AEROSPACE RECOMMENDED PRACTICE

ARP1705™ REV. C

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Superseding ARP1705B

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

RATIONALE

ARP1705 was revised from Revision B to C to increase the accuracy of the test fixture and increase the frequency range to 18 GHz.

ARP1705C has been reaffirmed to comply with the SAE Five-Year Review policy.

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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

2.1 Applicable Documents

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

1. ARP1173, Test Procedure to Measure the R.F. Shielding Characteristics of E.M.I. 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. MIL-STD-810G, Environmental Engineering Considerations and Laboratory Tests, October 2008.

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

2.2 Definitions

2.2.1 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)

2.2.2 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.

2.2.3 SHIELDING QUALITY

The shielding effectiveness to the E Field of a gasketed cover 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:

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

As an example, using Figure 1 and the subsequent equations and the following:

An incident plane wave of 377 V/m at 2 GHz
Transfer impedance of the gasket = 10^{-3} Ω-m

$Js \approx 1$ A/m
$e = 10^{-3}$ V
$2e = 2x10^{-3}$ V
$l \approx 2$ m @ R = 1 m
$\therefore E_T = 10^{-3}$ V/m

Shielding Effectiveness (E field)
$SE = 377/10^{-3} = 3.77x10^5$
$SQ = 377/10^{-3} = 3.77x10^5$
$\therefore$ @ R = 1 m
$SE \approx SQ$

3. BASIS FOR TEST METHOD

3.1 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.

3.2 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.,

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

where:

H_I = value of H field incident on the barrier

3.3 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.

3.4 Transfer Impedance of a Joint

The transfer impedance of a joint, with or without a gasket, normalized to a 1 m length, is defined by:

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

where:

V = voltage across joint (V)

J_S = current crossing Joint (A/m)

3.5 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.

3.6 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.

3.7 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:

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

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

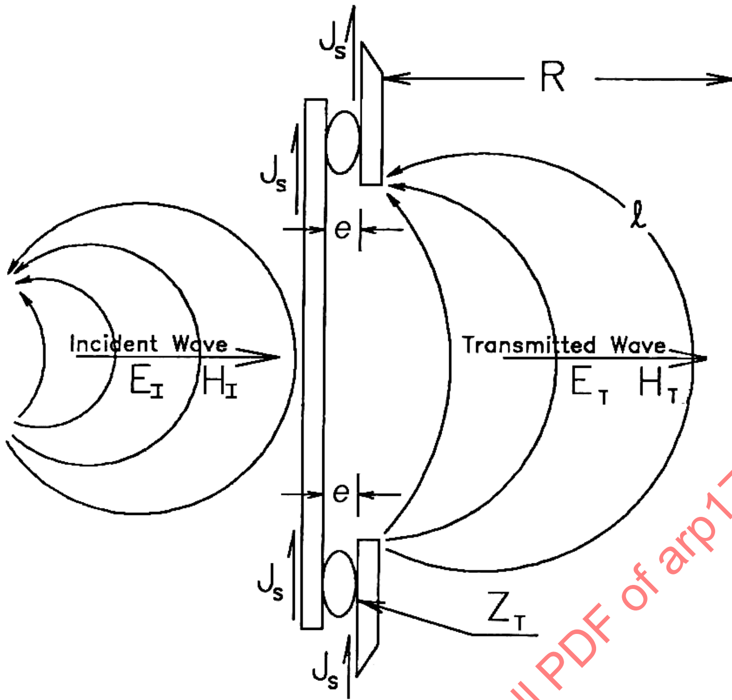


Figure 1 - Penetration of EM wave through EMI gasketed maintenance cover

where:

J_S = current due to EM Wave striking barrier (A/m)

$\approx H_I$

e = voltage across gasket

$= J_S Z_T$ (Volts)

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

4. TEST FIXTURES

Appendix B Figures B1 through B12 illustrate the construction of the 1705A test fixture. Appendix C Figures C1 through C11 illustrate the construction of the 1705C test fixture. The frame members of both fixtures are made from 6061-T6 aluminum. For quality control purposes the "shielding quality of the gasket" under test is performed using gold plated 6061-T6 aluminum contact joint surfaces. For shielding quality testing of the gasketed joint surfaces and for testing the effects of the various hostile environments illustrated in Appendix A and B, the contact joint surfaces are to be manufactured from the materials to be used in actual application and plated with the proposed surface coating.

4.1 Fixture Assemblies

4.1.1 Fixture 1705A

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 Ω 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 Ω 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.

4.1.2 Fixture 1705C

Figure C1 the gasket assembly under test (consisting of 50 Ω input assembly, input receiver cap, test sample under test, simple holder contact plate, output receiver base and receiver pin assembly.) The degree of compression of the gasket under test is controlled by the sample holder. Current is brought into the test fixture via input 50 Ω connector assembly. The voltage measured across the gasket is performed using the output connector assembly.

4.1.3 Fixture 1705C assembly notes (see Figure C12).

4.2 Maximum Gasket Dimensions

4.2.1 Fixture 1705A

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 inch

4.2.2 Fixture 1705C

The maximum outside diameter (OD) of the gasket under test is 0.75 inch (19 mm), minimum ID = 0.37 inch (9 mm) and a maximum height of 3/16 inch (5 mm).

4.3 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.

4.4 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 W broadband power amplifier driven by the swept frequency signal generator, a low-noise broadband preamplifier in front of the receiver may also be required.

5. NOTES

5.1 Revision Indicator

A 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, including technical revisions. Change bars and (R) are not used in original publications, nor in documents that contain editorial changes only.

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 for fixture 1705A and 10 kHz to 18.0 GHz for fixture 1705C.

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

    a. Attach the output of the signal generator (with 50 Ω output) to the input to the receiver, using tracking generator.

    b. Record the current delivered to the test fixture (i.e., divide the recorded voltage obtained above by 50 Ω 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 using test fixture 1705A and 1705C.

    b. Using test fixture 1705A and 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. Applicable for test fixture 1705A and 1705C.

    b. Using test fixture 1705A and 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 appropriate joint surfaces. The maximum size of the sample and sample placement is illustrated in Figure 13 and 4.2.2.

2. The testing is to be performed using receivers, spectrum analyzers or network analyzers in a sweep mode. A tracking generator is to be used to obtain a continuous sweep of data over the frequency range of interest.

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).

A.3.2.2 Shielding Quality Testing of EMI Gaskets

1. Place the gasket coupon under test between gold plated joint surface 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 of 1705A test fixture or the appropriate “insulated sample holder” of 1705C test fixture).

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.

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.

