NBS TECHNICAL NOTE 924

U.S. DEPARTMENT OF COMMERCE / National Bureau of Standards

Procedures for the Calibration of ASTM E127-Type Ultrasonic Reference Blocks

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CONTENTS

PROCEDURES FOR THE CALIBRATION OF ASTM E127-TYPE ULTRASONIC REFERENCE BLOCKS

D. J. Chwirut[a], G. F. Sushinsky[b], and D. G. Eitzen[a]

ABSTRACT

A service for the calibration of ASTM E127-type ultrasonic reference blocks has been established at the National Bureau of Standards. A single well-characterized reference block, carefully chosen to be as close as possible to "typical" or "nominal", has been designated as an interim standard against which other blocks can be compared. As refinements are made and the system becomes better understood, new standards may be developed leading to the development of an absolute national standard. The facilities and procedures used in this calibration service are described herein.

Key Words: Aluminum ultrasonic reference standards; ASTM-type reference standards; calibration; interim reference standard; longitudinal beam; measurement system; nondestructive evaluation; pulse-echo; ultrasonics.

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1. INTRODUCTION

The National Bureau of Standards (NBS) has established a service for the calibration of ASTM E127-type ultrasonic reference blocks (Fig. 1). At present, the calibration service is designed to determine the ultrasonic response of 7075 aluminum alloy reference blocks relative to the response obtained from a designated interim reference standard. This report is intended to give some of the background information leading to the calibration service, to outline, in brief, some considerations necessary for a proper measurement system, and to describe in detail the laboratory equipment and operating procedures to be used in the calibration service.

It should be emphasized that this is only an intermediate step toward the rationalization of a somewhat chaotic measurement system. Research is still underway, both at the NBS and elsewhere, to make improvements in the entire system. It is possible, and in fact likely, that as the state-of-the-art of ultrasonic measurements evolves, changes will be made in the calibration service.

Requests for information or comments about this calibration service should be addressed to

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2. BACKGROUND

In the late nineteen-forties, flat-bottomed hole artifacts were introduced as industrial reference standards for ultrasonic testing. As they developed, these standards were produced by several companies to a given set of physical dimensions. However, the consistency of the ultrasonic response obtained from nominally identical standards was not maintained between different sets of blocks. As the primary use of these standards shifted from equipment standardization to sensitivity setting and defect size characterization, the need for consistency of ultrasonic response became critical. This system was improved somewhat in 1958 with the adoption of ASTM E127-58T, "Tentative Recommended Practice for Fabricating and Checking Aluminum Alloy Ultrasonic Standard Reference Blocks" [1]. Some of the early history of reference blocks and the development of this original ASTM document can be found in [2] and [3].

As the field of ultrasonic testing and inspection continued to develop, the original ASTM E127 document was revised in 1964 and again in 1975 [4, 5]. The 1975 revision of E127 was adopted by the industry in spite of acknowledged significant weaknesses. The adoption was in part because the older version was about to expire and current purchasing agreements require that some referenceable document be in existence. Also, the ASTM E127 document is referenced in many other standards documents including several other ASTM documents. The 1975 document increased the allowable variability of the return signal amplitude from ±10 percent to ±2 dB (decibel) around a nominal value which is itself somewhat arbitrarily chosen.

This increase in allowable variability is not because ± 2dB is acceptable, but because it approximates the state-of-the-art of field blocks today. This amount of variability results in unfair competition between suppliers, disagreements at the supplier-user interface, and overdesigned systems and unnecessary system shutdowns or overhauls because of the large measurement uncertainty. This situation is clearly unacceptable.

Efforts to remedy this situation are underway in several laboratories. The participants of ASTM Section E7.06.02 are seeking a solution that will allow blocks to be fabricated, inexpensively, within a much tighter tolerance. At NBS, a program is underway, sponsored by the Air Force Materials Laboratory (AFML), National Aeronautics and Space Administration (NASA), and Army Materials and Mechanics Research Center (AMMRC), to attack the problem systematically and to provide a solution. The first year's effort [6] has identified several of the factors contributing to ultrasonic response variability. These include metallurgical, geometric, and measurement system problems. Efforts to eliminate these variables from the measurement process are continuing.

In the meantime, a limited calibration service is being offered to allow the comparison of users' blocks to a fixed reference. The data from this calibration must be interpreted with caution because of two limitations in the service. First, the reference standard has been chosen somewhat arbitrarily; the unit being measured has not been related to any SI units, is difficult to define, and is not absolute. Second, because of the arbitrariness of the reference and lack of total understanding of the entire measurement system, it is likely that changes will be made to the calibration process in the future. In interpreting data from the calibration service, it should be realized that a block with a slightly different response than the NBS interim reference standard is not, de facto, incorrect or unacceptable. More important, at this time, are the relative responses of the blocks used by different operational groups within an organization working to the same inspection requirements, competitors, or those involved in a buyer-seller relationship.

3. MEASUREMENT SYSTEM PHILOSOPHY

A generalized measurement system can be looked upon as consisting of three parts: the quantity being measured, the measurement algorithm or operating procedures, and the interpretive model which relates the measured signal to the physical quantity being measured through the laws of physics. As an example, consider the system for mass measurements. The quantity being measured could be the mass of a stainless steel artifact, and the algorithm could be comparison against a known mass on a two-pan balance under specified conditions. The model includes zero net moment on the balance, Newton's second law, Archimedes' principle, etc. One can define the system to be proper if the measurements are repeatable, within a known uncertainty, on the same quantity, on different systems, at different locations, and as long as all requirements of the algorithm and model are met. Usually, we must define a set of objects and a domain of operating conditions under which the system is proper. For example, a given mass measurement system may be proper only for stainless steel masses between 10^{-3} and 10^{3} grams (set) and a limited range of air densities (domain). More on this measurement philosophy can be found in [7, 8, 9].

The ultrasonic measurement system is much more complex than the mass system. What quantity is being measured? It certainly isn't hole diameter, although the information may be used to infer something about hole diameter. In a pure sense, we appear to be measuring "ultrasonic reflectivity" (i.e. $\frac{\text{return energy}}{\text{output energy}}$), although the model is not yet well-enough understood to allow an absolute determination of $\frac{\text{return energy}}{\text{output energy}}$. Therefore, ultrasonic measurement systems can now only be used strictly in a comparative sense.

We are thus led to the designation of an independently defined standard, not derived from any of the SI base units. This becomes the primary standard for this type of ultrasonic measurement. If, in the future, our understanding of the physics of the sound wave/medium/reflector interactions improves, possibly this measurement system can be related back to the SI base units. What remains for us now are the formulation of the <u>algorithm</u>, the definition of the <u>set</u> and <u>domain</u> under which the system is <u>proper</u>, and the assurance that the measurement system is under control and that the results are properly used in awareness that the <u>model</u> is weak.

For the calibration service described herein, the <u>quantity</u> is the ultrasonic response compared to the "unit". The "unit" has been temporarily defined by a 5-0050* aluminum-alloy reference block with its response set to

*ASTM E127-75 indentification system. 5 - indicates that the hole diameter is 5/64 ths in (2.0 mm). This is referred to as a "No. 5" block. 0050 - indicates that the metal travel distance is 0.50 in (12.7 mm).

read 80 divisions on an oscilloscope screen. The set has been restricted to 7075 aluminum alloy blocks, in the block sizes (hole diameter and metal distance combinations) specified in [5]. The domain is the most difficult to specify without making the process so restrictive as to be unreproducable or unusable. The instrument, pulser, pulse shape, pulse length, transducer type and frequency, water temperature, etc., all affect the measurements to some degree. Practically, a combination of these parameters must be selected that can be reproduced by users in the field, or a model to predict the effects that these variables will have on the measurements must be formulated. The algorithm itself has been selected to be representative of good practice in the field, with some necessary compromises being made for the sake of system stability or reproducibility. As a next step past the calibration service, it is anticipated that a program to determine the properness of field measurements will be initiated. Sets of reference blocks will be fabricated and carefully quantified by comparison to the interim standard on the NBS ultrasonic measurement system. These can then be circulated in sets to field users to determine if their relative responses are the same on all "nominally identical" systems, or to provide the appropriate transfer mechanism so that users' blocks can be calibrated with their own measurement systems. Changes to the algorithm or domain can then be made, if necessary, to assure the properness of the measurement system. This is the first step in the formulation of a Measurement Assurance Program (MAP). This is, in effect, a feedback loop involving users and the primary standards laboratory to assure that the standards are being disseminated properly and that good field measurements consistent with accepted standards are being taken.

4. MEASUREMENT FACILITY

Following is a description of the operating characteristics of the principal equipment used in the calibration service. Several equipment parameters have been identified as affecting the relative block-to-block response and are, therefore, specified or characterized in some manner. It is intended that facilities with similar equipment could obtain the same results using similar procedures. The overall laboratory setup is shown in Figure 2.

4.1 Transducers

In order to provide a common basis for comparison, all of the reference blocks will be calibrated using quartz transducers as described below. However, if the customer desires, additional comparisons will be made using the customer's transducer with our equipment. These transducers should be either 2.25, 5, or 10 MHz, and terminate in a standard UHF connection. Further additional measurement conditions can be discussed on an individual basis.

The transducers to be used for the basic calibration service are commercially available, 5 MHz (nominal) center-frequency, 0.375 in (9.5 mm) (nominal) diameter active quartz element, immersion ultrasonic search units. These have been designated lab standards 3 and 4 (LS-3 and LS-4). This type was chosen for two reasons - the reproducibility of nominally identical transducers appears to be much better than that of other types of transducers, and a significant amount of reference block data taken with this type of transducer is available.

