T9074-AT-GIB-010/2032

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NAVSEA TECHNICAL PUBLICATION

EDDY CURRENT INSPECTION OF HEAT EXCHANGER TUBING ON SHIPS OF THE UNITED STATES NAVY

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FOREWORD

This technical publication provides the minimum requirements to conduct the eddy current inspection of nonferromagnetic tubing in heat exchangers on Navy ships. For sleeved tubes, epoxy repaired tubes, or similarly altered tubes, procedure qualification shall be approved by NAVSEA prior to inspection. In this document, the term "heat exchanger" applies to condensers, reboilers, etc. Minimum requirements are specified for inspection personnel, equipment, procedures, evaluation, and reporting of results. The technical publication is organized as follows:

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DISTANCE SUPPORT INFORMATION
Contact the Navy Distance Support (Anchor Desk) via the web (http://www.anchordesk.navy.mil/), e-mail (help@AnchorDesk.navy.mil), or via the toll free number (1-877-4-1-TOUCH [86824]).

TMDER INSTRUCTIONS
Ships, training activities, supply points, depots, Naval Shipyards and Supervisors of Shipbuilding are requested to arrange for the maximum practical use and evaluation of NAVSEA technical manuals (TMs). All errors, omissions, discrepancies, and suggestions for improvement to NAVSEA TMs shall be submitted as a Technical Manual Deficiency/Evaluation Report (TMDER). All feedback comments shall be thoroughly investigated and originators will be advised of action resulting there from.

The NAVSEA/SPAWAR Technical Manual Deficiency/Evaluation Report form, NAVSEA 4160/1 is included at the back of the TM.

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Complete instructions for TMDER generation and submission are detailed on the NSDSA website at: https://nsdsa.nmci.navy.mil/tmder/tmder.asp?lvl=1.

CHAPTER 1
INTRODUCTION

1.1 SCOPE.

This publication provides the minimum requirements to conduct the eddy current inspection of nonferromagnetic tubing in heat exchangers on Navy ships. For sleeved tubes, epoxy repaired tubes, or similarly altered tubes, procedure qualification shall be approved by NAVSEA prior to inspection. In this document, the term “heat exchanger” applies to condensers, reboilers, etc. Minimum requirements are specified for inspection personnel, equipment, procedures, evaluation, and reporting of results.

1.2 DATA TRENDING.

A review of comparative inspections of the same heat exchanger by different inspection activities has concluded that there can be a relatively large amount of inspection variability in the results. Caution should be used when using the data generated with the procedures in this document for trending of the tube degradation. A comprehensive, statistical study of inspection consistency would be required to quantify the inspection variability.

CHAPTER 2
APPLICABLE DOCUMENTS

2.1 GENERAL.

The documents listed in this section are specified in sections 3, 4, or 5 of this publication. While every effort has been made to ensure the completeness of this list, document users are cautioned that they must meet all specified requirements of documents cited in sections 3, 4, or 5 of this publication, whether or not they are listed.

2.2 OTHER GOVERNMENT DOCUMENTS, DRAWINGS, AND PUBLICATIONS.

The following other Government documents, drawings, and publications form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

NAVAL SEA SYSTEMS COMMAND (NAVSEA)

INSTRUCTIONS

NAVSEAINST 9254.1 - Inspection of Steam Condensers in Nuclear Surface Ships & Submarines & Reboilers in Nuclear Surface Ships

(Copies of this document are available online at www.navsea.navy.mil.)

PUBLICATIONS

S9086-HY-STM-010/254 - NSTM Chapter 254, Condensers, Heat Exchangers, and Air Ejectors

T9074-AS-GIB-010/271 - Requirements for Nondestructive Testing Methods

(Copies of these documents are available from the Naval Logistics Library, 5450 Carlisle Pike, Mechanicsburg, PA 17055 or online at https://nll1.ahf.nmci.navy.mil.)

2.3 NON-GOVERNMENT PUBLICATIONS.

The following documents form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

AMERICAN SOCIETY FOR NONDESTRUCTIVE TESTING, INC. (ASNT)

SNT-TC-1A - Recommended Practice No. SNT-TC-1A: Personnel Qualification and Certification in Nondestructive Testing

(Copies of this document are available from ASNT, P.O. Box 28518, 1711 Arlingate Lane, Columbus, OH 43228 or online at www.asnt.org.)

2.4 ORDER OF PRECEDENCE.

Unless otherwise noted herein or in the contract, 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.

CHAPTER 3
DEFINITIONS

3.1 ABSOLUTE MODE.

Mode of operating an eddy current probe where signal response is based on the total detected electromagnetic properties of one section of the tube (and adjacent structures and conductive deposits). The absolute mode is sensitive to shallow or gradual wall loss, support structures, and conductive deposits.

3.2 CALIBRATION.

Calibration is the verification of proper equipment response against a known standard.

3.3 CALIBRATION STANDARD.

Representative tube with prefabricated defects used to standardize instrument set-up.

3.4 COIL.

Electric coil in an eddy current probe which induces electromagnetic current in the inspected part and detects the part's electromagnetic response.

3.5 DEFECT.

Defect is a discontinuity (for example, wall loss, pit, or crack) whose size, shape, orientation, location, or properties makes it detrimental to the useful service of the part in which it occurs or which exceeds the acceptance criteria for a given design.

3.6 DIFFERENTIAL MODE.

Mode of operating an eddy current probe in which adjacent coils are electrically connected in series opposition, so that electromagnetic conditions not common to both tube regions tested simultaneously by the opposed coils will imbalance the system and thereby yield an indication. The differential mode is sensitive to abrupt discontinuities and usually provides more reliable defect depth estimates.

3.7 FILL FACTOR.

Fill factor is a measure of the electromagnetic coupling between the coil and the test object. It is the square of the ratio of the coil diameter to the bore diameter for internal probes.

3.8 GAIN.

Gain is the amplification level setting for the receiving circuit in an instrument. Instrument gain is usually set to normalize response signal amplitude using a calibration standard.

3.9 INSPECTION ACTIVITY.

Inspection activity is the organization performing the inspection. Unless otherwise specified by the contract or order, the inspection activity shall be fully responsible for the quality of inspection results and the qualification or certification of individuals conducting inspections.

3.10 NON-DAMAGE ANOMALY (NDA).

Where large signals are detected with no associated flaw, and believed to be associated with a minor change on inside diameter (ID) resulting from the normal fabrication.

3.11 NOISE.

Noise is any undesired signal that tends to interfere with the normal reception or processing of a desired signal. In flaw detection, noise is an undesired response to physical or electromagnetic variables. Nearby welding, arc cutting, and high-speed electrical tools can cause unacceptable noise levels during eddy current testing.

3.12 OBSTRUCTED TUBE.

Obstructed tube is a tube which contains a dent, debris, scale, or other condition which prevents the probe from being inserted the full length of the tube.

3.13 PERMEABILITY VARIATION.

Defect-like signal not caused by a defect, but by local variation in a part's electromagnetic material properties (non-geometric). These variations can normally be overcome using magnetic bias probes.

3.14 PHASE ANALYSIS.

Phase analysis is an instrumentation technique which discriminates between variables in the test part by the different phase angle changes which these conditions produce in the test signal. For differential mode inspections, phase analysis is used to estimate defect through-wall extent and distinguish defects from other signal sources (for example, support structures and conductive deposits).

3.15 PHASE ANGLE.

Phase angle is the angular equivalent of the time displacement between corresponding points on two sine waves of the same frequency. In eddy current testing, phase angle is the angle on the display screen/monitor (measured clockwise) from the left horizontal to the eddy current signal of interest.

3.16 PLUGGED TUBE.

Plugged tubes (temporary, permanent) are described in S9086-HY-STM-010/254.

3.17 PROBE.

Probe is an eddy current sensor for use in a tube.

3.18 PROBE MOTION OR PROBE WOBBLE.

Lateral probe motion in the tube. This produces noise or signal variations not necessarily related to any defect. Probe motion should be minimized since signal variations interfere with sizing.

3.19 SIGNAL MIX.

Signal mix is the elimination or suppression of undesirable signals; for example, those signals caused by conditions such as tube support plates, conductive deposits, and ID variations (pilgering). Signal mixing allows mixing or subtraction of eddy current signals to enhance the signal-to-noise ratio.

3.20 SIGNAL-TO-NOISE RATIO.

Signal-to-noise ratio is the ratio of values of signal (response containing information) to that of noise (response containing no information). In general, the signal-to-noise ratio is the ratio of the vertical component of the signal of interest to the vertical component of the noise.

3.21 TEST AND INSPECTION.

The terms "test" and "inspection" are used interchangeably and refer to the performance of specific procedures and applications of acceptance criteria as required.

3.22 THINNING.

3.22.1 General Thinning. Wall loss in a tube, generally occurring gradually over several inches or more axially. General thinning such as acid attack, exfoliation corrosion, or steam erosion is usually detected in the absolute mode of inspection.

