NASA Technical Memorandum 84625

FABRICATION DIVISION
ULTRASONIC INSPECTION SPECIFICATION FOR
CRITICALLY STRESSED COMPONENTS

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February 1983

National Aeronautics and
Space Administration

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1. SCOPE

This specification governs the implementation of ultrasonic inspections with respect to metallic materials designated for critically stressed utilization at Langley Research Center (LaRC). This specification applies to the inspection of wrought metals, including forgings and forging stock; rolled billet, bar or plate; extruded bar, tube and shapes; and parts made therefrom, when specified by the engineering drawing, contract or purchase order. Application to welds, castings, or sandwich structures, or to sizes outside the acceptance standard size limitations specified in the material specifications is not intended.

2. APPLICABLE DOCUMENTS

The following documents form a part of this specification. Unless otherwise indicated the most current issue shall apply. Items not specifically herein addressed shall revert to the applicable sections of these documents.

2.1 Military Specification

Mil-I-8950B Inspection, Ultrasonic, Wrought materials, process for

2.2 American Society for Testing Materials

E 114-75 Ultrasonic Pulse-Echo Straight-Beam Testing by the Contact Method

E 127-80 Fabricating and Checking Aluminum Alloys Ultrasonic Standard Reference Blocks

E 214-68 Immersed Ultrasonic Testing by the Reflected Method using Pulsed Longitudinal Waves

E 317-79 Evaluating Performance Characteristics of Ultrasonic Pulse-Echo Testing Systems without the use of Electronic Measurement Instruments

E 428-71 Fabrication and Control of Steel Reference Blocks used in Ultrasonic Inspection

E 500-74 Standard Definitions of Terms Related to Ultrasonic Testing

E 587-76 Ultrasonic Angle-Beam Examination by the Contact Method

2.3 American Society for Non-Destructive Testing

Recommended Practice No. SNT-TC-1A - Supplement "C" - Ultrasonic Testing

3. REQUIREMENTS

3.1 Inspection Mode

The requirements of this specification may be fulfilled by utilization of contact and/or immersion ultrasonic inspection techniques.

3.2 Equipment

Equipment shall describe the complete testing system including but not limited to electronic instruments, interconnecting cables, transducers, etc.

3.2.1 Electronic Instruments

3.2.1.1 Electronic instruments shall be capable of generating frequencies between the range of 2.25 MHZ and 10 MHZ. Other frequencies may be utilized if equal or greater sensitivity can be demonstrated.

3.2.1.2 Instrument Vertical Linearity shall be within ±5% of the full screen height for a minimum of 80% of the calibrated screen height (base line to maximum calibrated screen point).

3.2.1.3 Instrument Calibrated Gain Control shall be accurate within ±10% over its useful range.

3.2.1.4 Instrument Performance Characteristics of: horizontal limit and linearity, vertical limit and linearity, resolution-entry surface and far surface, sensitivity and noise, accuracy of calibrated gain control shall be verified at the beginning of each period of extended use (or every 3 months, whichever is less).

3.2.2 Couplant

Couplant shall be Echo Laboratory Sonotrace 40 or equivalent material for contact inspections.

3.2.3 Immersion Equipment

The immersion inspection manipulating equipment shall be capable of providing measurable angular control of the transducer to maximize discontinuity response.

3.3 Personnel

3.3.1 Training and Certification

Inspection personnel shall have received current training in the techniques of ultrasonic inspection. The inspection agency shall have established a personnel certification plan based on the recommended practice of ASNT SNT-TC-1A Supplement "C", Ultrasonic Testing. This plan shall encompass the areas of training, experience, examination and qualification procedures. The inspection agency shall maintain a permanent record for each certified inspector which contains as a minimum the agency's requirements for certification, a list of applicants' training and experience, and copies of certification examinations. Only personnel certified to Levels II or III shall be authorized to perform inspections utilizing this specification.

