{(Eq. A1)}$$

Amps/meter is equal to the current as measured in A.3.2.1 divided by the length of the gasket in meters. Therefore, the transfer impedance of a gasket (or gasketed joint) is equal to the following:

$$\begin{aligned} Z_T &= (V_O / I_I)\, L_G \\ &= V_O - I_I + L_G (\text{dB}) \end{aligned} \qquad \text{(Eq. A2)}$$

where:

I_I = $V_I / 50$

= $V_I - 20 \log 50$ (dB)

V_O = Measured voltage out of Z_T fixture

I_I = Current into Z_T fixture

L_G = Length of gasket under test in meters

$$I_I = V_I / 50 = V_I - 20 \log 50 \text{ (dB)} \qquad \text{(Eq. A3)}$$

where:

V_I = Level of voltage delivered to Z_T fixture

$$\therefore Z_T = V_O - (V_I - 34) + 20 \log G_L \text{ (dB)} \qquad \text{(Eq. A4)}$$

If a 1 watt (+30 dB) amplifier is used add 30 dB to V_I

$$Z_T = V_O - (V_I + 30 - 34) + 20 \log G_L \text{ (dB)} \qquad \text{(Eq. A5)}$$

If a pre-amplifier (A_P) is also used then:

$$Z_T = V_O - A_P - (V_I + 30 - 34) + 20 \log G_L \text{ (dB)} \qquad \text{(Eq. A6)}$$

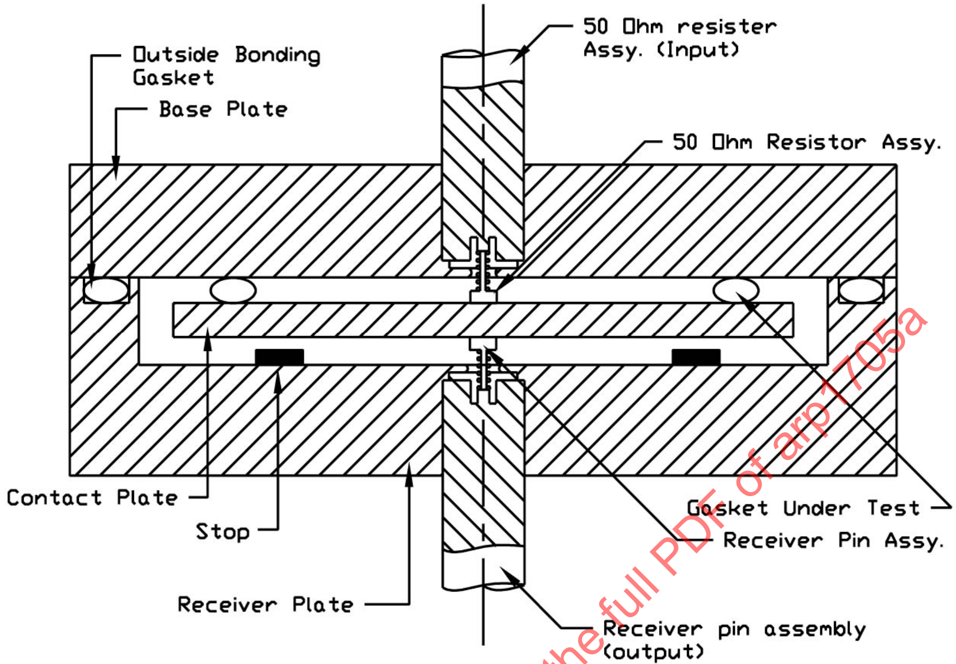
TABLE A1

Transportation/Storage Environments	
Environmental Stress Condition	Test Method/Procedure (MIL-STD-810D)
High Temperature (Dry/Humid)	Method 501.2
Low Temperature (Rain/Hail/Freezing)	Method 502.2
Thermal Shock	Method 503.2
Solar Radiation	Method 505.2
Fungus Growth	Method 508.3
Rain	Method 506.2
Humidity	Method 507.2
Salt Fog	Method 509.2