Certain characteristics of the transducers were measured to assist in determining their suitability for this work and to aid in their duplication or replacement. The axial profiles and Y_o^+ and Y_1^- beam profiles were measured, as outlined in [5], for five transducers of this type. These profiles for the two transducers with the closest characteristics (LS-3 and LS-4) are shown in Figures 3 and 4. The rf signal waveforms and frequency spectra of the signals reflected from a flat quartz plate, with the transducers excited by the broadband pulser described in [6], are shown in Figures 5 and 6. The relative power outputs versus excitation frequency at constant voltage are shown in Figures 7 and 8*. Some of the important characteristics of these transducers are summarized in Table 1. The beam symmetries, band widths, center frequencies, etc., for LS-3 and LS-4 are very similar and appear to make them acceptable for this type of work [5, 10, 11].

4.2 Ultrasonic Test Instrument

A commercial ultrasonic flaw detector forms the core of the NBS ultrasonic calibration facility. This instrument consists of three main modules; a pulser/receiver, timer, and power supply/display.

4.2.1 Pulser/Receiver

The pulser/receiver unit transmits tuned, high frequency rf pulses to the transducer, receives the return pulses from the transducer, amplifies the pulses, converts them to video pulses, and sends them to the timer. It is a fixed gain amplifier and variable attenuator receiver. Available frequencies

*These measurements were taken in the Auditory Acoustics Section at NBS. Further information about the procedure can be obtained from F. R. Breckenridge or C. E. Tschiegg, Auditory Acoustics Program Team, National Bureau of Standards, Washington, D.C. 20234.

are 2.25, 5, and 10 MHz. The adjustments that can be made to the pulser/receiver are: pulse length (time duration of output pulse), pulse tuning (optimizes output signal by compensating for cable and transducer impedance), attenuator controls (three switches control attenuation in 1-dB increments), "cal" screw (infinitely adjustable attenuator control), reject (noise suppressor), and frequency selector.

The ASTM documents [1, 4, and 5] rely on the response from steel ball references as primary standards in establishing the appropriate response from ultrasonic reference blocks. Experiments performed at the NBS laboratory [12] have shown that several factors affect this ball-to-block relationship. Such factors include pulser control adjustments of pulse length and "cal". Further experiments at this laboratory [12] have indicated a minimal effect of such variables on relative block-to-block characterization; but in keeping with good experimental practice, no control adjustments are made that would seriously affect either a ball-to-block or block-to-block calibration system. Therefore, for the purposes of this calibration service, the pulse length is not changed, and the "cal" adjustment is used only for signal adjustments less than ±0.5 dB. That is, the signal is set to the proper value within ±0.5 dB with the three switchs on the attenuator. The signal is then set to the "exact" value with the "cal" screw. The reject control is left off during all signal readings. All testing is done in the <u>normal</u> (pulse-echo) mode with the transducer connected to the <u>receive</u> jack. The rf waveform and frequency spectrum of the pulser output pulse are shown in Figure 9. This signal was taken from the center pin of the receive jack, with no transducer, in the "normal" mode, and was attenuated by 36 dB.

4.2.2 Timer

The timer unit provides variable horizontal time bases for displaying ultrasonic echo video traces as well as synchronizing signals for measuring and signal processing subunits. More specifically, the timer is designed to generate rate, sweep delay and sweep functions that can be varied by preset calibrated steps, or by vernier dials that are resetable and can be locked into position.

The only active control that affects the ultrasonic signals is the pulse rate, which controls the repetition rate of the output pulse. This control is kept at 500 Hz.

4.2.3 Power Supply/Display

The power supply/display unit includes the main instrument chassis and contains the appropriate low and high voltage power supplies to energize the other modules of the entire unit. It also contains the Cathode Ray Tube (CRT) display, with vertical graticule lines marked in tens from 0 to 120 units. The total screen height is 3.0 in (7.6 cm).

4.3 Immersion Tank

All measurements are taken by immersion testing. The tank and lab scanner described in [6], are used. The couplant is distilled water. The water temperature is maintained at 70-76 °F (21-24 °C). Experiments at this laboratory [12] have shown that within this range, changes in water temperature do not change relative block-to-block response.

4.4 Equipment Standardization

The test equipment must be adjusted in order that both the receiver amplifier and video display are linear over the range to be used. Failure to do so would result in different block-to-block response ratios being measured depending on the scope reading or attenuator setting.

Two methods frequently used to determine vertical linearity are the ball diameter vs. ultrasonic response at constant gain method [4] and the ratio of two responses vs. gain method [13]. However, knowledgeable people in the ultrasonics industry are not entirely happy with either of these methods. Therefore, a method combining some of the features of both methods was used. Ultrasonic response data were taken from steel balls at five different attenuator settings approximately covering the settings of interest. The standardization points were 1/16, 1/8, 1/4, 1/2, and 1 in (0.158, 0.318, 0.635, 1.27, and 2.54 cm) diameter steel balls with their ultrasonic responses set to read 50 units on the scope graticule. These data are shown in Figure 10. The linearity of the constant attenuation lines indicates that the oscilloscope display is linear for each of those settings. Additionally, the ratios of the slopes of adjacent lines are 2.01, 2.01, 2.00 and 2.00 moving from curve A to curve E. This indicates that the amplifier/attenuator system is linear within about one-half percent within this attenuator range. Finally, the ratios of the responses from the two smallest balls were constant within about ±5 percent for those settings for which readings were above about 20 units on the scope. These data allow us to define a vertical linearity limit of 100 divisions on the CRT.

4.5 Interim Reference Standard

A large amount of data was taken at the NBS ultrasonic facility on many reference blocks. Reference blocks of different sizes from different manufacturers were tested [12]. Based on the analysis of these data, a 5-0050 reference block, designated NBS-URB-IRS-1 (National Bureau of Standards - Ultrasonic Reference Block - Interim Reference Standard - 1), has been chosen as an interim reference standard against which other blocks will be compared. Additionally, six other reference blocks, designated CS-1 through 6 (Check Standard 1 through 6) have been chosen as check standards. The mean ultrasonic responses, and standard deviations of the readings, when compared to NBS-URB-IRS-1, have been carefully determined. These check standards will be read along with the blocks being calibrated to insure that the measurement system is under control and that all equipment settings have been made properly.

5. CALIBRATION PROCEDURE

5.1 Mechanics of Ultrasonic Reference Block Measurement

All measurements are made by immersion, pulse-echo, longitudinal wave, ultrasonic testing using the equipment described in Section 4. All blocks are generally clean and free of oil, grease, rust inhibitors, etc. General purpose solvents or cleaning agents, such as acetone, methyl-ethyl-ketone, etc., are used as necessary. The reference blocks are placed in the immersion tank and interrogated by the ultrasonic transducer. Distilled water is the couplant. A water distance of 3.50 ± 0.03 in (8.90 ± .08 cm) is maintained between the transducer face and the top surface of the block being tested. Initially this distance is set using a calibrated steel scale;

for subsequent measurements, a reference time location on the scope is selected for the top-surface reflection. The angle of the transducer with respect to the block is adjusted to obtain the maximum indication from the block entry surface. This step insures true perpendicularity between the transducer beam and the block entry surface. After a normal ultrasonic beam is obtained, the transducer is positioned laterally to obtain a maximum response from the hole bottom. When the maximum response has been obtained in this manner, the height of the indication on the scope is read to the nearest 0.5 percent of the vertical linear limit (1/2 unit on the scope graticule).

5.2 Distance-Amplitude Sets

The equipment sensitivity is set in the following manner. The reference standard is read, and the gain is adjusted to obtain a reading of 80 percent of the vertical linear limit. Since the reference standard is a No. 5 block, this establishes the sensitivity for all No. 5 blocks. For other block sizes, the gain is adjusted up or down according to the square of the hole diameter ratio. For No. 8 blocks, this corresponds to decreasing the gain by a factor of $\left(\frac{5}{8}\right)^2 = 0.39$. In practice, the gain is reduced (attenuation increased) to reduce a reading of 80 to 31.5 percent of the vertical linear limit. For No. 3 blocks, the transducer is manipulated off center to obtain a reading of 30. The gain is increased by $\left(\frac{5}{3}\right)^2 = 2.78$ by increasing the reading of 30 to 83 percent. For all hole diameter sizes, after the -0225 or -0250 block is read, the gain is increased by $\left(\frac{80}{30}\right) = 2.67$. All blocks -0175 and longer are then read. This is the same principle as the "A curve - B curve" scheme adopted in [5]. The relative sensitivity levels for the different distance-amplitude blocks are summarized in Table 2. For the No. 3, 5, and 8 blocks a check standard is read on both the A curve and B curve to help identify erroneous gain settings or equipment malfunctions. The reading from the check standard must be within the previously determined standard deviation in order for a run to be accepted. Three replicate runs are taken.

5.3 Area-Amplitude Sets

The sensitivity for testing area-amplitude reference blocks is set in the same manner as a distance-amplitude set, i.e., the reference standard is set to read 80 percent of the vertical linear limit. The No. 3, 5, and 8 blocks from the Area-Amplitude set are then read, as if they were parts of Distance-Amplitude sets. The sensitivity is then set so that the No. 8 block reads 100 percent of the vertical linear limit. The No. 7, 6, 5, and 4 blocks are read at this sensitivity. The gain is then increased by a factor of 3 (30 → 90 on the scope), and the No. 4, 3, 2, and 1 blocks are read. The gain is then increased by a factor of 3 again, and the No. 2 and 1 blocks are read. The relative sensitivity levels are summarized in Table 2.

