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Standard Practice for Fabrication and Control of Steel Reference Blocks Used in Ultrasonic Inspection Examination ¹

This standard is issued under the fixed designation E 428; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

This specification has been approved for use by agencies of the Department of Defense.

¹ This practice is under the jurisdiction of ASTM Committee E7 on Nondestructive Testing and is the direct responsibility of Subcommittee E07.06 on Ultrasonic Testing Procedures.

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1. Scope

1.1 This practice covers a procedure for fabrication and control of ~~metal-alloy standard~~ metal alloy reference blocks used in ~~ultrasonic inspection examination~~ that have a flat-surface sound entry, are cylindrical in shape, and contain flat-bottom holes (FBH) which may be used for checking the performance of ultrasonic inspection examination instrumentation and search units and for standardization and control of ~~ultrasonic inspections examination~~ of metal- alloy products. The reference blocks described are suitable for use with either the direct-contact method or immersion pulse-echo ~~ultrasonic inspection methods~~. ~~Also described is a procedure for checking the response characteristics of the reference blocks and their relationship to materials and products being inspected. methods.~~

1.2 While this procedure is basically designed for the fabrication and control of carbon and alloy steel blocks to be used in conjunction with the ~~inspection examination~~ of these materials, the fabrication and control procedures may also be suitable for the preparation of blocks for other types of materials such as nickel-base alloys, ~~titanium alloys, certain types of aluminum alloys, and so forth~~. Additional procedures and controls may be required when fabricating reference blocks from other than carbon or alloy steel material. This practice shall in no way preclude the specification or addition of any supplemented requirements as deemed necessary for the specific application. This practice, however, must not be confused with, nor does it supersede Practice E 127, specifically governing the fabrication and evaluation of 7075-T6 aluminum alloy ultrasonic standard reference blocks. It shall in no way preclude the specification of supplemental blocks.

NOTE 1—Practice E 127 and Guide E 1158 also describe procedures for selecting material, fabricating blocks, and checking response. Unlike this practice, Practice E 127 has requirements when the application requires them, for evaluation relative to a specified standard target.

1.3 The values stated in inch-pound units are to be regarded as the standard.

1.4 *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 ASTM Standards:

E 127 Practice for Fabricating and Checking Aluminum Alloy Ultrasonic Standard Reference Blocks²

E 1158 Guide for Material Selection and Fabrication of Reference Blocks for the Pulsed Longitudinal Wave Ultrasonic Examination of Metal and Metal Alloy Production Material²

E 1316 Terminology for Nondestructive Examinations²

3. Summary Terminology

3.1 Definitions— For definitions of Practice

3.1 ~~This practice details a basic fabrication and control procedure and defines minimum requirements to be met terms used in matching of the reference blocks with the material to be inspected. The physical characteristics of the hole are established by evaluating plastic replicas. this practice, see Terminology E 1316.~~

4. Summary of Practice

4.1 This practice details a basic fabrication and control procedure and defines the minimum requirements to be met in matching

² Annual Book of ASTM Standards, Vol 03.03.

carbon and alloy steel reference blocks with the material to be examined. Additional supplemental requirements may be needed when using this practice to fabricate reference blocks from other types of materials or with larger diameter holes. The physical characteristics of the hole may be established by evaluating plastic replicas. It must be recognized however that there are limitations on the size hole that may be replicated and evaluated.

5. Material Selection

4.1 One of the key factors in the successful use of reference blocks in procedures for the evaluation of materials is matching within the limits specified in this practice of the ultrasonic response from the reference blocks to the ultrasonic response from the materials being inspected. This is accomplished by (1) preparing reference blocks from a grade of

5.1 The material with the required acoustic response in relation to the material to be inspected, or by (2) determining significant ultrasonic differences between the reference blocks and the material to be inspected and compensating for the differences by adjusting the instrument.

4.2 The method most widely accepted by ASTM has been the use of reference blocks fabricated from materials with ultrasonic responses similar to the material to be inspected. The following procedures are recommended for inspecting and qualifying materials from which reference blocks are to be fabricated:

4.2.1 The material to be used for reference blocks should be similar in its acoustic attenuation to the material which is to be inspected; examined. The grain size, heat treat condition, physical and chemical composition, surface finish, and manufacturing procedure (rolling, forging, etc.) are variables to be considered in matching acoustic responses.