3.3.2 Vision

The following minimum requirements shall apply for visual acuity of inspection personnel:

3.3.2.1 Distant vision, either corrected or uncorrected, shall equal 20/30 in at least one eye.

3.3.2.2 Near vision, either corrected or uncorrected, shall be such that the applicant can read Jaeger type No. 2 at a distance of 16 inches, or pass the Diopter method of near vision examination.

3.3.2.3 Vision tests shall be performed by an oculist or optometrist or by any other recognized person, such as a Level III examiner. At qualification and one year from the effective date of qualification, and each year thereafter, qualified personnel shall be required to pass the vision tests specified herein.

3.4 Time of Inspection

Material shall be inspected in a regular geometry configuration such as cylinders, rectangular and square bars, plate stock, etc. Machining shall be performed only to the extent necessary to bring the material to this configuration and prepare the surfaces.

3.5 Class of Inspections

Ultrasonic inspection quality levels are divided into classes and modes as follows:

- Straight Beam - AAA, AA, A, B, and C Reference Par. 2.1
- Angle Beam - 1, 2, 3

When more than one mode or class of inspection is required for a particular part or when designated areas of a part do not require ultrasonic inspection, design drawings shall be zoned and graded to illustrate the requirements.

3.5.1 Straight Beam Classes

3.5.1.1 Class AAA areas:

3.5.1.1.1 Discontinuity indications in excess of the response from a 1/64-inch diameter

flat-bottomed hole at the estimated discontinuity depth shall not be acceptable. In the absence of a test block containing a 1/64-inch hole the following criteria shall govern. Discontinuity indications greater than 25 percent of the response from a 3/64-inch diameter flat-bottomed hole at the estimated discontinuity depth shall not be acceptable.

3.5.1.1.2 Discontinuity indications greater than 10 percent of the response from a 3/64-inch diameter flat-bottomed hole at the estimated discontinuity depth shall not have their centers closer than 1 inch or exhibit any linearity.

3.5.1.1.3 Hash or sonic noise shall not exceed 5 percent of the response height from a 3/64-inch diameter flat-bottomed hole at the estimated discontinuity depth.

3.5.1.1.4 With the instrument set so that the first back reflection from the correct test block is at 80 percent of the screen saturation adjusted for non-linearity, the material shall be inspected for loss of back reflection. Any loss in back reflection in excess of 20 percent shall not be acceptable.

3.5.1.2 Class AA areas:

3.5.1.2.1 Discontinuity indications in excess of the response from a 3/64-inch diameter flat-bottomed hole at the estimated discontinuity depth shall not be acceptable.

3.5.1.2.2 Discontinuity indications greater than 10 percent of the response from a 3/64-inch diameter flat-bottomed hole at the discontinuity depth shall not have their centers closer than 1 inch or exhibit a length greater than 1/8-inch.

3.5.1.2.3 Hash or sonic noise shall not excced 10 percent of the response height received from a 3/64-inch diameter flat-bottomed hole at the estimated discontinuity depth.

3.5.1.2.4 With the instrument set so that the first back reflection from the correct test block is at 80 percent of the screen saturation adjusted for non-linearity, the material shall be inspected for loss of back reflection. Any loss in back reflection in excess of 50 percent shall be considered not acceptable.

3.5.1.3 Class A areas:

3.5.1.3.1 Discontinuity indications in excess of the response from a 5/64-inch diameter flat-bottomed hole at the estimated discontinuity depth shall not be accepted.

3.5.1.3.2 Multiple indications in excess of the response from a 3/64-inch diameter flat-bottomed hole shall not have their indicated centers closer than 1 inch.

3.5.1.3.3 Elongated (stringer) type defects in excess of 1 inch in length shall not be acceptable if, at any point along the length, the discontinuity indication is equal to or greater than the response from a 2/64-inch diameter flat-bottomed hole for stainless and alloy steels, and a 3/64-inch diameter flat-bottomed hole for other metals.