5.4 Reports

Typical Reports of Calibration are shown in the Appendix. Because no satisfactory physical model has yet been found that accurately predicts the distance-amplitude response data, the average of all data taken to date is included for comparison purposes. For the area-amplitude sets, the best-fit straight line through the origin (by least squares) is shown.

6. SUMMARY

A service for the calibration of ASTM-type ultrasonic reference blocks has been established. The rationale leading to the establishment of this service and the equipment and procedures used are described in detail. Extension of this service into a formal Measurement Assurance Program (MAP), to insure the consistency of field measurements, is planned.

7. ACKNOWLEDGMENTS

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Table 1 - Characteristics of Ultrasonic Transducers

Characteristic	Ref. Figure	Lab Std 3	Lab Std 4
Y_o^+, in (cm) [11]	3, 4	3.62(9.2)	3.5 (8.9)
Y_1^-, in (cm) [11]	3, 4	1.62(4.1)	1.62(4.1)
Maximum peak ratio at Y_1^-	3, 4	1.12	1.10
-6dB beam width at Y_o^+, in (cm)	3, 4	0.11(0.28)	0.11(0.28)
Center frequency (a), MHz	5(b), 6(b)	4.86	4.85
Center frequency (b), MHz	7, 8	4.90	4.85
-6dB bandwidth (a), MHz	5(b), 6(b)	0.91	1.0
No. of cycles > 10 percent of max. [14]	5(a), 6(a)	8	8

(a) From spectrum analyzer, broadband pulser, return signal from flat plate.

(b) Frequency at maximum power output.

Table 2 - Instrument Sensitivity Levels for Calibration of ASTM-Type Ultrasonic Reference Blocks

A. Distance - Amplitude Sets

Block	No. 5	No. 3	No. 8
Reference Standard	G(a)	G	G
-0050 through -0250	G	$\left(\frac{25}{9}\right)G$	$\left(\frac{25}{64}\right)G$
-0175 through 0600	$\left(\frac{8}{3}G\right)$	$\left(\frac{25}{9}\right)\left(\frac{8}{3}\right)G$	$\left(\frac{25}{64}\right)\left(\frac{8}{3}\right)G$

B. Area-Amplitude Sets

Block	Gain	Gain	Gain
No. 8	G´(b)	--	--
7	G´	--	--
6	G´	--	--
5	G´	--	--
4	G´	3G´	--
3	--	3G´	--
2	--	3G´	9G´
1	--	3G´	9G´

(a) G is the gain required to obtain a reading of 80 percent of vertical linear limit from the reference standard.

(b) G´ is the gain required to obtain a reading of 100 percent of vertical linear limit from the No. 8 block.

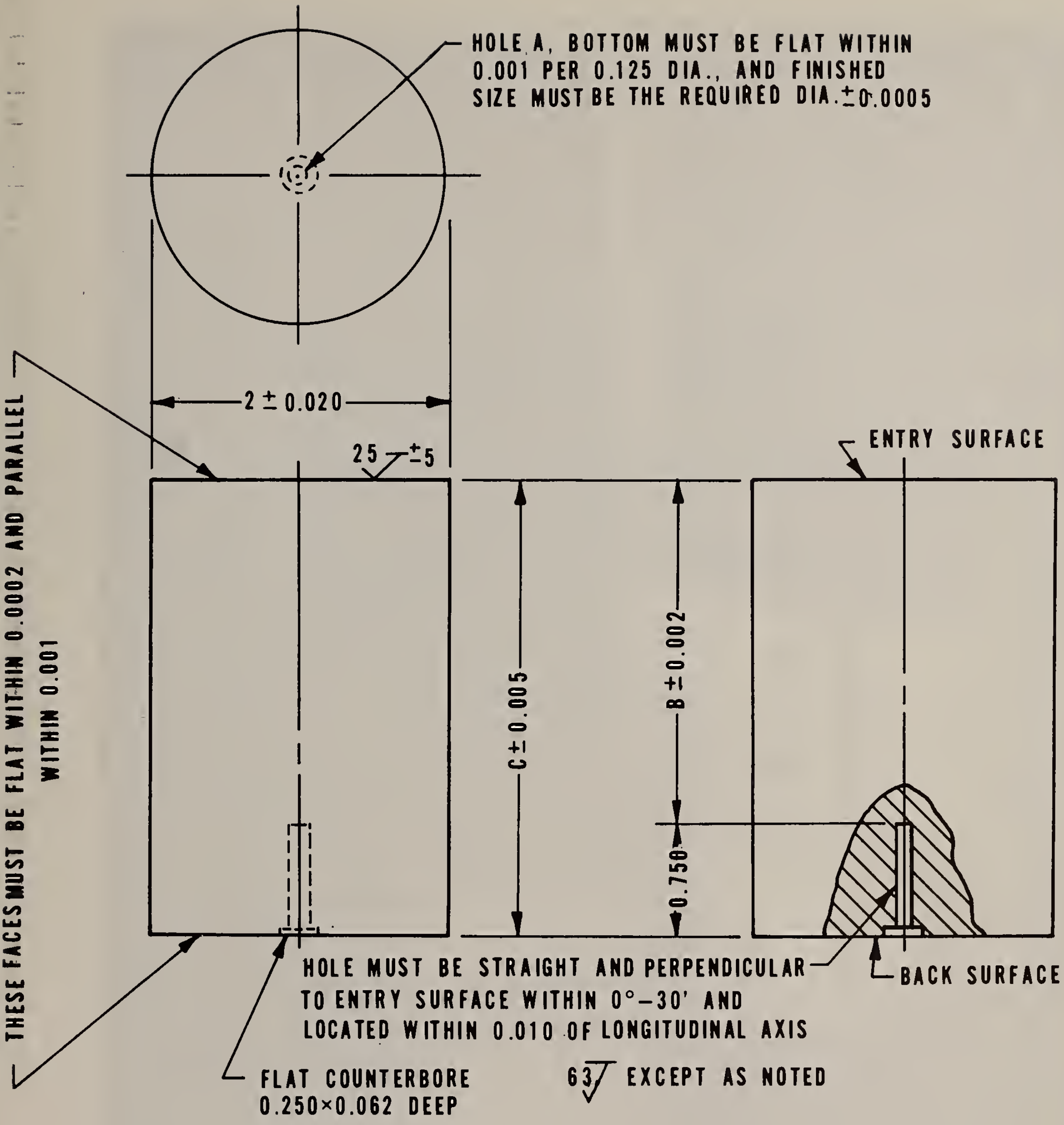


Figure 1. ASTM E127 ultrasonic standard reference block all dimensions in inches (1 in = 25.4 mm).

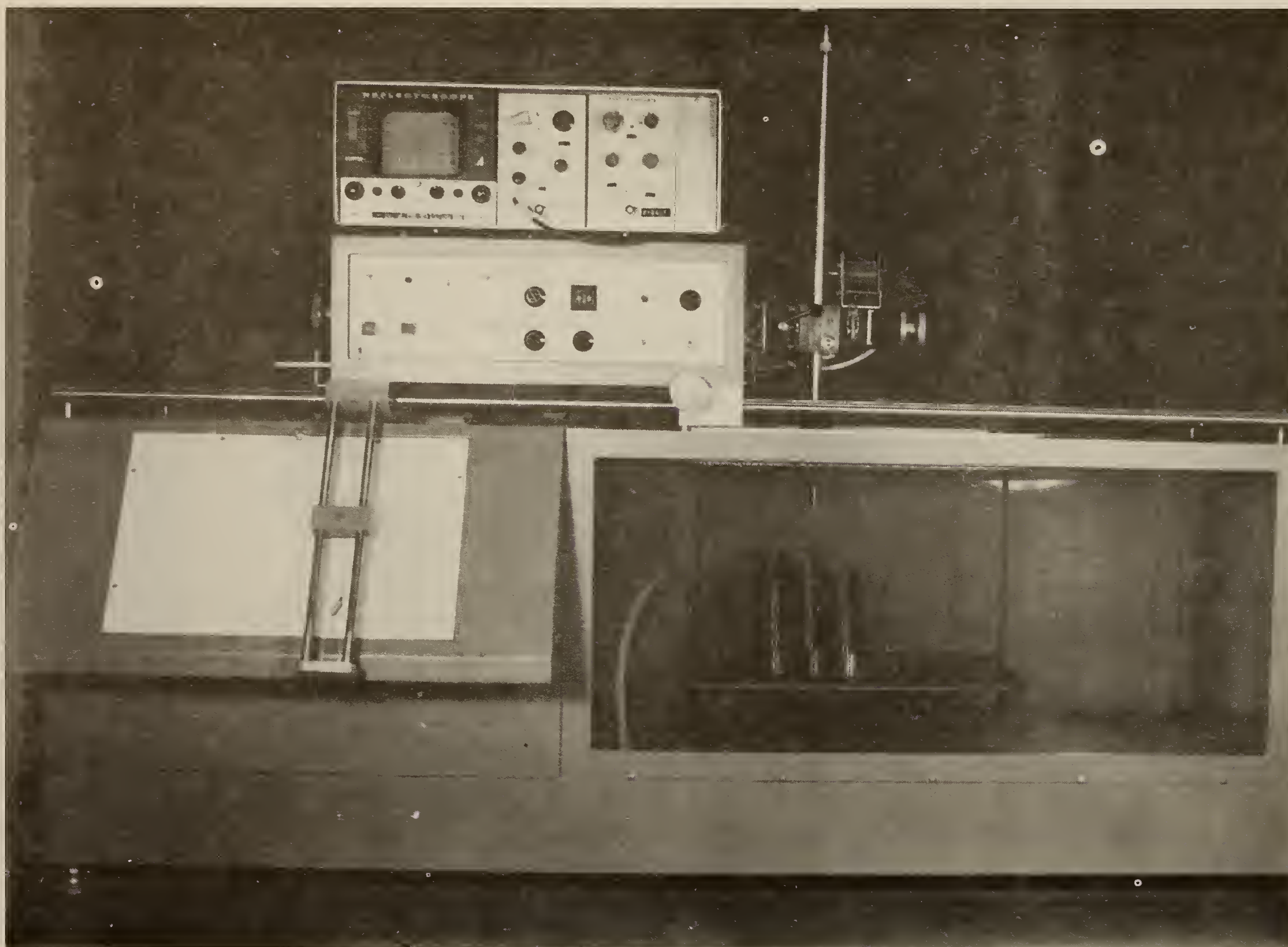


Figure 2. Ultrasonic reference block calibration facility.