3.22.2 Localized Thinning. Wall loss occurring over a short length of the tube. Localized thinning is generally characterized by beginning and reaching maximum wall loss within about 1 inch of tube length. Localized thinning, such as wear and localized loss, is usually detected in the differential mode of inspection.

3.22.3 Non-Uniform Thinning. General or localized thinning that occurs over a small extent of the tube circumference.

3.22.4 Uniform Thinning. General or localized thinning that occurs around the majority of the tube circumference.

3.23 VECTOR ANALYZER.

Vector analyzer is a device used to measure signal-phase angle.

CHAPTER 4
GENERAL REQUIREMENTS

4.1 EQUIPMENT.

The equipment package shall provide the capability to perform eddy current inspections required by this publication. Specific inspection techniques may not require the use of all equipment specified in 4.1.1 through 4.1.8. Each activity shall be responsible for selecting and using test equipment to meet the requirements of the inspection to be performed. Signal display and recording equipment shall have a frequency response so that differences in peak signal amplitudes between static (probe stationary) and dynamic (probe in motion at inspection speed) are less than 10 percent. Eddy current instruments shall be calibrated as specified in the manufacturer's specifications (oscillator accuracy, output voltages, and so forth) at intervals not to exceed 12 months and whenever the equipment has been repaired.

4.1.1 Multi-Frequency Eddy Current Instrument. A multi-frequency eddy current instrument shall be used to detect impedance changes produced by tube discontinuities, display the principal changes on a display screen/monitor, and record the data on a media storage device. In addition, the instrument shall be capable of:

a. Operating at the required test frequency(s).
b. Operating in the differential and absolute modes, either sequentially or simultaneously. Instruments with the capability to perform the differential and absolute modes of inspection simultaneously at multiple frequencies may be used to preclude re-inspection.
c. Balancing the impedance bridge automatically or manually.
d. Enabling 360-degree rotation of the phase.
e. Adjusting the gain to provide amplification of the eddy current signals.
f. Suppressing or eliminating undesirable signals by signal mix.

4.1.2 Strip Chart. The inspection system shall incorporate instrumentation that produces a two-or-more channel strip chart display of the eddy current instrument output voltages. The strip chart display may be an integral part of the eddy current instrument.

4.1.3 Media Storage Device. A removable media storage device shall be used to record the output voltages from the eddy current instrument (for example, CDs, DVDs, hard drives, thumb drives). The recorder may be an integral part of the eddy current instrument.

4.1.4 Probe Puller. Where practicable, a probe puller or pusher that pulls at a constant speed shall be used. Manual probing may be performed with local eddy current Examiner approval.

4.1.5 Probes. Inside diameter (ID) probes shall be used to provide inspection coverage of heat exchanger tubing. A fill factor of 0.80 or higher shall be used (see 3.7). A fill factor less than 0.80 may be used, with eddy current Examiner approval, on tubes which are partially obstructed (oval tubes, dents, etc.). Insufficient cleaning of the tubes or unavailability of the correct size probes are not acceptable conditions for using a fill factor less than 0.80. Dependent upon inspection requirements, one or more of the following probes shall be used:

a. A differential coil probe with two coils, each having a coil length of 0.060 to 0.125 inch. Coil separation shall not be less than one-half the coil length and not greater than one coil length.

b. An absolute coil probe with a coil length of 0.060 to 0.125 inch shall be used to evaluate tube wall loss due to thinning. If the instrument can operate a differential coil in the absolute mode, a separate absolute coil is not necessary.

c. Other probes may be used for special applications. For example, axial wound, rotating, pancake, magnetic bias, profilometry probes, etc.

4.1.6 Calibration Standards. Calibration standards shall be manufactured from a length of tubing of the same nominal size, wall thickness, and material type (straight or finned, seamed or seamless, chemical composition and heat treatment) as that to be examined. The actual dimensions of the diameter, wall thickness, and calibration discontinuities shall be measured and verified. Records of the verification shall be available for review. Depending on the inspection being performed, one or more of the calibration standards specified in 4.1.6.1 through 4.1.6.4 shall be required. The calibration standards described in 4.1.6.1 through 4.1.6.4 shall be fabricated as illustrated in the figures, or, for ease of use and procurement, they may also be fabricated in segments and used as a set of shorter, multiple standards. Additional or duplicate notches may be added to calibration standards. The standards specified in 4.1.6.1 through 4.1.6.4 are also applicable for the inspection of finned tubing. The center of discontinuities machined into finned tubing shall be centered between the fins. Also, the depth of discontinuities in finned calibration standards shall be based on the root of the fins, not the outside diameter (OD) of the fins.

4.1.6.1 ASME-Type Calibration Standard. The ASME-type calibration standard shall be used for the differential mode phase angle analysis evaluation of local volumetric discontinuities such as pitting as shown in Figure 6-1.

4.1.6.2 Thinning Standard. The 360-degree machined ring standard (see Figure 6-2) shall be used to evaluate uniform thinning such as that caused by acid attack or exfoliation corrosion, which tends to have a large circumferential extent. The milled flat thinning standard (see Figure 6-3) shall be used to evaluate non-uniform thinning, such as that caused by steam erosion, which generally occurs on only part of a tube's circumference. The selection of the appropriate thinning standard shall be made by the analyst based on the understanding of the damage mechanism and additional evaluation options as specified in 4.1.7, 4.1.8, and 5.3.2. In some specific cases, a separate voltage curve is built based on a combination of the signal responses from the 360-degree machined ring standard and milled flat standard (see 5.3.2).

4.1.6.3 Tapered Area Sensitivity Standard. The tapered area sensitivity standard (see Figure 6-4) shall be used to verify sensitivity in the tapered region of finned tubing, such as that used in air conditioning condensers.

4.1.6.4 Slotted Standard. The slotted standard (see Figure 6-5) using a length of tube with an axial and circumferential slot machined into the OD shall be used to verify the capability of the equipment to detect axial and circumferential cracks.

4.1.6.5 Optional Discontinuity-Free Standard. When the use of an external reference probe is required, in lieu of using a discontinuity-free area of a reference standard, a discontinuity-free reference standard, which meets the dimensional and material requirements of the applicable figure, may be used.

4.1.7 Borescope. An optical borescope may be used for verification of eddy current indications on the tube inner diameter and accessible areas of the tube outer diameter, for example, near tube ends and in tapered regions of finned tubing.

4.1.8 Ultrasonic Probe. An ultrasonic probe may be used for verification of eddy current indications. Ultrasonic measurements may also be used for the characterization of thinning as an aid in selecting the appropriate thinning calibration standard. Ultrasonic measurements shall be performed as specified in T9074-AS-GIB-010/271. Furthermore, the use of ultrasonic systems that use computer-assisted analysis or imaging as part of the data analysis and presentation require specific NAVSEA approval.

4.2 PROCEDURE.

Each inspection activity shall prepare and maintain written eddy current test procedures, which conform to this publication. The procedures shall be approved by the cognizant certified eddy current Examiner and include the following information:

a. Material type (straight or finned, seamed or seamless, chemical composition and heat treatment), outer diameter, and wall thickness of the tubing to be inspected.

b. Probe sizes and types, including manufacturer and model number (or coil size, spacing, etc., if standard model not available).

c. Test frequency(s).

d. Eddy current equipment manufacturer and model.

e. Scanning method (for example, hand probe or mechanized probe drive). If a mechanized probe drive is used, identify manufacturer, model, and pull speed.

f. Calibration procedure and calibration standards.

g. Data recording equipment and procedures.

h. Data recording and format requirements.

i. Procedure for interpreting results. This procedure shall also identify specific reporting thresholds of signals, if used.

j. Tube numbering method.

k. Any other variables or requirements that affect eddy current test results or are needed to describe the test.

l. Signature of the certified eddy current Examiner.

4.2.1 Procedure Qualification. Procedures shall be qualified by performing an operational test. The qualification shall include testing the calibration standards to prove known discontinuities can be readily detected and evaluated using the written procedure. The cognizant certified eddy current Examiner shall witness the qualification.

4.3 PERSONNEL.

Personnel shall be certified as specified in T9074-AS-GIB-010/271. In addition to the eddy current personnel requirements in T9074-AS-GIB-010/271, personnel interpreting eddy current data shall be certified as an Inspector (Level II) or Examiner (Level III) specifically for the evaluation of eddy current data from nonferromagnetic tubing. This special certification requires additional training, experience, and examination specifically in data analysis. The amount of additional training, experience, and testing shall, as a minimum, be equal to the eddy current inspector qualification requirements. The "25-percent rule" specified in ASNT SNT-TC-1A may be used to simultaneously obtain eddy current and eddy current analysis work experience.

CHAPTER 5
DETAILED REQUIREMENTS

5.1 HEAT EXCHANGER INSPECTION PREPARATION.

Full access to all tubes at one end of the heat exchanger and limited access to the opposite end is required.