4.2.2 The

5.1.1 The general evaluation procedure consists of directing shall be to introduce a longitudinal pulse-echo beam into either side of the ~~m~~ block on the axis to be used for determining metal-path distance. An immersion test examination method using clean, deaerated clean water as a couplant or, a contact method using an appropriate couplant (oil, glycerin, etc.) and so forth is satisfactory. The examination instruments, frequency, and search unit used in the evaluation of the raw material intended for the fabrication of the reference blocks shall be similar comparable to that used in the inspection examination of the production materials.

4.5.21.32 The material used for reference blocks shall be 100 % scanned while the inspection examination system is adjusted to display, whenever possible, an acoustic noise level from the material of 20 % of full-scale deflection (FSD). In cases of materials that are acoustically transparent to the extent that this requirement cannot be satisfied, a readable acoustic noise level shall be displayed. The acoustic noise level from the material is not to be confused with inherent electrical instrument noise often observed when the system sensitivity is adjusted to its maximum level range.

4.2.4 The

5.1.3 The material used for reference blocks shall be free of discrete ultrasonic discontinuity indications greater than twice the amplitude of the noise level displayed in accordance with the requirements of 4.5.1.2.3.

4.5.21.54 Attenuation shall be checked by comparing multiple reflections from the back surface of the test block material with that of the material to be inspected; examined. With the amplitude from the first back reflection adjusted to 90 % of FSD, the sum of the amplitude of the first three back reflections from both samples shall compare within ± 25 % or as required by the application. On samples that are to have FBHs smaller than $\frac{3}{64}$ in. (1.2 mm) in diameter, the decay patterns shall compare within ± 10 % or as required by the application.

4.5.21.65 Lowering the test examination frequency tends to minimize discernible differences in response. At 1.0 MHz, a large group of materials may be acoustically penetrable with relatively similar results and may satisfy the requirements of 4.2.5; 5.1.4. At frequencies such as 5.0 MHz and higher, microstructure changes usually yield readily discernible differences in acoustic response and restrict the applicability of reference blocks.

56. Fabrication Procedure

56.1 Unless otherwise specified, select the blocks to be made from those listed in Table 1. Block sets conforming to customary commercial practice are grouped as follows:

56.1.1 Distance-Amplitude Response (D/A),

56.1.2 Area-Amplitude Response (A/A), and

56.1.3 Basic (selected from D/A and A/A groups).

56.2 All blocks are to be fabricated in accordance with Fig. 1. Dimension “A” (metal travel) and Dimension “D” (FBH diameter) are given in Table 1; Dimension “E” (block length) is derived. The following machining sequence is recommended:

NOTE 2—This practice may be used to produce blocks with flat-bottom holes of a larger diameter than described. Utilization of larger flat-bottom holes shall be by agreement of the using parties.

56.2.1 Machine all blocks to a uniform 32 rms finish and to the required dimensional tolerances.

56.2.2 Drill the test hole to the nominal $\frac{3}{4}$ in. (19.0 mm) depth with a standard drill point.

56.2.3 Carefully prepare a flat-bottom drill or cutter with cutting edges square and flat within 0.0005 in. (0.013 mm) and perpendicular to its longitudinal axis (flatness, squareness, etc., should be checked at a minimum of 60 \times magnification on an optical comparator).

TABLE 1 Standard Block Sizes and Recommended Block Sets

NOTE 1—Material to be as specified by the user.

NOTE 2—All dimensions and tolerances are to be in accordance with Fig. 11.

NOTE 3—1 in. = 25.4 mm.

NOTE 4—Block sets shown are typical of established commercial practice; more or fewer blocks may be required for specific applications.