3.5.1.3.4 Multiple discontinuities giving an indication less than the response from a 3/64-inch diameter flat-bottomed hole are acceptable only if the back reflection pattern is 50 percent or more of the back reflection pattern of sound material of the same geometry. The sound beam must be normal to the front and back surfaces to insure that loss of back reflection is not caused by surface roughness, surface waviness, or part geometry variation.

3.5.1.4 Class B areas:

3.5.1.4.1 Discontinuity indications in excess of the response from an 8/64-inch diameter flat-bottomed hole at the estimated discontinuity depth shall not be acceptable.

3.5.1.4.2 Discontinuity indications in excess of the response from a 5/64-inch diameter flat-bottomed hole at the estimated discontinuity depth shall not have their indicated centers closer than 1 inch.

3.5.1.4.3 Elongated (stringer) type defects in excess of 1 inch in length shall not be acceptable, if, at any point along the length, the discontinuity indication is equal to or greater than the response from a 5/64-inch diameter flat-bottomed hole.

3.5.1.4.4 Multiple discontinuities giving an indication less than the response from a 5/64-inch diameter flat-bottomed hole are acceptable only if the back reflection pattern is 50 percent or more of the back reflection pattern of sound material of the same geometry. The sound beam must be normal to the front and back surfaces to insure that the loss of back reflection is not caused by surface roughness, surface waviness, or part geometry variation.

3.5.1.5 Class C areas:

Discontinuity indications in excess of the response from an 8/64-inch diameter flat-bottomed hole at the estimated discontinuity depth shall not be acceptable.

3.5.2 Angle Beam Classes

3.5.2.1 Class 1 areas:

3.5.2.1.1 Discontinuity indications in excess of the response from a 1/16-inch high letter "I" die stamp at the estimated depth shall not be acceptable.

3.5.2.1.2 Discontinuity indications in excess of 50% of the response from a 1/16-inch high letter "I" die stamp (50% of reference level) which have their centers closer than 1 inch or exhibit any linearity shall not be acceptable.

3.5.2.1.3 Hash or sonic noise shall not exceed 10% of the response height of a 1/16-inch high letter "I" die stamp at the estimated depth.

3.5.2.2 Class 2 areas:

3.5.2.2.1 Discontinuity indications in excess of the response from a 1/8-inch high letter "I" die stamp at the estimated depth shall not be acceptable.

3.5.2.2.2 Discontinuity indications in excess of 50% of the response from a 1/8-inch high letter "I" die stamp (50% of the reference level) which have their centers closer than 1 inch or exhibit a length greater than 1/4-inch shall not be acceptable.

3.5.2.2.3 Hash or sonic noise shall not exceed 20% of the response height from a 1/8-inch high

letter "I" die stamp at the estimated depth.

3.5.2.3 Class 3 areas:

Discontinuity indications in excess of the response from a 3/16-inch high letter "I" die stamp at the estimated depth shall not be acceptable.

3.6 Reference Standards

Reference standard reflectors - flat bottom holes and steel die stamp letter "I" - shall be placed in the material to be inspected. The simultaneous inspection of one material type with similar processing history, dimensions, surface finish, contour and heat treating shall require the placement of reference standard reflectors in one part only. Where material utilization prohibits this practice, a stand-alone reference block shall be fabricated with the aforementioned factors being the same as the material to be inspected.

3.6.1 Contoured Surfaces

When inspecting through contoured surfaces and when it is impractical to scan through flat surfaces, test standards contoured to match the part being inspected are required. Other compensatory techniques are prohibited.

3.6.2 Reference Standard Depth

The minimum depth for straight beam reference standard reflectors - flat bottom holes - shall be 5% of the thickness to be inspected or 2 inches, whichever is less. Where excess material allows, holes should be a minimum of 1 inch from all edges.