5.1.1 Heat Exchanger Design Review. Prior to inspection, the heat exchanger technical publication and other documentation as required shall be used to determine the following:

a. Tube material type, straight or finned, seamed or seamless, chemical composition and heat treatment, size, wall thickness, length, and layout.

b. Total number of tubes and number of tubes per section, if applicable.

c. Location and number of tube sheets and supports.

d. Location of steam connections, baffles, and partitions.

e. Location of visual inspection access points.

5.1.2 Tube Cleaning. Tubes shall be free of obstructions and cleaned to allow passage of eddy current probes. Tube cleaning methods are provided in S9086-HY-STM-010/254. The high-pressure water jet (hydroblast) cleaning method may be required if determined necessary by the Level III Examiner (unacceptable signal-to-noise, tube obstruction, etc.). Each tube shall be air dried after cleaning.

5.1.3 Tube Identification. Each heat exchanger tube is identified by a unique letter or number grid system as specified in the component technical publication or NAVSEA drawing. If the technical publication or drawing is unknown:

a. Contact NAVSEA's Heat Exchanger Branch for nuclear ship steam condensers.

b. For all other heat exchangers, number tubes using letter designations for tube rows and number designations for tube columns, starting with "A1" in the upper-left corner of the tube sheet from which the inspection is being performed.

5.1.4 Extent of Inspection. The extent of the inspection shall be as directed by the contract or design requirement. Minimum information provided to the inspection activity will include the type of discontinuities required to be detected, inspection extent, and acceptance criteria (see 5.3). Unless otherwise specified, as a minimum, all tubes shall be inspected for local and general thinning, local volumetric defects (pitting), and denting.

5.2 EDDY CURRENT INSPECTION PROCEDURE.

The minimum procedures for eddy current inspection of heat exchanger tubes shall be as specified in 5.2.1 through 5.2.5.

5.2.1 Equipment. Inspection equipment selected shall be based on the type of discontinuity to be detected and shall meet the appropriate requirements of 4.1. Removable media storage recordings shall be made of all inspections and channels. Strip charts (paper or electronically displayed) shall be used as needed for evaluation. Calibrations, recalibrations, and calibration verifications shall be recorded on the same storage media and strip charts as the inspection data.

5.2.2 Calibration Techniques. The eddy current test system shall be calibrated utilizing the standards specified in 4.1.6 for the type of discontinuity to be detected. The calibration operation shall include the complete testing system. Calibration standards shall be oriented such that the calibration discontinuities are positioned in the upward position (12 o'clock) during calibration. Calibration shall be performed before the start of each inspection utilizing one or more of the techniques specified in 5.2.2.1 through 5.2.2.3. Recalibration shall be as specified in 5.2.3.

5.2.2.1 Differential Mode Probe Calibration. The following requirements apply for calibrating a differential mode eddy current system:

5.2.2.1.1 90-10 CuNi Material. A standard calibration curve (see Figure 6-6) shall be used for the measurement of all flaws measured with the primary frequency in the differential mode. To support the use of the standard curve for this material, the following calibration requirements shall be used:

a. Required test frequencies are shown in Table 5-1. The use of other frequencies requires NAVSEA approval.

b. The eddy current system will produce a response from the ASME standard 20 percent flat bottom-hole with a signal-to-noise ratio of 3-to-1 minimum. The signal shall span 3.5 to 5 major screen divisions or 4 to 6 volts, as applicable. Signal phase and amplitude must be distinguishable, without saturation, for each applicable calibration discontinuity.

c. The phase angle of the through-drilled hole in the ASME standard shall be set to 40 degrees, ±5 degrees. The signal response from the through-wall hole shall be first down and to the right on the viewing screen. The ±5 degree tolerance shall be used to adjust the signal response resulting from probe motion/noise to be as horizontal as possible. Calibration discontinuity responses shall be distinguishable from probe motion/noise signals.

d. Signal mixing to suppress tube support signals is required. Verify adequate signal mixing by showing the ASME 20 percent flat bottom-holes can be clearly discerned and sized with the tube support simulation ring centered over the hole.

e. Record the calibration data as specified in 5.2.1. For the primary frequency in the differential mode, the flaw depth evaluation curve in Figure 6-6 shall be used. For the mixed channel, a flaw depth evaluation curve shall be established from the mix channel recorded calibration data. Percent defect depth and phase angle constitute the vertical and horizontal axes of the curve, respectively (see Figure 6-6). Instruments equipped with a vector analyzer and built-in calibration curve may be used in lieu of this plotted curve for estimating defect depth, providing the built-in calibration curve agrees with the calibration discontinuity signals with ±2 degrees of phase angle.

5.2.2.1.2 All Materials Except 90-10 CuNi Material. The following calibration requirements shall be used:

a. Required test frequencies are shown in Table 5-1. Other frequencies are permitted, with eddy current Examiner approval, if Table 5-1 frequencies will not meet calibration requirements.

b. Primary frequency selection will permit the ASME calibration standard (see Figure 6-1) 20 percent flat bottom-holes signal phase angle to be between 90 and 120 degrees clockwise from the through-wall hole signal. This phase separation will not always be achievable on a mix channel.

c. The eddy current system will produce a response from the ASME standard 20 percent flat bottom-hole with a signal-to-noise ratio of 3-to-1 minimum. The signal shall span 3.5 to 5 major screen divisions or 4 to 6 volts, as applicable. Signal phase and amplitude must be distinguishable, without saturation, for each applicable calibration discontinuity.

d. The phase angle of the through-drilled hole in the ASME standard shall be set to 40 degrees, ±5 degrees. The signal response from the through-wall hole shall be first down and to the right on the viewing screen. The ±5 degree tolerance shall be used to adjust the signal response resulting from probe motion to be as horizontal as possible. Calibration discontinuity responses shall be distinguishable from probe motion/noise signals.

e. Signal mixing to suppress tube support signals is required. Verify adequate signal mixing by showing the ASME 20 percent flat bottom-holes can be clearly discerned and sized with the tube support simulation ring centered over the hole.

f. Record the calibration data as specified in 5.2.1. Establish a flaw depth evaluation curve from the data. Percent defect depth and phase angle constitute the vertical and horizontal axes of the curve, respectively (see Figure 6-6). Instruments equipped with a vector analyzer and built-in calibration curve may be used in lieu of this plotted curve for estimating defect depth, providing the built-in calibration curve agrees with the calibration discontinuity signals with ±2 degrees of phase angle.

5.2.2.2 Absolute Mode Probe Calibration. The following requirements apply for calibrating an absolute mode eddy current system.

a. Probe frequency shall be approximately one-half of that specified for the differential mode primary frequency in 5.2.2.1. Other frequencies are permitted, with certified eddy current Examiner approval.

b. Signal mixing to suppress tube support signals is not required, but inspection frequencies shall be selected such that mixing can be performed if determined necessary by the data analyst. The mix frequency should be approximately half the primary absolute channel frequency. Other frequencies are permitted, with certified eddy current Examiner approval. When performed, verify adequate signal mixing by detecting the 20 percent calibration discontinuity for the 360-degree ring standard and the 30 percent calibration discontinuity of the milled flat standard with a minimum signal-to-noise ratio of 3-to-1 with the tube support ring positioned at the defect. For both thinning standards, center the ring over the edge of the applicable discontinuity.

c. The eddy current system shall produce a response from the 20 percent through-wall discontinuity in the applicable calibration standard with a signal-to-noise ratio of 3-to-1 minimum. The signal shall span 1 to 2 major screen divisions. Signals shall be distinguishable for each calibration discontinuity. Other spans may be used with eddy current Examiner approval if the noise level causes the trace to move off the screen excessively.

d. Signal response to probe motion/noise shall be horizontal on the viewing screen, and calibration discontinuity responses shall be oriented upward and be distinguishable from probe motion/noise signal.

e. Establish a calibration curve from the calibration data. The known depths of machined discontinuities and their corresponding signal deflections constitute the vertical and horizontal axes of the curve, respectively (see Figure 6-7).

f. To measure ID thinning, create an additional channel and adjust signal rotation so that the response from the ID thinning notches on the applicable standard moves upward at approximately 90 degrees. Then establish a volt vs. percent wall-loss calibration curve using these signals measuring the maximum vertical response. In some specific cases, a separate voltage curve is built based on a combination of the signal responses from the 360-degree machined ring standard and milled flat standard (see 5.3.2).