Metal Travel and Designator			Distance/Amplitude, 19 in each set			Basic Set, 10 Total			Area/Amplitude Set, 8 total							
Nominal MT	Dim. "A"	Desig.	Diameter of Flat-Bottom Holes (1/8th in./1.6mm) Dimension "D"													
(in.)	(in.)	(mm)	3	5	8	3	5	8	1	2	3	4	5	6	7	8
1/16	0.0625	(1.6mm)	-0008	3	5	8	...	...	...				
1/8	0.125	(3.2mm)	-0012	3	5	8	...	5	...							
1/4	0.250	(6.4mm)	-0025	3	5	8	...	5	...							
3/8	0.375	(9.5mm)	-0038	3	5	8	...	...	...				
1/2	0.500	(12.7mm)	-0050	3	5	8	...	5	...							
5/8	0.625	(15.9mm)	-0062	3	5	8	...	...	...				
3/4	0.750	(19.1mm)	-0075	3	5	8	...	5	...							
7/8	0.875	(22.2mm)	-0088	3	5	8	...	...	...				
1	1.000	(25.4mm)	-0100	3	5	8	...	...	...				
1 1/4	1.250	(31.8mm)	-0125	3	5	8	...	...	...				
1 1/2	1.500	(38.1mm)	-0150	...	...	...	...	5	...							
1 3/4	1.750	(44.5mm)	-0175	3	5	8	...	...	...				
2	2.000	(50.8mm)	-0200	...	...	...	...	...	...	
2 1/4	2.250	(57.2mm)	-0225	3	5	8	...	...	...				
2 1/2	2.500	(63.5mm)	-0250	...	...	...	...	...	...	
2 3/4	2.750	(69.9mm)	-0275	3	5	8	3	5	8							
3	3.000	(76.2mm)	-0300	...	...	...	...	...	...	
3 1/4	3.250	(82.6mm)	-0325	3	5	8	...	...	...				
3 1/2	3.500	(88.9mm)	-0350	...	...	...	...	...	...	
3 3/4	3.750	(95.3mm)	-0375	3	5	8	...	...	...				
4	4.000	(101.6mm)	-0400	...	...	...	...	...	...	
4 1/4	4.250	(108.0mm)	-0425	3	5	8	...	...	...				
4 1/2	4.500	(114.3mm)	-0450	...	...	...	...	...	...	
4 3/4	4.750	(120.7mm)	-0475	3	5	8	...	...	...				
5	5.000	(127.0mm)	-0500	...	...	...	...	...	...	
5 1/4	5.250	(133.4mm)	-0525	3	5	8	...	...	...				
5 1/2	5.500	(139.7mm)	-0550	...	...	...	...	...	...	
5 3/4	5.750	(146.1mm)	-0575	3	5	8	...	5	8							
6	6.000	(152.4mm)	-0600	...	...	...	...	...	...	
6 1/4	6.250	(158.8mm)	-0625	...	...	...	...	...	...	
6 1/2	6.500	(165.1mm)	-0650	...	...	...	...	...	...	



56.2.4 Continue to drill as needed to remove all the conical configuration of the bottom of the hole.

56.2.5 Remove drill, check cutting edge, regrind, if necessary.

56.2.6 Remove an additional 0.005 in. (0.13 mm) of material from the hole bottom.

56.2.7 Recheck cutting edges of the drill on the optical comparator, regrind, if necessary, and repeat 56.2.5 and 56.2.6. Careful attention must be given to the squareness of corners of the cutter, the slightest radius reduces the reflective area of the hole bottom.

67. Checking Physical Characteristics

67.1 All dimensions of the reference blocks including the diameter and perpendicularity of the test hole examination hole may be checked by normal quality control procedures for physical measurements. The configuration, squareness, flatness, and surface finish for hole bottoms 3/64 in. (1.2 mm) in diameter and larger may be checked by the following recommended technique for making and evaluating plastic replicas:

67.1.1 Clean hole with a suitable oil-free noncorrosive solvent and dry with a stream of dried and filtered air.

67.1.2 Mix the replicating material in accordance with the manufacturer's instructions.

67.1.3 Force the material into the hole with a disposable medical syringe and needle of adequate size.

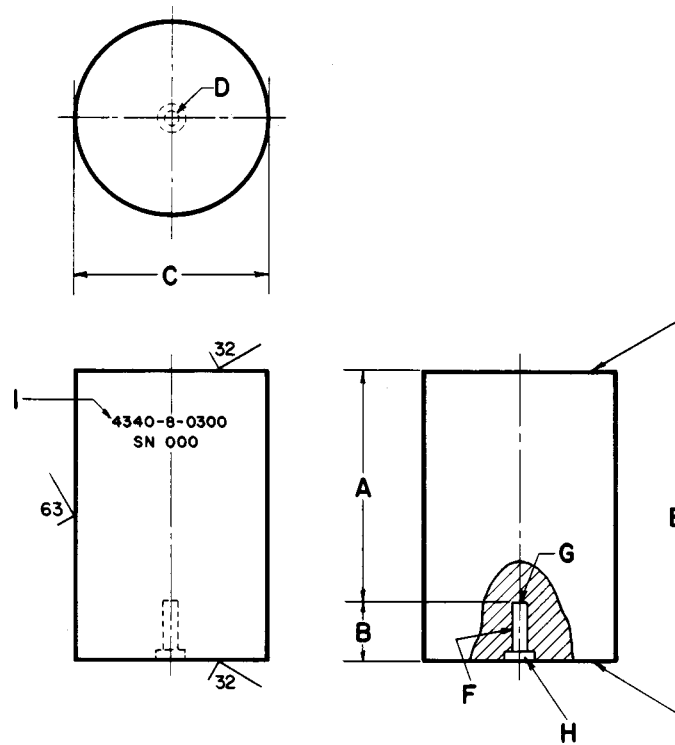
67.1.4 Fill the hole beginning at the bottom and gradually moving outward making certain that no air pockets or bubbles remain in the hole.

67.1.5 Insert a small wire, pin, needle, or other suitable object that will serve as a rigid core and facilitate removal of the replica.

67.1.6 After curing, the replica may be removed and examined. The replica shall indicate that the hole bottom is flat within 0.001 in. (0.03 mm)/1/8 in. (3.2 mm) of diameter and roughness shall not be greater than 16 rms finish. For record purposes, the replica may be projected on a comparator screen and photographed as shown in Fig. 2.

78. Checking Ultrasonic Response Characteristics

78.1 Reference blocks that exhibit satisfactory external physical characteristics and proper configuration of the replicated hole shall be subjected to additional testing examination to check their ultrasonic-response characteristics. If the ultrasonic-response characteristics are to be established by immersion techniques, the drilled flat-bottom holes shall be cleaned and temporarily plugged by a press-fit TFE-fluorocarbon insert or sealed by some other suitable technique to ensure a leak-tight closure. It is recommended that blocks fabricated as sets be compared with each other to determine their relative ultrasonic-response



- A—Metal travel distance ± 0.015 in. (0.38 mm)
- B—Hole depth $\frac{3}{4}$ in. nominal $\pm \frac{1}{16}$ in. (1.6 mm)
- C—Block diameter tolerance ± 0.030 in. (0.76 mm)
 - 2 in. (50.8 mm) dia for test distances up to 6 in. (152 mm)
 - $2\frac{1}{2}$ in. (63.5 mm) dia for test distances over 6 in. up to 12 in. (305 mm)
 - Larger dia or serrations may be required for test distances over 12 in.
- D—Hole diameter tolerance ± 0.0005 in. (0.013 mm) for holes $\frac{1}{16}$ in. (1.6 mm) and smaller, ± 0.001 in. (0.03 mm) for holes larger than $\frac{1}{16}$ in. (1.59 mm)
- E—Surfaces to be flat within 0.0005 in. (0.01 mm) and parallel to within 0.001 in. (0.02 mm).
 - Due to possible edge build-up during the plating process, this tolerance applies only to the area exclusive of that within $\frac{1}{8}$ in. (3.2 mm) of the block edges.
- F—Hole must be straight and perpendicular to the test surface within $0^{\circ} 20$ min.
- G—Hole bottom must be flat within 0.001 in./ $\frac{1}{8}$ in. (1 mm/125 mm) and located within 0.015 in. (0.38 mm) of longitudinal axis.
- H—Counterbore minimum of $\frac{1}{8}$ in. larger than test hole and minimum $\frac{1}{8}$ in. deep.
- I—Flat counterbore 0.250 diameter by 0.064 in. deep.
- I—Typical Block Identification:
 - 4340 = Typical alloy designation.
 - 8 = Hole size in $\frac{1}{64}$ -in. increments.
 - 0300 = Metal travel in 00.00 in.