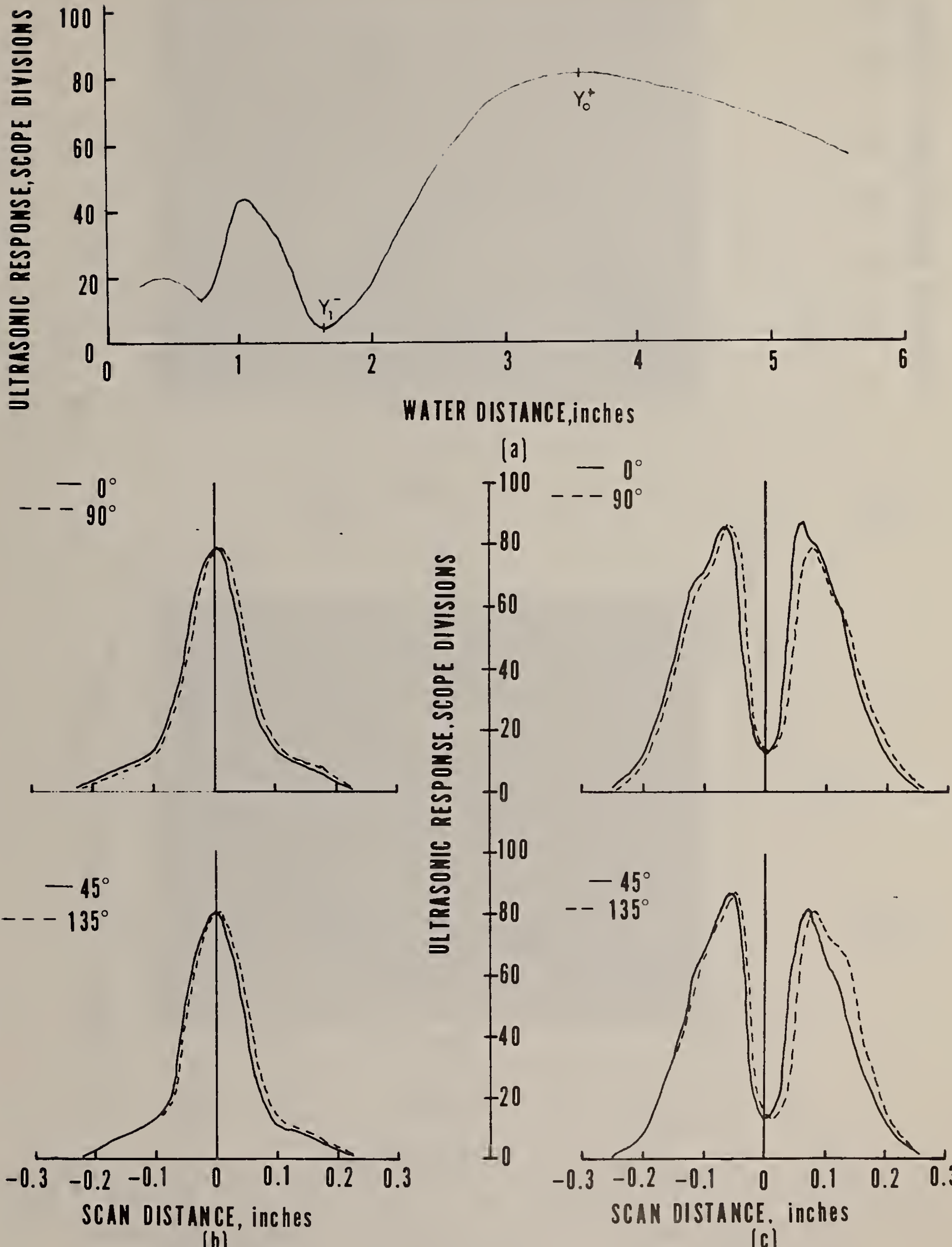


Figure 3. Transducer profiles for LS-3. (a) Axial profile, (b) Y_o^+ beam profile (water distances, 3.62 in), (c) Y_1^- Beam profile (water distance, 1.62 in). Target is 0.500 in diameter steel ball.

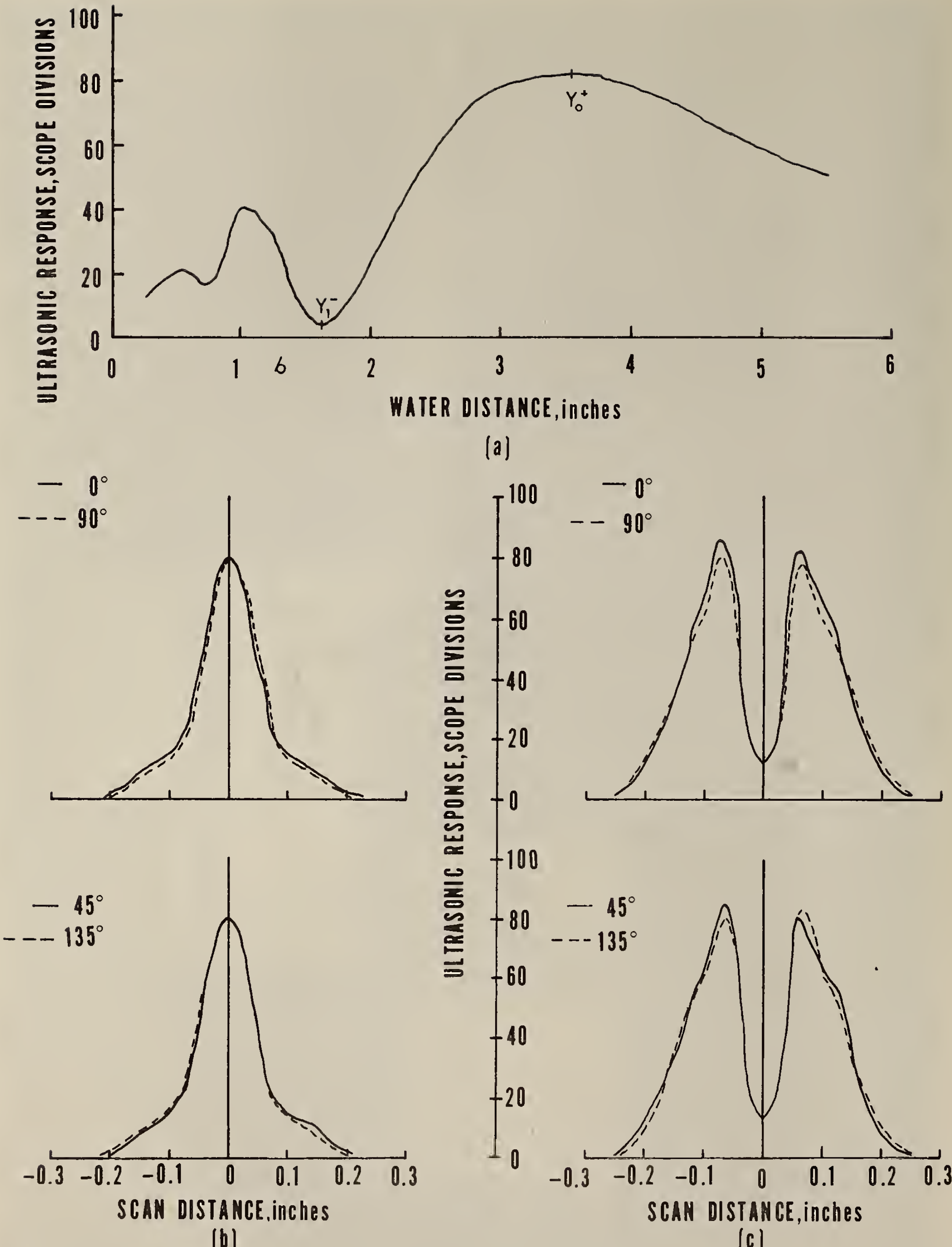


Figure 4. Transducer profiles for LS-4, (a) axial profile Y_o^+ beam profile (water distance, 3.5 in), (c) Y_1. Beam profile (water distance, 1.62 in). Target is 0.500 in diameter steel ball.