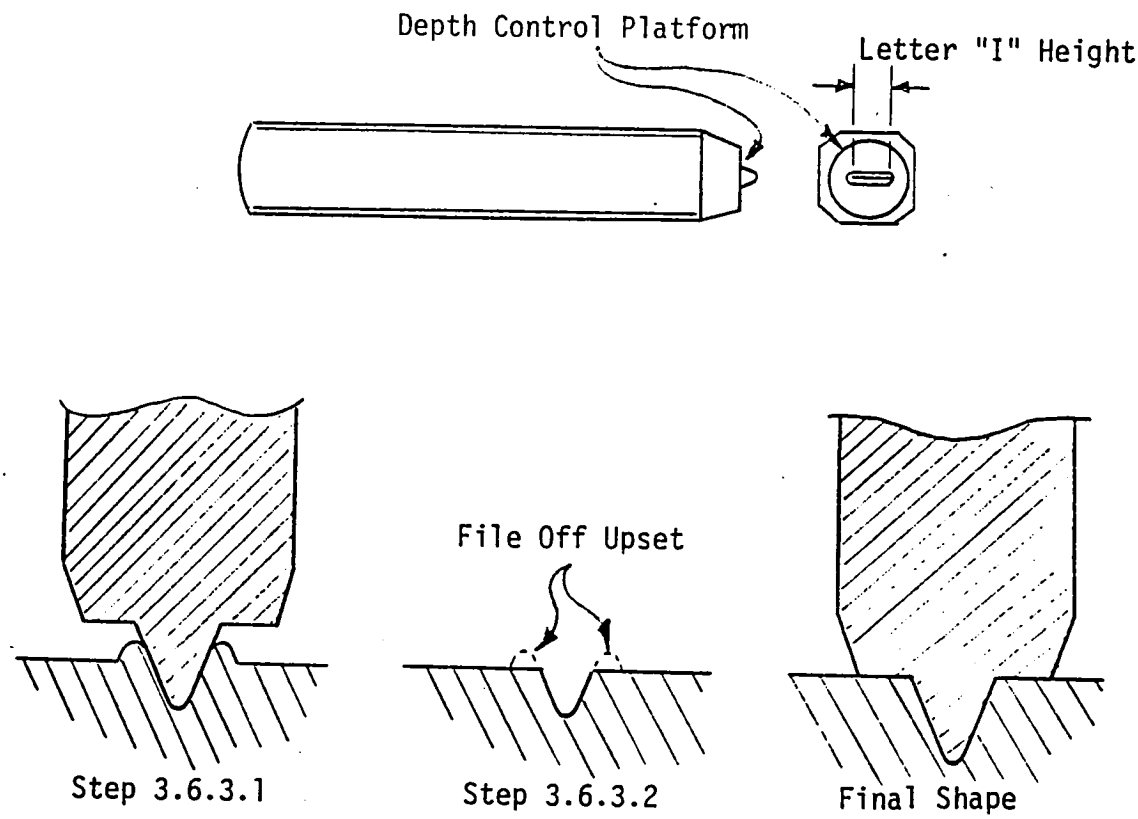
3.6.3 Angle Beam Reference Standard Reflectors

Letter "I" steel die stamps as manufactured by Young Brothers Stamp Works, Inc., Muscatine, Iowa, and available from the NDE Group at NASA, Langley Research Center, shall be placed in the material surface utilizing the following technique:

3.6.3.1 Impress the die stamp into the material surface.

3.6.3.2 File off upset surface material down to the original contour.

3.6.3.3 Repeat steps 3.6.3.1 and 3.6.3.2 above until the die depth control platform uniformly contacts the material surface. (See illustration, figure 1.)



Angle Beam Reference Standard Impressing Technique

Figure 1

3.6.4 Reference Standard Reflector Sizes

3.6.4.1 Straight Beam Inspections

Class	Hole Size
AAA	1/64 inch dia. or 3/64 inch dia. - No. 56 Drill
AA	3/64 inch dia. - No. 56 Drill
A	5/64 inch dia.
B	5/64 inch dia.
C	8/64 inch dia.