Table 5-1. Required Primary Test Frequencies for Differential Mode Phase Analysis. 1/, 2/, 3/

Material Type	Wall Thickness (inch)	Frequency, kHz (±5 kHz)
70-30 CuNi	0.049	150
70-30 CuNi	0.065	88
80-20 CuNi	0.065	75
90-10 CuNi	0.049	70
Titanium	0.028	600
Titanium	0.035	350
Titanium	0.049	180

NOTES:

1/ For tubes not listed, required test frequencies shall be determined by using the following formula:

$F = 10\rho/T^2$

where:

F = test frequency in Hertz

ρ = resistivity of tubing in microhm-centimeter

T = wall thickness of tubing in inches

2/ Signal mixing to suppress outer diameter tube support signals is required. Signal mixing shall be accomplished using a subtractor frequency. The subtractor frequency shall be one-half the primary frequency when the primary frequency is below 300 kHz; the subtractor frequency should be one-fourth the primary frequency when the primary frequency is 300 kHz or above. If signal mixing is needed for unwanted inner diameter signals such as dents, pilgering, or bulges, a subtractor frequency twice the primary frequency shall be used. If these subtractor frequencies do not provide an adequate mix, the subtractor frequency can be modified, subject to certified eddy current Examiner approval.

3/ The availability of inspection data collected at twice the primary frequency can be very useful for the analysis of low-voltage signals in the differential mode of inspection. It is recommended that this high frequency data be collected during the data acquisition whenever possible.

5.2.2.3 Special Probe Calibration for Crack Detection. The following requirements apply for calibrating an eddy current system to detect cracks.

a. The probe design and test frequencies used shall result in discerning each slot in the slotted calibration standard, excluding the 20-percent slot (see Figure 6-5).

b. The eddy current instrument shall produce a clear response to each slot in the standard, excluding the 20-percent slot, with a signal-to-noise ratio of 3-to-1 minimum.

c. Signal response to probe motion/noise shall be horizontal on the viewing screen, and calibration slot responses shall be distinguishable from probe motion/noise signals.

d. Verify, for each slot orientation, that the 40-percent slot can be detected with a minimum signal-to-noise ratio of 3-to-1 with the tube support simulation ring centered over the slot.

5.2.3 Recalibration. Any change of test probe, extension cables, eddy current instrument, recording instruments, or power interruption shall require system recalibration. Calibration shall be verified:

a. Every 4 hours (minimum).

b. If the equipment has been left unattended.

c. When calibration is suspected of being in error.

d. At the beginning and end of each recording media device.

e. After any change in equipment setting which could affect calibration.

f. After any change of operator.

g. At the completion of the inspection.

Should the system be found to be out-of-calibration, the equipment shall be re-calibrated and all tubes inspected since the last valid calibration shall be re-inspected. Out-of-calibration includes changes more than ±5 degrees phase angle from the calibration curve for the differential mode of calibration, or ±10 percent voltage change for the mid-range discontinuity of the standard for the absolute mode.

5.2.4 Noise Interference. If noise occurs during inspection that interferes with signal interpretation, the inspection shall be discontinued until the noise is either eliminated, or reduced to a level which no longer interferes with signal interpretation. Typical noise sources encountered during an eddy current inspection include pit-like signals in the differential mode with a tighter than usual lissajous display. Re-inspection of the tube with a magnetic bias probe will usually provide sufficient additional information to determine whether the indication is false.

5.2.5 Special Requirements for Titanium Tubes. To prevent unnecessarily plugging titanium tubes, all titanium tubes that the eddy current inspection indicates have defects deep enough to require plugging must be re-inspected with both the original probe and a magnetic bias probe to check whether the indications are repeatable.

5.3 INSPECTION AND EVALUATION.

Inspection and evaluation techniques shall be as specified in 5.3.1 through 5.3.9.

5.3.1 Detection of Local Volumetric Defects. The following techniques shall be used to detect and estimate defect depths for inner and outer diameter volumetric defects. These techniques are usable for localized defects including pitting, wear, intergranular attack, localized thinning, etc. Using the differential inspection mode, calibrate the system using the ASME calibration standard (see Figure 6-1) and the procedure specified in 5.2.2.1. Signal mixing is required to suppress tube support signals and may be needed to suppress other interferences such as dents and conductive deposits. Defect depths shall be estimated using the flaw depth evaluation curve discussed in 5.2.2.1 or a similar curve based on the mix. The use of inspection data collected at twice the primary frequency (see Table 5-1, Note 3) can be very useful during the analysis of low-voltage signals to help differentiate between noise due to surface deposits, and deep attack originating from the tube OD. Inspection results shall be reported as specified in 5.4.

5.3.2 Detection of Thinning. The following describes techniques that shall be used for detection and depth measurement of OD and ID general tube thinning. The inspection shall be conducted using the absolute mode of inspection. Localized wall thinning shall also be evaluated using differential mode phase angle analysis as described in 5.3.1 (the analyst shall determine which inspection mode is the most appropriate to size a particular discontinuity). The system shall be calibrated using the appropriate ID or OD discontinuities in 360-degree machined ring standard or the milled flat calibration standard (see Figure 6-2 and Figure 6-3) and the procedure specified in 5.2.2.2. The OD discontinuities shall be used to build a curve to evaluate OD flaws and the ID notches shall be used to build a curve to evaluate ID flaws. When the absolute mode of inspection is being used and the circumferential extent of a discontinuity is unknown, the milled flat standard may be used until the discontinuity reaches or exceeds a rejectable depth; when the discontinuity reaches or exceeds a rejectable depth, the flaw should be inspected with a supplemental technique (such as an 8×-style or MRPC probe) to better characterize the circumferential extent of the discontinuity such that the appropriate calibration standard can be used. A flaw evaluation voltage curve shall be used to determine depth of thinning during production inspections. Results shall be recorded and reported as specified in 5.4.

5.3.2.1 Special CVN Calibration for Inner Diameter Thinning. For CVN 90-10 CuNi applications only, the following calibration curve shall be used as the default curve when the actual nature of the ID thinning is unknown. A separate ID thinning voltage calibration curve shall be built using a combination of the 360-degree machined ring standard and the milled flat standard. Data points shall be based on the average (arithmetic mean) of the signal responses from each of the comparable depth ID notches in the 360-degree machined ring standard and milled flat standard. If the analyst obtains additional information (for example, MRPC data, ultrasonic data, pulled tube information) that indicates one of the standard ID thinning calibration curves (milled flat or ring) is more appropriate, that curve shall be used.

5.3.3 Detection of Cracks. The following describes techniques that shall be used for eddy current inspection of heat exchanger tubes for omni-directional cracks in localized areas. The system shall be calibrated using the calibration standard specified in 4.1.6.4 and the procedure specified in 5.2.2.3. The tube support simulation ring shall be used to assure that the slots in the calibration standard can be reliably detected adjacent to and under the tube support ring. During inspection, any crack-like signal shall be reported. Results shall be recorded and reported as specified in 5.4.

5.3.4 Detection of Denting. Denting shall be evaluated using the techniques discussed in 5.3.1 (differential data) only. Additional techniques are not required. Dent signals with peak-to-peak signal amplitudes greater than twice the amplitude of the shallowest applicable calibration discontinuity shall be reported under 5.4 requirements.

5.3.5 Evaluation of Permeability Variations. Magnetic bias probes shall be used in conjunction with the original inspection probes to evaluate suspected permeability variation signals if the depth measured using the original probe will require tube plugging, inspection expansion, or potential expansion. Probes shall be as specified in 4.1.5. Using the magnetic bias probe, calibrate the inspection system using the ASME calibration standard (see 4.1.6.1) and the procedures specified in 5.2.2.1.

5.3.6 Obstructed Tubes. Obstructed tubes shall be identified. The location and nature of the obstruction and the extent of the tube inspected shall also be reported. If practical, smaller probes or supplemental cleaning methods shall be used to facilitate complete tube inspection (see 4.1.5).

5.3.7 Extent of Inspection. Tubes shall be scanned for the full length of the tube between the inner surfaces of the innermost tube sheets, including under the tube supports.

5.3.8 Data Review. Review the data stored on the recorded media for acceptability. If for any reason the data is judged to be unacceptable, all affected tubes shall be re-tested. The following shall cause the data to be judged unacceptable:

a. Calibration of test system incorrect to test procedures (wrong test frequency, wrong configuration, etc.).
b. Any dead channel due to test system malfunction, unless that channel is of no significance to the final inspection results.
c. Excessive noise, which may mask small volume indications. A signal-to-noise ratio of 3-to-1 is required, unless the Level III Examiner determines that this cannot be achieved, in which case the signal-to-noise level that is achieved must be reported.
d. Periodic tape spike due to loss of oxide on tape or any electronic data storage defects which may cause erroneous signals.
e. Periodic probe “drop-out” due to a broken wire, sparking, or dead short.
f. Excessive data wandering.
g. Saturated signals from a discontinuity on a channel used for evaluation of the flaw depth (re-calibration with lower gain settings and re-testing is required).

5.3.9 Defect Evaluation.

a. Review the strip chart data displayed to determine if the tube exhibits one of the following:

(1) No reportable indications.

(2) Pit or pit-like indications.

(3) Thinning indications.

