The Engineering Society For Advancing Mobility Land Sea Air and Space®
INTERNATIONAL
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AEROSPACE MATERIAL SPECIFICATION

SAE AMS 2631B

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Submitted for recognition as an American National Standard

Superseding AMS 2631A

ULTRASONIC INSPECTION
Titanium and Titanium Alloy Bar and Billet

1. SCOPE:

1.1 Purpose:

This specification covers the procedure for ultrasonic inspection of wrought titanium and titanium alloy products 0.50 inch (12.7 mm) and over in cross-sectional thickness.

1.2 Application:

This procedure has been used typically for locating internal defects, such as cracks, voids, spongy areas, and other structural discontinuities, which may or may not be exposed to the surface, but usage is not limited to such applications.

1.2.1 Testing normally will be by longitudinal wave procedure, but shear wave procedure may be used when agreed upon by purchaser and vendor.

2. APPLICABLE DOCUMENTS:

The following publications form a part of this specification 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.

2.1 SAE Publications:

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

AMS 2380 Approval and Control of Premium-Quality Titanium Alloys
AMS 4928 Titanium Alloy Bars, Wire, Forgings, and Rings, 6Al - 4V, Annealed

SAE J300 Crankcase Oil Viscosity Classification

2.2 ASTM Publications:

Available from ASTM, 1916 Race Street, Philadelphia, PA 19103-1187.

ASTM E 127 Fabricating and Checking Aluminum Alloy Ultrasonic Standard Reference Blocks
ASTM E 317 Evaluating Performance Characteristics of Ultrasonic Pulse-Echo Testing Systems Without the Use of Electronic Measurement Instruments
ASTM E 428 Fabrication and Control of Steel Reference Blocks Used in Ultrasonic Inspection

2.3 U.S. Government Publications:

Available from DODSSP, Subscription Services Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

MIL-STD-410 Nondestructive Testing Personnel, Qualification and Certification (Eddy Current, Liquid Penetrant, Magnetic Particle, Radiographic and Ultrasonic)

2.4 ANSI Publications:

Available from American National Standards Institute, Inc., 11 West 42nd Street, New York, NY 10036.

ANSI B46.1 Surface Texture

2.5 ASNT Publications:

Available from American Society for Nondestructive Testing, 1711 Arlingate Plaza, P.O. Box 28518, Columbus, OH 43228-8518.

SNT-TC-1A Recommended Practice, Personnel Qualification and Certification in Nondestructive Testing

2.6 ATA Publications:

Available from Air Transport Association, 1301 Pennsylvania Avenue, Suite 1100, Washington DC 20004-1707.

ATA-105 Guidelines for Training and Qualifying Personnel in Nondestructive Testing

3. TECHNICAL REQUIREMENTS:

3.1 Qualification:

3.1.1 (R) Personnel: Shall be qualified and certified in accordance with MIL-STD-410. Alternate procedures, i.e. ASNT-TC-1A or ATA-105, may be used if specified by the drawing or purchase order. It is the suppliers responsibility to ensure that personnel are certified and function within the limits of the applicable specification or procedure.

3.1.2 Facilities: Shall be subject to survey and approval by purchaser. Reference specifications, procedures, and documentation necessary to verify the qualification of equipment and test personnel shall be available to purchaser, when requested.

3.1.3 (R) Written Procedure: Ultrasonic inspections performed in accordance with this specification shall be detailed in written procedures. Procedures shall identify the type of ultrasonic equipment, method(s) of test, ultrasonic test reference, search unit type, style, corrected beam/type focusing and frequency, method of reporting indications, and all other instructions that pertain to the actual test. Procedures shall be detailed sufficiently that another qualified investigator could duplicate the test and obtain equivalent information.

3.2 Equipment:

3.2.1 Basic Ultrasonic Test Instrument: Shall be capable of producing, receiving, and displaying high-frequency electrical pulses at the required frequencies and energy levels. The ultrasonic instrument shall be of the pulse-echo type capable of operating at 2.25 through 10 MHz except as permitted in 3.2.2.2. Gates, distance-amplitude correction systems, and other electronic aids to ultrasonic testing and interpretation shall be used as required. An alarm system, a recorder, or an auto-stop device, or combination of these, may be used.