FIG. 1 Ultrasonic Reference Block Physical Dimensions and Tolerances

characteristics. This is particularly desirable in the cases of sets containing flat-bottom holes smaller than $\frac{3}{64}$ in. (1.2 mm) in diameter that cannot be satisfactorily replicated.

78.2 Area/Amplitude Response Curves— An area/amplitude set may contain several blocks with same external dimensions and distance from the entry surface to the selected FBHs of varying sizes. An area/amplitude-response curve may be obtained by adjusting the test examination sensitivity to give a signal with an amplitude of 30 to 40 % of FSD from the block nearest the middle of the range of the reflector sizes. Without changing any test examination parameters, the ultrasonic response from the remaining blocks with both smaller and larger size reflectors are plotted on the response curve. A typical area/amplitude curve for a set of 4340 steel blocks is shown in Fig. 3. Any block that exhibits an erratic ultrasonic response and does not fall within the apparent normal area/amplitude-response curve is considered unsatisfactory and shall not be used. Modification of the FBH to meet the required ultrasonic response is not an acceptable procedure.

78.3 Distance/Amplitude Response Curves— A distance/amplitude set may contain a number of blocks with identical dimensions and hole sizes but with varying distances from the entry surface to the FBHs. A distance/amplitude-response curve may be obtained by adjusting the test sensitivity to give a signal with an amplitude of 70 to 80 % of FSD from a block with a distance from the entry surface to the FBH in the lower $\frac{1}{4}$ of the distance range. Without changing any test parameters, the ultrasonic response from the remaining blocks with both shorter and longer distances are plotted on the response curve. A typical distance/amplitude curve for a set of Type AISI 4340 steel blocks is shown in Fig. 4. Any block that exhibits an erratic ultrasonic response and does not fall within the apparent normal distance/amplitude-response curve should be considered unsatisfactory and shall not be used. Under no circumstances may the FBH be altered to change the ultrasonic-response characteristics of the reference block.

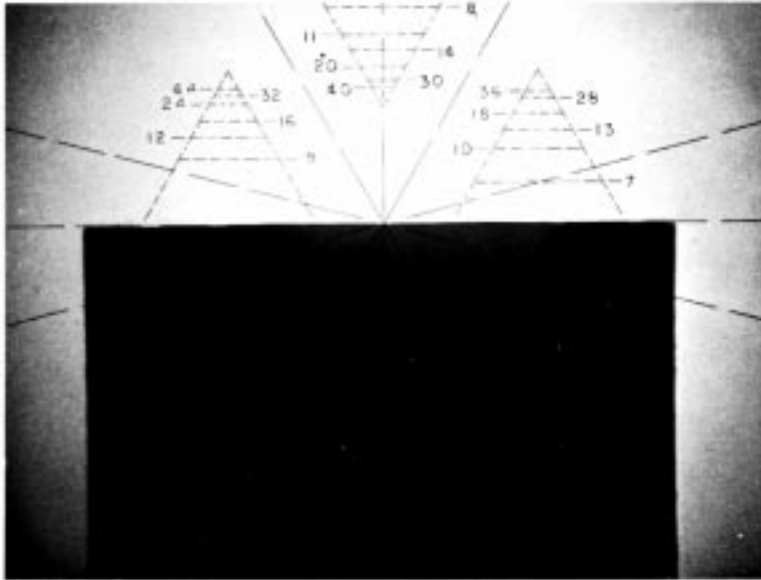
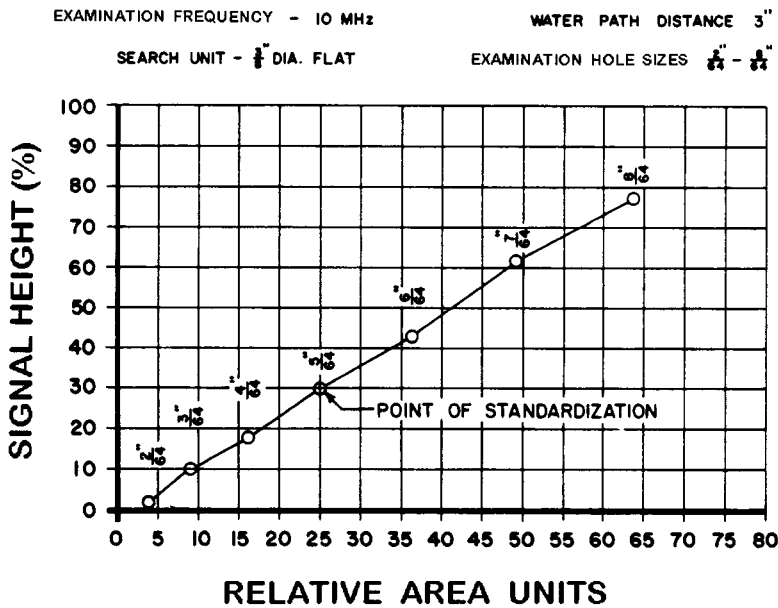