(4) Dents, deposits, bulges, cracks, distorted signals, or any other unusual condition.

A detectable discontinuity is defined as a discontinuity which can be readily identified by an analyst, as opposed to a signal barely discernable and difficult to re-identify. The local Level III Examiner should provide the necessary direction to the analyst as to what constitutes a detectable condition. Possible options for the Level III Examiner to use to provide this direction (which could vary from job to job) include:

(a) All differential channel signals with a voltage greater than 0.5 volts peak-to-peak.

(b) Discontinuities with a signal-to-noise ratio greater than or equal to 3-to-1.

(c) Absolute channel signals greater than or equal to 4 percent.

(d) A combination of these approaches.

(e) Other comparable strategies or signal levels selected by the Level III Examiner.

DISCONTINUITIES SHOULD BE MEASURED USING AN UNMIXED CHANNEL WHENEVER POSSIBLE DUE TO THE ERRORS ASSOCIATED WITH SIZING USING A MIXED CHANNEL NEAR A TUBE SUPPORT.

b. No reportable indications. For all tube materials except titanium, if the tube contains no reportable discontinuities enter No Recordable Discontinuity (NRD) in the report. For titanium tubes that contain no detectable discontinuities, enter No Detectable Discontinuity (NDD) in the final report (see 5.4).

c. Pit or pit-like indications. Scroll to the center of the signal for the nearest named location. Select the correct name for the location. Discontinuity positions may be entered as either a positive or a negative number, noting that the positive direction is defined by the direction in which the tube support numbers are increasing. Then scroll to the indication and measure the signal using the peak-to-peak or maximum rate features, as required. Enter the appropriate entries into the data fields, as described in Appendix A. Enter the information into the final report (see 5.4).

d. Multiple pits or pit-like indications. Scroll to the center of the signal for the nearest named location. Select the correct name for the location. Then scroll to the deepest indication, and measure the signal using the peak-to-peak or maximum rate features, enter the depth for the deepest indication, and enter the appropriate entries into the data fields, as described in Appendix A. Enter the information into the final report (see 5.4). While the specific keystrokes will vary depending upon the data analysis software being used, the intent is to record the location of the start and end of the multiple indications, and the depth of the deepest of these indications.

e. Thinning indications. Scroll to the center of the signal for the nearest named location. Select the correct name for the location. Scroll to the deepest area of thinning, measure the vertical maximum of the signal, scroll and enter the start of the thinning, scroll and enter the end of the thinning, and then enter the appropriate entries into the data fields, as described in Appendix A. Enter the information into the final report. While the specific keystrokes will vary depending upon the data analysis software being used, the intent is to record the location of the start and end of the thinning, and the depth of the deepest area of thinning.

5.4 REPORTING AND RECORD REQUIREMENTS.

5.4.1 Reporting. Inspection activities shall prepare inspection reports and include the following:

5.4.1.1 Inspection Summary Cover Letter. Unless otherwise specified (for example, when following NAVSEAINST 9254.1), inspection reports shall have a summary cover letter that shall include the following information:

a. Ship hull number.

b. Units inspected and date.

c. Extent of inspection for each unit (number of tubes in the unit and the number inspected by each inspection technique as described in 5.3).

d. Maximum indicated wall loss in each major heat exchanger section (for example, air cooling sections in condensers).

e. Number of tubes with 20-percent wall loss or greater.

f. Number of tubes that were plugged or replaced, including the reason for plugging or replacement. Identify percentage of tubes with plugs.

g. Number of previously plugged tubes.

h. Number of tubes with crack indications.

i. Any unusual defects or characteristics observed in performing the inspection or in analyzing the test results. Unusual characteristics include uninterpretable defect signals, and the presence of conductive deposits, distorted support plate signals, or denting (see 5.3.4).

5.4.1.2 Detailed Test Parameters. The following inspection data shall be included in the inspection report:

a. Ship hull number and condenser.

b. The inspection procedure used.

c. Identification of instrumentation and probes, including serial numbers.

d. Inspector names.

e. Date.

f. Instrument settings that affect calibration (for each channel, settings for frequency, mode, phase, gain, and so forth).

g. Calibration standard description and serial numbers.

h. A list of inspection results for each tube inspected with a reportable condition (report as specified in Appendix A).

i. Characterization of denting extent, including approximate percentage of tubes with reportable denting in each major heat exchanger section and support location and approximate maximum and average dent signal amplitudes for reportable signals.

j. A list of tubes with 20-percent wall loss or greater (report as specified in Appendix A). For condensers with titanium tubes, report all detectable indications (see 5.3.9).

k. A list of tubes that were plugged or replaced, including the reason for plugging or replacement (report as specified in Appendix A).

l. A list of all previously plugged tubes (report as specified in Appendix A).

m. A list of all tubes with crack indications (report as specified in Appendix A).

n. A technique sheet with details of the data acquisition and analysis shall be prepared as specified in the content and format illustrated in the example provided in Figure 6-8. Minor deviations from the example format are acceptable, but all content covered in the example shall be included.

5.4.1.3 Detailed Inspection Results. For each tube inspected, report the deepest indication of 20-percent wall loss or greater and any indications of cracking. For condensers with titanium tubes, report all detectable indications (see 5.3.9).

5.4.1.4 Tube Sheet Diagrams. The appropriate standard tube sheet diagrams shall be included in the report. Tube identification shall be as specified in the standard tube sheet diagram used. The diagrams shall be marked to identify all tubes inspected, the location of tubes with 20-percent wall loss or greater, and to identify blocked, cracked, or plugged tubes.

5.4.1.5 Metallographic or Metallurgical Reports. Include results of any analysis performed on the condenser tubes inspected. Supporting information and reports shall be referenced.

5.5 MAINTENANCE OF INSPECTION RECORDS.

Unless otherwise specified in the contract or order, information necessary to verify and support the inspection results, for example, calibration curves, calibration work sheets, and recorded media shall be maintained by the inspection activity for 12 years after completing the inspection (or until a ship is decommissioned). As a minimum, each removable media storage device shall be labeled with the following information:

Ship.

Condenser(s).

Inspection date.

Inspection activity.

Procedure, personnel, and equipment qualification records shall be maintained in accordance with T9074-AS-GIB-010/271. Supporting information shall be auditable and stored in such a manner as to be protected from damage and deterioration. NAVSEA shall be notified prior to disposal of eddy current inspection records.

CHAPTER 6
NOTES

6.1 INTENDED USE.

This publication is intended to be used to establish nondestructive testing requirements for eddy current inspections of heat exchanger tubing.

6.2 SUBJECT TERM (KEY WORD) LISTING.

Absolute mode

Calibration

Condenser

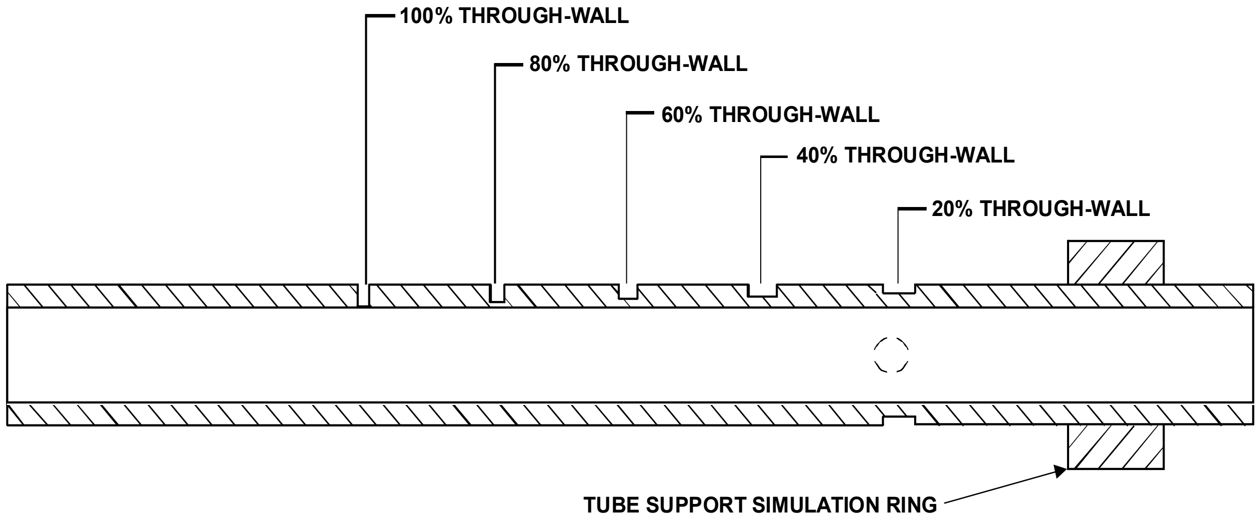
Differential mode

Gain

Probe

Sensitivity

Signal-to-noise ratio



NOTES:

1. Standards shall be manufactured from a length of tubing of the same nominal outer diameter +0/-0.005-inch, nominal wall thickness, and material type (straight or finned, seamed or seamless, chemical composition and heat treatment) as that to be examined.
2. The through-wall hole shall be 0.052-inch diameter for ¾ inch OD tubing and smaller, and 0.067 inch for larger ODs.
3. 80-percent through-wall hole shall be $^5/_{64}$-inch diameter.
4. 60-percent through-wall hole shall be $^7/_{64}$-inch diameter.
5. 40-percent through-wall hole shall be $^3/_{16}$-inch diameter.
6. Four 20-percent through-wall holes, $^3/_{16}$-inch diameter, shall be 90 degrees apart around the tube circumference.
7. Hole depth and diameter tolerance shall be ±0.003 inch.
8. Minimum discontinuity spacing shall be 1 inch. Minimum distance from discontinuities to end of tube shall be 2 inches.
9. Tube support simulation ring material type and thickness shall be the same as found in the component being inspected. The ring shall be a slip-fit and the radial dimension shall be 0.300-inch minimum. Ring to tube diametral clearance shall be 0.020-inch maximum.
10. Holes shall be flat-bottom.