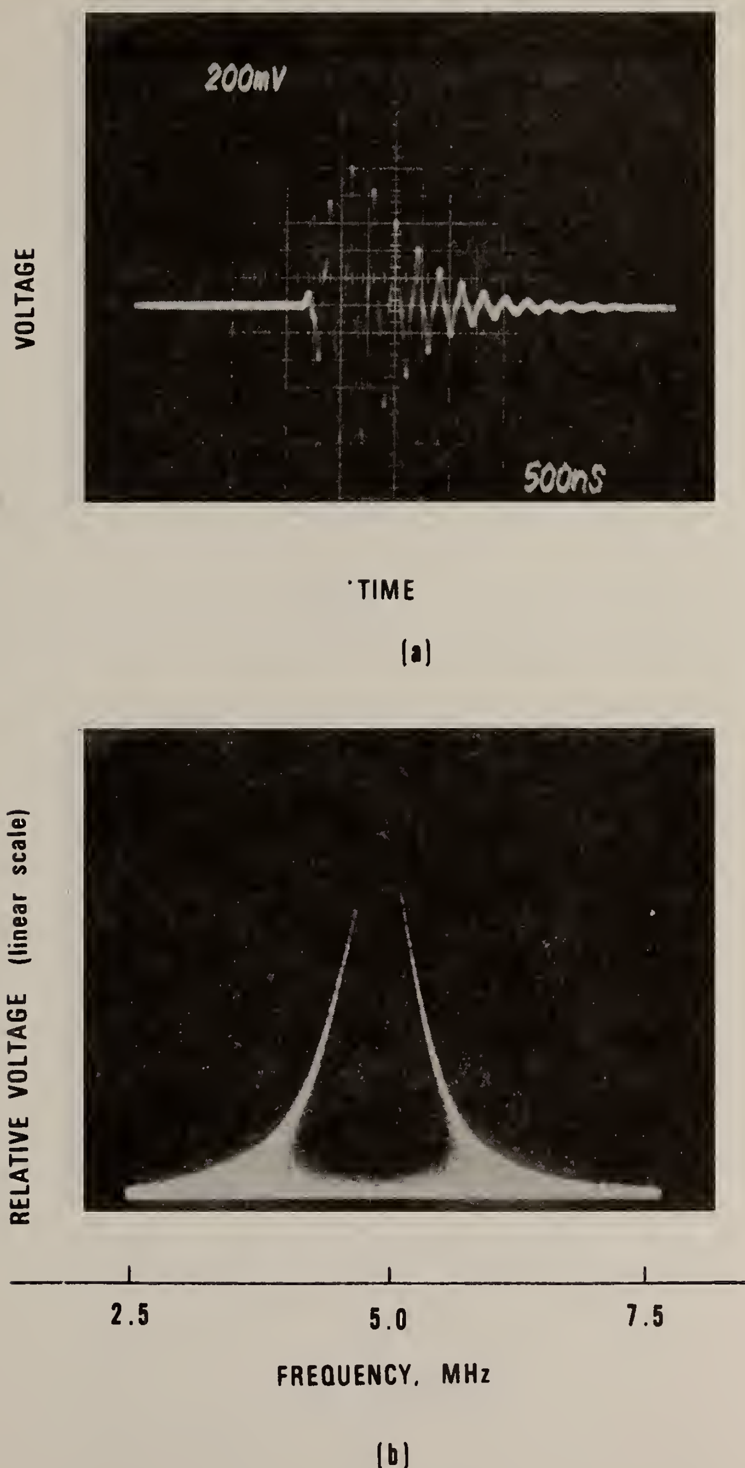


Figure 5. (a) R F waveform, and (b) frequency spectrum of pulse reflected from flat quartz plate, transducer LS-3, broadband pulser.

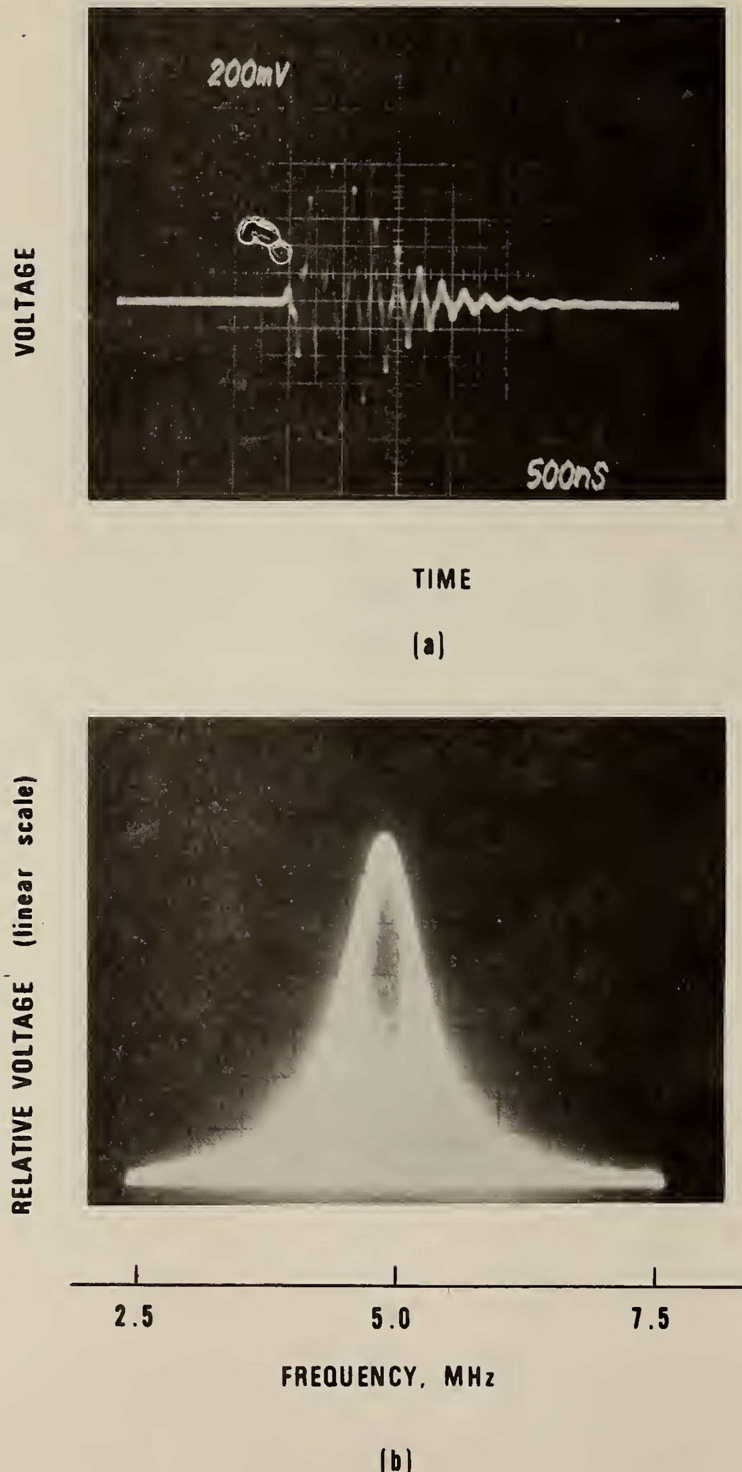


Figure 6. (a) Waveform, and (b) frequency spectrum of pulse reflected from flat quartz plate, transducer LS-4, broadband pulser.

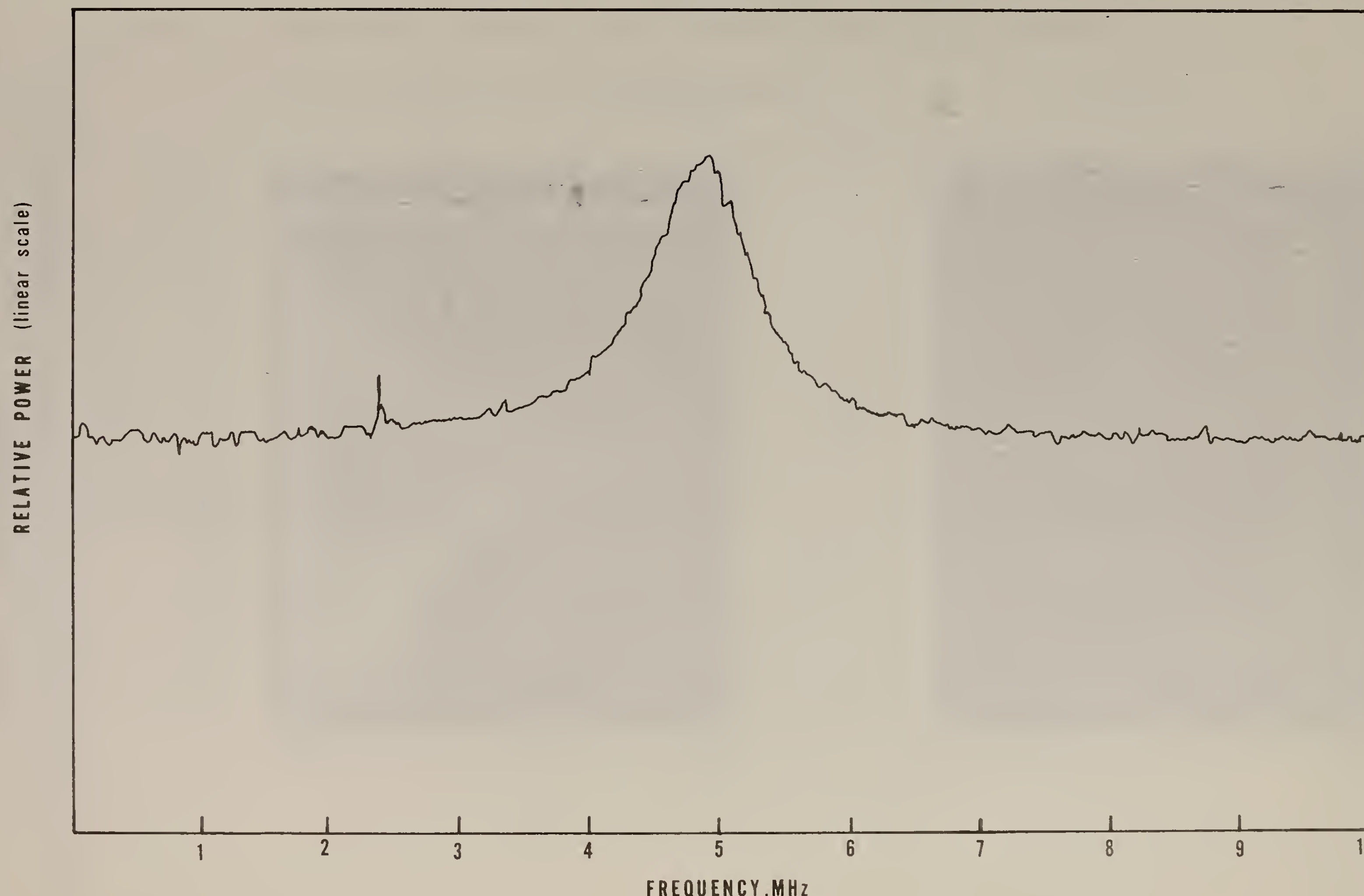


Figure 7. Relative power output versus excitation frequency for transducer LS-3.