FIG. 2 Shadow-Graph (20× Magnification) of $1\frac{1}{64}$ in. (6.4 mm) Diameter Flat-Bottom Hole Replica as Viewed on 62.5× Optical Comparator with Commercial Viewing Screen (Reduced $\frac{1}{2}$)



NOTE 1—This response curve shows the relationship of a set of area/amplitude when tested at the above examination parameters. The curve may vary when the examination is performed at other frequencies with different diameter search units and different water path distances or if a contact test method is used.

FIG. 3 Typical Area Amplitude Ultrasonic Response Curve from 4340 Steel Reference Blocks

78.4 Area/amplitude and distance/amplitude response curves are greatly affected by variations in the configuration of the beam of the search unit, by the near field/far field characteristics and by the horizontal and vertical linearity responses of the test instrument. Therefore, consideration should be given to the operating characteristics of the search unit and instrument (generally available from the equipment manufacturer) when evaluating the response curves from the reference blocks.

89. Block Identification and Finish

89.1 Reference blocks exhibiting acceptable physical dimensions and ultrasonic-response characteristics may be submitted to the following procedures for identification and application of protective finish:

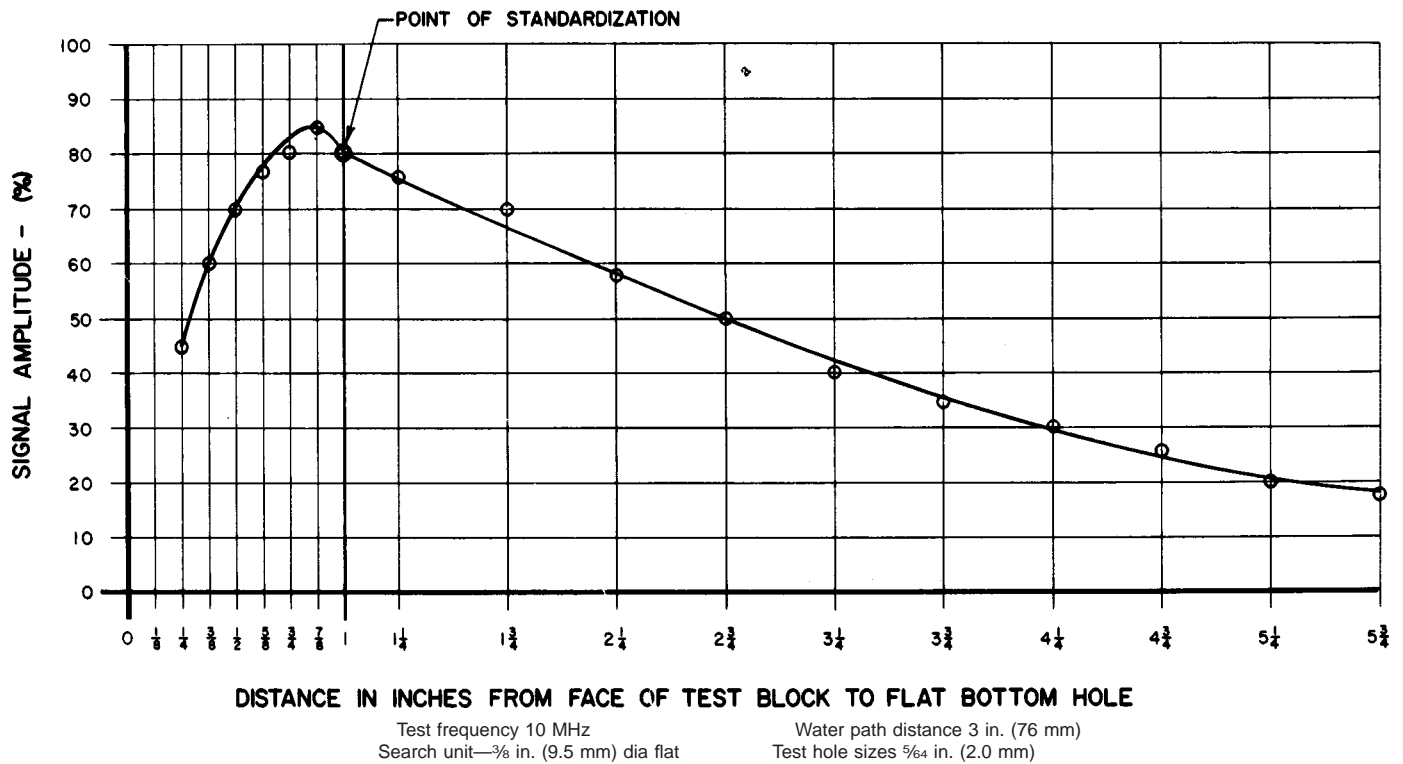
89.1.1 *Identification*—Each block must be permanently marked (metal stamping or engraving required) with the material AISI alloy or grade, or both, size of the test examination hole in $\frac{1}{64}$ -in. (0.4 mm) increments and distance in inches from the entry surface to the FBH. For example, the identification of 4340-5-0300 signifies an AISI 4340 steel reference block with a $\frac{5}{64}$ -in.