TABLE A2

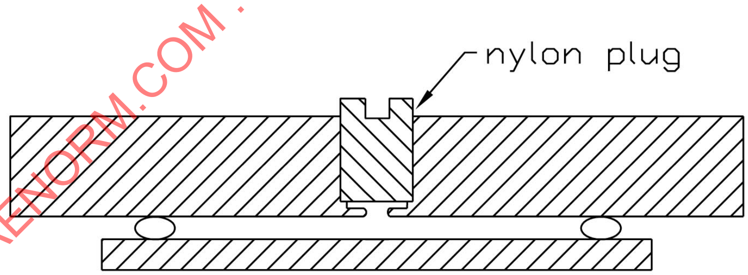
Mission/Sortie Environments	
Environmental Stress Condition	Test Method/Procedure (MIL-STD-810D)
High Temperature	Method 501.2
Salt Fog	Method 509.2
Explosive Atmosphere	Method 511.2
Rain	Method 506.2
Emersion	Method 512.2
EMP/Lightning	MIL-STD-461 Req CS12

APPENDIX B - FIGURES



Notes:
1. Use 1/4-20 nylon socket head cap screws for holding contact plate to base plate.
2. Non conductive (plastic or fiber) washers or spacers are to be used for controlling space between contact plate and base plate (controls compression of gasket.)
3. The outside bonding gasket is used to insure a low resistance between the base plate and receiver plate.

FIGURE B1 - GASKET ASSEMBLY UNDER TEST



Notes:
1. When subjecting the gasketed joint to a hostile environment, the gasket, base and contact plate assembly are to be subjected to the environments. The following items are to be added to the assembly as shown: a nylon plug made from 5/8 dia. 6/6 white nylon rod, .5 inches long, with 5/8-24 threads, and a screwdriver slot on top.
2. A nylon plug is used to prevent damage to 5/8-24 threads and prevent moisture and salt fog environment from entering through the threaded hole when the EMI gasket is protected by environmental seal.