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:

$$Z_T = (V_O / I_I)\ L_G \qquad \text{(Eq. A2)}$$

$$\text{since } I_I = V_I / 50$$

where:

V_I = voltage delivered to Z_T fixture

V_O= voltage measured at the Z_T fixture output connector

I_I= current into Z_T fixture

L_G= length of gasket under test in meters

$$Z_T = (50\ V_O / V_I)\ L_G \qquad \text{(Eq. A3)}$$

$$\text{And } Z_T\ (\text{dB}) = 20 \log (50 + V_O - V_I) + 20 \log L_G \qquad \text{(Eq. A4)}$$

When the measurements are observed in dB:

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

$$\text{where: } 20 \log 50 = 34 \text{ dB}$$

$$\text{and } Z_T = 10^{(Z_T\ (\text{dB}) / 20)} \qquad \text{(Eq. A6)}$$

If an amplifier or pre-amplifier is used to provide the required dynamic range as illustrated in Figure B14, the gain in dB of the amplifier(s) is to be added to the value in dB of V_I.

i.e., Equation A5 becomes:

$$Z_T\ (\text{dB}) = V_O\ (\text{dB}) - \left[V_I\ (\text{dB}) + G_A\ (\text{dB})\right] + 34\ (\text{dB}) + 20 \log L_G$$

where:

G_A = gain from amplifier(s) in dB

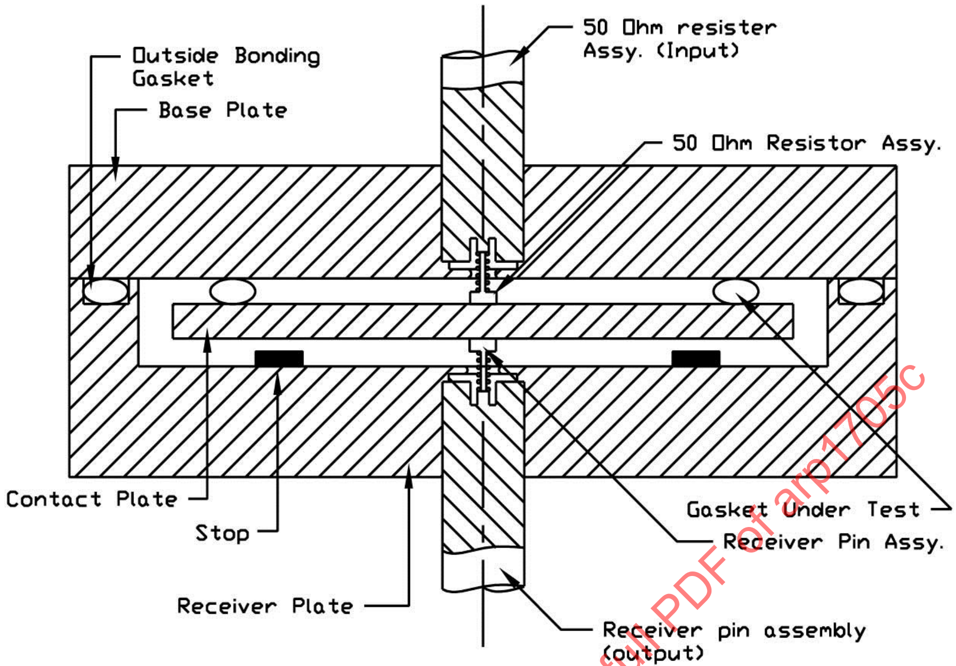
Table A1

Transportation/Storage Environments	
Environmental Stress Condition	Test Method/Procedure (MIL-STD-810G)
High Temperature (Dry/Humid)	Method 501
Low Temperature (Rain/Hail/Freezing)	Method 502
Thermal Shock	Method 503
Solar Radiation	Method 505
Fungus Growth	Method 508
Rain	Method 506
Humidity	Method 507
Salt Fog	Method 509

Table A2

Mission/Sortie Environments	
Environmental Stress Condition	Test Method/Procedure (MIL-STD-810G)
High Temperature (Dry/Humid)	Method 501
Humidity	Method 507
Salt Fog	Method 509
Explosive Atmosphere	Method 511
Rain	Method 506
Emersion	Method 512

APPENDIX B - TEST FIXTURE 1705A FIGURES

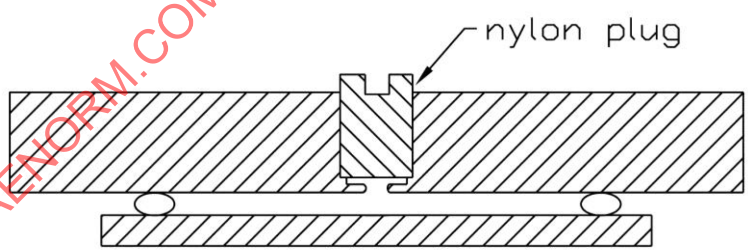


NOTES: 1. Use 1/4-20 nylon socket head cap screws for holding contact plate to base plate.

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 - 1705A test fixture (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 diameter 6/6 white nylon rod, 0.5 inch 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

