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INCH-POUND

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DEPARTMENT OF DEFENSE
TEST METHOD

INSPECTION PROCEDURE FOR DETECTION AND MEASUREMENT OF DEALLOYING CORROSION ON ALUMINUM BRONZE AND NICKEL-ALUMINUM BRONZE COMPONENTS

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FOREWORD

Inspection Procedure for Detection and Measurement of Dealloying Corrosion on Aluminum Bronze end Nickel-Aluminum Bronze Components

1. This Military Standard is approved for use by the Naval Sea Systems Command, Department of the Navy, and is available for use by all Departments and Agencies of the Department of Defense.

2. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Commander, Naval Sea Systems Command, SEA 55Z3, Department of the Navy, Washington, DC 20362-5101 by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

3. Inspection for the presence and depth of dealloying corrosion on aluminum bronze and nickel-aluminum bronze components is accomplished by performing two individual tests: the silver nitrate spot test and the eddy current test.

4. The silver nitrate test is used to verify the presence of dealloying at a specific location on the component. The test is accomplished by applying a drop of an aqueous silver nitrate solution to a cleaned area on the bronze component surface. The solution will immediately display a black color in dealloyed areas due to a reaction with the free copper present. If the solution is applied to an area on the original component surface to verify the presence of dealloying on the component, the test is termed the "surface" silver nitrate test. When the solution is placed within an excavation to indicate the depth to which dealloying has progressed below the metal surface, the test is termed the "subsurface" silver nitrate test.

5. The eddy current test consists of analyzing the impedance changes in a test coil that is scanned across the component surface. High frequency alternating current in the test coil induces eddy currents in the electrically conductive bronze. Alloy compositional changes brought about by dealloying corrosion alter the magnetic permeability characteristics of the bronze. This permeability change disturbs the flow of the induced eddy currents and thereby is reflected on the eddy current test instrument output display as an indication of dealloying. The eddy current test, as described herein, can only be used as a qualitative tool to indicate the surface area extent and relative depth of dealloying, subject to the limits of eddy current penetration, and not as a quantitative tool to measure dealloying depth.

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FIGURES

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1. SCOPE

1.1 Scope. This standard provides the inspection activity with the necessary information to inspect aluminum bronze and nickel-aluminum bronze components for dealloying corrosion on surfaces that have come in contact with seawater. Minimum requirements are specified for inspection personnel, equipment, procedures, and acceptance criteria, and for recording and reporting results.

1.2 Purpose. This standard specifies the minimum requirements necessary to conduct the silver nitrate spot test and the eddy current test (ET) to determine the presence and depth of dealloying on aluminum bronze and nickel-aluminum bronze components on submarines.

2. REFERENCED DOCUMENTS

2.1 Government documents.

2.1.1 Specifications and standards. The following specifications and standards form a part of this standard to the extent specified herein. Unless otherwise specified, the issues of these documents are those listed in the issue of the Department of Defense Index of Specifications and Standards (DODISS) and supplement thereto, cited in the solicitation (see 6.2).

SPECIFICATIONS

FEDERAL
QQ-C-390 - Copper Alloy Castings (Including Cast Bar).
QQ-C-450 - Copper-Aluminum Alloy (Aluminum Bronze) Plate, Sheet, Strip, and Bar (Copper Alloy Numbers 606, 610, 613, 614, and 630).

MILITARY
MIL-B-24480 - Bronze, Nickel-Aluminum (UNS No. C95800) Castings for Seawater Service.
MIL-B-16166 - Bronze, Aluminum: Forgings, Heat-Treated.

STANDARD

MILITARY
MIL-STD-271 - Requirements for Nondestructive Testing Methods.
MIL-STD-45662 - Calibration Systems Requirements.

(Unless otherwise indicated, copies of federal and military specifications and standards are available from the Naval Publications and Forms Center, (ATTN: NPODS), 5801 Tabor Avenue, Philadelphia, PA 19120-5099.)

2.1.2 Other Government publications. The following other Government publications form a part of this document to the extent specified herein. Unless otherwise specified, the issues are those cited in the solicitation.

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PUBLICATIONS

NAVAL SEA SYSTEMS COMMAND (NAVSEA)
0948-LP-045-7010 - Material Control Standard.
0941-LP-041-3010 - Submarine Safety Design Review Procedure Manual.

(Application for copies should be addressed to the Naval Publications and Forms Center, (ATTN: NPODS), 5801 Tabor Avenue, Philadelphia, PA 19120-5099.)

2.2 Non-Government publications. The following document forms a part of this document to the extent specified herein. Unless otherwise specified, the issues of the documents which are DOD adopted are those listed in the issue of the DODISS cited in the solicitation. Unless otherwise specified, the issues of documents not listed in the DODISS are the issues of the documents cited in the solicitation (see 6.2).

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)
B 124 - Copper and Copper-Alloy Forging Rod, Bar and Shapes (DoD adopted)
B 150 - Standard specification for Aluminum Bronze Rod, Bar, and Shapes. (DoD adopted)
B 169 - Aluminum Bronze Plate, Sheet, Strip and Rolled Bar (DoD adopted)
B 283 - Copper and Copper-Alloy Die Forgings (Hot-Pressed) (DoD adopted)

(Application for copies should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.)

(Non-Government standards and other publications are normally available from the organizations that prepare or distribute the documents. These documents also may be available in or through libraries or other informational services.)

2.3 Order of precedence. In the event of a conflict between the text of this document and the references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

3. DEFINITIONS

3.1 Introduction. Certain technical terms used throughout this standard are defined below to familiarize the reader with terminology common to the subject covered. The terms "test" and "inspection" are used interchangeably and refer to the performance of specific procedures and their associated evaluation criteria.

3.2 Absolute coil. An absolute coil is a single coil that responds to the total detected electromagnetic properties of the area under the coil without comparison to another area of the test object or to an external reference standard.

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3.3 Air null point. The air null point is the operating point of the eddy current system which has been balanced with the probe held in air such that it is unaffected by any conductive material.

3.4 Aluminum bronze/nickel-aluminum bronze. Aluminum bronze/nickel-aluminum bronze are metallurgically complex, copper-base alloys whose principal alloying elements include aluminum and iron (and nickel, in the case of nickel-aluminum bronze). Typical specifications covering aluminum bronze and nickel-aluminum bronze alloys are MIL-B-24480, QQ-C-390, QQ-C-450, ASTM B 150, and MIL-B-16166.

3.5 Cathode ray tube (CRT). CRT is the cathode ray tube or other X-Y storage monitor capable of displaying the eddy current instrument output phase and amplitude signals.

3.6 Dealloying. Dealloying is a seawater corrosion phenomenon in which one constituent of certain aluminum bronze/nickel-aluminum bronze alloys is selectively attacked, often with no visible evidence on the metal surface. Dealloying may extend to a depth below the surface of the bronze, significantly reducing the strength and ductility of the component. Figure 1 and Figure 2 illustrate typical dealloyed metal appearance.

3.7 Eddy currents. Eddy currents are circulating electrical currents induced in an isolated electrical conductor by an alternating magnetic field.

3.8 Equipment. Equipment is the general term used to include all nonconsumable hardware necessary to perform an inspection.

3.9 Government inspector. The Government inspector is a Government official, as defined in MIL-STD-271, who is charged with the responsibility for assuring that the materials, processes, fabrication technique and testing personnel meet specification and contractual requirements.

3.10 Inspection activity. Inspection activity is the organization performing dealloying inspections of U. S. Navy aluminum bronze/nickel aluminum bronze components to which this standard is applicable. Unless otherwise specified in the applicable contract or purchase order, the inspection activity shall be responsible for the quality of inspection results and the qualification and certification of personnel performing inspections.

3.11 Kilohertz (kHz). Kilohertz is a unit of frequency equal to one thousand cycles per second.

3.12 Lift-off. Lift-off is the change in output indication caused by a change in the magnetic coupling between the probe coil and the test object whenever the spacing between them is varied.

3.13 Machined Surface. A machined surface is any surface that has been planed or shaped by a surface finishing machine.

3.14 Magnetic permeability. Magnetic permeability is a quantity related to the ease with which a magnetic flux can be established within a material. Numerically, magnetic permeability is expressed as $\Delta B/\Delta H$, the ratio of a change in flux density, B, to a change in the magnetizing force H.

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3.15 Material Point. Material point is the point on the CRT impedance plane display corresponding to the test coil impedance when the probe is in proximity of an electrically conductive material.

3.16 Non-machined surface. A non-machined surface is any surface that is in the as-cast condition, or as-ground in a factory cleaning operation.

4. GENERAL REQUIREMENTS

4.1 Component access. Installed components found to be dealloyed but not readily accessible for the subsurface silver nitrate test shall be removed if determination of the depth of dealloying by the subsurface silver nitrate test is authorized.

4.2 Component cleanliness. Prior to inspection, seawater-exposed surfaces shall be cleaned of mud, oil, marine fouling, and any other foreign matter that could interfere with the inspection.

4.2.1 No abrasive tools which smear the relatively soft bronze shall be used. Wire brushes shall not be used. Stiff non-metallic brushes or plastic scrapers are the preferred surface cleaning tools.

4.2.2 Thin coatings of nonmagnetic, nonconductive paint or tightly-adhering calcium carbonate scales which do not interfere with free movement of the eddy current probe are not required to be removed. Paint or other coatings shall be checked for their effect on the eddy current inspection by comparing the signal response between a coated area and an adjacent area with the coating removed. When the probe is traversed across the interface of the two areas, any discernible signal, other then in the direction of lift-off, shall require removal of the coating.

4.3 Material verification. Prior to inspection, the component shall be verified to be composed of either aluminum bronze or nickel-aluminum bronze by reference to plan detail, or by direct chemical evaluation.

4.4 Component sketch. Prior to beginning the inspection, inspection personnel shall possess a sketch of the component to be inspected (see 6.3 and appendix). The sketch shall identify component surfaces exposed to seawater and shall define and show component wall thickness in the areas subject to inspection as shown on Figure 3. The purpose of the component sketch is as follows:

(a) To provide component information necessary for dealloying inspection and evaluation.
(b) To serve as the document on which dealloying inspection results are recorded.

4.5 Component exposure. Prior to inspection, the component surface area exposure shall be identified as partially exposed to seawater or totally exposed to seawater.

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4.6 Extent of inspection.

4.6.1 The eddy current test in accordance with this standard shall be performed to the maximum extent practical on surfaces designated as exposed to seawater.

(a) If the extent of practical eddy current testing is 75 percent or more of the total amount of component surface area exposed to seawater, the component shall be evaluated in accordance with the acceptance criteria in 5.3.
(b) If the extent of practical eddy current testing is less than 75 percent of the component surface area exposed to seawater, the inspectable area shall be inspected, the information recorded, and the component shall be evaluated in accordance with 5.3.1(c).

4.6.2 Component wall thicknesses of 0.25 inch or less which are exposed to seawater shall be inspected by the surface silver nitrate test and the eddy current test, and evaluated in accordance with 5.3. The subsurface silver nitrate test shall not be performed on wall thicknesses of 0.25 inch or less without specific approval from NAVSEA in each instance.

4.6.3 Threaded sections of components shall be inspected only if localized areas on the threaded surface can be cleaned of contaminants and surface oxide to permit the surface silver nitrate test. Government inspector concurrence shall be obtained for threaded surfaces considered non-inspectable.