FIGURE B1A - GASKET ASSEMBLY SUBJECTED TO HOSTILE ENVIRONMENTS

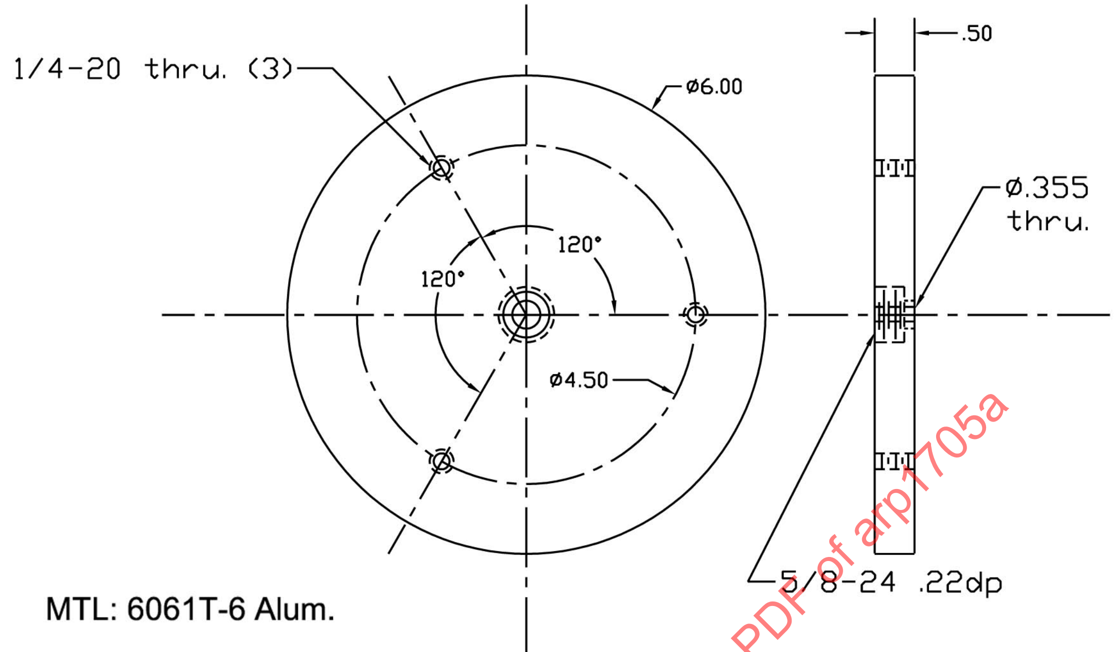


FIGURE B2 - BASE PLATE