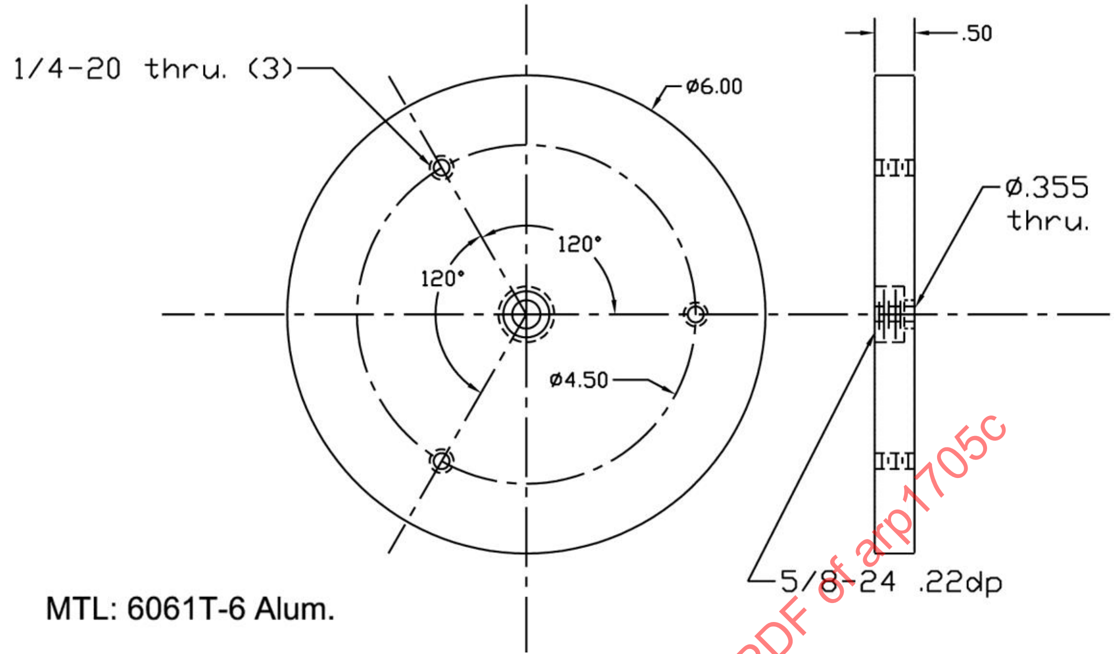


Figure B2 - Base plate

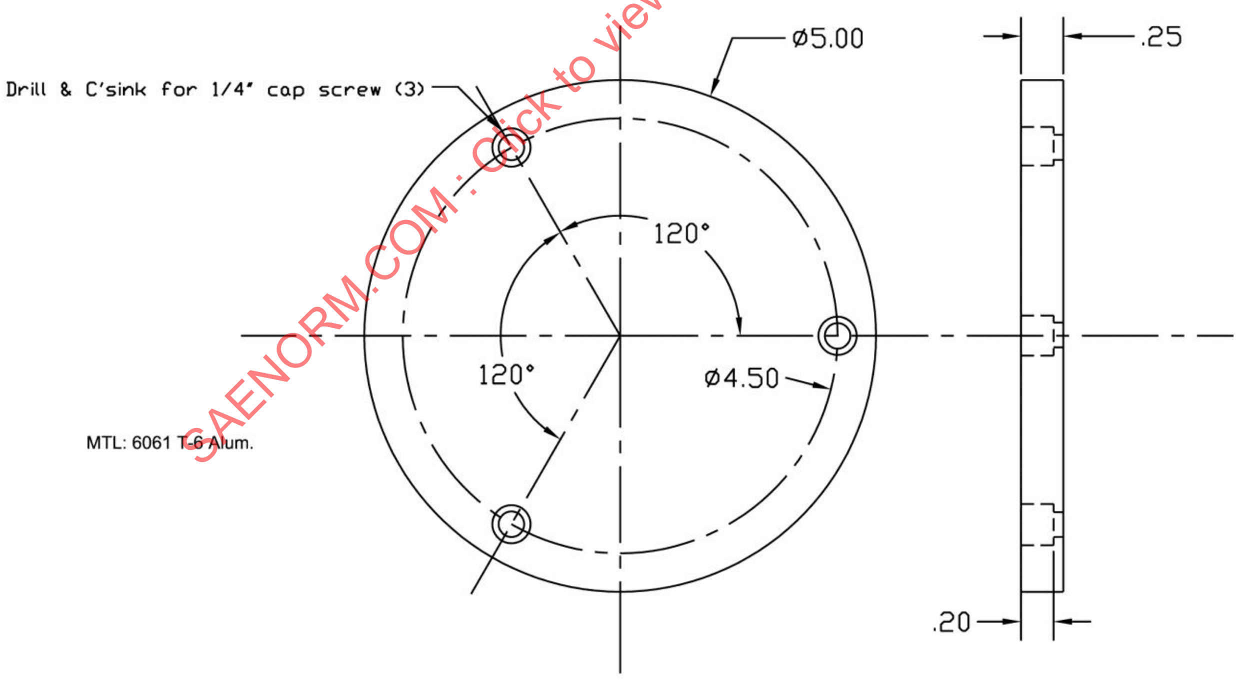
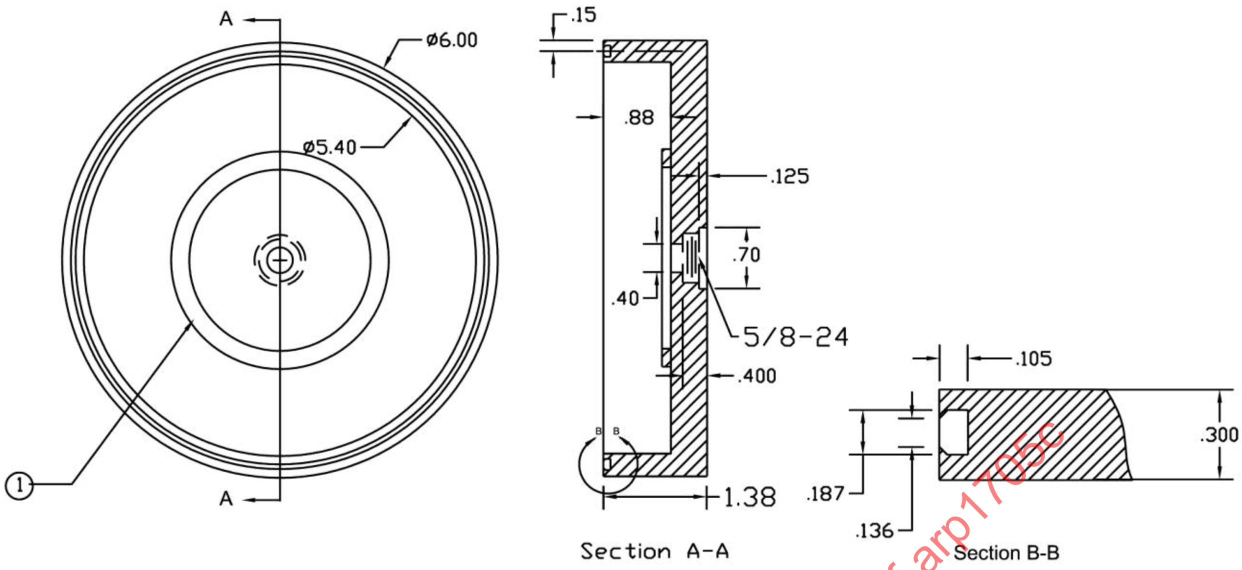
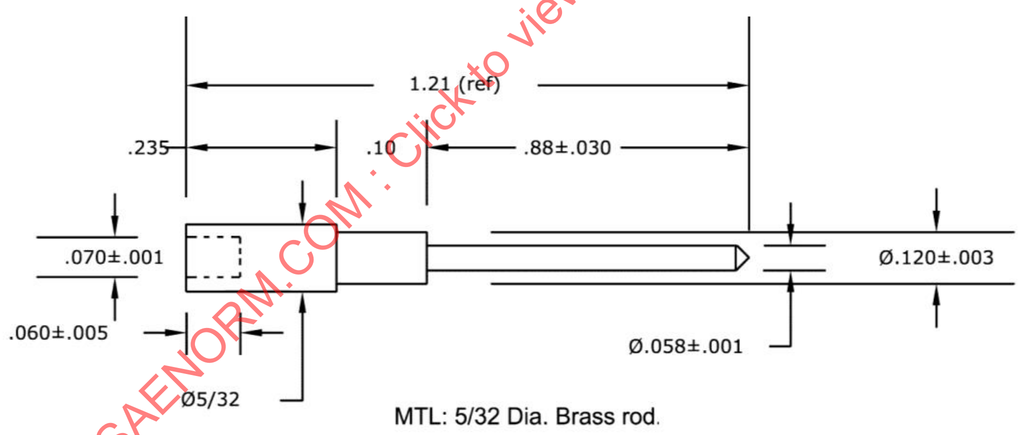


Figure B3 - Contact plate



NOTE: 3.0 OD x 2.5 ID x 0.125 PVC spacer attached to receiver plate using adhesive per FED STD A-A-3097 type V class III.