3.6.4.2 Angle Beam Inspection Letter "I" Steel Die Stamp

Class	Die Size
1	1/16 inch "I"
2	1/8 inch "I"
3	3/16 inch "I"

3.7 Surface Condition

All sound entry surfaces shall be machined to eliminate mill finish and rough cutting where required. The minimum acceptable surface finish by class is:

Class	Finish
AAA, AA,1	62-100 RMS
A, B, 2	100-150 RMS
C, 3	150-200 RMS

3.8 Inspection Technique

The inspection techniques utilized to inspect materials shall be capable of determining discontinuity size, extent, and conformance to the required ultrasonic inspection classification. The ultrasonic frequency, sensitivity, and crystal which present the most accurate definition of the required quality level shall be employed.

3.8.1 Electronic Instrument

A pulse-echo type ultrasonic instrument shall be utilized for all inspections.

3.8.2 Inhibitor Agent

A suitable inhibiting agent shall be added to the water in immersion testing to inhibit corrosion and reduce the formation of surface air bubbles.

3.8.3 Scanning Speed

Scanning speed shall not exceed 6 inches of inspected material per second. This speed shall be based on outside circumferential distance when inspecting ring components from the outside or inside diameters.

3.8.4 Transducer Indexing

Unless otherwise specified (reference paragraph 3.5) 100% of all material volume shall be ultrasonically inspected. Transducer dimension perpendicular to the scan direction.

3.8.5 Straight Beam Inspection Technique

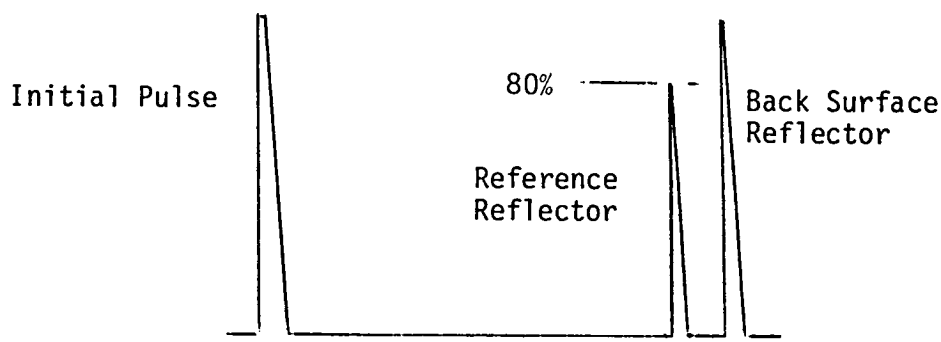
3.8.5.1 Equipment Standardization

3.8.5.1.1 Prior to any inspection activities, the electronic instrument shall be powered up and allowed to stabilize for a minimum of 15 minutes. The equipment system - instrument, interconnecting cables, transducer, and any fixturing or positioners - shall be standardized as a unit.

3.8.5.1.2 Any subsequent changes in components shall require restandardization of the system.

3.8.5.1.3 As a minimum, the system shall be standardized daily before any inspection activity and every 4 hours thereafter. In addition, the standardization shall be verified after any 30 minute period of non-use (lunch and/or break time), or after an interruption in line power.

3.8.5.1.4 The equipment system shall be standardized by acoustically coupling the transducer over a selected reference standard reflector - flat bottom hole - and adjusting the instrument sweep controls to present an initial pulse, back surface reflection and reference standard reflection on the display. (See illustration, Figure 2.) The instrument gain and associated pulse shape controls are adjusted to present the applicable reference standard reflector signal of 80% screen height. This represents the reference level.



Straight Beam Inspection Instrument Display

Figure 2

Reject and filtering controls should be used at the lowest practical settings to minimize base line noise or hash.

3.8.5.1.5 Near surface sensitivity and resolution shall be verified by coupling the transducer to a stand-alone reference standard of similar material, contour and surface finish having an equal size reference standard reflector at a metal distance equal to 10% of the inspected thickness or 0.125 inches, whichever is greater. When specified for critical areas of components where near surface resolution is essential, the latter metal distance shall be decreased to 0.062 inches.