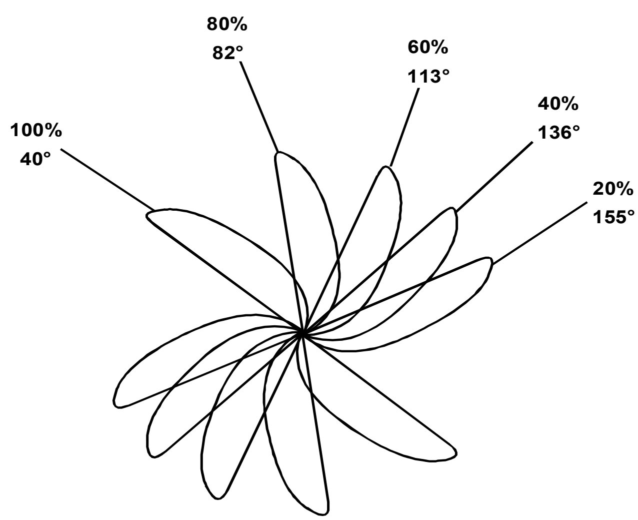
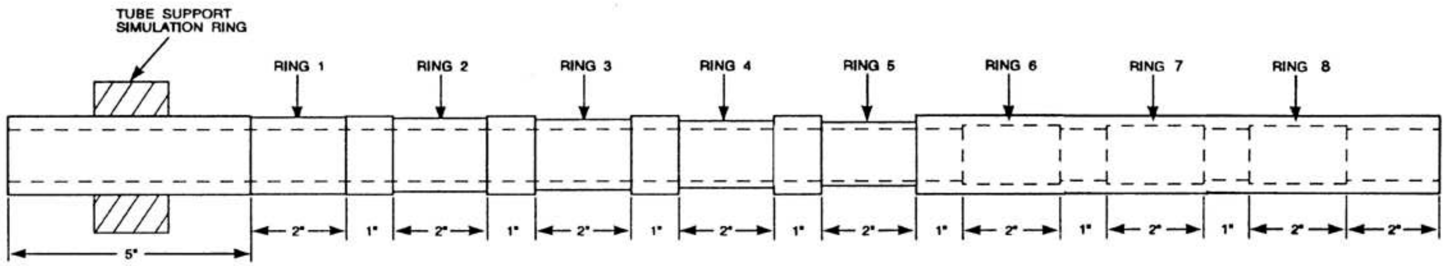


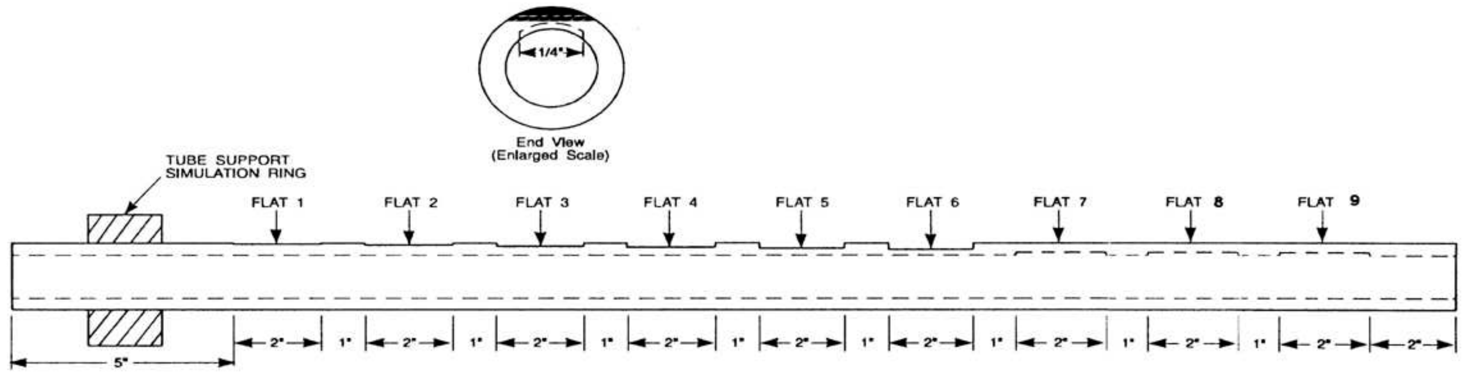
Figure 6-1. ASME-Type Calibration Standard with Typical Signal Presentation.



NOTES:

1. Standards shall be manufactured from a length of tubing of the same nominal outer diameter +0/-0.005 inch, nominal wall thickness, and material type (straight or finned, seamed or seamless, chemical composition and heat treatment) as that to be examined.
2. Depth of calibration discontinuities shall be as follows:
   Ring 1 - 10 percent through-wall
   Ring 2 - 20 percent through-wall
   Ring 3 - 30 percent through-wall
   Ring 4 - 40 percent through-wall
   Ring 5 - 50 percent through-wall
   Ring 6 - 20 percent through-wall (ID)
   Ring 7 - 40 percent through-wall (ID)
   Ring 8 - 60 percent through-wall (ID)
3. Depth tolerance shall be ±0.003 inch. Tolerance for other dimensions shall be ±1 of 0.020 inch.
4. Machined surface finish shall be 63 Roughness Height Rating (RHR) maximum.
5. Tube support simulation ring material and thickness shall be the same as found in the component being inspected. The ring shall be a slip-fit and the radial dimension shall be 0.300 inch minimum. Ring to tube diametral clearance shall be 0.020 inch maximum.

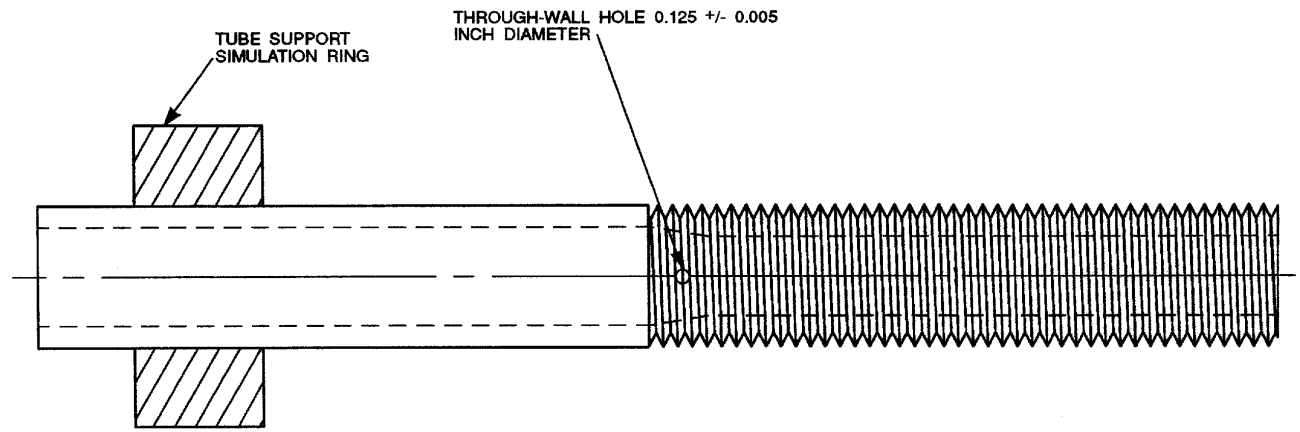
Figure 6-2. 360-Degree Machined Ring Standard.