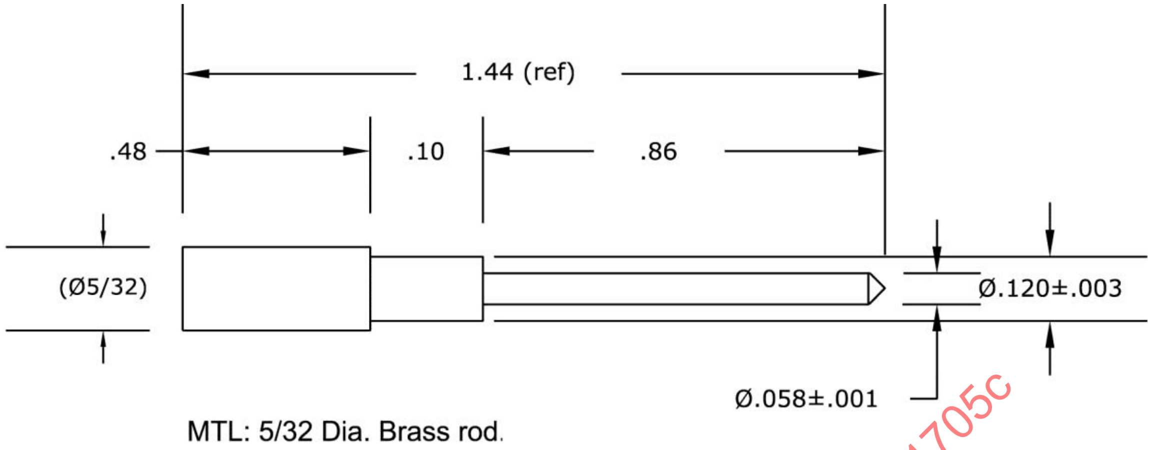
Figure B4 - Receiver plate



NOTES: 1. Solder 50 Ω 5 W film resistor into the top of the pin using 60/40 solder.
The resistor is 50 Ω ± 2% at 25 °C over the frequency range of DC to 18 GHz.
It measures 0.181 to 0.193 inches long with an OD of 0.060 to 0.066 inches.
A solder terminal 1/16 inch long is at both ends of the resistor.

2. Closed end spring (5/32 OD x 0.016 wire x 1.0 long), is part of the assembly.

Figure B5 - 50 Ω resistor pin assembly



NOTE: Closed end spring (5/32 OD x 0.016 wire x 1.0 long) is part of the assembly.

Figure B6 - Receiver pin assembly

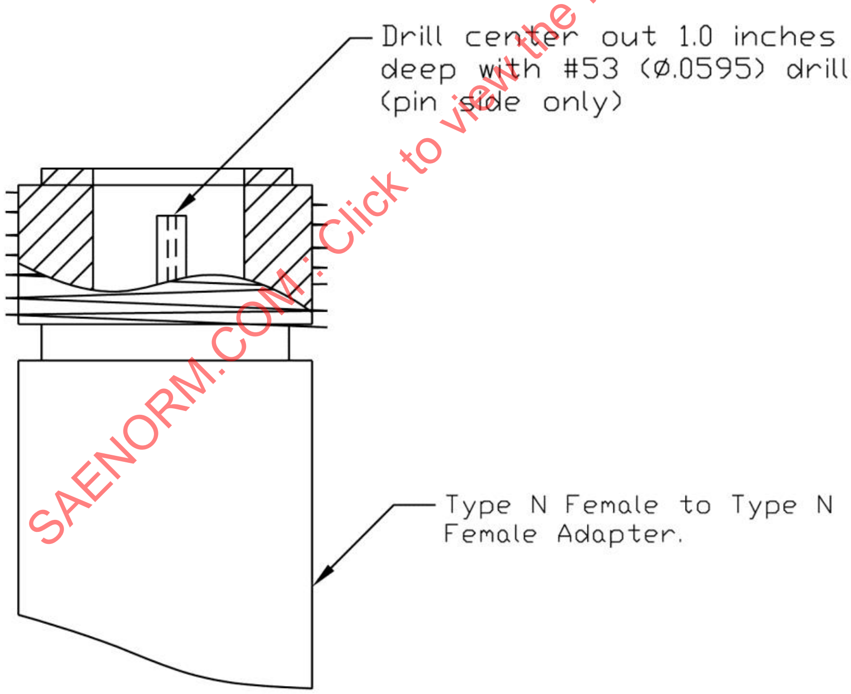
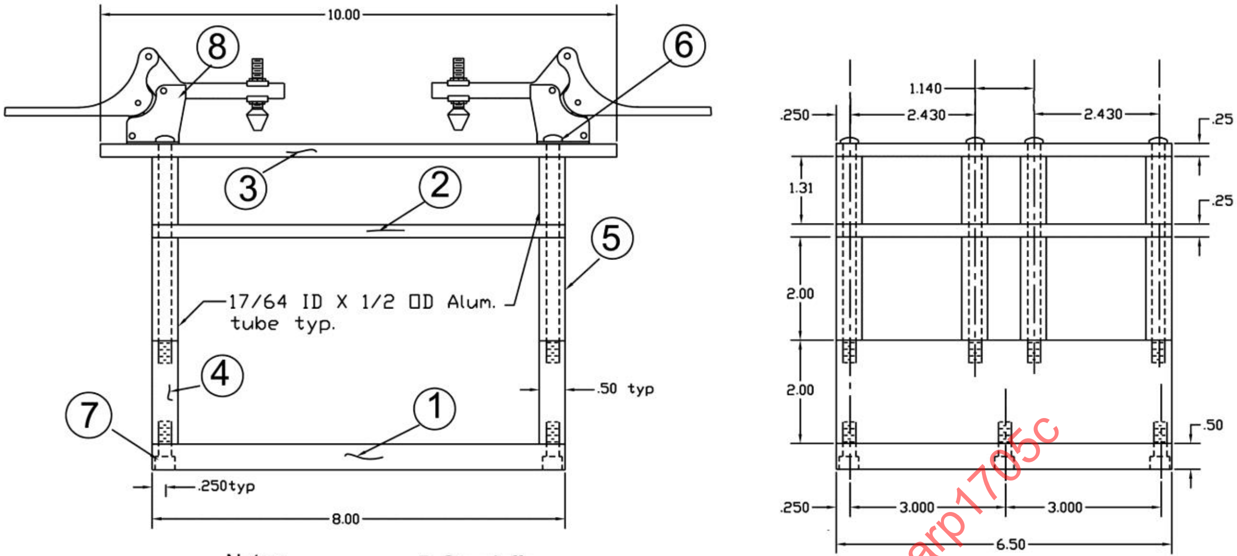


Figure B7 - Type N modified adapter



Notes:
1. Base Plate
2. Pressure Plate
3. Locating Plate.
4. SideBars
5. Standoffs.
   -8 pcs 1/2 OD. X .31 ID X 2.00 inches long
   -8 pcs 1/2 OD. X .31 ID. X 1.31 inches long
6. 1/4-20 X 4.0 inches long (8 pcs.) Pan Head Screws
7. 6 pcs. 1/4-20 X 1/2 inch long Socket Head Cap Screw
8. Toggle clamp: 500 pound, Horizontal handle with extra hand clearance.