3.8.5.1.6 Scanning Level

All scanning shall be performed with an instrument sensitivity of at least twice the reference level (+6 Db). Where material surface and/or grain interference prevent this, it shall be noted in the inspection report, and the maximum scanning speed shall be reduced to 3 inches per second, reference paragraph 3.8.3.

3.8.5.2 Scanning Modes

Unless otherwise specified, material shall be subjected to volumetric ultrasonic inspection with scanning from

two directions 90° to each other on each surface as follows:

3.8.5.2.1 Plate Stock: from each face through the thickness and on a minimum of one length and width edge.

3.8.5.2.2 Rectangular and Square Bars: from each width and height face, and from each end.

3.8.5.2.3 Cylindrical Stock and Rings: from all cylindrical outside and inside surfaces and from each end.

3.8.5.3 Defects identified by the aforementioned technique may necessitate the fabrication of a stand-alone reference standards to afford accurate defect grading with respect to depth. When so required, the reference standard shall contain flat bottom holes of standard diameters at the same depths as the indicated defect within ± 1/16-inch for defect depth up to 1/4-inch, within ± 1/8-inch for defect depth from over 1/4-inch to 1 inch, within ± 1/4-inch for defect depths from over 1 inch to 3 inches, and within ± 1/2-inch for defect depths over 3 inches. The material, surface finish and contour, shall be equal to the inspected material.

3.8.6 Angle Beam Inspection Technique

3.8.6.1 Equipment Standardization

The equipment system is required to meet the same requirements as specified in Par. 3.8.5.1 with respect to warm up and standardization verifications.

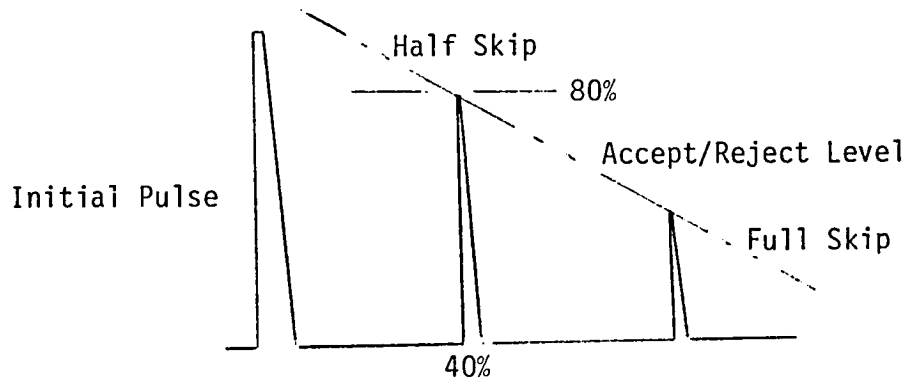
3.8.6.2 Angle-beam search units which produce sound incident beams at 45° in the inspected material are recommended for this inspection. Other incident angles may be necessitated by material thickness and/or specification requirements.

3.8.6.3 Angle-Beam Reference Standard Reflectors--Letter "I" steel die stamp of the specified class size--shall be placed on the inspection and reflecting surfaces of the material to be inspected utilizing the technique as described in Par. 3.6.3.

3.8.6.4 The selected angle-beam search unit is acoustically coupled to the examination surface and positioned to focus the sound beam on reflecting surface edge (half skip). The resulting peaked reflection signal, i.e., the reflecting surface intersect, is positioned on the instrument screen at 40% width. The search unit is repositioned to focus the sound beam after reflection on an examination surface edge (full skip). The position of the resulting peaked reflection signal, i.e., the examination surface intersect, is noted on the instrument display.