3.2.1.1 Instrument Linearity: The instrument performance characteristics shall be evaluated in accordance with ASTM E 317 except as follows:

3.2.1.1.1 (R) The calibration block used for evaluating vertical linearity shall be as shown in Figure 1.

3.2.1.1.2 The vertical linearity plot and the tolerance limits shall be as shown in either Figure 2 or Figure 3.

3.2.1.1.3 The horizontal linearity check shall be made by plotting signal displacement against known thickness in the range of 1 to 5 inches (25 to 125 mm) in 1-inch (25-mm) increments; the allowable difference in thickness between that indicated by the signal displacement and the actual measured thickness shall be within ±3% of the measured thickness of the respective block. Substitute performance checks are permissible when agreed upon by purchaser and vendor.

3.2.1.2 Instrument Sensitivity: Instrument sensitivity or gain controls shall function so that a given amount or degree of sensitivity can be repeated or returned to with an accuracy of ±10% of the original pip height. If signal attenuators are used, they shall be accurate over the attenuation range and test frequency used so that the attenuation measurement will represent an amplitude ratio within ±10% of the correct value. The decibel (dB) attenuation value may be converted to an amplitude ratio by use of tables with dB versus voltage ratios. Alternately, it may be calculated from the relationship in Equation 1.

$$\text{Amplitude Ratio} = \text{Log}\ \frac{-1}{10}\ \frac{\text{dB}}{20} \qquad \text{(Eq. 1)}$$

3.2.2 (R) Ultrasonic Search Units: Shall be capable of transmitting and receiving ultrasonic vibrations at the frequency and energy levels specified below. The frequency used shall be the highest practical ultrasonic frequency which will provide the required penetration, resolution, and signal to noise.

3.2.2.1 Search Unit Dimensions and Styles: For both contact and immersion tests with either longitudinal or shear mode, the choice of transducer dimension, style, type, etc is dependent on the test and the approved test procedure. In general, for immersion testing, flat-faced or corrected-beam transducers with diameters 3/8 through 3/4 inch (9.5 through 19.0 mm) are acceptable. Contact units with a maximum area of 1 square inch (6.5 cm^2) with 1/2 inch (12.7 mm) minimum to 1-1/8 inch (28 mm) maximum dimensions are acceptable for longitudinal testing, while 1 square inch (6.5 cm^2) or 1 by 1/2 inch (25 by 12.7 mm) transducers are acceptable for shear testing. Use of a focused, paint brush, liquid delay, special size, or other special transducer is acceptable when agreed upon by purchaser and vendor.

3.2.2.2 (R) Shall be the highest practical frequency which will provide the penetration and resolution required. Frequencies lower than 2.25 MHz for longitudinal inspections or 1.0 MHz for shear inspections shall not be used unless agreed upon by purchaser and vendor.

3.2.3 Voltage Regulator: If fluctuations in line voltage cause variations exceeding ±5% in a signal with an amplitude equal to the upper linearity limit of the instrument, a voltage regulator shall be used on the power source; this requirement does not apply to battery-powered units.

3.2.4 Couplant:

3.2.4.1 Immersion Method: For inspection by the immersion method, clean tap water shall be used as the couplant material; rust inhibitors, wetting agents, or both, may be added. The water shall be free of visible air bubbles which could interfere with the ultrasonic test.

3.2.4.2 Contact Method: For inspection by the contact method, SAE 30 motor oil in accordance with SAE J300 or cellulose gum shall be used as the couplant material. Other types of couplant materials that have been proven acceptable for a particular type of test may be used if agreed upon by purchaser and vendor. Chloroprene rubber sheet or similar materials may be used between the transducer and the product being tested to prevent excessive transducer wear provided adequate compensation for its use is made.

3.2.5 Longitudinal Reference Standards: Shall be fabricated from AMS 4928 titanium alloy or from other titanium alloy acoustically similar to the alloy to be tested. The procedures established in ASTM E 127 and ASTM E 428 are recommended for manufacturing ultrasonic reference blocks for straight beam testing.

3.2.5.1 Acoustic compatibility between the reference standard material and the material to be tested shall be within 25 and 75% (-2.5 and -12 dB). If the acoustic compatibility is within 25% (-2.5 dB), no gain compensation is required for inspection. If the acoustic compatibility differences are greater than 25% (-2.5 dB) but less than 75% (-12 dB), the instrument sensitivity shall be increased to compensate for the differences in acoustic compatibility.