Figure B8 - Frame assembly

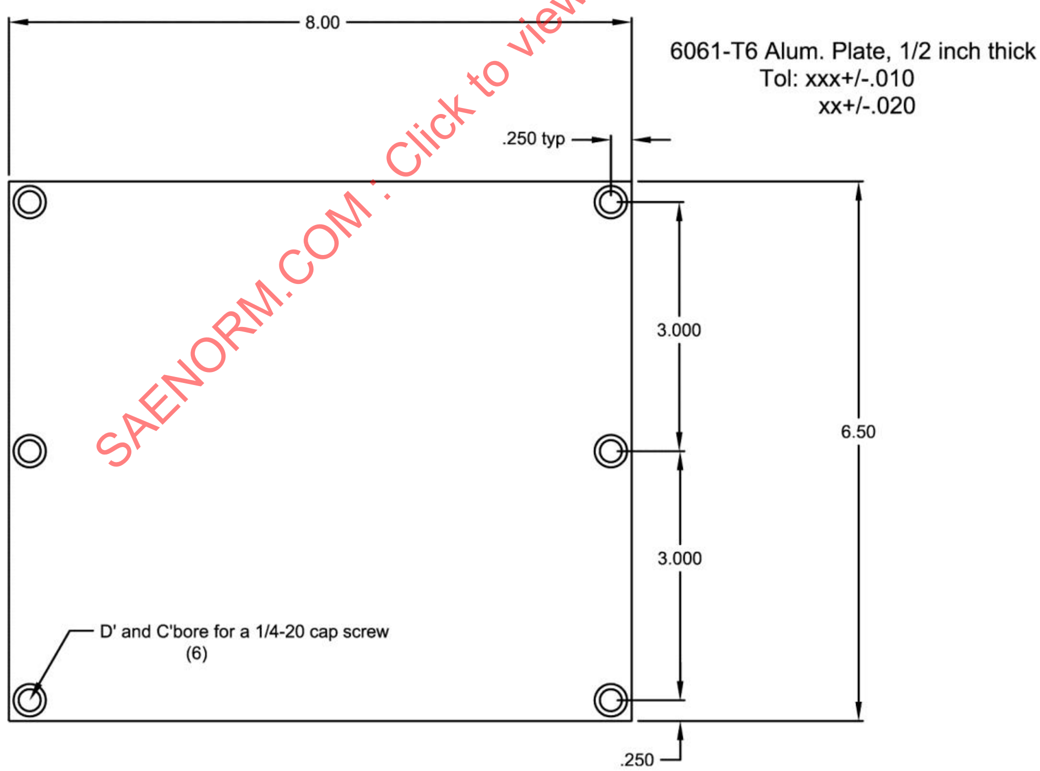
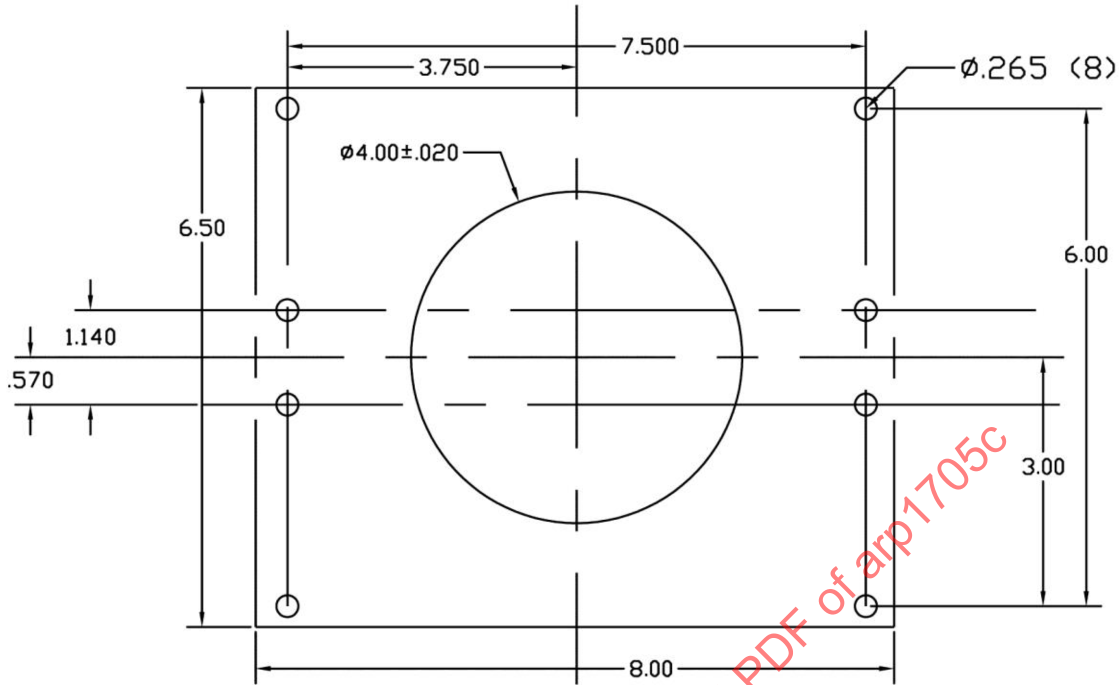
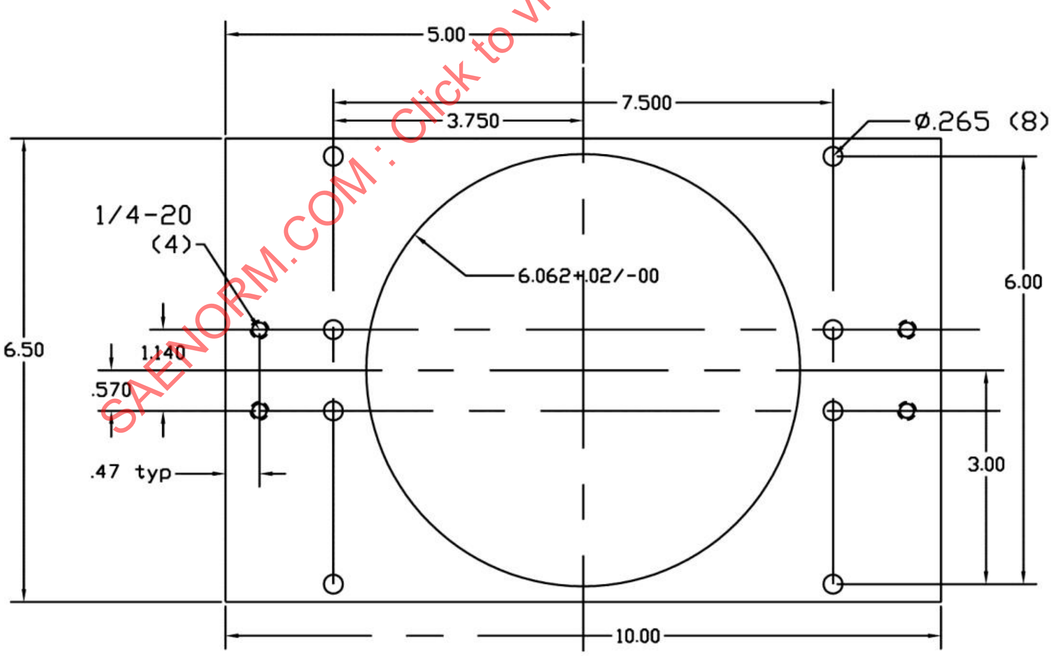