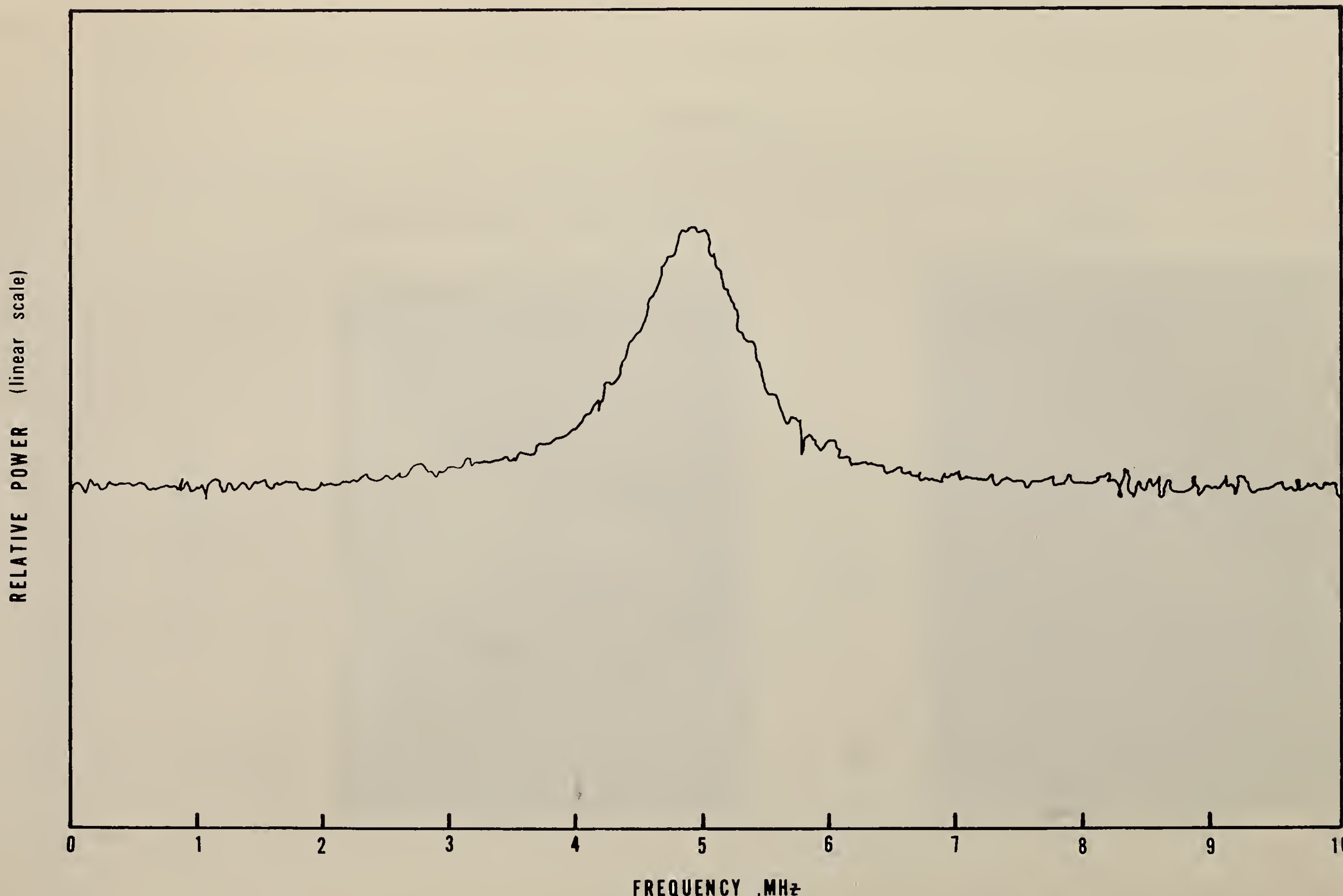


Figure 8. Relative power output versus excitation frequency for transducer LS-4.

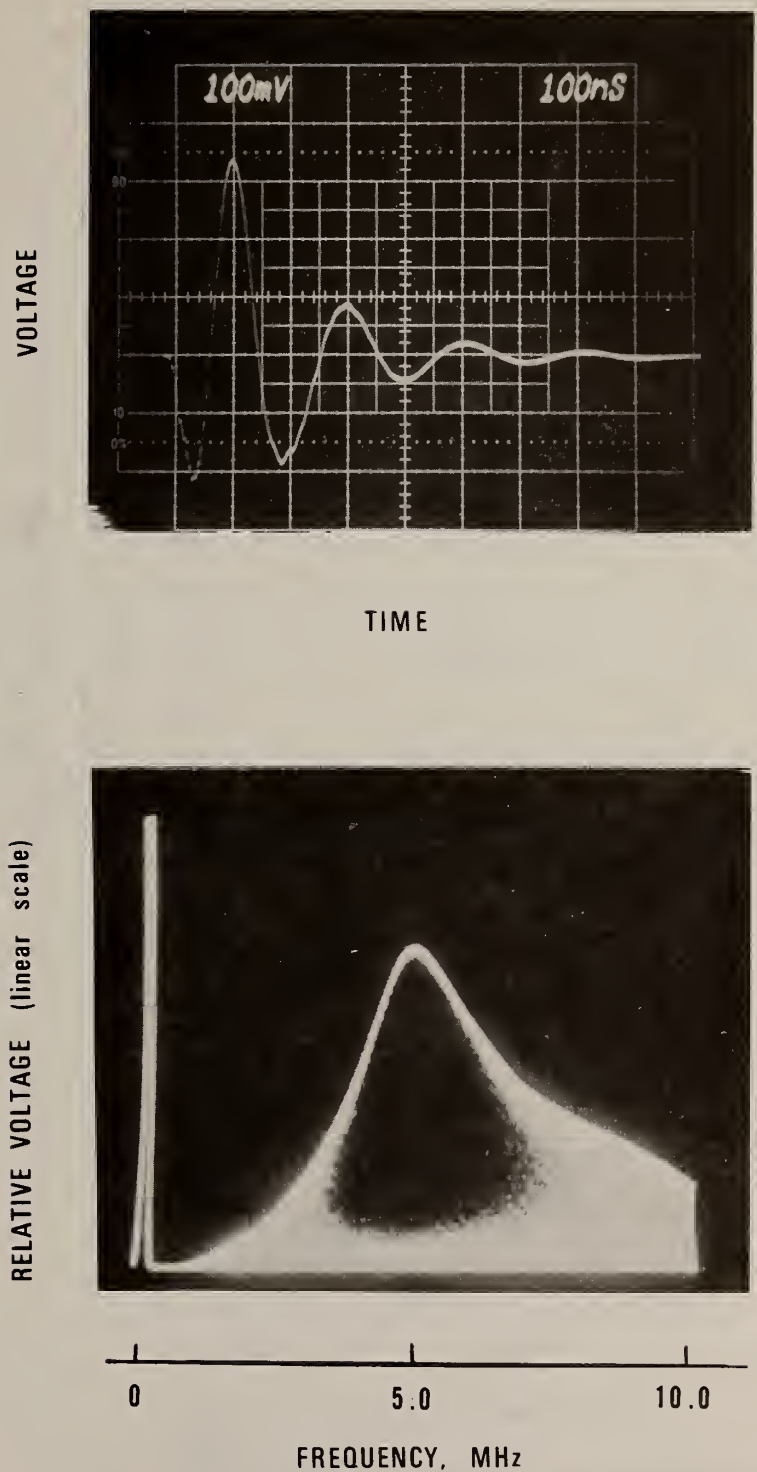


Figure 9. Pulser output waveform and frequency spectrum. Taken from center pin of "receive" jack, normal mode, 5 MHz, no transducer, attenuated.