3.2.5.1.1 The most acceptable acoustic compatibility comparison is the comparison of the first unsaturated back reflection from the reference standard and the part being tested. The db per inch (25 mm) comparison using back reflections is also frequently used. Other acoustic compatibility comparison measurements may be used when permitted by purchaser.

3.2.5.2 For testing flat surfaces, flat test blocks shall be used. For testing curved surfaces, the reference standards shall have similar contour within approximately ±25% of the radius of curvature of the dimensions being tested. Surface finish of the calibration standard shall be similar to that of the material being tested.

3.2.5.3 For longitudinal wave calibration, the calibration reflectors shall be flat-bottom holes. The distance from the entry face of the ultrasonic beam to the bottoms of the calibration holes are recommended as follows, based on the material contour and section thickness "T". Alternate calibration points may be used when agreed upon by purchaser and vendor.

3.2.5.3.1 Rounds 0.5 to 2 Inches (12.7 to 51 mm), Inclusive, in Diameter: 1/2T and 1/4 inch (6.4 mm).

3.2.5.3.2 (R) Rounds Over 2 to 5 Inches (51 to 127 mm), Inclusive, in Diameter: 1/2T, 1/4T, and 1/4 inch (6.4 mm).

3.2.5.3.3 Rounds Over 5 Inches (127 mm) in Diameter: 1/2T, 1/4T, 1/8T, and 3/8 inch (9.5 mm). If frequencies below 5 MHz are used, the minimum metal travel of 1/2 inch (12.7 mm) may be used.

3.2.5.3.4 Flat-Faced Material 0.5 to 2 Inches (12.7 to 51 mm), Inclusive, in Cross-Section: T-1/8 inch (-3 mm), 1/2T, and 1/4 inch (6.4 mm).

3.2.5.3.5 Flat-Faced Material Over 2 to 5 Inches (51 to 127 mm), Inclusive, in Cross-Section: T-1/2 inch (-12.7 mm), 1/2T, 1/4T, and 1/4 inch (6.4 mm).

3.2.5.3.6 Flat-Faced Material Over 5 to 9 Inches (125 to 229 mm), Inclusive, in Cross-Section: 1/2T, 1/4T, 1/8T, and 1/2 inch (12.7 mm).

3.2.5.3.7 Flat-Faced Material Over 9 Inches (229 mm) in Cross-Section: 1/2T, 1/4T, 1/8T, and 1/2 inch (12.7 mm). If frequencies below 5 MHz are used, the minimum metal travel of 3/4 inch (19 mm) may be used.

3.2.6 Angle Beam Reference Standards: Angle beam testing may use the longitudinal mode with the beam refracted at a predetermined angle (usually 45 degrees) or the true shear (transverse) wave may be used with the refracted angle between 30 and 60 degrees, usually 45 degrees.

3.2.6.1 In immersion testing to establish an approximate 45 degree refracted longitudinal angle in titanium, a 10 degree incident angle is used.

3.2.6.2 In immersion testing to establish an approximate 45 degree refracted shear angle in titanium, a 20 degree incident angle is used.

3.2.6.3 For contact testing, the refracted angle in the part is determined by the angle of the wedge or shoe that is used between the transducer and the part being tested.

3.2.6.4 The same acoustical compatibility requirements between reference standard material and test material as is required for longitudinal wave standards applies to angle beam reference standards.

3.2.6.5 (R) The style of angle beam reference standards shall be acceptable to purchaser.

3.3 Surface Preparation:

3.3.1 The surfaces to be inspected shall be common geometrical sections such as round, square, and octagonal. Flat-face product shall be prepared to ensure flatness of the various faces.

3.3.2 (R) Texture of surfaces to be inspected shall be not rougher than 250 microinches (6 µm). For longitudinal mode tests to Class AA or A1 requirements and for shear mode tests, surface texture of approximately 125 microinches (3 µm) is desirable. Surface texture is defined in ANSI B46.1.

3.3.3 Surface discontinuities remaining after surface preparation shall not be removed before ultrasonic inspection because local grinding depressions will cause sonic wave attenuation, loss of back reflection, and inability to locally meet standards. Surfaces shall be free from loose scale, machining or grinding particles, oil, grease, cutting compounds, and other foreign material.