Figure B9 - Fixture base plate



MTL: 6061T-6 alum. 1/4 thick

Figure B10 - Pressure plate



MTL: 6061T-6 alum. 1/4 thick

Figure B11 - Locating plate

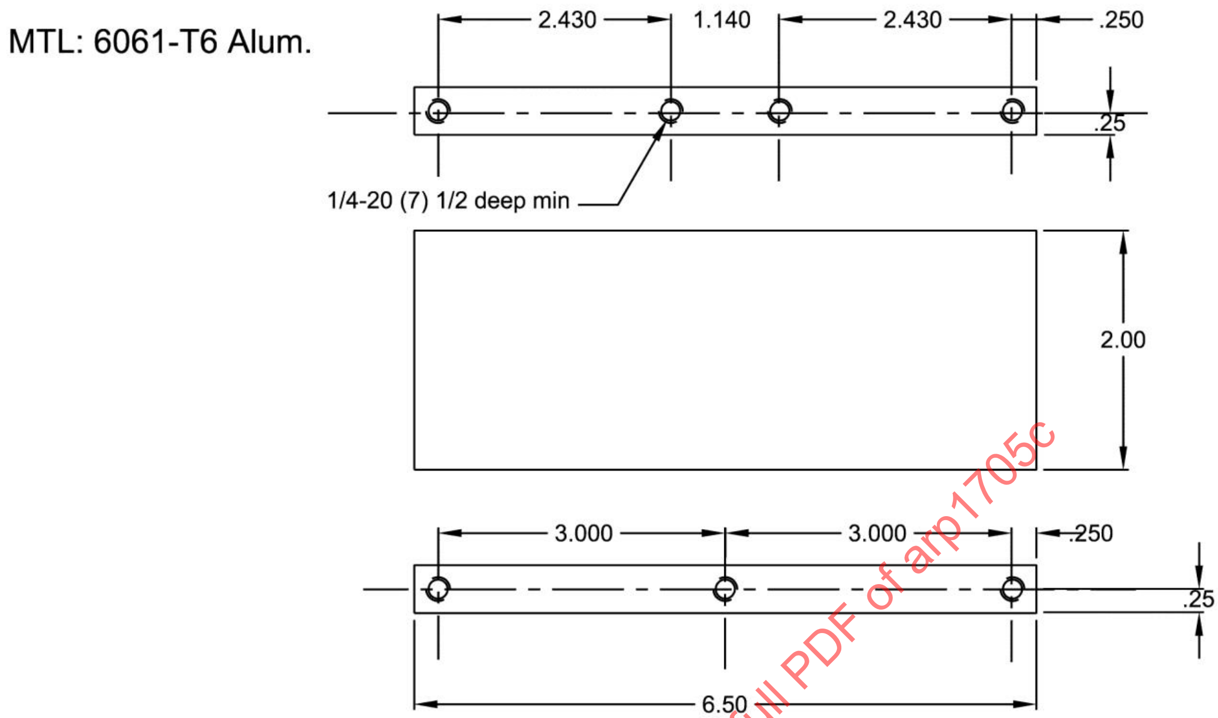


Figure B12 - Side bars

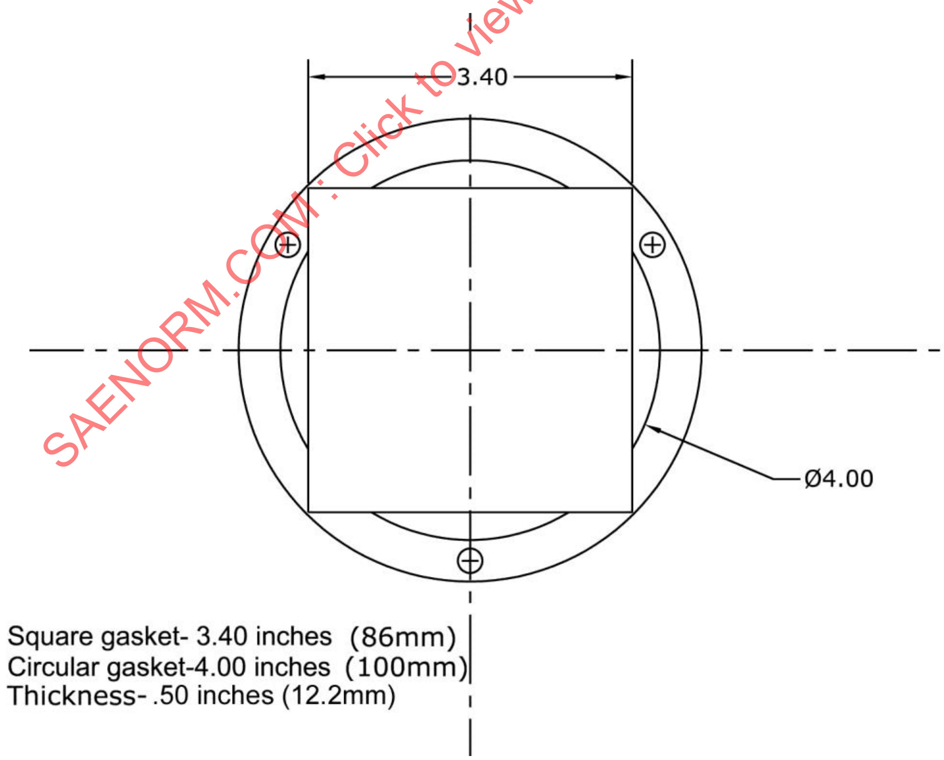
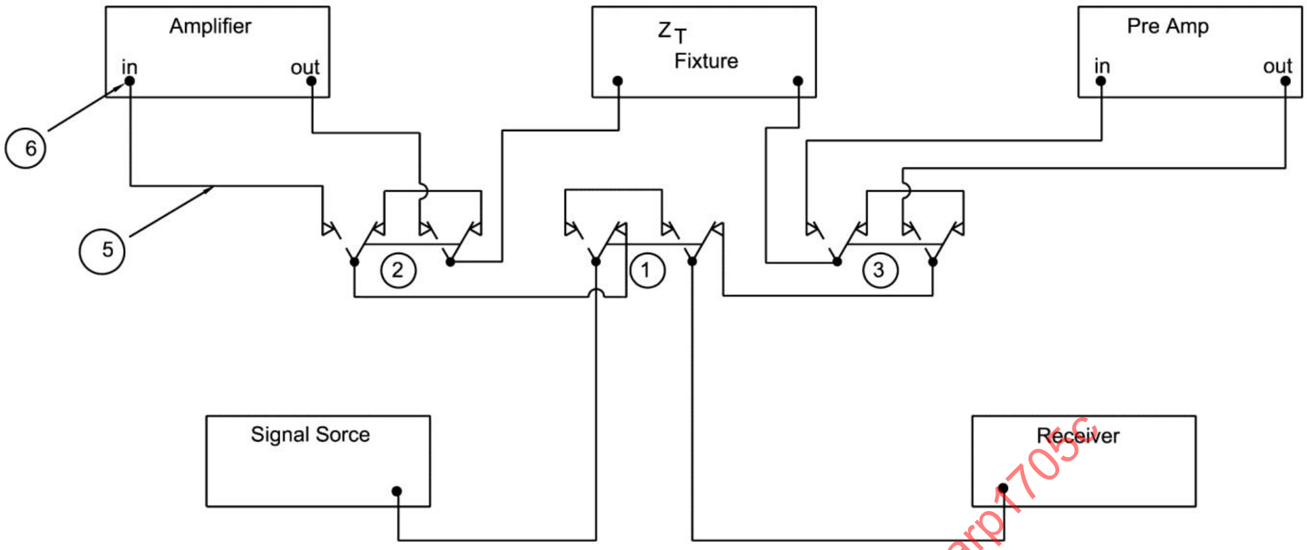


Figure B13 - Maximum gasket dimensions



NOTES:
1. Switch 1, used to obtain current spectrum density
2. Switch 2, used to amplify signal source
3. Switch 3, used to amplify output of ZT fixture.
4. The switches are high isolation microwave frequency switches. If switches are not used, then the contact is made by manually connecting the coaxial cables together.
5. Coaxial cables:
   (a) Semi-rigid, SMA male to SMA male
   (b) 18 GHz flexible SMA male to SMA male
6. Coaxial adapters, SMA female to N male