NOTES:

1. Standards shall be manufactured from a length of tubing of the same nominal outer diameter +0/-0.005 inch, nominal wall thickness, and material type (straight or finned, seamed or seamless, chemical composition and heat treatment) as that to be examined.
2. Depth of calibration discontinuities shall be as follows:
   Flat 1 - 10 percent through-wall
   Flat 2 - 20 percent through-wall
   Flat 3 - 30 percent through-wall
   Flat 4 - 40 percent through-wall
   Flat 5 - 50 percent through-wall
   Flat 6 - 60 percent through-wall
   Flat 7 - 20 percent through-wall (ID)
   Flat 8 - 40 percent through-wall (ID)
   Flat 9 - 60 percent through-wall (ID)
3. Depth tolerance shall be ±0.003 inch. Tolerance for other dimensions shall be $\pm^{1}/_{16}$ inch. Maximum corner break radius of 0.020 inch.
4. Machined surface finish shall be 63 RHR maximum.
5. Tube support simulation ring material and thickness shall be the same as found in the component being inspected. The ring shall be slip-fit and the radial dimension shall be 0.300 inch minimum. Ring to tube diametral clearance shall be 0.020 inch maximum.

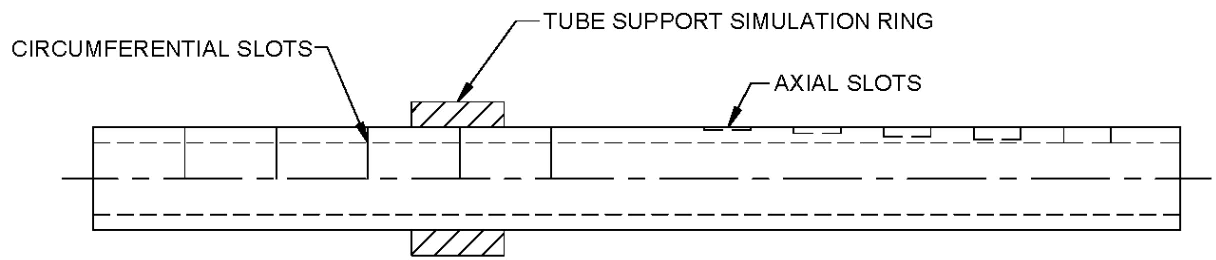
Figure 6-3. Milled Flat Thinning Standard.



NOTES:

1. Standards shall be manufactured from a length of tubing of the same nominal outer diameter +0/-0.005 inch, nominal wall thickness, and material type (seamed or seamless, chemical composition and heat treatment) as that to be examined.
2. Length of the standard shall be approximately 12 inches with one-half of the length finned.
3. Through-wall hole should be located approximately midway in the tapered section.
4. Tube support simulation ring material and thickness shall be the same as found in the component being inspected. The ring shall be slip-fit and the radial dimension shall be 0.300 inch minimum. Ring to tube diametral clearance shall be 0.020 inch maximum.

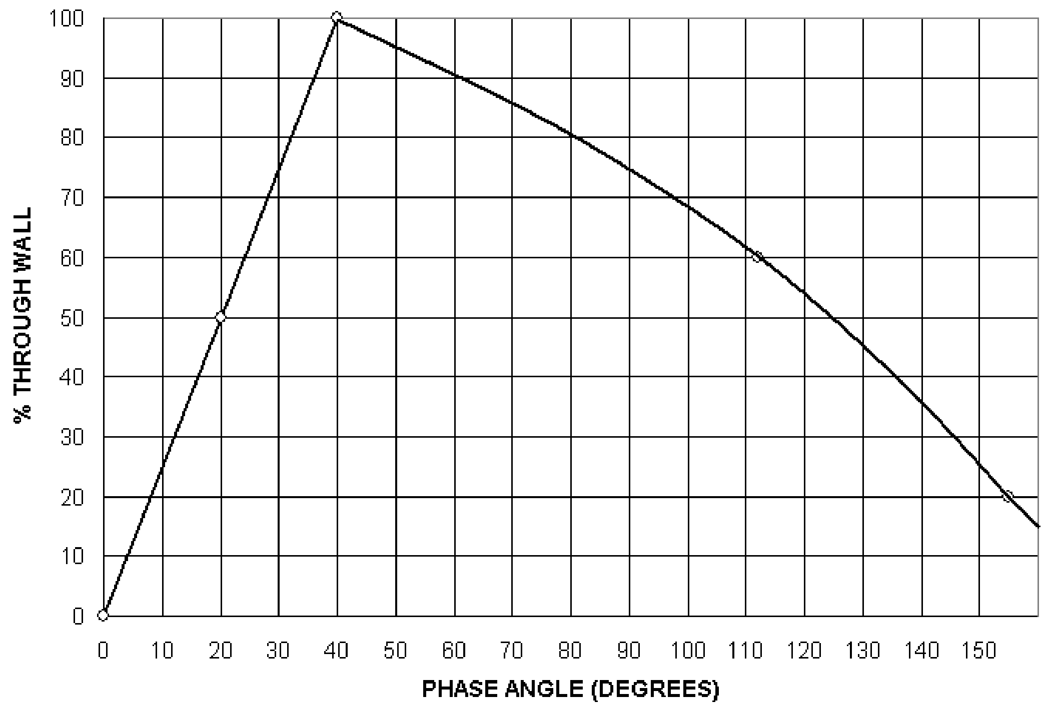
Figure 6-4. Tapered Area Sensitivity Standard.



NOTES:

1. Standards shall be manufactured from a length of tubing of the same nominal outer diameter +0/-0.005 inch, nominal wall thickness, and material type (straight or finned, seamed or seamless, chemical composition and heat treatment) as that to be examined.
2. Circumferential slot dimensions shall be 20, 40, 60, 80, and 100 percent through-wall ±0.003 inch, 0.006±0.003 inch wide, and shall extend 90 degrees around the tube circumference. Slot separation shall be 1 inch.
3. Axial slot dimensions shall be: 0.250±0.003 inch long, 20, 40, 60, 80, and 100 percent through-wall ±0.003 inch deep, and 0.012±0.003 inch wide. Slot separation shall be 1 inch.
4. Slot locations are approximately as shown. Minimum distance from discontinuities to end of tube shall be 2 inches.
5. Tube support simulation ring material and thickness shall be the same as found in the component being inspected. The ring shall be slip-fit and the radial dimension shall be 0.300 inch minimum. Ring to tube diametral clearance shall be 0.020 inch maximum.

Figure 6-5. Slotted Standard.

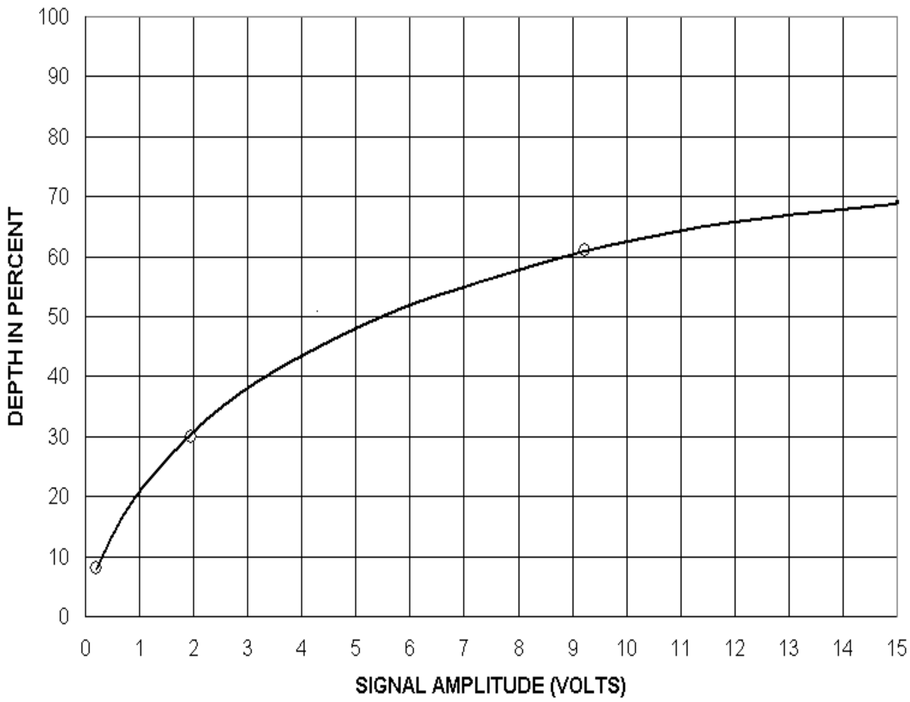


DEG	%
40	100
112	60
155	20

NOTE:

1. This is also the required curve for 90-10 CuNi material, as described in 5.2.2.1.

Figure 6-6. Typical Defect Evaluation Curve for Differential Mode Phase Angle Analysis.



Volts	%
0.21	8
1.96	30
9.22	61

Figure 6-7. Typical Absolute Mode Calibration Curve for Wall Thinning.

