

Solid Composite Laminate
NDI Reference Standards

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1. SCOPE:

This recommended practice establishes a generic composite reference standard that will accommodate nondestructive inspections (NDI) on the full array of glass fiber and carbon fiber laminates found on aircraft.

1.1 Purpose:

The purpose of this Aerospace Recommended Practice (ARP) is to describe the design and production of solid composite laminate calibration standards to be used in ultrasonic, resonant, and tap test NDI equipment calibration for accomplishment of damage assessment and post-repair inspections. It is intended that these standards be adopted by aircraft Original Equipment Manufacturers within procedures contained in their Nondestructive Testing Manuals. Depending on the nature of the inspection, it may be necessary to compensate for variations in material properties through the use of correction factors or by adjusting for these differences on the part or structure being inspected. When using these standards consideration must be given to surface coatings such as paint or lightning protection plies. This is a reference standard construction document and not an inspection document. Inspection procedures, from OEM or users' maintenance manuals, must accompany the use of these reference standards for each unique family of composite laminate construction.

1.2 Background:

The CACRC Inspection Task Group developed this ARP in an effort to establish a single, generic set of composite laminate reference standards that would accommodate inspections on the full array of laminates found on aircraft. The advantages of industry-wide acceptance of these composite standards include: 1) provides a consistent approach to composite inspections thus improving inspection reliability, 2) reduces standard procurement costs, and 3) aids in future assessments of composite inspection technologies. Specific use of the laminate standards described in this ARP can be achieved through the OEM inspection procedures found in Nondestructive Testing Manuals and Nondestructive Testing Standard Practice Manuals.

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1.3 Supporting Data:

Through-transmission ultrasonics was applied to the series of existing Boeing, Douglas, and Airbus laminate standards, as well as, material samples gathered from a variety of sources, in order to measure the velocity and relative attenuation properties in the laminates. Acoustic impedance for these materials was then derived using measured velocity and material density values. Upper and lower bounds for these key material properties were established for both carbon graphite (tape and fabric) and fiberglass laminates. A material search identified G11 Phenolic as a material that has velocity, acoustic impedance, and attenuation values that closely matched those of carbon graphite and fiberglass. More precisely, the G11 properties are midway between graphite and fiberglass laminates. While G11 is not an exact match with either carbon graphite or fiberglass materials, it was decided that G11 is ideally suited for use as a generic standard because of the normal variations ($\pm 10\%$) found within laminate specimens, as well as, variations reported during field inspections on similar laminate structures. In addition, it was found that the consistency of G11 Phenolic material from one batch to the next was much better than the consistency observed in either carbon graphite or fiberglass standards previously fabricated. Finally, G11 Phenolic standards can improve on existing solid laminate standards since the material is inexpensive, can be reliably manufactured and is easy to machine into a solid laminate standard (i.e. plate with multiple thicknesses). Prototype laminate standards were fabricated from the G11 material and inspection data was accumulated to validate the use of G11 standards for use in carbon and fiberglass laminate inspections.

2. REFERENCES:

2.1 Applicable Documents:

The following publications form a part of this specification to the extent specified herein. The applicable issue of the referenced publications shall be the issue in effect on the date of the purchase order.

2.1.1 U.S. Government Publications: Available from DODSSP, Subscription Services Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

MIL-L 24768	Insulation, Plastics, Laminated, Thermosetting, General Specification for
MIL-I-24768/3	Insulation, Plastic, Laminated, Thermosetting, Glass Cloth, Epoxy Resin (GEB)

2.1.2 NEMA Publications: Available from NEMA, 1300 North 17th Street, Suite 1847, Rosslyn, VA 22209.

LI 1-1998	Industrial Laminated Thermosetting Products (Grade G11)
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2.2 Nomenclature:

ARP	Aerospace Recommended Practice
NDI	Nondestructive Inspection
NDT	Nondestructive Testing
NEMA	National Electric Manufacturers Association
OEM	Original Equipment Manufacturer

3. TECHNICAL REQUIREMENTS:

3.1 Fabrication and Material:

Fabrication of the solid composite laminate standards (See attached engineering design drawings G11-STD-1, G11-STD-2, G11-STD-3, and G11-STD-4) is straightforward and consists of three machining tasks: 1) face the upper and lower surfaces of a thick sheet of G11 Phenolic material¹ such that the two surfaces are flat and parallel and the resulting plate thickness will allow for the steps shown in the drawings, 2) cut the Phenolic plate into four 5.75 inches [146 mm] H X 4 inches [101.6 mm] W bricks, and 3) machine flat-bottomed holes into the bricks to produce the thickness steps shown in the engineering drawings. The machined plates should be lapped to make a smooth inspection surface that mimics those found on aircraft laminate structure. Finally, the thickness designations should be labeled and the flat-bottomed holes should be marked with a circle to aid inspection probe placement.

Figure 1 shows schematics of the solid laminate standards while Figure 2 contains a photo of the prototype laminate standard set. Key issues addressed by the designs are as follows: 1) protection against moisture ingress - extensive exposure to water submersion showed that water absorption is not a problem with G11 material, 2) locating probe - the location of each skin thickness has been identified on the laminates to allow for proper positioning of the transducer and each thickness has been labeled, 3) surface finish - the surface finish is improved via a lapping process to produce more consistent responses from transducers, 4) size and ease of handling - the set of 24 thicknesses has been distributed over four different plates, and 5) one ply resolution - the thinnest skin was reduced from 0.010 inch thick to 0.007 inch thick (0.25 mm thick to 0.18 mm) to closer represent one ply.