Figure B14 - Test configuration schematic

APPENDIX C - TEST FIXTURE 1705C FIGURES

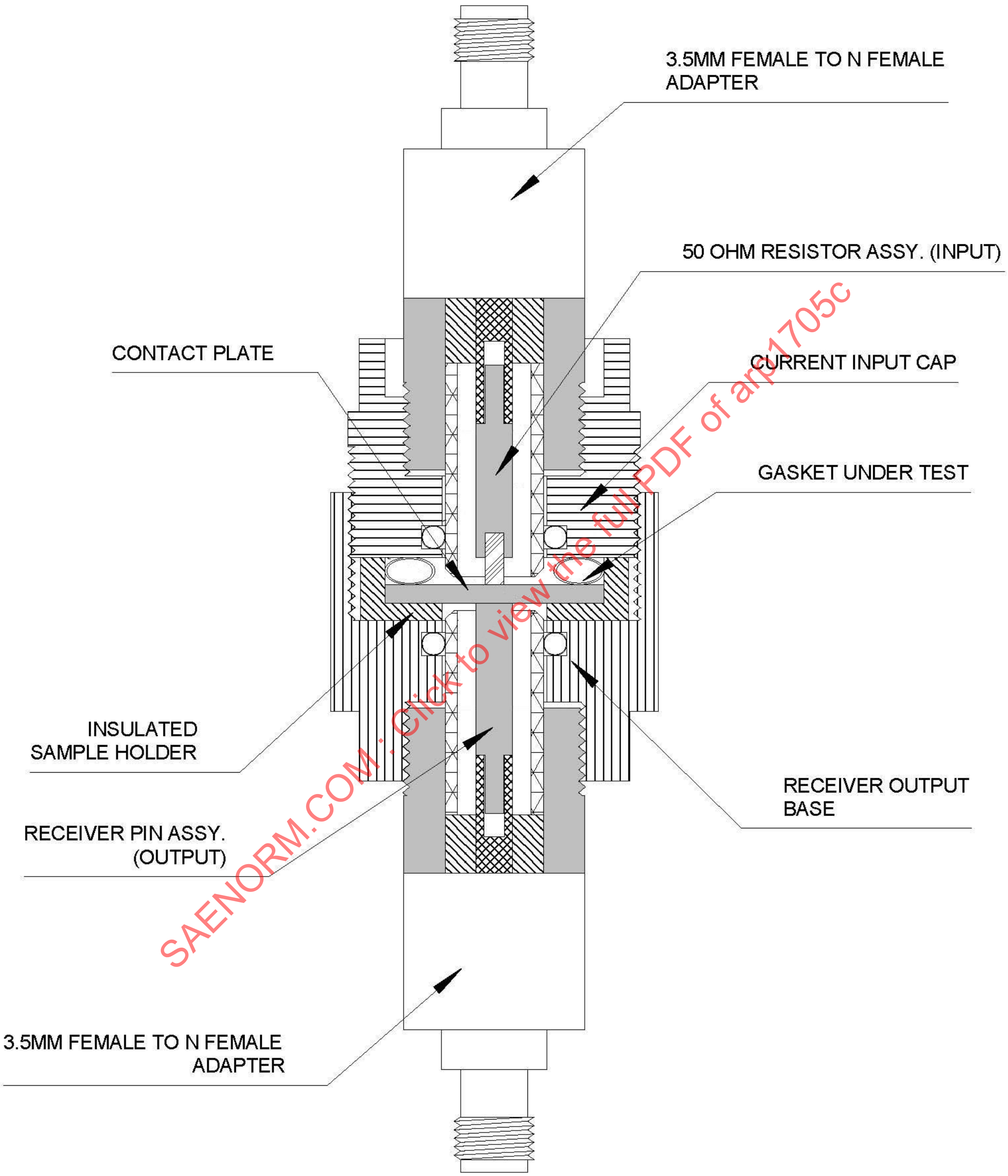
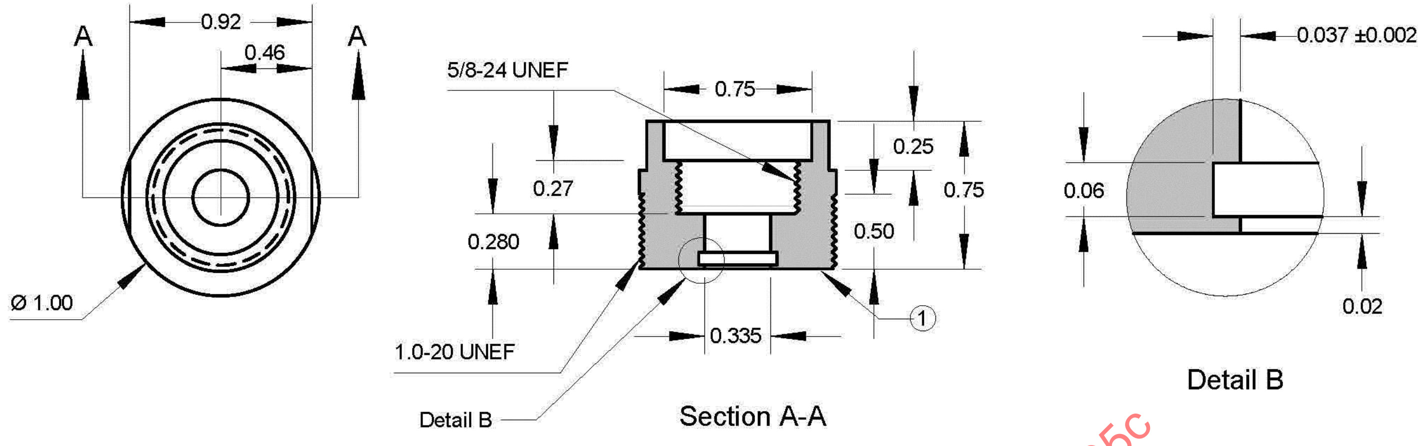