3.4 Calibration of Apparatus:

Before inspecting the product, the apparatus shall be adjusted, using appropriate reference blocks, to produce, from the simulated imperfections, clearly defined indications of sufficient height to ensure that the product under test can be inspected as required to locate any imperfections of detrimental size, nature, and location. The minimum pip height shall be not less than 20%, the maximum pip height shall be not greater than 80% of the vertical limit or the upper linearity limit, whichever is less. Set up height shall be twice the noise level or as otherwise approved by purchaser.

3.4.1 Instruments of the vacuum tube type shall be warmed up for not less than 30 minutes before being used; instruments using solid state electronic components shall be warmed up for not less than 10 minutes before being used. Sufficient time shall also be allowed for temperature of water, reference blocks, and product to stabilize before calibration and testing.

3.4.2 Calibration Check: To ensure valid results, a calibration check shall be made prior to the test of each part configuration or start of each shift of operation and at the completion of each test or shift, as appropriate. Any change in equipment operation that requires a recalibration of the test system shall require retesting of all product or parts tested since the previous calibration.

3.5 General Scanning Procedure:

3.5.1 Calibration for determination of loss in the back reflection pattern shall be performed on parallel surfaces of the product being tested. The back reflection pattern from the full material thickness section of the test block at the scanning sensitivity shall be observed. If the back reflection pattern from the product being tested averages a variation of more than ±50% from that recorded from the test block, testing shall be stopped until corrective action is taken.

3.5.2 The permissible background noise shall not exceed 50% of the response height from the reference standard of the same alloy as the product being tested. Greater background noise levels may be permitted by purchaser or lesser background noise levels may be specified.

3.5.3 Whenever possible, a dynamic alarm check shall be made to determine the operational scanning speeds, pulse repetition rates, and index increments, and to ensure that the alarm system is capable of detecting all rejectionable defects at these operating conditions.

3.5.4 If a dynamic alarm check cannot be made or if alarms cannot be used, the operational parameters shall be as follows:

3.5.4.1 (R) Pulse repetition rate should be a minimum of 600 pulses per second (600 PPS). The exact rate used shall be based on the beam diameter and surface speed.

3.5.4.2 For manual scanning without alarm systems, a scanning speed not greater than 5.0 inches (127 mm) per second is recommended.

3.5.4.3 (R) For alarm systems with or without automatic scanning, a scanning speed not greater than 20 inches (508 mm) per second is recommended. The exact speed shall be based on the beam diameter and repetition rate.

3.5.5 When the alarm system is used during testing, it shall be set at the equivalent of “Hold” or “Manual Reset”.

3.5.6 The instrument control settings and test parameters established during calibration shall not be changed during testing of the product. The pulse length and reject control shall be set at the minimum that will afford the proper resolution without affecting acceptable linearity.

3.5.7 Distance Amplitude Correction: Electronic distance amplitude correction is recommended; however, distance amplitude curves plotted on the screen face (Cathode Ray Tube) using distance amplitude calibration blocks may be used if the minimum pip height complies with 3.4. Testing using the highest sensitivity from the distance amplitude calibration blocks and evaluating to the proper metal travels is also permitted provided noise levels do not obscure required information.

3.5.8 Zone testing may be used with separate calibrations and/or transducers for each zone. (R)

3.6 Immersion Testing:

3.6.1 Longitudinal (Straight) Beam Testing: The sound beam entry angle shall be adjusted until the sound beam is perpendicular to the test surface. Where appropriate, the maximum signal amplitude from the entry surface may be used to determine this condition. Where not appropriate (e.g., a highly-focused search unit), an alternate procedure such as multiple reflections may be used. During testing, the angle established shall not vary more than ±2 degrees.

3.6.2 Angle Beam Testing: Products may be inspected with both longitudinal and shear wave motions at preselected angles. Once established, the surface entry angle shall not vary more than ±2 degrees.

3.6.3 Water Travel: The water travel distance shall be the optimum for the transducer and the metal travels encountered during testing. The water travel distance for testing shall be within ±0.25 inch (±6.4 mm) of that used for calibration.

3.6.4 (R) The maximum indexing increment used in scanning a product shall be 70% of the effective beam diameter. The effective beam diameter is determined by recording of the total traverse distance at the appropriate gain settings across the nearest hole in the test block through which not less than 50% signal amplitude is displayed.