TEST FREQUENCY - 10 MHz

WATER PATH DISTANCE 3"

SEARCH UNIT - $\frac{3}{8}$ " DIA. FLAT

TEST HOLE SIZES $\frac{1}{4}$ "



NOTE 1—This response curve shows the relationship of a set of distance/amplitude when tested at the above test parameters. The curve may vary when the test is performed at other frequencies with different diameter search units and different water-path distances or if a contact test method is used.

FIG. 4 Typical Distance/Amplitude Ultrasonic-Response Curve from 4340 Steel Reference Blocks

(2.0-mm) diameter FBH at a 3-in. (76-mm) distance from the test examination surface. Where several sets and types of blocks are being used, a serial number identification must be used. Serial numbers are important when comparing sets of blocks to their respective response curves and to other sets of blocks.

91.1.2 Protective Finish—After plugging of the FBHs, a protective coating may be applied to the exterior surfaces of reference blocks fabricated from corrodable-type materials. However, the coating must not significantly affect the physical dimensions or ultrasonic-response characteristics of the blocks. Generally, nickel plating to a maximum thickness of 0.0008 in. (0.020 mm) is an acceptable coating for carbon and alloy steel blocks which are to be used in a corrosive environment.

910. Plugging Procedure

910.1 Reference blocks that have met the requirements for physical dimensions and ultrasonic response and have been properly identified may be plugged in accordance with the following recommended procedure:

910.1.1 Clean the test examination hole with a noncorrosive solvent and dry with a stream of filtered and dried air.

910.1.2 Insert a press-fitted plug (same alloy as reference block) in the counterbore opening as shown in Fig. 1.

910.1.3 Seal the opening by peening the edges of the plug to move the metal outward against the sides of the counterbore.

910.1.4 Grind as needed to blend the back surface and plug to the required tolerances shown in Fig. 1.

910.2 An optional plugging method that may be used on reference blocks fabricated from noncorrodable alloys is as follows:

910.2.1 Clean the test examination hole as described in 910.1.1.

910.2.2 Insert a 1/8-in. (3.2-mm) long press-fitted phenolic or TFE-fluorocarbon plug to 1/2 the hole length.

910.2.3 Fill the remainder of the hole with silicone rubber compound or suitable epoxy sealant.

910.2.4 Blend the plug to the back surface as needed. The machined counterbore may be omitted if this plugging technique is used. An adequate air gap must be maintained at the hole bottom.

101. Keywords

101.1 area-amplitude reference blocks; distance-amplitude reference blocks; metal alloy reference blocks; nondestructive testing; ultrasonic reference blocks

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