The starting thickness of Phenolic plate should be at least 1 inch [25.4 mm] thick for the thickest laminate standard (G11-STD-4) with thickness steps ranging from 0.5 inch [12.7 mm] to 1.0 inch [25.4 mm]. For the other three laminate standards (G11-STD-1 through G11-STD-3) with thickness steps ranging from 0.007 inch [0.18 mm] to 0.45 inch [11.43 mm], the starting thickness of the G11 Phenolic plate should be 0.5 inch [12.7 mm]. This will produce the most uniform standards with responses that closely match fiberglass and carbon laminates.

1. Use NEMA Grade G11 fabricated in accordance with MIL-I-24768/3 Type GEB. Do not use NEMA Grade G11/FR5 (fire retardant) which is fabricated in accordance with MIL-I-24768/28 Type GEB-F.

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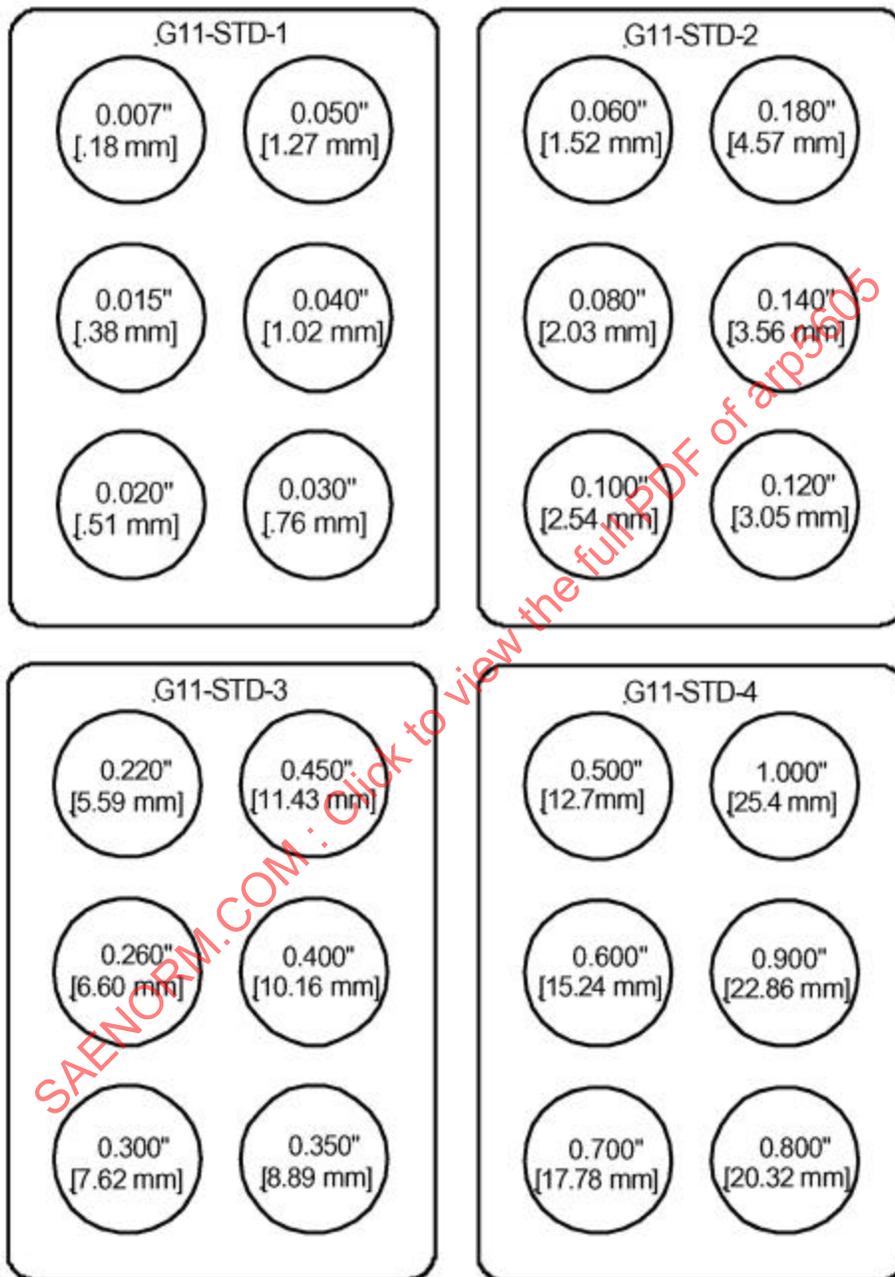


FIGURE 1 - G11 Solid Laminate Standard Set
(numbers in circles represent skin thickness, in inches [or mm in brackets], of each flat bottom hole)

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FIGURE 2 - Front and Back Photos of G11 Solid Laminate Set

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3.2 Acceptance Criteria:

- The G11 Laminate Reference Standards must be certified by a series of mechanical thickness measurements. The material thickness in each flat-bottomed hole must be measured using micrometer or other thickness measurement device that is traceable to primary or secondary standards and has a resolution of 0.001 inch [0.0254 mm]. Measurements shall be made at a minimum of three places within the hole, spaced approximately 1/2 inch [12.7 mm] apart, and recorded. All measurements shall meet the required thickness tolerance callout.

3.3 Engineering Design Drawings:

Engineering design drawings for composite laminate reference standards are as shown in Figures 3 through 6.

4. NOTES:

4.1 Key Words:

Non-destructive inspection, composite laminate, reference standards, NDI

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