3.7 Contact Testing:

3.7.1 Straight Beam Testing: Visual inspection of the search unit shall be made to verify that the wear face surface is intact. Periodic visual inspections shall be made during tests to ensure that the search unit facing has not degraded. Any cracking, chipping, break-up, or uneven wear conditions shall disqualify the search unit and the test.

3.7.2 Angle Beam Testing: Angle beam entry and testing mode shall be established as part of the test procedure.

3.7.3 Indexing: Indexing increments used in scanning a product shall be not greater than one-half the transducer diameter or the effective beam diameter, determined in accordance with 3.6.4, whichever is less. When practical, transducer indexing shall be controlled by a mechanical system.

3.8 Surface Area of Product to be Scanned:

3.8.1 Bars and Forging Stock:

3.8.1.1 Rounds, All Diameters: The entire circumference.

3.8.1.2 Flat-Faced Product 2 to 5 Inches (51 to 127 mm), Inclusive, in Cross Section: Test all adjacent faces representing 50% of the periphery.

3.8.1.3 Flat-Faced Product Over 5 Inches (127 mm) in Cross Section: All faces.

3.8.1.4 Single-face or opposite-face tests of all flat-faced rectangular product may be made if shear or refracted longitudinal wave testing is substituted for the adjacent face test. These tests and the calibration and testing parameters shall be as agreed upon by purchaser and vendor.

4. QUALITY ASSURANCE PROVISIONS:

4.1 Acceptance Classes:

4.1.1 (R) Four classes of ultrasonic quality for longitudinal wave inspection are defined in Table 1. Drawings, quality control specifications, or purchase orders will specify the applicable class. Melting parameters are defined in AMS 2380.

TABLE 1 - Ultrasonic Quality Classes

Ultrasonic Classification	Single Discontinuity Hole Size No.* Grade 1	Single Discontinuity Hole Size No.* Grade 2
AA	2	2
A1	3	3
A	5	4
B	8	6

* Diameter, in 64ths of an inch, of a flat-bottom hole in the reference standard (1/64 inch = 0.4 mm).

4.1.1.1 All indications 75% or greater than the rejection level for each class shall be explored and evaluated.

4.1.1.2 Any discontinuity with an indication greater than the response from a reference flat-bottom hole at the estimated discontinuity depth of the size given is not acceptable.

4.1.1.3 Loss of unsaturated back reflection pattern greater than 50%, when compared with nondefective material in the same, similar, or like product, is not acceptable when this loss of back reflection pattern is accompanied by any increase in signal, at least double the normal background noise signal, between the front and back surfaces.

4.1.1.4 Noise levels exceeding the limits of 3.5.2 are not acceptable.

4.1.2 Acceptance standards for inspection by procedures other than normal longitudinal and standards not covered in Table 1 shall be as agreed upon by purchaser and vendor.

4.2 Disposition:

4.2.1 Product exhibiting evaluated indications not in excess of established standards may be accepted without remedial operations.

4.2.2 Product exhibiting evaluated indications in excess of established standards but in a location which will be removed during manufacturing operations may be approved by authorized personnel for acceptance and shall be reported to purchaser.

4.2.3 Product containing discontinuities in excess of established standards and not covered by 4.2.2 shall be rejected.

4.3 Records:

The testing source shall prepare and maintain on file, for the time specified by purchaser, records of the requirements and techniques for each size and configuration of product. When requested by purchaser, these records shall be made available for inspection.

5. PREPARATION FOR DELIVERY:

Not applicable.

6. ACKNOWLEDGMENT:

A vendor shall mention this specification number and its revision letter in all quotations and when acknowledging purchase orders.

7. REJECTIONS:

Product inspected in accordance with this specification and not meeting specified requirements, or modifications authorized by purchaser, will be subject to rejection.

8. NOTES:

8.1 The (R) symbol 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 specification. If the symbol is next to the specification title, it indicates a complete revision of the specification.