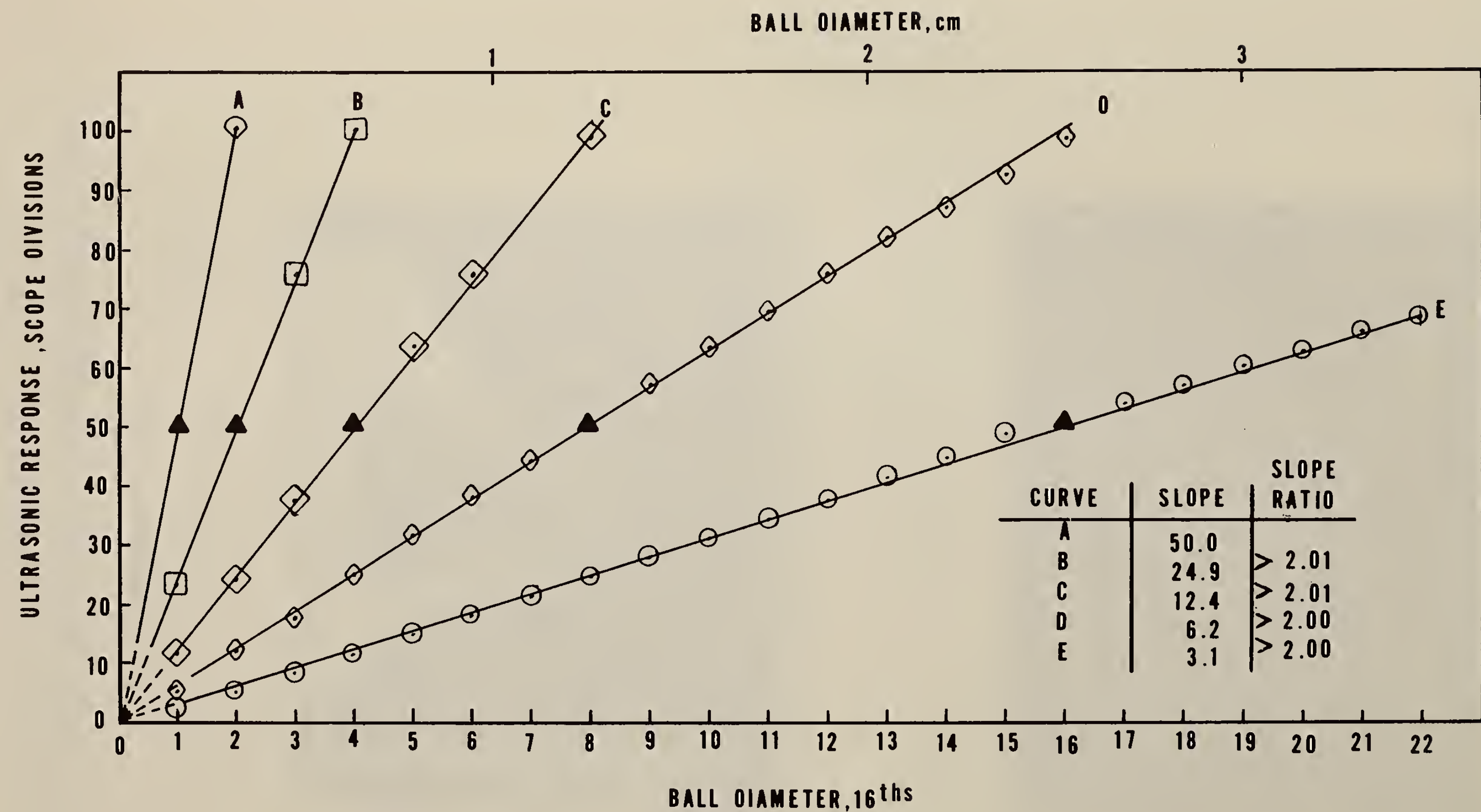


Figure 10. Ball diameter versus ultrasonic response data for linearity check.

APPENDIX

Typical Reports of Calibration for Distance-Amplitude and Area-Amplitude Sets of Ultrasonic Reference Blocks.

FORM NBS-443
(REV. 12-65)

U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS
WASHINGTON, D.C. 20234

Lab No.
Cost Center No.
Order No.
Date:

REPORT OF CALIBRATION

ULTRASONIC REFERENCE BLOCKS
Distance-Amplitude Set
S.N. 123

submitted by

Hypothetical Company
Anywhere, USA

The ultrasonic reference block distance-amplitude set cited above was evaluated following the procedures outlined in NBS Technical Note 924, "Procedures for the Calibration of ASTM E 127-Type Ultrasonic Reference Blocks." The equipment and reference standard used for the evaluation were as described in that report.

The data for three runs are shown on the enclosed table and graph. The amplitude of the ultrasonic signal reflected by the flat-bottomed hole is measured with the equipment gain set such that the amplitude of the signal received from the interim reference standard is fixed. The test block amplitude is thus "relative" to the interim reference standard. For comparison purposes only, the average values for all blocks previously evaluated are included. This is statistical information only and does not imply anything about the accuracy or acceptability of any of the blocks included.

Errors in setting the equipment sensitivity are undetermined. However, these errors are considered to be random and contribute to the standard deviation of the measurements. Based on the available data, it is estimated that the standard deviation of the mean of three readings is about 0.8 units.

Measurements were taken by the following NBS personnel:

______________________, ______________________, ______________________.

For the Director,
Institute for Basic Standards

Enclosures

RESULTS OF CALIBRATION

ULTRASONIC REFERENCE BLOCKS

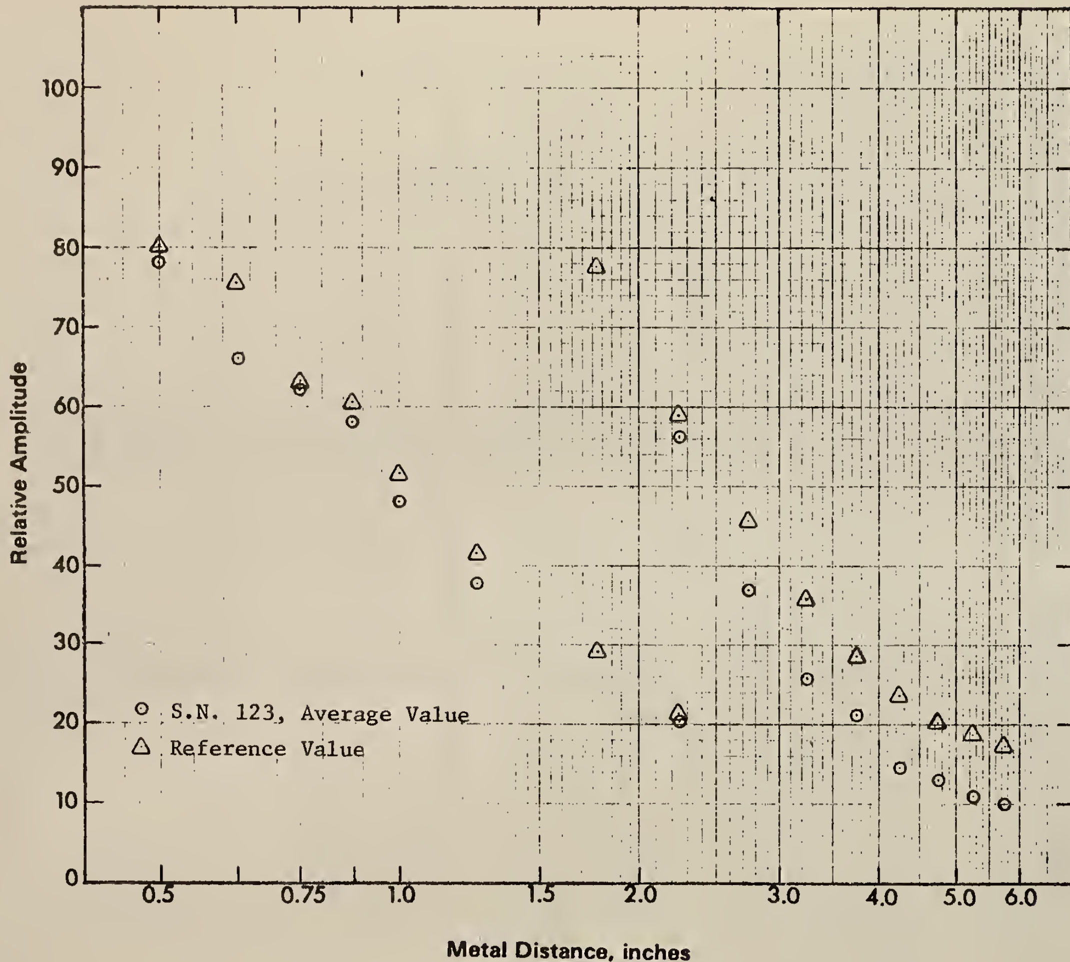
Distance-Amplitude Set

Submitted by Hypothetical Co.
Block Set 123
Hole Diameter 5 64ths

BLOCK I.D.	Reading 1 Value	Reading 1 Gain	Reading 2 Value	Reading 2 Gain	Reading 3 Value	Reading 3 Gain	Average	Reference Value (a)
NBS-URB-IRS-1	80	G1	80	G2	80	G3	80	-
CS-3(Nominal)	-		-		-		63.8	-
CS-3 (Read)	63		63		63		63	-
-0050	77.5		78.5		78		78	80.1
-0062	66		66		66		66	75.5
-0075	62		62		62		62	63.1
-0088	58		58.5		57.5		58	60.3
-0100	47.5		48		47.5		47.7	51.5
-0125	38		38		37.5		37.8	41.5
-0175	-		-		-		-	29.1
-0225	20		20.5		20		20.2	21.5
CS-4(Nominal)	-	2.67G1	-	2.67G2	-	2.67G3	28.1	-
CS-4 (Read)	27.5		28.5		28		28	-
-0175	-		-		-		-	77.6
-0225	55.5		57		56		56.2	58.7
-0275	37		37.5		36.5		37	45.7
-0325	25		26.5		26		25.8	35.9
-0375	20.5		21		21		20.7	28.3
-0425	14		14.5		15		14.5	23.6
-0475	12.5		13		13.5		13	20.1
-0525	10		11		11		10.7	18.6
-0575	10		10		10		10	17.2

	Reading 1	Reading 2	Reading 3
Observer	GDB	GFS	DJC
Date	3/2/76	3/3/76	3/4/76
Transducer	LS-4	LS-4	LS-4
Water Temp. °C	23.9	23.3	23.3

(a) Average of all data taken to date



BLOCK SET: S. N. 123

MFGR: Unknown

SUBMITTED BY: Hypothetical Co.