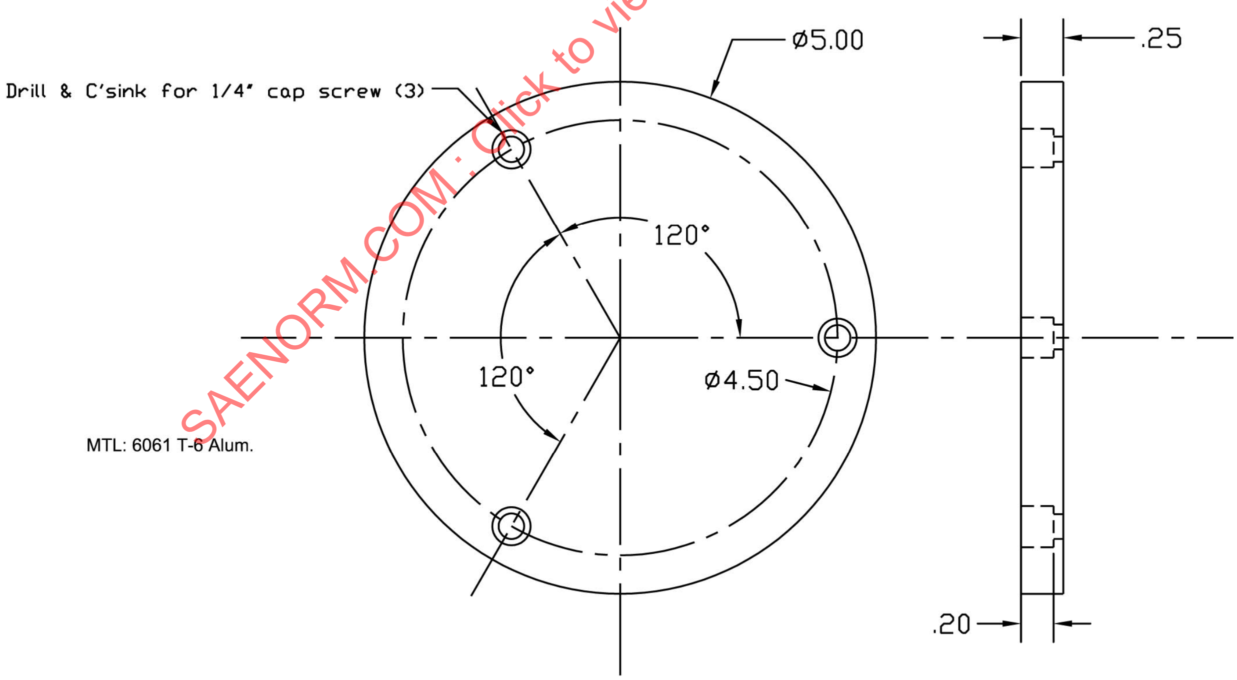
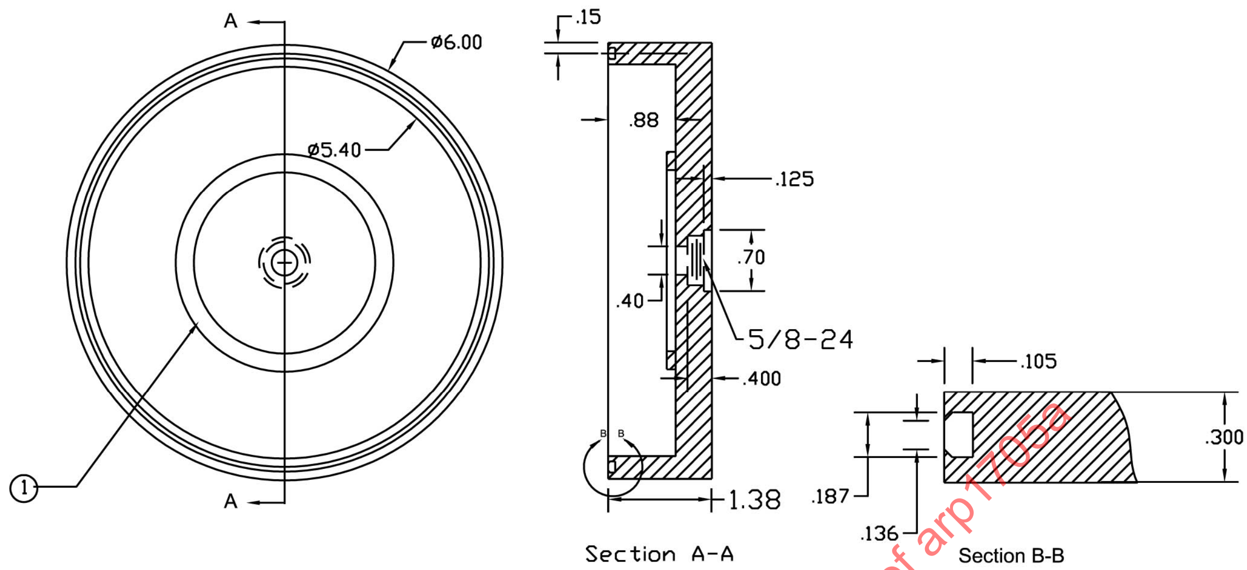
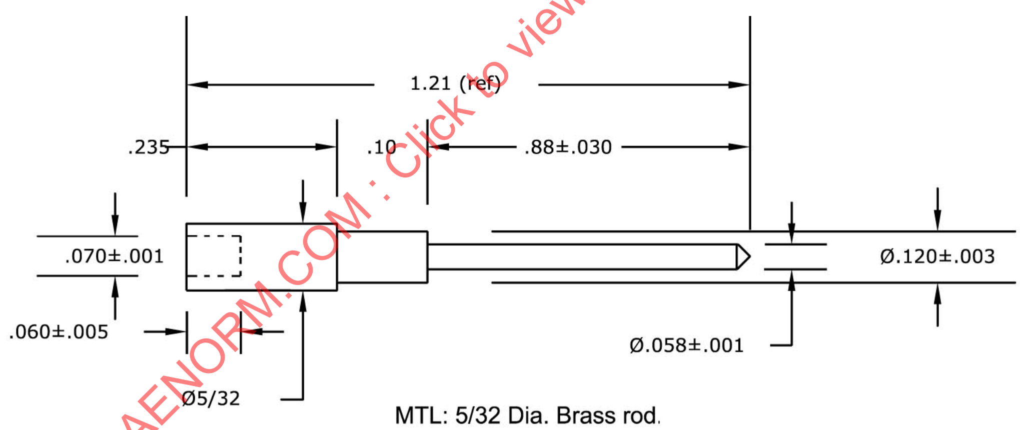