4.6.4 Since it involves metal removal, the subsurface silver nitrate test may be performed on machined surfaces only when specifically authorized by the activity's cognizant engineering code. If it is decided that metal should not be removed from the machined surface, the information from the surface silver nitrate test and the eddy current test shall be recorded and the component referred for evaluation in accordance with 5.3.1(c).

4.6.5 For component surfaces which require the subsurface silver nitrate test as specified in 5.1.5.12(a) or 5.1.6.7.1(a), but which are inaccessible to excavation or satisfactory evaluation of the test due to component configuration, the information from the surface silver nitrate test and the eddy current test shall be recorded and the component referred for evaluation in accordance with 5.3.1(c).

4.6.6 The subsurface silver nitrate test shall not be performed on wrought product forms without specific NAVSEA approval.

4.7 Equipment. The test equipment and materials used shall meet or exceed the minimum required features or capabilities listed below.

4.7.1 Eddy current instrument. The basic eddy current instrument shall have the following features:

(a) Ability to excite the test coil probe with alternating current at a frequency between 2 and 5 kHz.
(b) Manual or automatic impedance balancing or nulling.
(c) Adjustable instrument sensitivity/gain.

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(d) Three hundred sixty degree rotation of the CRT display phase angle.

4.7.2 CRT display. The CRT display shall be an X-Y storage display monitor which can accept, display, and store both X and Y components of the ET instrument output signal by the vector point method. Stored display shall be erasable at the operator's option, and the erasure shall occur instantaneously when the appropriate control is actuated.

4.7.3 Test coil probe. The test coil probe shall be an absolute coil probe which can operate at the selected test frequency. Coil diameter shall be between 1/2-inch and 3/4-inch. Probe barrel may be any convenient length. Curved or other specially shaped probe faces that facilitate probe-to-casting contact and minimize lift-off are permitted. Differential coil probes or magnetic saturation probes shall not be used. Use of probe coils smaller than 1/2-inch is not permitted to determine the location of maximum dealloying depth since they do not operate well in the specified frequency range, and have limited depth of penetration. However, in areas of restricted access, smaller diameter probes may be used to detect areas where dealloying is present.

4.7.4 ET performance verification reference block. The ET performance verification reference block shall be a block of aluminum bronze or nickel-aluminum bronze with at least one naturally dealloyed metal region and one sound (non-dealloyed) metal face. One block may be used for the inspection of any material covered by this standard. Face dimensions shall be not less than 1 by 1 inch square. Thickness shall not be less than 1/2-inch, and extent of dealloying shall not exceed 0.025 inch. The block shall be permanently identified with a unique serial number. It shall be used to demonstrate satisfactory ET equipment performance prior to inspection.

4.7.5 Silver nitrate performance verification reference block. The silver nitrate performance verification reference block shall be similar in size to the ET block described in paragraph 4.7.4. The block shall be permanently identified with a unique serial number. It shall be used to demonstrate satisfactory silver nitrate solution strength prior to inspection.

4.7.6 **Silver nitrate solution.** The silver nitrate solution shall be used to verify the presence of dealloying at localized areas. The solution preparation and application shall be in accordance with NAVSEA 0948-LP-045-7010.

CAUTION

Do not splash or spray the silver nitrate solution. The solution is caustic and irritating to the skin and mucous membranes. Rubber or plastic gloves and eye protection should be worn while handling the silver nitrate solution. Skin or membrane areas exposed to the solution should be flushed immediately with fresh water. If the solution enters the eyes, wash them for at least 15 minutes with fresh water and get immediate medical attention.

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Dissolve 5 grams of silver nitrate ($AgNO_3$) in 100 milliliters (mL) of distilled water. In a separate container, mix 2 mL of 6 percent hydrogen peroxide (H_2O_2) with 50 mL of methyl or ethyl alcohol. Mix the two solutions together.

4.7.6.1 Solution reaction times stated herein are based on freshly-prepared solution. Reaction time for silver nitrate solution shall be established prior to inspection, in the working shift in which the inspection is performed, as specified in 5.2.3.

4.7.6.2 The silver nitrate solution decomposes slowly when exposed to light and heat. The solution container shall be treated to exclude light. A dark-colored container or a container covered with opaque material is recommended. The solution may also be refrigerated to prolong shelf life.

4.7.7 Medicine dropper (or other applicator). A medicine dropper or other applicator shall be used for dispensing the silver nitrate solution.

4.7.8 Absorbent paper towels. Absorbent paper towels shall be used to clean the component surface before and after the silver nitrate test and to absorb excess silver nitrate solution applied to the surface.

4.7.9 Abrasive cloth, paper, or disks. One hundred grit or finer abrasive should be used to remove oxides from component surfaces. Rough as-cast surfaces will require heavier grit abrasive or grinding to remove surface roughness.

4.7.10 Portable power tool. A 1/4-inch to 3/8-inch drive electric drill or similar tool shall be used to drive the rotary file during component surface excavation.

4.7.11 Rotary file. The rotary file shall have a rounded end with a minimum 3/8-inch diameter. It shall be used to excavate a component surface for the subsurface silver nitrate test.

4.7.12 Depth gauge. The depth gauge shall have a knife edge base and a needle point that can measure in 0.005 inch graduations, directly or indirectly; may be dial indicator (Starrett gauge number 643, or equal), micrometer type, or other. It shall be used to measure dealloying depth in component excavations after the subsurface silver nitrate test has revealed the dealloyed metal/sound metal interface. The gauge shall meet the calibration system requirements of MIL-STD-45662.

4.7.13 Grease pencil (china marker). A pencil or marker shall be used to contain and hold the droplet of silver nitrate solution, especially on vertical surfaces.

4.7.14 Fresh water. Fresh water shall be used to moisten paper towels for removal of the silver nitrate solution upon completion of the test.

4.8 Qualification.

4.8.1 Procedures. Activities' inspection procedures shall be in accordance with this standard and the requirements of MIL-STD-271.

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4.8.2 Personnel - eddy current. Eddy current inspections in accordance with this standard shall be performed only by qualified personnel who have been certified in accordance with MIL-STD-271.

4.8.3 Personnel - silver nitrate. Silver nitrate inspections in accordance with this standard shall be performed only by personnel who have qualified by demonstrating their ability to perform the inspection to the satisfaction of the activity's eddy current examiner.

4.8.4 Equipment. The eddy current equipment shall be qualified as specified in 5.1.4.

4.9 Inspection sequence. The general inspection sequence is as shown on Figure 4.

5. DETAILED REQUIREMENTS

5.1 Eddy current test (see 6.3).

5.1.1 Introduction. The aluminum bronze and nickel-aluminum bronze alloys covered by the standard contaIn sufficient iron to give these alloys magnetic permeability; that is, they are slightly-to-moderately attracted to a magnet. This magnetic permeability characteristic has two important effects on the eddy current inspection for dealloying. First, the depth of eddy current penetration which determines the depth of dealloying that can be detected is significantly less than if the metal exhibited no ferromagnetic behavior. Second, it is the localized reduction in magnetic permeability caused by the decreased iron content in dealloyed metal that is the principal material variable measured in the eddy current test. Since every individual component has its own unique composition and its own unique relative magnetic permeability, the eddy current can be used only as a qualitative tool to indicate the presence of dealloying on a component and its relative depth at different areas on that particular component.

5.1.2 Equipment required. The equipment required is the eddy current instrument, CRT display, test coil probe, and ET performance verification reference block. A detailed description of these items is specified in 4.7.

5.1.3 Surface condition. Surfaces to be inspected shall be reasonably smooth and free of foreign matter that might interfere with free movement of the probe. Eddy current inspection may be performed on surfaces that are covered or partially covered by thin coatings of paint or tightly adhering calcium carbonate scale. Only surfaces or lands that are at least as wide as the test probe coil diameter shall be inspected by eddy current.

5.1.4 Equipment performance verification. Satisfactory eddy current equipment performance shall be verified at the job site immediately prior to the start of an inspection, and shall be repeated:

(a) At least every 4 hours.
(b) Whenever the equipment is moved from one job site to another.
(c) Whenever electrical power to the instrument or to the probe is interrupted, or the equipment is left unattended.

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(d) Whenever the inspector has reason to suspect that conditions affecting equipment performance have changed.
(e) At the completion of each inspection.

If the performance check indicates unsatisfactory performance, all areas inspected since the last performance check shall be reinspected. Note that the recommendations for positioning of the CRT trace in the following paragraphs are for purposes of clarity and consistency when describing the technique and referring to the various figures. As long as suitable phase separation is obtained, the direction in which the trace moves is not relevant, so long as areas of sound material can be distinguished from dealloying.

5.1.4.1 Make the appropriate probe and power connections to the eddy current instrument.

5.1.4.2 Turn the instrument power on and allow a few minutes for instrument warmup.

5.1.4.3 Select the desired frequency (2 to 5 kHz).

5.1.4.4 Null the instrument with the probe in the air (do not place the probe on the test surface). Verify that the instrument is nulled by rotating the phase control. If the CRT spot describes an open circle on the screen, use the automatic null or the manual X and R balance controls to move the spot to the center of the circle. Repeat this step until the CRT spot no longer traces an open circle. This is the air null point. The instrument shall be re-nulled whenever the instrument sensitivity/gain control or frequency setting is changed and whenever there is a discernible drift of the air null point from the marked air null point on the screen.

5.1.4.5 After null is achieved, position the spot on the oscilloscope to the upper left quadrant of the screen using the CRT vertical and horizontal positioning controls. The position of the air null point shall be marked on the CRT.

5.1.4.6 Place the probe on the sound metal surface of the ET performance verification reference block. Adjust the phase and sensitivity/gain controls until the trace of the CRT moves down and to the right with the sound base material point resting on the same horizontal grid line as the null point (see Figure 5) approximately 1/2 inch from the right side of the screen. If the sensitivity/gain control is adjusted, re-null the instrument in air.

5.1.4.7 Touch the probe to the dealloyed metal surface of the ET performance verification reference block, and observe that the CRT trace again moves out to the right of the air null point, but falls below the sound metal trace, as shown on Figure 5.

5.1.4.8 Satisfactory equipment performance shall be demonstrated by the instrument's capability to perform each of the above steps specified. If the equipment fails to perform satisfactorily during any performance check conducted during an inspection, the inspector shall obtain equipment that is in good working condition and shall re-inspect all components inspected since the previous satisfactory performance verification.

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5.1.5 Inspection procedure for components partially exposed to seawater. The inspection shall be conducted as follows.

5.1.5.1 Set up the eddy current equipment and verify satisfactory equipment performance as specified in 5.1.4.

5.1.5.2 Review the component sketch to determine component surface areas that have not been exposed to seawater.

5.1.5.3 Select a non-exposed area with a surface contour appropriate to the probe face contour, ensuring that the selected area is at least as wide as the probe coil diameter.

5.1.5.4 Perform the surface silver nitrate test as specified in 5.2.4 on the selected area to confirm the absence of dealloying.

5.1.5.5 Touch the probe to the non-dealloyed reference location established above and observe which directIon the CRT trace moves.

5.1.5.6 Rotate the ROTATION/PHASE control until the CRT trace for the non-dealloyed reference location moves horizontally to the right of the air null point. The endpoint of this trace is the base metal point for the component. The base metal point should be positioned on the same horizontal screen grid line as the air null point.