3.8.6.5 The angle-beam search unit is repositioned to detect the reflecting surface reference reflector (half skip), and this peaked signal is observed at the 40% screen width. Instrument gain and pulse shape controls are adjusted to bring this signal to 80% screen height. This point is marked on the display. Without further

adjustments to instrument controls the search unit is repositioned to receive the examination surface reference reflector (full skip). The height of this peaked signal is noted and its top marked on the display screen. A line is drawn on the display screen connecting these two points and extending beyond them. This line represents the accept/reject level for angle beam inspection, and this instrument gain setting is the reference level. (See Illustration Figure 3.)



Angle Beam Inspection Instrument Display
Figure 3

3.8.6.6 In lieu of the technique described in Paragraph 3.8.6.5 electronic instruments equipped with distance amplitude correction may be utilized to present a horizontal reference line (accept/reject level) at 80% screen height. Half skip and full skip reference reflectors shall be utilized to verify the effectiveness of this technique.

3.8.6.7 Scanning Level

All scanning shall be performed with an instrument sensitivity of at least twice the reference level (+6 Db). Where material surface and/or grain interference prevent this, it shall be noted in the inspection report and the maximum scanning speed shall be reduced to 3 inches per second. (Ref. Par. 3.8.5)

3.8.6.8 Scanning Modes

Unless otherwise specified, material shall be subjected to a volumetric ultrasonic inspection on each surface as follows:

3.8.6.8.1 Plate stock or plate shaped forgings: From each top and bottom surface with scanning performed end-to-end and side-to-side, with the angle-beam search unit facing each edge in turn (4 scans).

3.8.6.8.2 Rectangular and Square Bars: From each surface height and width with the angle-beam search unit facing each end of the bar (8 scans).

3.8.6.8.3 Cylindrical Stock: All cylindrical surfaces with the angle-beam search unit facing each end of the cylinder (2 scans).

3.9 Record of Inspection

Upon completion of all inspection activities, a report shall be generated which shall contain as a minimum the following information:

3.9.1 Inspection Agency

3.9.2 Inspector's Name

3.9.3 Level of Certification

3.9.4 Description of material inspected to include heat and order numbers or other positive identification

3.9.5 Date of Inspection

3.9.6 Place of Inspection

3.9.7 Equipment to include:

Instrument type, model, serial number

Transducer type, model, serial number

Couplant type, manufacturer

Etc.

3.9.8 Techniques utilized to include, with scanning level for each

Modes of inspection(s)

Classes of inspection(s)

3.9.9 Results

3.10 Rejected Material

Material which does not meet the quality level specified may be utilized only if subsequent machining operations will remove defective regions. As such, an accurate and positive means of defect location and documentation must be initiated. Material so utilized should be reinspected to insure complete removal of defects before final use certification.

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NASA TM-84625		

4. Title and Subtitle	5. Report Date
Fabrication Division Ultrasonic Inspection Specification for Critically Stressed Components	February 1983
	6. Performing Organization Code 505-31-53-11
7. Author(s)	8. Performing Organization Report No.
Robert F. Berry, Jr.	
9. Performing Organization Name and Address	10. Work Unit No.
NASA Langley Research Center Hampton, VA 23665	11. Contract or Grant No.
12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
National Aeronautics and Space Administration Washington, DC 20546	Technical Memorandum
	14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

An ultrasonic inspection specification has been developed which incorporates existing industry practices for straight beam modes with a new approach to the angle beam reference standard. Whereas previously reference standards for angle beam inspection were created utilizing expensive and time-consuming electrical discharge machine techniques, the new method employs a commercially available letter "I" die stamp to impress a controlled shape ultrasonic reflector using common hand tools.

The specification is designed to produce very stringent inspections and is primarily intended for utilization in the grading of material used in high load-low safety factor applications, such as cryogenic wind tunnel models and support hardware.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
Ultrasonic Inspection Angle Beam Reflector	Unclassified--Unlimited Subject Category 38

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	21	A02

N-305

For sale by the National Technical Information Service, Springfield, Virginia 22161