DATE:

METHOD: Immersion

INSTRUMENT: Tuned P/R

TRANSDUCER: LS-4

FREQ: 5 MHz

SIZE: 0.375 in Dia.

TYPE: Quartz

Calibration Results - Ultrasonic Reference Blocks

Distance - Amplitude Set

75 YEARS NBS 1901-1976

FORM NBS-443
(REV. 12-65)

U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS
WASHINGTON, D.C. 20234

Lab No.
Cost Center No.
Order No.
Date:

REPORT OF CALIBRATION

ULTRASONIC REFERENCE BLOCKS
Area Amplitude Set

submitted by

Hypothetical Company
Anywhere, USA

The ultrasonic reference block area amplitude set cited above was evaluated following the procedures outlined in NBS Technical Note 924, "Procedures for the Calibration of ASTM E127-Type Ultrasonic Reference Blocks". The equipment and reference standard used for the evaluation were as described in that report.

The data for three runs are shown on the enclosed table and graph. The amplitude of the ultrasonic signal reflected by the flat-bottomed hole is measured with the equipment gain set such that the amplitude of the signal received from the interim reference standard is fixed. The test block amplitude is thus "relative" to the interim reference standard. For comparison purposes only, the best fit straight line through the origin (by least squares) is included.

Errors in setting the equipment sensitivity are undetermined. However, these errors are considered to be random and contribute to the standard deviation of the measurements. Based on the available data, it is estimated that the standard deviation of the mean of three readings is about 0.8 units.

Measurements were taken by the following NBS personnel:

________________________, ________________________, ____________________.

For the Director,
Institute for Basic Standards

Enclosures

RESULTS OF CALIBRATION

ULTRASONIC REFERENCE BLOCKS

Area-Amplitude Set

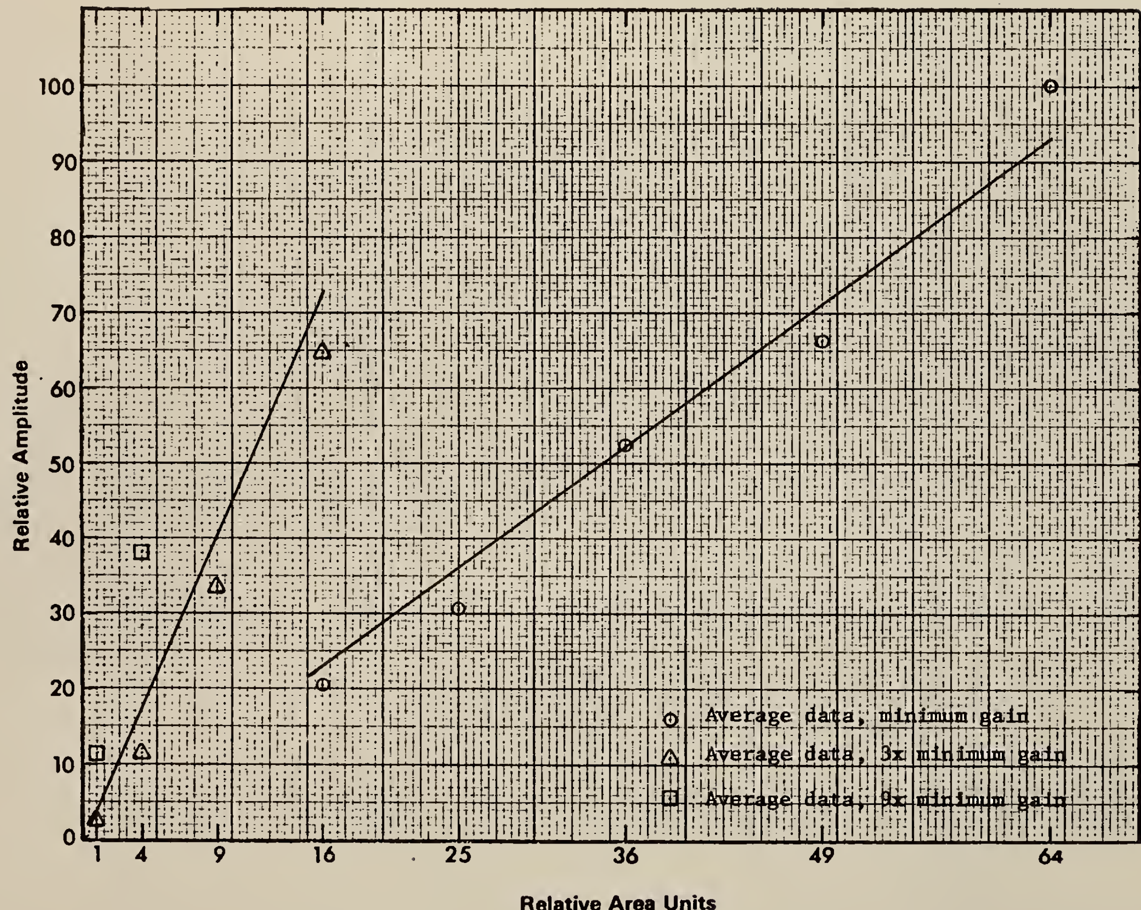
Submitted by Hypothetical Co.
Block Set as Indicated Below
Metal Distance 3 in

		Reading 1		Reading 2		Reading 3			Reference
BLOCK I.D.	S/N	Value	Gain	Value	Gain	Value	Gain	Average	Value
NBS-URB-IRS-1	-	80	G1	80	G5	80	G9	80	-
CS-4 (Nominal)	-	-	2.67G1	-	2.67G5	-	2.67G9	28.1	-
CS-4 (Read)	-	28		28.5		27.5		28.0	-
5-0300	A-0673	32.5		33		31		32.2	40.8(a)
NBS-URB-IRS-1	-	80	G2	80	G6	80	G10	80	-
CS-6 (Nominal)	-	-	1.04G2	-	1.04G6	-	1.04G10	35.2	-
CS-6 (Read)	-	34.5		35.5		35.5		35.2	-
8-0300	A-0706	43		44		42		43	40.8(a)
NBS-URB-IRS-1	-	80	G3	80	G7	80	G11	80	-
CS-2 (Nominal)	-	-	7.41G3	-	7.41G7	-	7.41G11	77.8	-
CS-2 (Read)	-	77		77		76.5		76.8	-
3-0300	A-0729	32.5		32		30		31.5	40.8(a)
8-0300	A-0706	100	G4	100	G8	100	G12	100	92.9(b)
7-0300	A-0705	66		66		66.5		66.2	71.1
6-0300	A-0655	52.5		52.5		52		52.3	52.3
5-0300	A-0673	31		31		30.5		30.8	36.3
4-0300	A-0686	21		20.5		20		20.5	23.2
4-0300	A-0686	65.5	3G4	64.5	3G8	64	3G12	64.7	73.3
3-0300	A-0729	34		33.5		33		33.5	41.2
2-0300	A-0639	12		11		11		11.3	18.3
1-0300	A-0735	3		25		2		2.5	4.6
2-0300	A-0639	39	9G4	39	9G8	36.5	9G12	38.2	-
1-0300	A-0735	11		11.5		11		11.2	-

BLOCK I.D.	S/N	Reading 1 Value	Reading 1 Gain	Reading 2 Value	Reading 2 Gain	Reading 3 Value	Reading 3 Gain	Average	Reference Value
Observer		DJC		GDB		GFS			
Date		3/1/76		3/1/76		3/2/76			
Transducer		LS-4		LS-4		LS-4			
Water Temp. C		24.4		23.9		24.4			

(a) Average of all data taken to date.

(b) From least squares linear fit through origin.



BLOCK SET: as indicated on table

MFGR: XYZ Company

SUBMITTED BY: Hypothetical Company

DATE:

METHOD: Immersion

INSTRUMENT: Tuned P/R

TRANSDUCER: LS-4

FREQ: 5 MHz

SIZE: 0.375 in. Dia.

TYPE: Quartz

Calibration Results - Ultrasonic Reference Blocks

Area - Amplitude Set

DEPARTMENT OF COMMERCE • UNITED STATES OF AMERICA

75 YEARS NBS 1901 1976

NBS-114A (REV. 7-73)

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15. SUPPLEMENTARY NOTES

16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

A service for the calibration of ASTM E127-Type ultrasonic reference blocks has been established at the National Bureau of Standards. A single well-characterized reference block, carefully chosen to be as close as possible to "typical" or "nominal", has been designated as an interim standard against which other blocks can be compared. As refinements are made and the system becomes better understood, new standards may be developed leading to the development of an absolute national standard. The facilities and procedures used in this calibration service are described herein.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

Aluminum ultrasonic reference standards; ASTM-type reference standards; calibration; interim reference standard; longitudinal beam; measurement system; nondestructive evaluation; pulse-echo; ultrasonics.

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