5.1.5.7 Adjust the SENSITIVITY/GAIN control until the base metal point is approximately 1/2-inch from the right-hand border of the screen. Readjust the air null point and ROTATION/PHASE controls as necessary. Lock the ROTATION/PHASE and SENSITIVITY/GAIN controls in position.

5.1.5.8 Touch the probe to the component surface to be inspected. Readjust the SENSITIVITY/GAIN control as necessary. If the SENSITIVITY/GAIN control is adjusted, repeat 5.1.5.7, disregarding the 1/2-inch guideline. Slowly scan the probe across the component surface while observing the CRT screen. Scanning technique may be static or continuous. If continuous scanning is used, scanning rate shall not exceed 3 inches per second.

5.1.5.9 Dealloying on the seawater-exposed component surface is indicated by the CRT trace moving significantly downward (clockwise) away from the sound base metal trace. "Significantly," as used here, means greater than one trace width, as illustrated on Figure 6. As the figure shows, increasing depth of dealloying is indicated on the CRT screen by increasingly downward (clockwise) trajectories of the CRT trace. The deepest dealloying will be indicated by the most-downward trajectory of the CRT trace.

5.1.5.9.1 Weld repairs to aluminum bronze and nickel-aluminum bronze components often create localized areas of anomalous magnetic permeability due to a mismatch between the filler metal alloy and the component alloy. Low permeability weld repairs will cause a downward (clockwise) motion of the CRT trace similar to the presence of dealloying. Since weld repairs should not react to the silver nitrate solution unless the repair area is itself dealloyed, eddy current results which cause the inspector any doubt as to their origin should be confirmed using the surface silver nitrate test as specified in 5.2.4.

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5.1.5.9.2 Electro-deposited copper plating on valve guide seats or other machined sealing surfaces creates localized areas of low magnetic permeability/ high electrical conductivity which will cause a downward (clockwise) motion of the CRT trace similar to the presence of dealloying. In addition, copper plated areas are visually indistinguishable from the bronze surface and will cause the silver nitrate solution to react in a manner similar to the presence of dealloying. When the presence of plating on machined sealing surfaces cannot be confirmed by reference to plan detail or by direct evidence, indications of dealloying on these surfaces should be investigated by abrasively removing a few thousandths of an inch of metal at one or more locations on the suspect surface and repeating the surface silver nitrate test as specified in 5.2.4. Authorization shall be obtained prior to performing any metal removal operations on machined surfaces, as specified in 4.6.4.

5.1.5.9.3 The CRT trace responses to two other testing conditions are presented on Figure 7. Lift-off, caused by variations in the probe-to-component-surface distance, will alter the length of the CRT trace but will not affect the angular trajectory of the trace. Component discontinuities, such as cracks or voids, will alter the angular trajectory of the trace. Discontinuities will always cause the CRT trace to move in an upward (counter-clockwise) direction away from its previous position. ET results which cause the inspector any doubt as to their origin should be confirmed using the surface silver nitrate test as specified in 5.2.4.

5.1.5.10 Scan the entire accessible portion of the component surface identified on the component sketch as exposed to seawater. Overlapping coverage or grid mapping are not required. The CRT screen may be erased at the inspector's discretion. Periodically return the probe to the non-dealloyed reference location on the component to confirm the initial sound metal CRT trace (see 5.1.4).

5.1.5.11 Mark the area on the component where the deepest dealloying is indicated on each different wall thickness.

5.1.5.12 Perform the surface silver nitrate test as specified in 5.2.4 at each location marked above to confirm the presence of dealloying.

(a) When the surface silver nitrate test confirms the presence of dealloying, the subsurface silver nitrate test in accordance with 5.2.5 shall be performed to measure dealloying depth (except as specified in 4.6.2, 4.6.4, 4.6.5, and 4.6.6).

(b) When the surface silver nitrate test does not confirm the presence of dealloying, the location tested shall be recorded as free of dealloying, and the surface silver nitrate test shall be performed at a minimum of one additional location of that same wall thickness where the eddy current test indicated the presence of dealloying. If dealloying is indicated, return to (a) above; if not, the location shall be recorded as free of dealloying.

5.1.6 Inspection procedure for components totally exposed to seawater. Using the surface silver nitrate test, the inspector shall make a reasonable effort to identify a non-dealloyed reference location on the surface of

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components totally exposed to seawater. If the inspector is able to find a non-dealloyed reference location, he shall perform the eddy current test in accordance with 5.1.5.5 through 5.1.5.12. If the inspector is unable to find a non-dealloyed location, he shall perform the eddy current test as described below.

5.1.6.1 Set up the eddy current equipment and verify satisfactory equipment performance as specified in 5.1.4.

5.1.6.2 Touch the probe to the surface of the component to be inspected and observe which direction the CRT trace moves.

5.1.6.3 Rotate the ROTATION/PHASE control until the CRT trace for the component moves horizontally to the right of the air null point. The endpoint of the trace should be positioned on the same horizontal screen grid line as the air null point.

5.1.6.4 Adjust the SENSITIVITY/GAIN control until the endpoint of the component CRT trace is approximately 1/2-inch from the right-hand border of the screen. Readjust the null and ROTATION/PHASE controls as necessary. Lock the SENSITIVITY/GAIN control in position.

5.1.6.5 Slowly scan the probe across the entire accessible portion of the component surface while observing the CRT screen. Overlapping coverage or grid mapping are not required. Scanning technique may be static or continuous. If continuous scanning is used, scanning rate shall not exceed 3 inches per second. The CRT screen may be erased at the inspector's discretion. If the CRT trace for the component moves upward (counter-clockwise) or downward (clockwise) off the screen during an inspection, use the ROTATION/PHASE CONTROL to return the trace to the screen.

5.1.6.6 The area of deepest dealloying will be indicated by the most downward (clockwise) trajectory of the CRT trace, as shown on Figure 6. Eddy current test responses to weld repairs, electro-deposited copper plating, and other testing conditions specified in 5.1.5.9.1 through 5.1.5.9.3 are also applicable to components totally exposed to seawater.

5.1.6.7 If the CRT trace moves significantly upward (counter-clockwise) or downward (clockwise) from the initial trace position, mark the area on the component where the most downward (clockwise) trace is produced on each different wall thickness.

5.1.6.7.1 Perform the surface silver nitrate test as specified in 5.2.4 at each location marked above to confirm the presence of dealloying.

(a) When the surface silver nitrate test confirms the presence of dealloying, the subsurface silver nitrate test in accordance with 5.2.5 shall be performed to measure dealloying depth (except as specified in 4.6.2, 4.6.4, 4.6.5, and 4.6.6).

(b) When the surface silver nitrate test does not confirm the presence of dealloying, the location tested shall be recorded as free of dealloying, and the surface silver nitrate test shall be performed at a minimum of one additional location of that same wall thickness

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where the eddy current test indicated the presence of dealloying. If dealloying is indicated, return to (a) above; if not, the location shall be recorded as free of dealloying

5.1.6.8 If the CRT trace does not move significantly away from the initial trace position, the component may either be uniformly dealloyed or dealloyed to a depth exceeding the eddy current depth of penetration into the component. When this occurs, perform the subsurface silver nitrate test in accordance with 5.2.5 to measure the depth of dealloying at a minimum of two locations, including the thinnest accessible wall thickness (except as specified in 4.6.2, 4.6.4, 4.6.5, and 4.6.6).

5.1.7 Inspection procedure for threaded sections of components. Threaded surfaces that are exposed to seawater present a unique inspection situation. The electromagnetic coupling between the eddy current probe and a threaded surface is not equivalent to the coupling between the probe and a smooth, regular surface. Consequently, the CRT material point and resulting impedance trace for non-dealloyed metal on a threaded surface is not the same as that for sound metal on a smooth surface on the same component. Never use a non-dealloyed location on a smooth, regular surface of a component as the non-dealloyed ET reference location for inspection of a threaded surface. Threaded areas exposed to seawater shall be inspected separately from the remainder of the component. The threaded area shall be considered as an area totally exposed to seawater and shall be inspected as specified in 5.1.6, except as modified below.

5.1.7.1 Threaded surfaces shall not be inspected if the pitch of the threads is too fine to permit satisfactory surface silver nitrate testing (see 4.6.3).

5.1.7.2 Due to the difficulty in removing contaminants and oxide from threaded surfaces, it is not necessary for the inspector to attempt to identify a non-dealloyed reference location on the threaded area before proceeding with the eddy current inspection.

5.1.7.3 Eddy current inspection of internal threads on small diameter bores is best accomplished using a probe with a short barrel length and a convex-curved working face to facilitate probe handling.

5.1.7.4 As with other machined surfaces, the restriction as specified in 4.6.4 applies to the performance of the subsurface silver nitrate test on threaded surfaces.

5.1.8 Inspection notes.

5.1.8.1 Periodically check for any drift of the signal from the marked air null point. Re-null the instrument as necessary. If the phase control is used to check the null, check that the phase is set to the same angle as before the null check.

5.1.8.2 If battery power is used extensively, periodically perform the battery check recommended by the instrument manufacturer and shift operation to external line power as appropriate. Battery checks and changes in the power source are subject to the requirements of 5.1.4.

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5.2 Silver nitrate test (see 6.3).

5.2.1 Introduction. The surface and subsurface silver nitrate tests verify the presence of dealloying and its depth below the surface at specific locations on aluminum bronze and nickel-aluminum bronze alloy components. A solution of silver nitrate applied to a cleaned surface displays a black color in dealloyed areas due to reaction with the free copper present. The silver nitrate tests provide a direct visual indication of dealloying and serve as a proof check of results obtained in the eddy current test.

5.2.2 Equipment/materials required. The equipment and materials listed below are required for the test procedures. However, only items (a) through (g) are required for the surface silver nitrate test. A detailed description of these items is specified in 4.7.

(a) Silver nitrate solution.
(b) Abrasive cloth, paper, or disks.
(c) Medicine dropper or other suitable applicator.
(d) Absorbent paper towels.
(e) Silver Nitrate performance verification reference block.
(f) Grease pencil (china marker).
(g) Supply of fresh water.
(h) Portable power tool.
(i) Rotary file.
(j) Depth gauge.

5.2.3 Solution check. Prior to the start of each inspection, the silver nitrate solution shall be tested for adequate strength and effectiveness, and to establish the solution reaction time. The solution reaction times stated herein are based on freshly prepared solution. Reaction time for other than fresh solution may vary. The solution check shall be performed as specified in 5.2.3.1 through 5.2.3.4.

5.2.3.1 Select an area within the dealloyed region on the silver nitrate performance verification reference block and remove surface contaminants and oxide by polishing with 100 grit or finer abrasive. Remove loosened material from the surface.

5.2.3.2 Apply a droplet of the silver nitrate solution to the prepared area and observe the reaction. Solution application guidelines are specified in 5.2.4.2.

5.2.3.3 Satisfactory solution performance is indicated by the solution turning black within five seconds after application. Figure 8 illustrates typical test results. If the silver nitrate solution does not react in this manner, discard and prepare fresh solution as specified in 4.7.6.