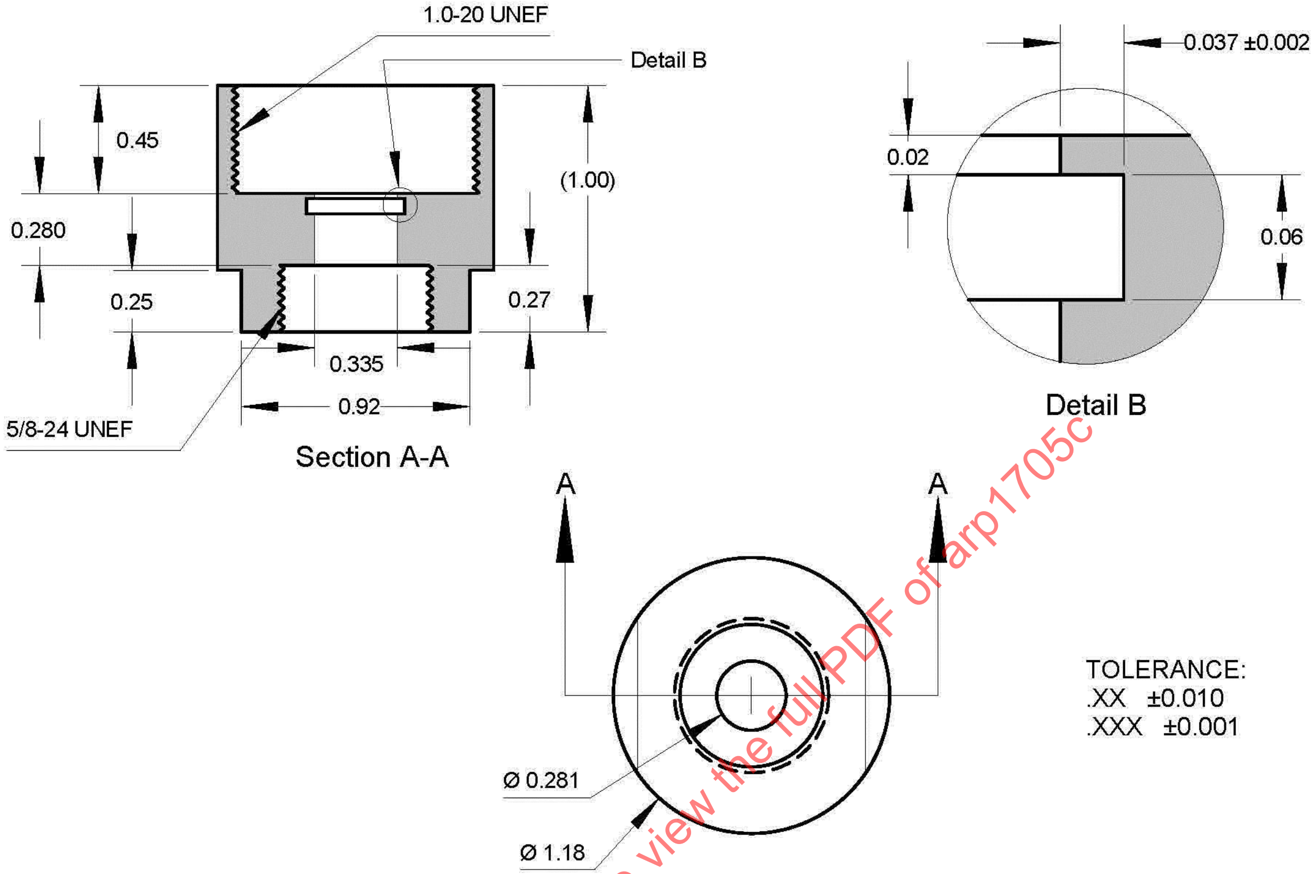
Figure C1 – 1705C test fixture
(gasket assembly under test)



TOLERANCE:
.XX ±0.010
.XXX ±0.001

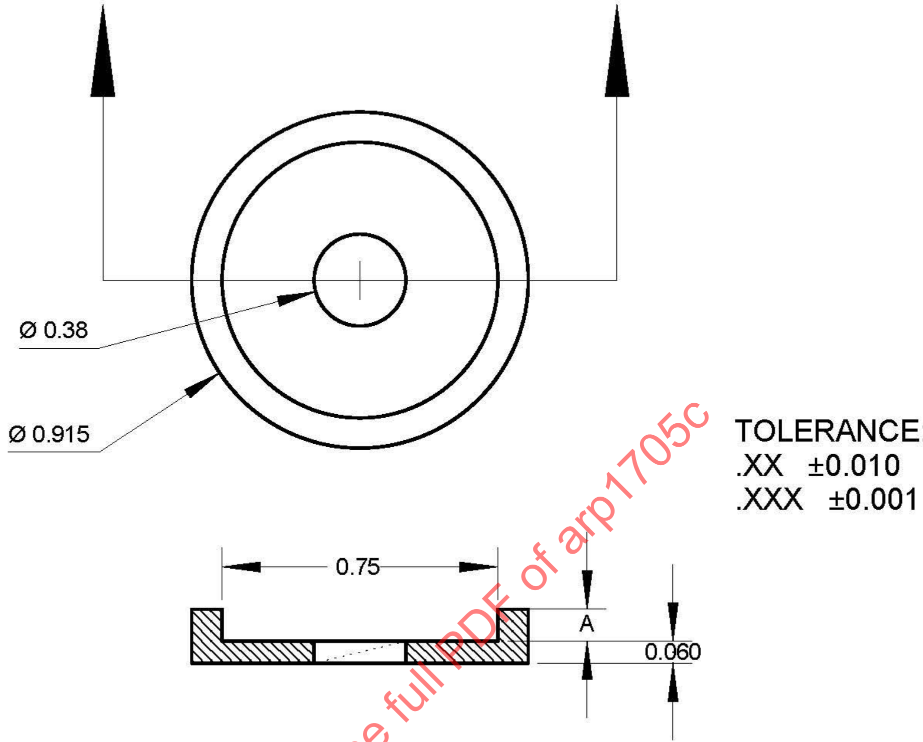
NOTES:
MATERIAL: 1.0 DIA
QUALITY CONTROL TESTING: 6061-T6 ALUMINUM
SURFACE MARKED (1)
GOLD PLATED
GASKETED JOINT TESTING: MATERIAL AND FINISH AS REQUIRED
TO COMPRESS SAMPLE TO PROPER DEFLECTION: TURN CAP CLOCKWISE
UNTIL FIRM, THEN USE 15/16 OPEN END WRENCHES UNTIL SNUG

Figure C2 - Current input cap



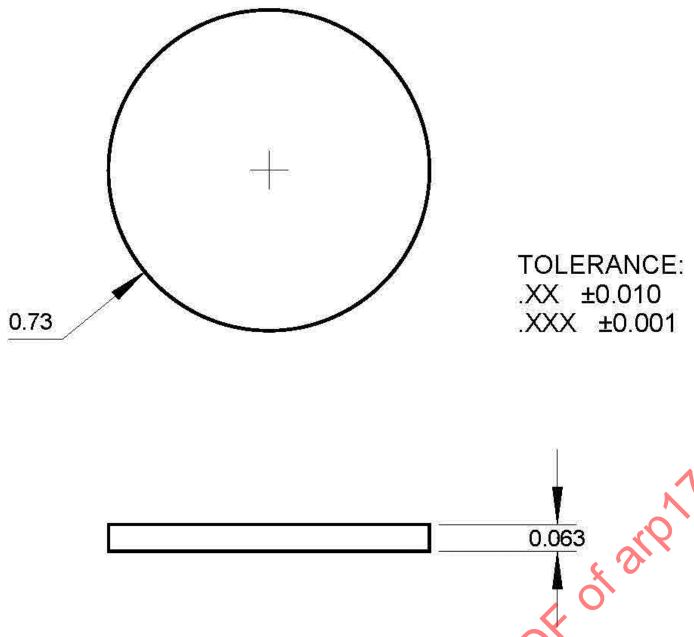
MATERIAL: 1-3/16 DIA 6061-T6 ALUMINUM

Figure C3 - Receiver output base



NOTES:
1. MATERIAL: 1.0 DIA PHENOLIC
A. DIMENSION TO BE: HEIGHT OF GASKET UNDER TEST + 0.063 - DEFLECTION

Figure C4 - Insulated sample holder



NOTES:
QUALITY CONTROL TESTING: 6061-T6 ALUMINUM, GOLD PLATED

GASKETED JOINT TESTING: MATERIAL AND FINISH TO BE CONSISTENT WITH SYSTEM REQUIREMENTS

Figure C5 - Contact plate