8.2 Test Conditions:

It is essential that thorough understanding be developed between purchaser and vendor regarding interpretation of the results of inspection and how they shall be recorded and reported. Ultrasonic testing is so comprehensive that it is necessary that all interested parties fully recognize that indications may appear which do not reflect conditions detrimental to use of the product. Agreement between purchaser and vendor should be established in advance on the following:

Surface finish
Internal structure
Location and extent of areas to be scanned
Size of transducer and type of search unit
Test frequency
Type and grade of couplant
Method of calibration of equipment

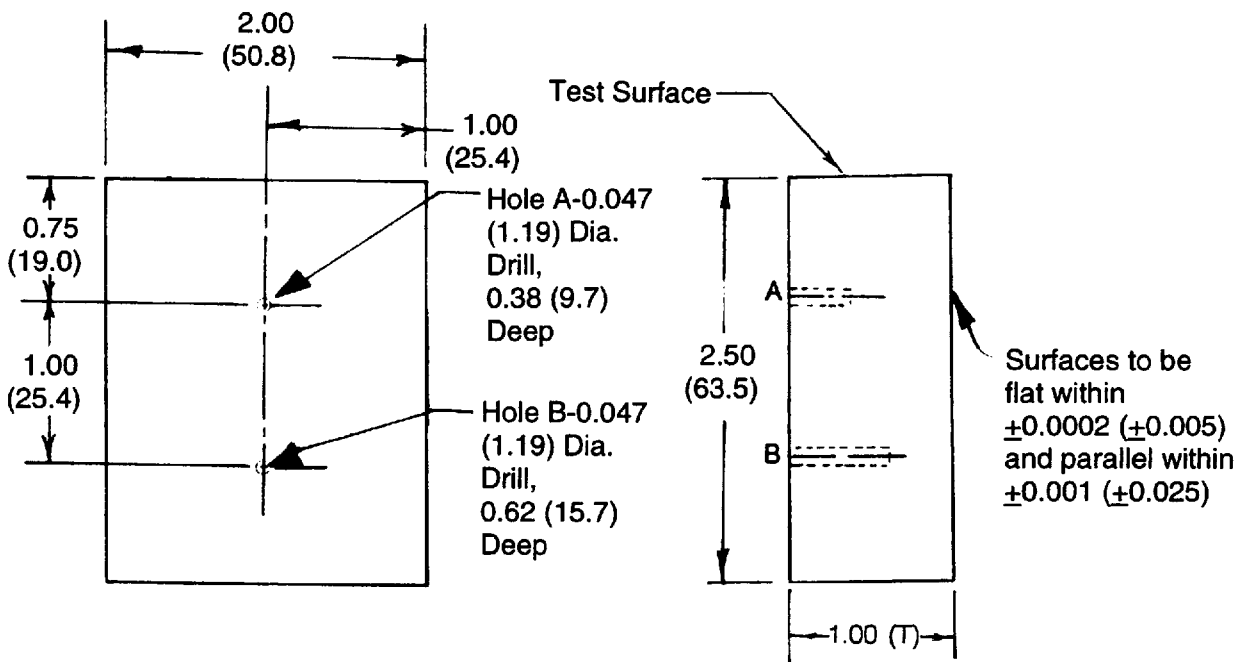
8.3 Local grinding depressions will cause sonic wave attenuation, loss of back reflection, and inability to locally meet standards.

8.4 Definitions of terms used in AMS are presented in ARP1917.

8.5 Dimensions in inch/pound units are primary; dimensions in SI units are shown as the approximate equivalents of the primary units and are presented only for information.

8.6 Processes meeting the requirements of this specification have been classified under Federal Standardization Area Symbol “NDTI”.

PREPARED UNDER THE JURISDICTION OF AMS COMMITTEE “K”



Note 1: Thickness (T) may be increased to accommodate larger search units provided the depth of hole A is T/2 -0.12 (3.0) and the depth of hole B is T/2 +0.12 (3.0).

Note 2: Dimensions are in inches (millimeters) except as noted.

(R) Note 3: All surfaces 63 √ (1.6 ∝m)