5.2.3.4 After evaluation, wipe away the residual silver nitrate solution with a water-moistened towel.

5.2.4 Surface silver nitrate test. The surface silver nitrate test is performed:

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(a) To confirm the absence of dealloying at the eddy current test reference location on the component.
(b) To confirm the presence of dealloying at the surface prior to performing the subsurface silver nitrate test for dealloying depth.
(c) To confirm any eddy current results which cause the inspector any doubt as to their origin.

The test shall be conducted as follows:

5.2.4.1 Surface preparation. Remove all paint, dirt, grease, or other contaminants from the test area. If the test area is on a non-machined surface, file or lightly grind the area to remove all surface roughness. If the test area is on a machined surface, lightly sand the area with 100 grit or finer emery paper or comparable abrasive material. In both cases, surface oxide on the test area shall be removed abrasively immediately prior to application of the silver nitrate solution. A smooth, shiny, bare metal surface shall be obtained. Remove all loosened material from the cleaned area by wiping with a clean, dry towel.

5.2.4.1.1 Adequate surface preparation cannot be overemphasized. As-cast surface roughness shall be removed to prevent accumulation of foreign material in surface crevices. Never use wire brushes for surface cleaning in any of the dealloying test procedures. Wire brushing smears the relatively soft bronze and may distort test results.

5.2.4.2 Surface silver nitrate solution application. Apply the silver nitrate solution to the test area by dropping, swabbing, or flowing. Avoid smearing the solution after the initial application. A circle drawn with grease pencil (china marker) will contain the solution on vertical surfaces. Never spray the silver nitrate solution on the test area. Avoid applying excessive solution—a small droplet is adequate. Avoid testing areas significantly larger than the area shown on Figure 8. Never "paint" the solution over large areas of the component surface. Always observe the safety precautions as specified in 4.7.6 when handling the solution.

5.2.4.3 Test evaluation. Dealloying is indicated by the solution turning black immediately after application. The solution will remain clear on areas free of dealloying. Figure 8 illustrates typical test results. After evaluation, wipe away the residual silver nitrate solution with a water-moistened towel.

5.2.5 Subsurface silver nitrate test. The subsurface silver nitrate test is performed to determine the depth to which dealloying has penetrated a component after it has been confirmed on the surface. The test shall be conducted as specified in 5.2.5.1 through 5.2.5.5.2.

5.2.5.1 Surface preparation. General surface preparation shall be as specified in 5.2.4.1 for the surface silver nitrate test. The surface silver nitrate test as specified in 5.2.4 shall always be performed in the test area to confirm eddy current results prior to excavation.

5.2.5.2 Excavation. Using the powered rotary file, begin excavating into the component surface at the selected test area. Figure 9 illustrates the

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proper excavation technique. The excavation should be a wide, dished opening with sloping sides to permit accurate dealloying depth measurement as specified in 5.2.5.5. Excavate in increments not exceeding 0.020 inch in depth. After each increment, apply the silver nitrate solution within the excavation as specified in 5.2.5.3.

5.2.5.3 Subsurface silver nitrate solution application. Apply the solution to the test excavation by dropping, swabbing, or flowing. Avoid smearing the solution after the initial application. After approximately 5 seconds, remove excess solution by touching the tip of a loosely twisted paper towel to the surface of the solution, as shown on Figure 10. Always observe the safety precautions as specified in 4.7.6 when handling the solution. Evaluate the results in accordance with 5.2.5.4.

5.2.5.4 Test evaluation. The presence of dealloying is indicated by the silver nitrate solution turning black immediately after application. The solution will remain clear on areas free of dealloying. In this way, the test will clearly display the interface between dealloyed metal and non-dealloyed base metal within the excavation, as shown on Figure 11.

5.2.5.4.1 If the dealloyed/non-dealloyed interface is revealed within the excavation, measure the depth of dealloying as specified in 5.2.5.5.

5.2.5.4.2 If the dealloyed/non-dealloyed interface is not revealed, and the excavation depth has not reached band B of the acceptance curve shown on Figure 12, continue to excavate as specified in 5.2.5.2 and reapply the silver nitrate solution in accordance with 5.2.5.3.

5.2.5.4.3 If the dealloyed/non-dealloyed interface is not revealed, and the excavation depth has reached band B of the acceptance curve shown on Figure 12, excavation may continue only if minimum specified thickness has not been reached. If minimum drawing thickness has been reached, discontinue excavating. Further excavation shall not be performed without specific technical approval. If the decision is made to stop further excavation, the test information accumulated up, to that point shall be recorded, and the component referred for evaluation and further instructions.

5.2.5.5 Depth measurement. Using the depth gauge as illustrated on Figure 13, measure the distance from the component surface to the lowest portion of the dealloyed/non-dealloyed interface. This distance shall be reported as the depth of dealloying at the test area. Gauge readings shall be recorded to the nearest 0.005 inch (that is, 0.015, 0.020, 0.025, and so forth). Hold the depth gauge normal to the component surface and zero the gauge point at the surface prior to measurement. Avoid tilting or rocking the gauge during zeroing and measurement.

5.2.5.5.1 In addition, use the depth gauge to measure the distance from the component surface to the deepest point of the excavation. This distance shall be reported as the maximum excavation depth at the test area. Gauge readings shall be recorded to the nearest 0.005 inch.

5.2.5.5.2 After measurement of dealloying depth, wipe away the residual silver nitrate solution with a water-moistened towel.

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5.3 Acceptance criteria (see 6.3).

5.3.1 Evaluation. Components or areas of components that are free of dealloying are acceptable. Wrought product forms shall be evaluated in accordance with 5.3.1(c). Figure 12 does not apply to wrought material. The evaluation criteria described below are generally based on the proportion of a given wall thickness that has dealloyed.

(a) Using the values for dealloying depth and casting wall thickness for each test area, determine whether the test area falls into band A or B of the curve shown on Figure 12.

(b) For cases where the values fall into band A, the casting is acceptable and no engineering evaluation is required.

(c) For cases where one or more test areas fall into band B, as otherwise required by 4.6, and for all wrought product forms, an evaluation shall be performed to determine whether the component shall be retained for further service. The evaluation shall be based on at least the following data:

  (1) Engineering analysis of the area of concern, covering at least the requirements of NAVSEA 0941-LP-041-3010.
  (2) Actual thickness of the area of concern versus minimum required thickness.
  (3) Actual area of dealloying.
  (4) System in which the component is installed.
  (5) Location and size of the component.
  (6) Chemical and physical properties of the component, from records, if available.

(d) Evaluation data and the information used by the inspection activity to determine acceptance or rejection shall be forwarded to NAVSEA for review and approval.

5.3.2 Disposal of rejected castings. No rejected casting shall be arbitrarily scrapped by the inspection activity. Authorization shall be obtained from NAVSEA prior to disposal of castings.

6. NOTES

(This section contains information of a general or explanatory nature that may be helpful, but is not mandatory.)

6.1 Intended use. This standard contains minimum requirements necessary to conduct the eddy current test and the silver nitrate test used to determine the presence and depth of dealloying on aluminum bronze and nickel-aluminum bronze components on submarines.

6.2 Issue of DODISS. When this standard is used in acquisition, the applicable issue of the DODISS must be cited in the solicitation (see 2.1.1 and 2.2).

6.3 Data requirements. The following Data Item Descriptions (DID's) must be listed, as applicable, on the Contract Data Requirements List, (DD Form 1423) when this standard is applied on a contract, in order to obtain the

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data, except where DOD FAR Supplement 27.475-1 exempts the requirement for a DD Form 1423.

Reference Paragraph	DID Number	DID Title	Suggested Tailoring
5.1, 5.2 and 5.3	DI-MISC-80653	Test reports	-----

The above DID's were those cleared as of the date of this standard. The current issue of DOD 5010.12-L, Acquisition Management Systems and Data Requirements Control List (AMSDL), must be researched to ensure that only current, cleared DID's are cited on the DD Form 1423.

6.4 Subject term (key word) listing.

Castings
Cathode ray tube
Eddy current
Lift-off
Magnetic permeability
Silver nitrate

Preparing activity:
Navy - SH
(Project NDTI-N081)

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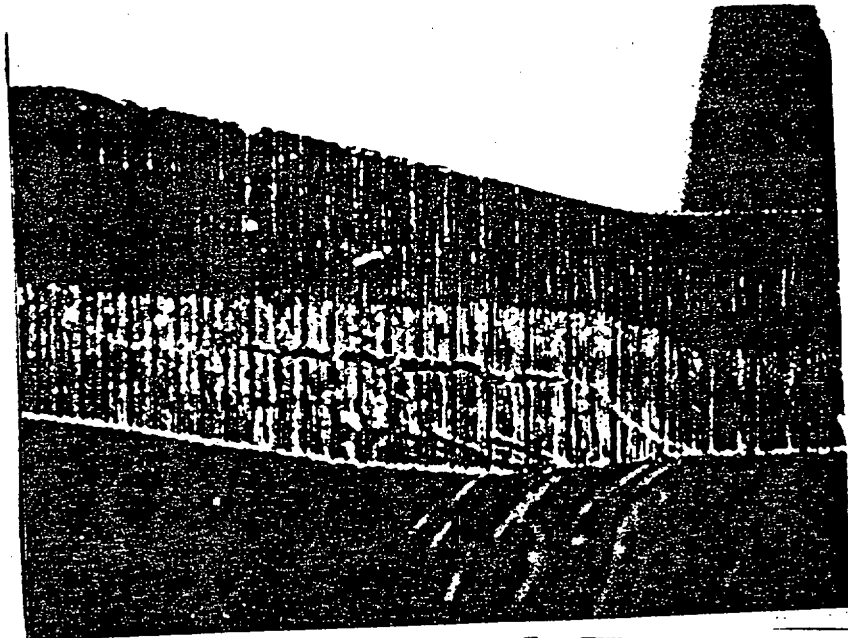
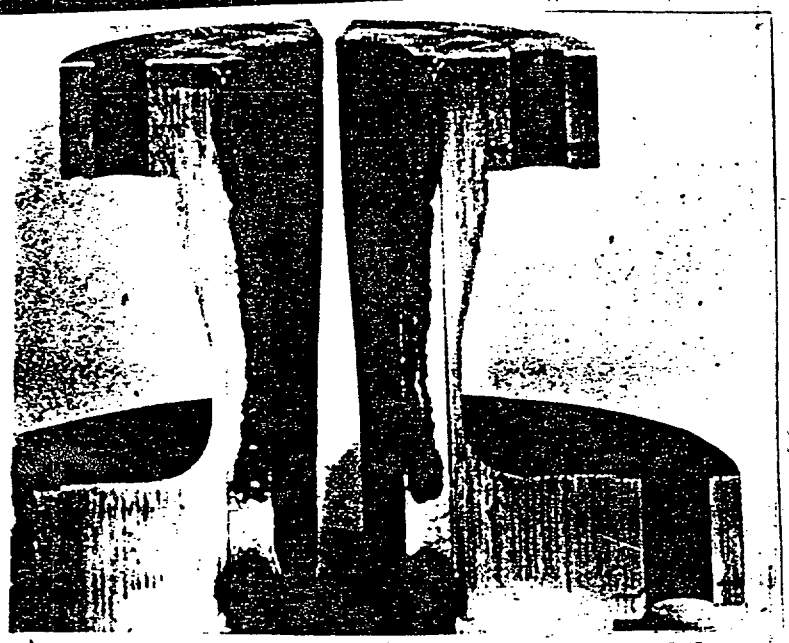


A. Saw-cut surface.



B. Fracture surface.

NOTES: A. On a saw-cut surface, dealloyed metal appears lighter in color than the surrounding sound metal.
B. On a fracture surface, dealloyed metal appears darker in color than the surrounding sound metal.