FIGURE B3 - CONTACT PLATE



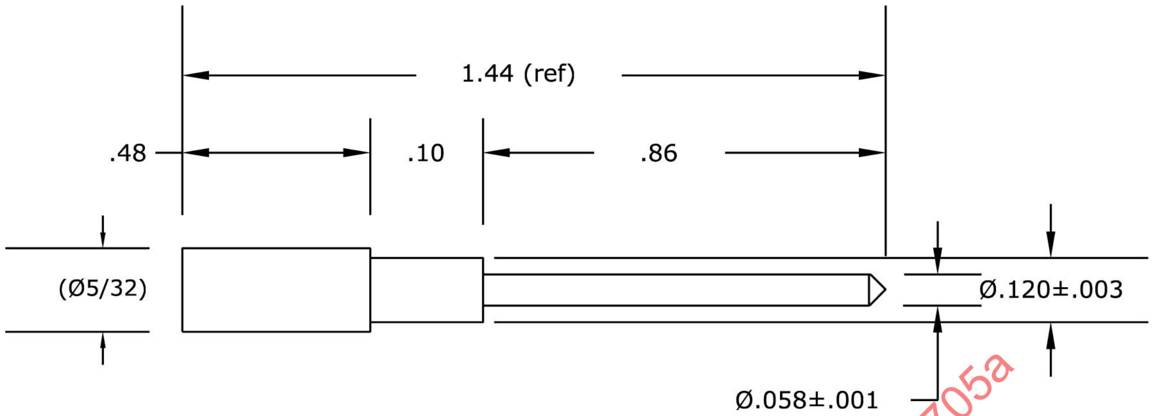
Note: 3.0 OD x 2.5 ID x .125 PVC spacer attached to receiver plate using adhesive per MIL-A-46050C type V class III.

FIGURE B4 - RECEIVER PLATE



Notes:
1. Solder 50 ohm 5 watt film resistor into the top of the pin using 60/40 solder. The resistor is 50 ohm ± 2% at 25 °C over the frequency range of DC to 18 GHz. It measures .181 to .193 inches long with an OD of .060 to .066 inches. A solder terminal 1/16 inch long is at both ends of the resistor.
2. Closed end spring (5/32 OD x .016 wire x 1.0 long), is part of the assembly.

FIGURE B5 - 50 OHM RESISTOR PIN ASSEMBLY



MTL: 5/32 Dia. Brass rod.

Note: Closed end spring (5/32 OD x .016 wire x 1.0 long) is part of the assembly.

FIGURE B6 - RECEIVER PIN ASSEMBLY

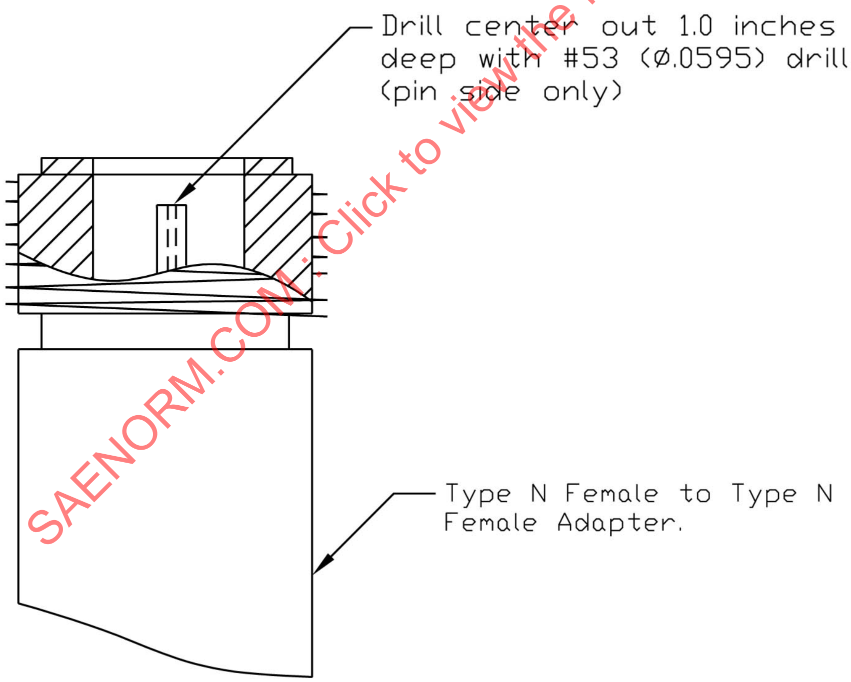


FIGURE B7 - TYPE N MODIFIED ADAPTER