FIGURE 1- Calibration Block Use for Evaluating Vertical Linearity

VERTICAL LINEARITY PLOTS

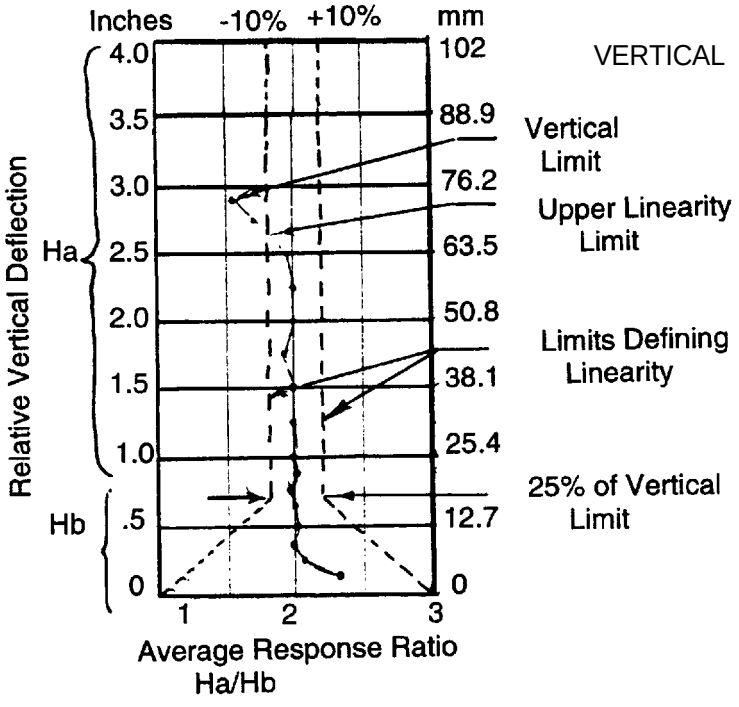


FIGURE 2

Typical plots of ultra-sonic responses (Hole B Fig. 1) as a function of varying vertical deflection (Hole A Fig. 1). Initial set-up: Adjust the instrument sensitivity and position the transducer over the calibration block, Figure 1, so that (1) the signal height (Ha) from Hole A will be at a convenient height between 50% and 70% of the Vertical Limit and (2) the Response Height (Hb) from Hole B will be sucha that the Ratio of Ha/Hb equals 2.

Adjust controls in steps so that Ha is set at approximately 0.25 inch (6.4 mm) intervals and plot values for Ha against Ha/Hb.

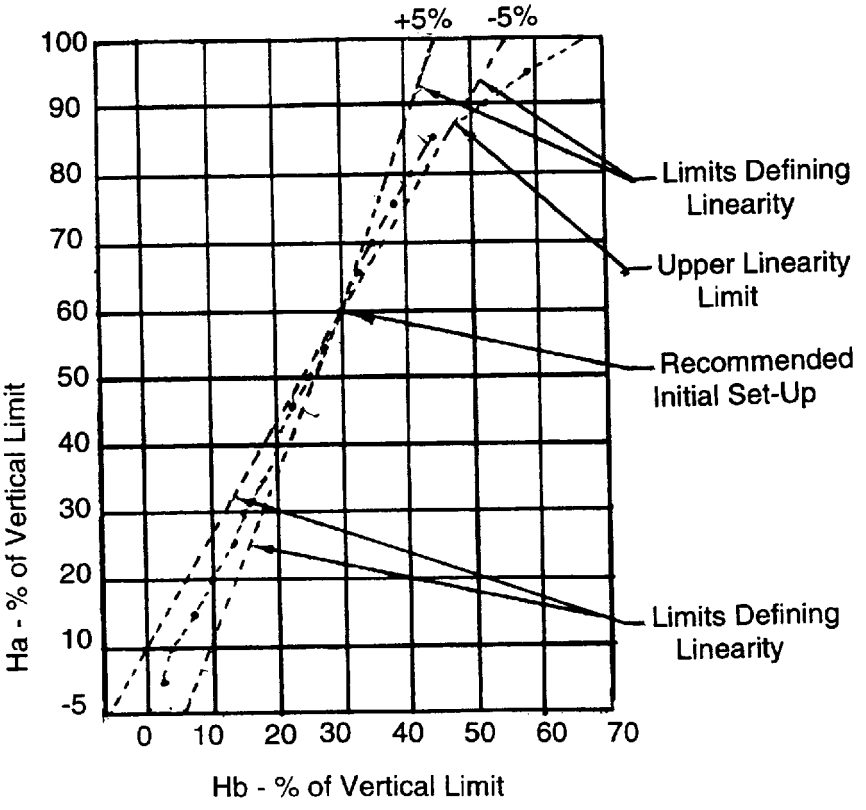


FIGURE 3

Set-up and plotting same as in Fig. 2 except all screen heights are converted to % of Vertical Limits and % Ha is plotted against % Hb rather than ratio of Ha/Hb.

Note that limit lines originate at the initial set-up point and will change if the set-up is changed.

The Vertical Limit equals 100%.