Figure 1. Appearance of dealloying on saw-cut and fracture surfaces of an aluminum bronze valve tailpiece.

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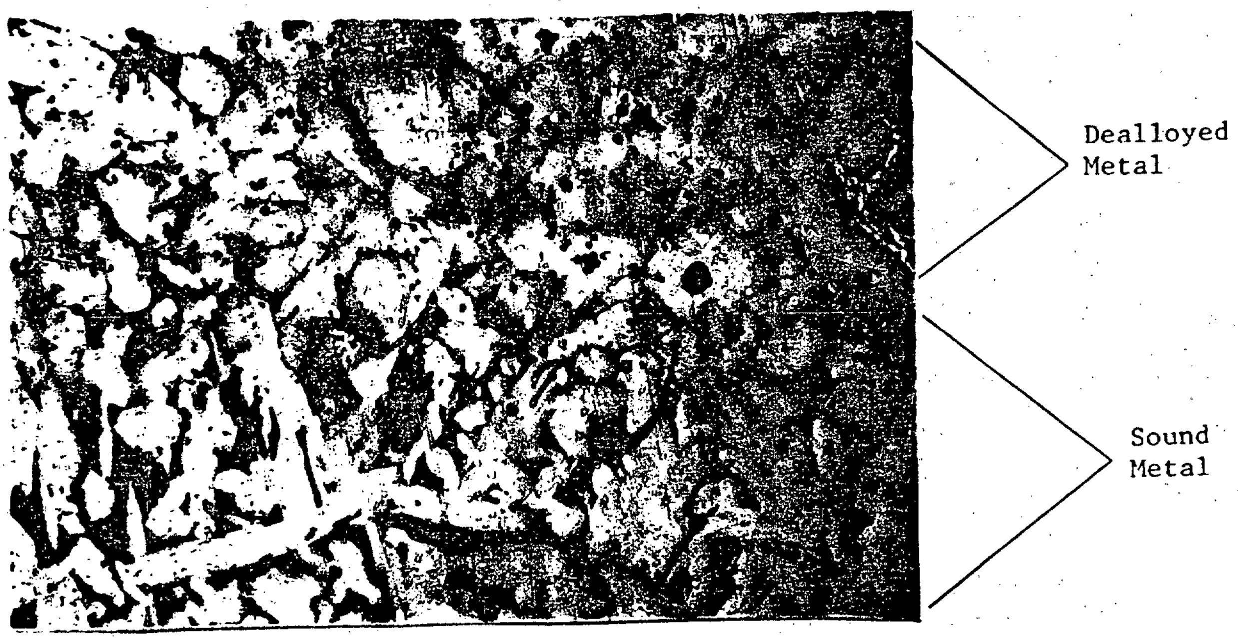

Figure 2. Microstructural appearance of the dealloyed/sound metal interface from an aluminum bronze valve tailpiece.

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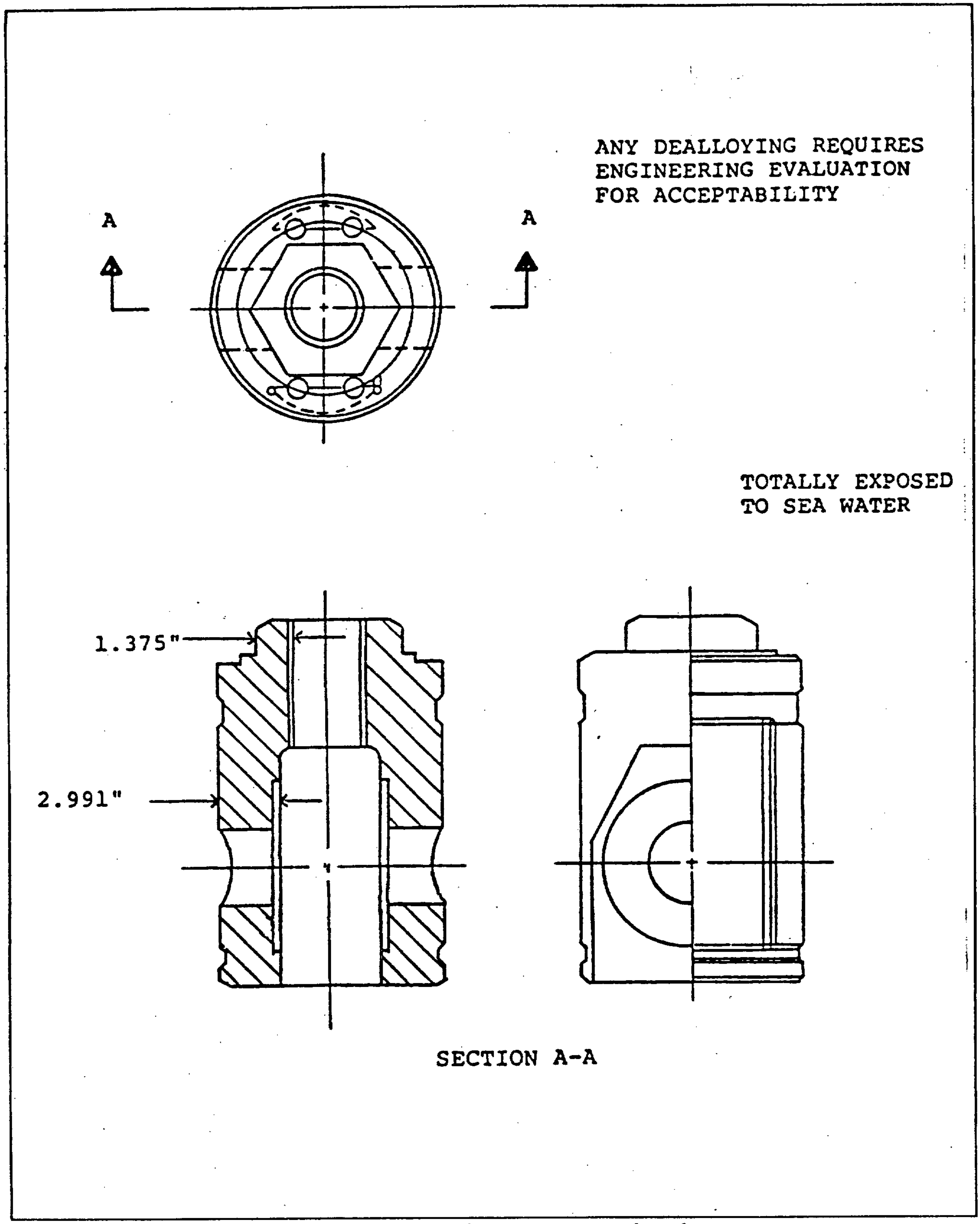

Figure 3. Sample component sketch.

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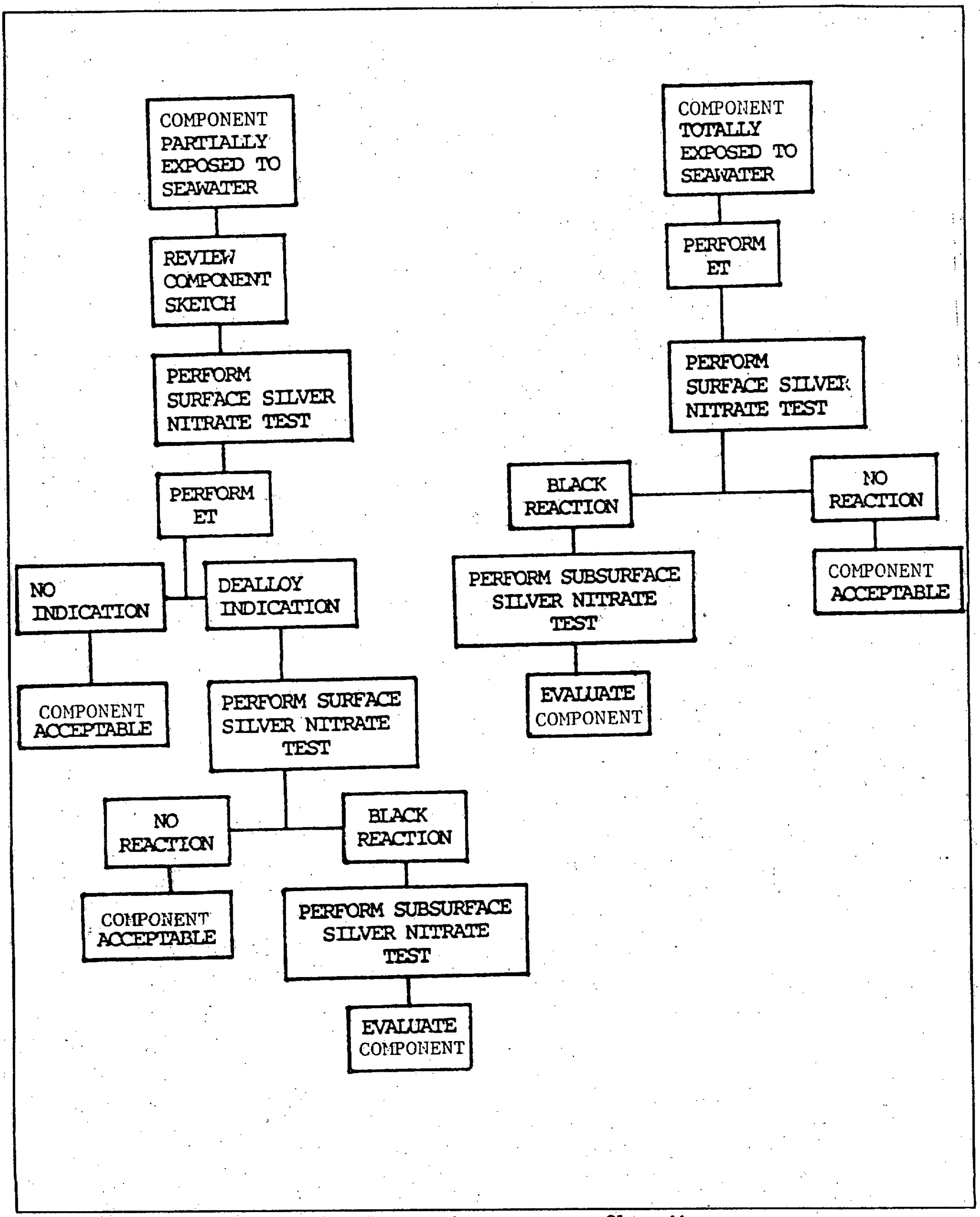

Figure 4. Inspection sequence flow diagram.

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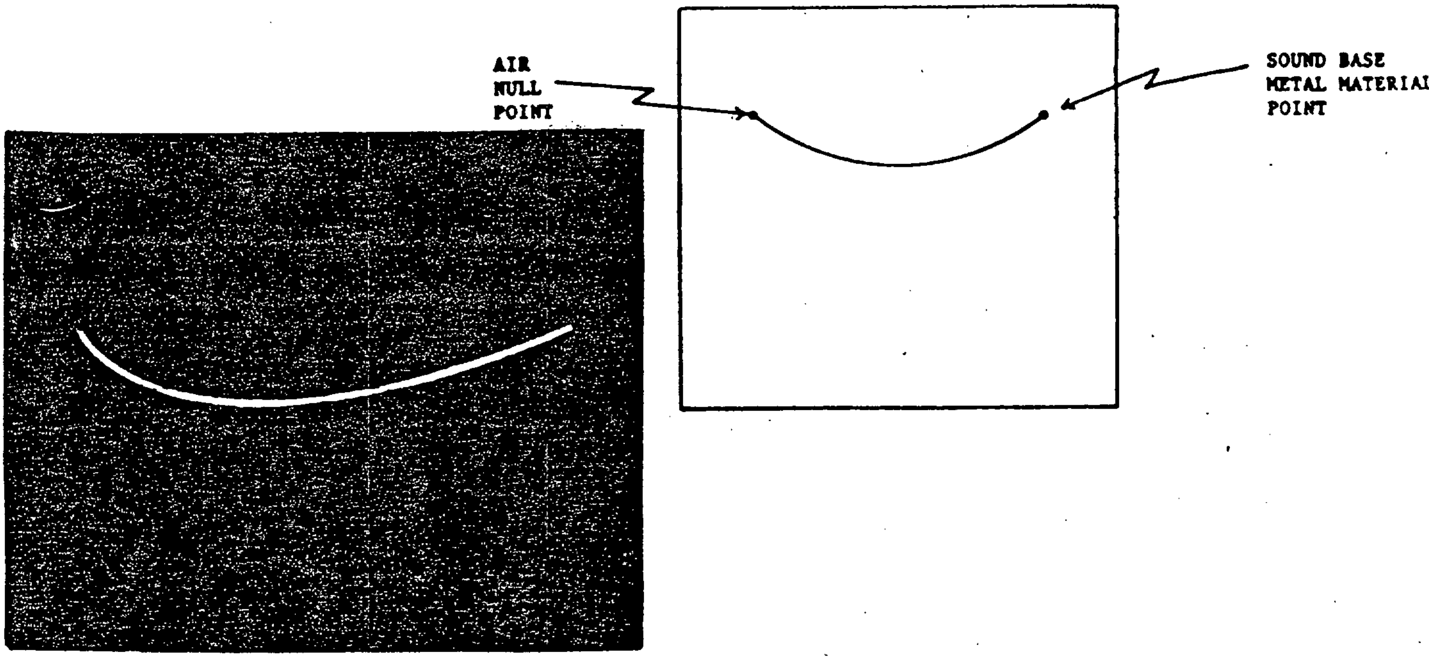
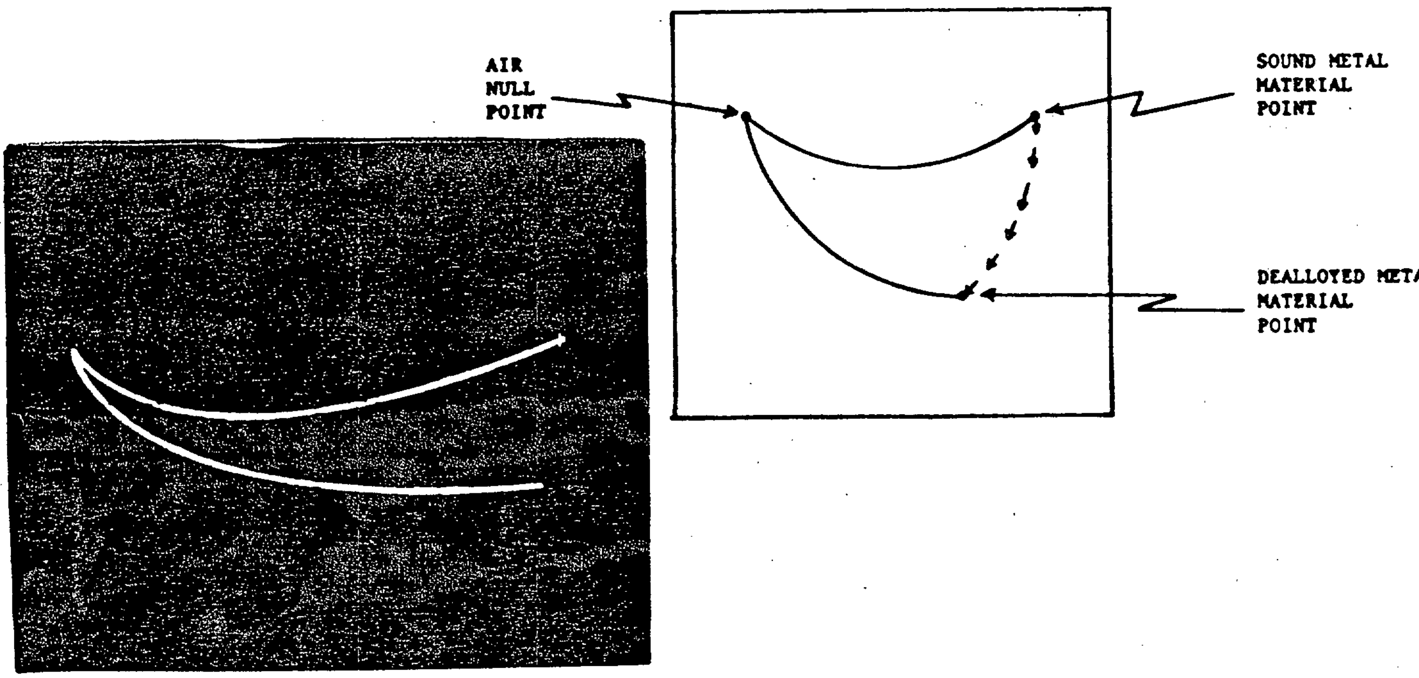


A. Sound base metal reference response.



B. Dealloyed metal reference response.

Figure 5. <u>CRT screen showing performance verification response</u>.

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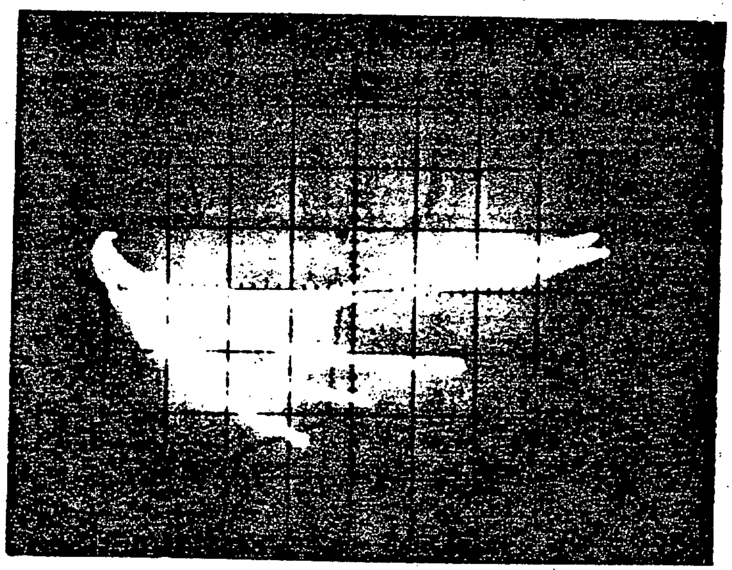

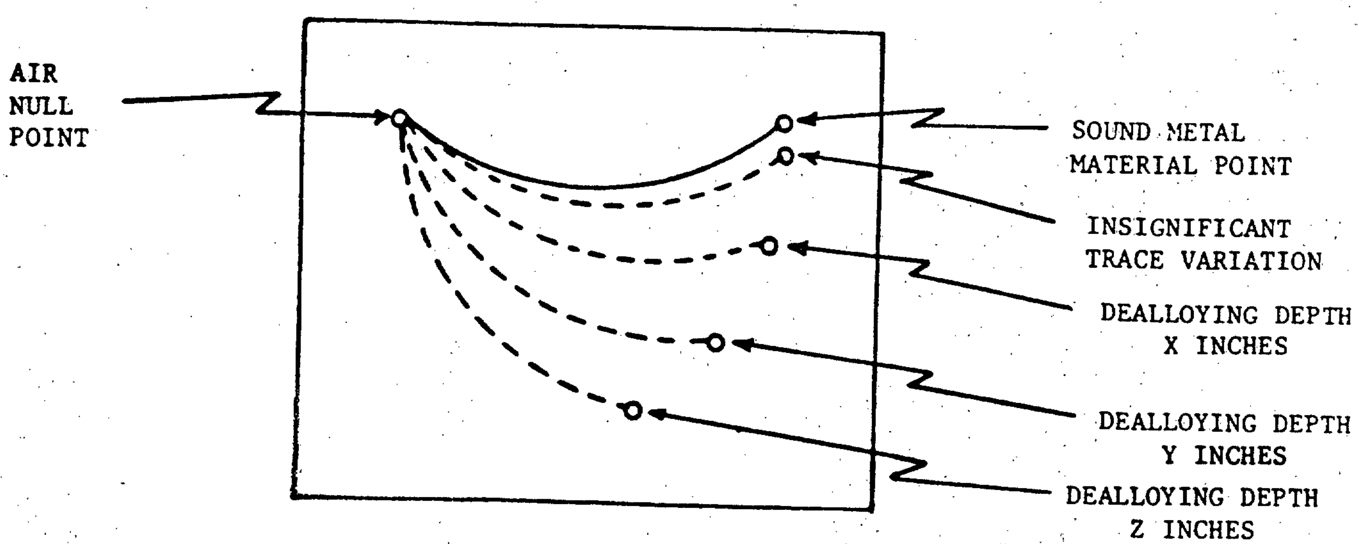

Figure 6. CRT screen showing dealloying response.

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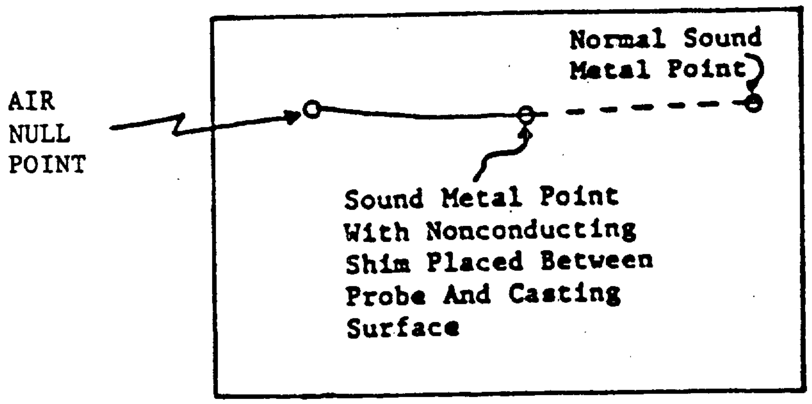
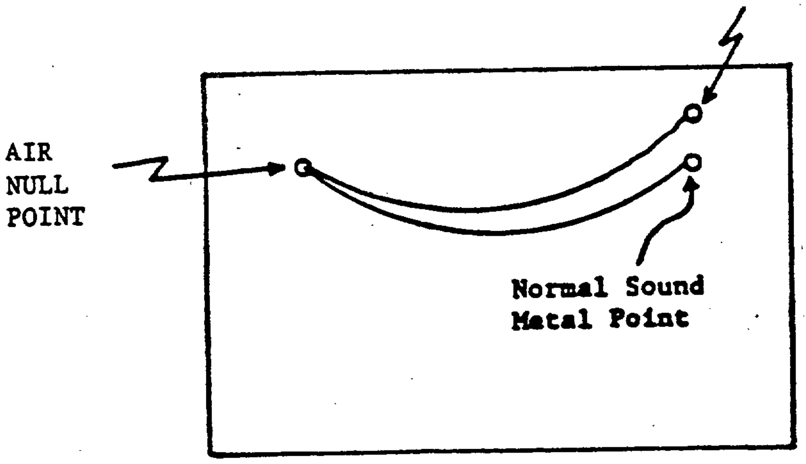


NOTE: EFFECT OF LIFT-OFF IS TO SHORTEN TRACE LENGTH; ANGULAR TRAJECTORY OF TRACE IS NOT AFFECTED

A. Response to lift-off.



NOTE: EFFECT OF COMPONENT DISCONTINUITY IS TO MOVE TRACE UPWARD (COUNTER-CLOCKWISE)

B. Response to subsurface component defect with no dealloying present.

FIGURE 7. CRT screen showing response to lift-off and component defects.

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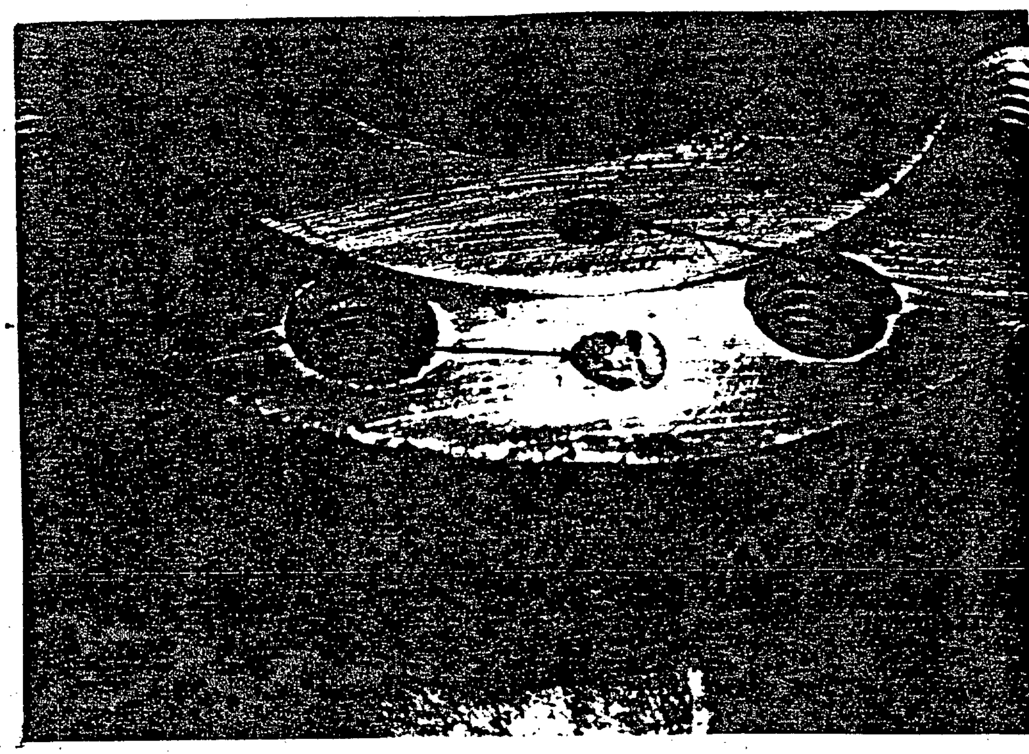
NON-DEALLOYED METAL



DEALLOYED METAL

FIGURE 8. Silver nitrate solution response to dealloyed metal and non-dealloyed metal.

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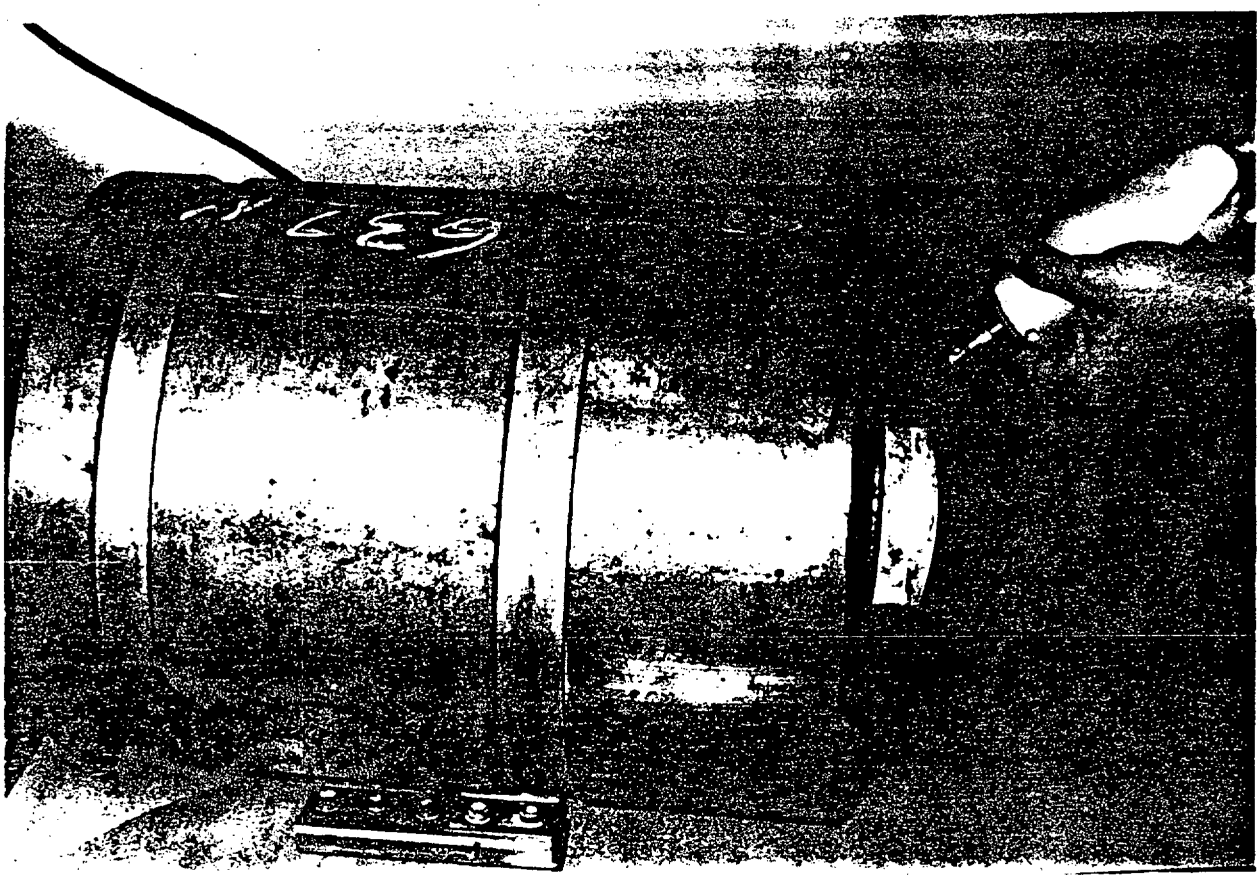

FIGURE 9. Excavating casting for subsurface silver nitrate test.

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FIGURE 10. Removing excess silver nitrate solution from excavation.

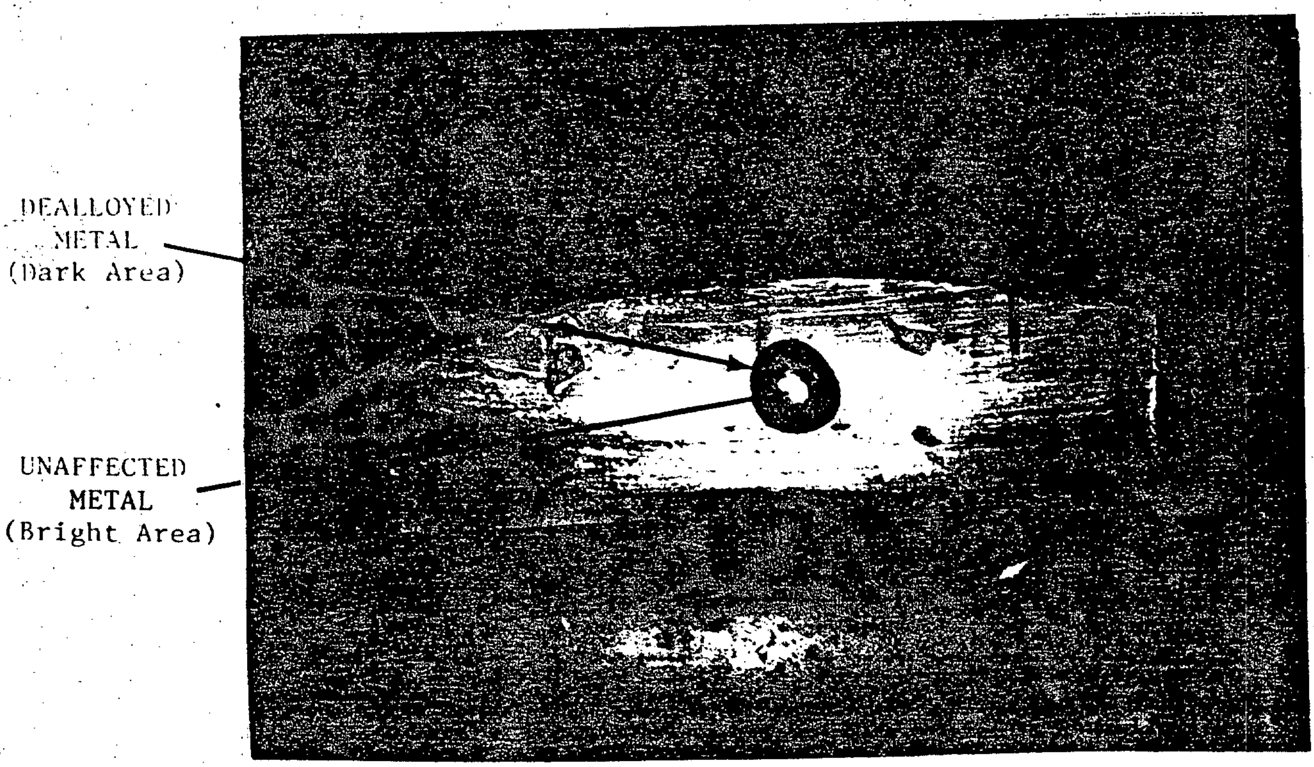

FIGURE 11. Test results showing interface of dealloyed and non-dealloyed metal in an excavation.

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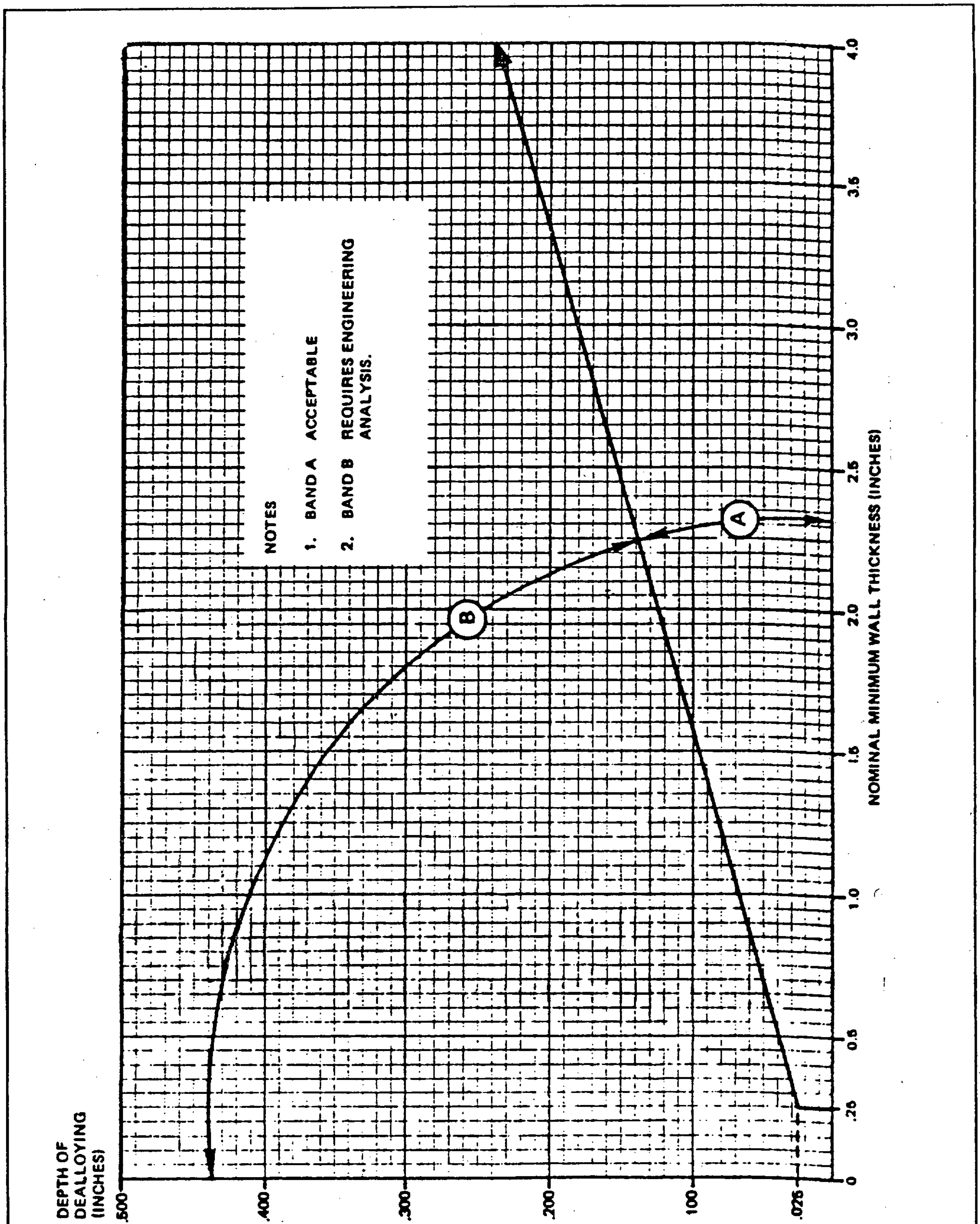

Figure 12. Dealloying acceptance curve for cast NiAlBRZ/AlBRZ.

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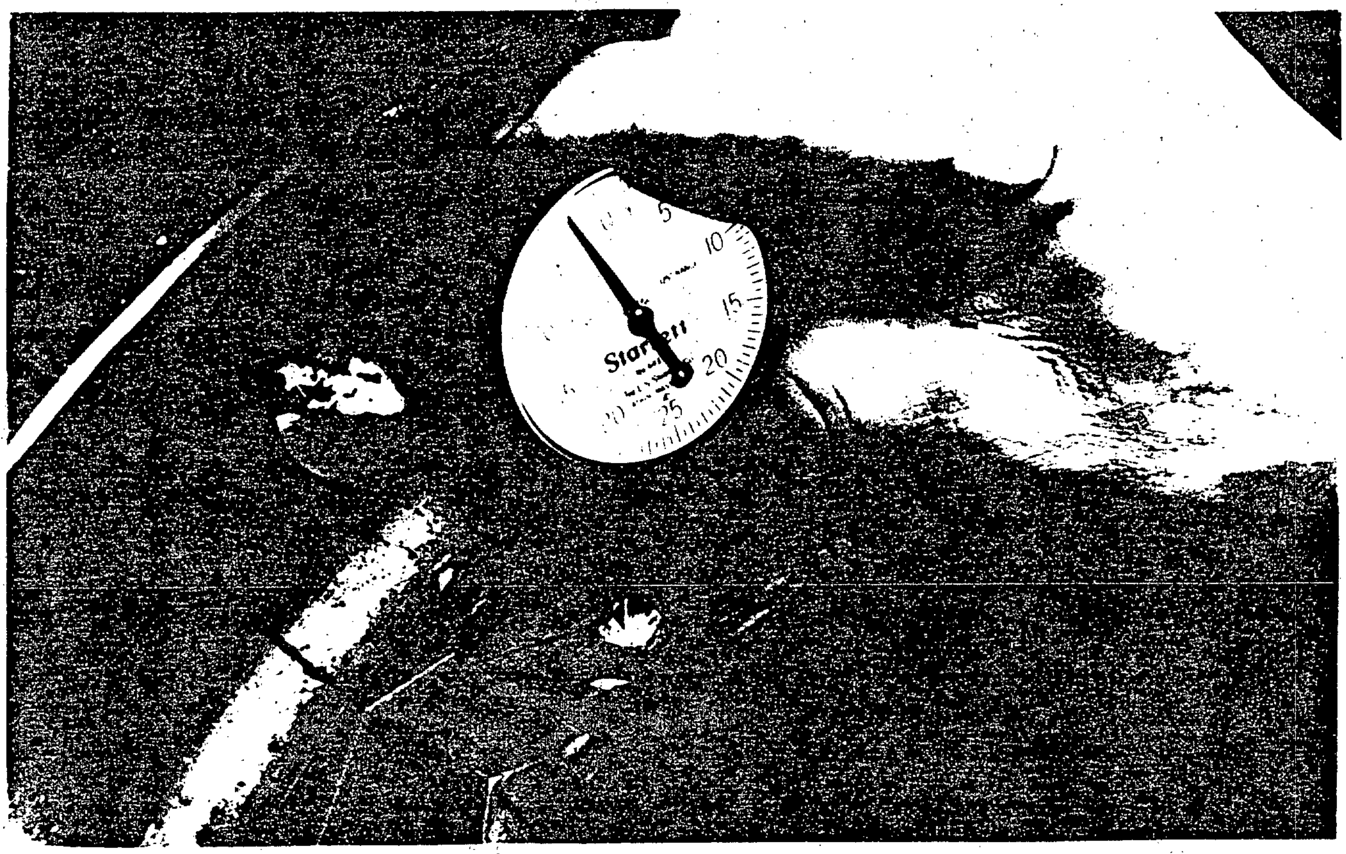

FIGURE 13. Measuring depth of dealloying.

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APPENDIX

TEST REPORT TECHNICAL CONTENT REQUIREMENTS

10. SCOPE

10.1 Scope. This appendix covers the technical requirements that should be included when eddy current inspection of aluminum bronze components for dealloying test evaluation data reports are required by the contract or order. This appendix is mandatory only when Data Item Description DI-MISC-80653 is cited on the DD Form 1423.

20. APPLICABLE DOCUMENTS

This section is not applicable to this appendix.

30. REPORTS

30.1 Reports. When required by the contract or order, the eddy dealloying evaluation data report shall include unique identification of the casting, eddy current inspection details, details of the silver nitrate inspection, areas inspected by the eddy current, results of the engineering evaluation and additional specifics of the inspection and evaluation. Specific report content requirements shall contain the following information:

(a) Sketch of component and inspection information:

(1) Name and hull number of the ship with which the component is associated.
(2) Component name and part number.
(3) Applicable drawing number or plan number.
(4) Identification of the component as partially exposed or totally exposed to sea water.
(5) Number and revision of procedure used to inspect and evaluate the component.
(6) Eddy current instrument model and serial number and test coil probe types (diameter and working face shape).
(7) Eddy current test frequency.
(8) Performance verification reference block serial number.
(9) Locations inspected by the surface silver nitrate test to identify a non-dealloyed reference location prior to ET.
(10) Areas inspected by the eddy current test and the estimated fraction of the sea water exposed surface that was inspected (example: less than 25 percent, 25 percent to less than 50 percent, 50 percent to less than 75 percent, 75 percent or more).
(11) Estimated percentage of the inspected area which showed the presence of dealloying.
(12) Location of the maximum depth of dealloying as determined by ET on each wall thickness tested.
(13) Locations inspected by the subsurface silver nitrate test to determine depth of dealloying.
(14) Wall thickness, maximum depth of dealloying, and maximum excavation depth for each site where the subsurface silver nitrate test was performed.

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(15) Location and dimensions of weld repaired or plated areas identified by ET.
(16) Disposition of the inspected component as acceptable or as requiring engineering evaluation.
(17) Signature of the inspectors and dates of inspection.
(18) A drawing or sketch of the component marked up to reflect design dimensions and actual measurements as necessary to support an independent review of the engineering review of the engineering analysis.

(b) Evaluation data, information, and results of the engineering evaluation, if performed (see 5.3.1).
(c) Format similar to Figure 14.

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DEALLOYING INSPECTION DATA RECORD

1. Ship/hull no. ____________________
2. Component description/part no.: ____________________
3. Applicable drawing/plan no.: ____________________
4. Component partially exposed or totally exposed to seawater: ____________
5. Inspection procedure: ____________________
6. Instrument model/serial no.: ____________________
7. Probe types: ____________________
8. Inspection frequency: ____________________
9. Performance block serial no.: ____________________
10. On the accompanying component sketch:

    (a) Encircle with a dotted line the areas tested by the surface silver nitrate test to identify a non-dealloyed reference location.

    Did dealloying occur in these areas? ____________________

    (b) Encircle with a solid line the areas inspected by the eddy current test.

    Indicate the approximate percentage of seawater-exposed surface which was inspected: ____________________
    (If less than 75 percent explain in "Remarks" below)

11. Indicate the approximate percentage of the inspected area which showed dealloying: ____________________
    (If no dealloying was present, enter "None")

FIGURE 14. Sample dealloying inspection data record

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DEALLOYING INSPECTION DATA RECORD (Continued)

12. On the accompanying component sketch:

(a) Indicate with an "X" the locations where the maximum depth of dealloying occurred as determined by ET.

(b) Indicate with an "O" the locations where the subsurface silver nitrate test was performed to determine depth of dealloying. If these do not coincide with the "X" areas, explain in "Remarks" or on component sketch.

13. Maximum depth of dealloying on each wall thickness tested by the subsurface silver nitrate test.

Wall thickness								
Depth of dealloying								
Excavation depth								

14. Component disposition: ____________ Component acceptable
____________ Engineering evaluation required

15. Remarks:

16. Inspectors ____________ Date of inspection ____________________

FIGURE 14. Sample dealloying inspection data record(Continued)