EDDY CURRENT TUBE INSPECTION TECHNIQUE SHEET S/N: ETTS #

ET Technique Sheet		
Serial No.: ETTS #	Rev. 0	Pages: 6
Approved by:	Date: 05/10/2007	
1. SCOPE		
Specifications: NAVSEA T9074-AT-GIB-010/2032 Rev. 1 NAVSEA INSTRUCTION 9254.1E		

Instrument: ZETEC MIZ-43	**Tubing**: 70/30 CuNi, 5/8" OD X 0.065" WT
Data Recording Equipment: DELL I-OMEGA ZIP DRIVE, 250 MB DISK (Record to hard drive & transfer data to disk)	**Calibration Standards** (SERIAL NUMBER): **ASME** (135 - 951), **MILLED-FLAT** (135 - 1105), **360°-RING** (135 – 1109), **ID THINNING** (135 – 1312)
Acquisition Software: ZETEC PC ACQUISITION 43 VER. 3A (Prototype)	**Analysis Software**: ZETEC ET ANALYSIS 32-BIT REV. 3D (Prototype)
Test Procedure: NDTP 4855.25 Rev. B and applicable Inspection Notices	**Probe Extension**: ZETEC 4-PIN/10 ft. **Slip Ring**: ZETEC 4-PIN

2. SCAN PARAMETERS		
Direction: IN/OUT to RTN	**Probe Speed**: 48 in/sec[1/]	**Sample Rate**: 2000 samples/sec[1/]

3. PROBES	
Type: ZETEC A-460-BS/LF/TBB (Primary) or A-450-BS/LF/TBB ZETEC A-460-MBS/LF or A-450-MBS/LF	BOBBIN – 50', 5/16" sheath MAG BIAS – 50', 5/16" sheath

4. DATA ACQUISITION				
	Calibration (Differential Channels)			
Channel / Freq	**Ch 1 / 88 kHz**	**Ch 3 / 44 kHz**	**Ch 5 / 20 kHz**	**Ch 7 / 180 kHz**
Phase Rotation	ASME 100% TWH 40°	ASME 100% TWH 40°	ASME 100% TWH 40°	ASME 100% TWH 40°
Span Setting	ASME 20% TWH 3.5 - 5 divisions	ASME 20% TWH 3.5 - 5 divisions	ASME 20% TWH 3.5 - 5 divisions	ASME 20% TWH 3.5 - 5 divisions
	Calibration (Absolute Channels)			
Channel / Freq	**Ch 2 / 88 kHz**	**Ch 4 / 44 kHz**	**Ch 6 / 20 kHz**	**Ch 8 / 180 kHz**
Phase Rotation	ASME 100% TWH 40°	ASME 100% TWH 40°	ASME 100% TWH 40°	ASME 100% TWH 40°
Span Setting	ASME 100% TWH 1 - 2 divisions	ASME 100% TWH 1 - 2 divisions	ASME 100% TWH 1 - 2 divisions	ASME 100% TWH 1 - 2 divisions

Miz 43 Configuration															
Sample Rate: 2000[1]	**Board #1**						**Board #2**						GAIN	PROBE DRV (V)	PROBE GAIN
FREQUENCY 1-4	**Probe 1**			**Probe 2**			**Probe 1**			**Probe 2**					
	A	**D**		**B**	**C**		**A**	**D**		**B**	**C**				
FREQ #1	●		√	●					√				X2	16.0	X2
88kHz	D			A											
FREQ #2	●			●									X2	16.0	
44kHz	D			A											
FREQ #3	●			●									X2	16.0	
20 kHz	D			A											
FREQ #4	●			●									X2	16.0	
180 kHz	D			A											

Figure 6-8. Sample Eddy Current Technique Sheet.

DATA ACQUISITION cont.
Data Acquisition Notes
1. Preferred pull speed is 48 in/sec. For pull speeds from 12 to 24 in/sec set the sample rate at 1000. For speeds greater than 24 in/sec set the sample rate at 2000. 2. Hardware nulls shall only be performed prior to starting a cal group. Software nulls may be performed anytime during a cal group. 3. Set the spans and rotations for each channel prior to creating a summary. 4. Track cal groups to ensure that the number sequence is maintained (i.e. 1,2,…10) - To prevent tubes from being unnecessarily analyzed, when retesting a tube write a message prior to retesting and also provide a written note with the data for the analyst. 5. Ensure that the full tube length is inspected. The analyst is required to be able to measure up to the tube sheet on both ends. 6. If a test plan is used, ensure that it is disabled when standards are being recorded and also when retests are being performed during a cal group (i.e. when recollecting a tube). 7. Verify the tube trace includes ITSIOT-ITSRT and all TSPs and that the pull speed is consistent. **8. Data collectors are only required to maintain pages 1 and 2 of this document.**

10D Auto Cycle Setup (when used)	
Shut-off threshold: 6000	**Hold-off time:** 500-1000
1. Adjust the shut-off threshold and hold-off time to ensure that the entire tube is recorded including the ITIO and ITRT. 2. Do not use the auto cycle when running standards.	

5. DATA ANALYSIS				
	Calibration (Differential Channels)			
Channel / Freq	**Ch 1 / 88 kHz**	**Ch 3 / 44 kHz**	**Ch 5 / 20 kHz**	**Ch 7 / 180 kHz**
Phase Rotation	In Ch 1, set probe motion horizontal with ASME 100% TWH at 40° plus or minus 5° degrees, signal excursion first down and to the right. For Ch 3, 5, and 7 rotate the 100% TWH to the same phase angle as Ch1.			
Span Setting	ASME 20% TWH, ~ 3.5 - 5 divisions without saturation for each calibration discontinuity (signal-to-noise ratio 3-to-1 minimum.)			
	Calibration (Absolute Channels)			
Note: Signal response to probe motion shall be horizontal on the viewing screen and response to all calibration discontinuities shall be oriented upward and be distinguishable from probe motion signal.				
Channel / Freq	**Ch 2 / 88 kHz**	**Ch 4 / 44 kHz**	**Ch 6 / 20 kHz**	**Ch 8 / 180 kHz**
Phase Rotation	Probe motion horizontal with discontinuity signal response up.			
Span Setting	Milled Flat 20% OD ~ 1-2 divisions			
Note: It is not necessary to create Mix/filter channels or calibration curves for P2, P3, and P4 unless required to evaluate thinning indications under tube support plates or for evaluation of uniform thinning. P5 and P6 are necessary only if ID thinning is present and requires evaluation.				

Figure 6-8. Sample Eddy Current Technique Sheet – Continued.

Calibration (Mix/Other Channels)				
Channel / Freq	**Ch P1 (Ch 1/3) 88/44 kHz Diff.** (ASME Mix)	**Ch P2 (Copy of Ch 4) 44 kHz Abs.** (360° Ring Filter)	**Ch P3 (Ch 4/6) 44/20 kHz Abs.** (Milled Flat Mix)	**Ch P4 (Ch 4/6) 44/20 kHz Abs.** (360° Ring Mix)
Configure	Suppress TSP Ring on ASME Std in flaw free area (or actual TSP if problem mixing).	Create Plain Copy filter P2, from Ch. 4	Suppress TSP Ring on 360° Ring Std in flaw free area	Suppress TSP Ring on 360° Ring Std in flaw free area
Phase Rotation	ASME 100% TWH. Probe Motion Horiz. (~35°, signal excursion first down and to the right.)	Probe Motion Horizontal with discontinuity signal response up.	Probe Motion Horizontal with discontinuity signal response up.	Probe Motion Horizontal with discontinuity signal response up.
Span Setting	ASME 20% TWH ~ 3.5-5 divisions w/o saturation for each cal std flaw.	360° Ring 20% OD ~ 2 divisions	Milled Flat 20% OD ~ 2 divisions	360° Ring 20% OD ~ 2 divisions

Calibration (Mix/Other Channels)		
Channel / Freq	**Ch P5 (Copy of Ch 4) 44 kHz Abs.** (Milled Flat Filter)	**Ch P6 (Copy of Ch 4) 44 kHz Abs.** (360° Ring Filter)
Configure	Create Plain Copy filter P5, from Ch. 4	Create Plain Copy filter P6, from Ch. 4
Phase Rotation	Rotate signal so that the ID notches on the standard go up (approximately 90°) from horizontal	Rotate signal so that the ID notches on the standard go up (approximately 90°) from horizontal
Span Setting	Milled Flat 20% ID ~ 1-2 divisions	360° Ring 20% ID ~ 1-2 divisions

Voltage Normalization				**Calibration Curves** 1/		
Channel	**Signal**	**Set**	**Normalize**	**Type**	**Channel**	**Set Point**
1	ASME 20% FBH	4.0 Volts (V p-p)	All Channels	Phase	1, P1	ASME 100% TWH, 60% FBH, 20% FBH
				Magnitude	4, P3	Milled Flat (OD) 0%, 30%, 60%
				Magnitude	P2, P4	360° Ring (OD) 0%, 30%, 60%
				Magnitude	P5	Milled Flat (ID) 0%, 20%, 60%
				Magnitude	P6	360° Ring (ID) 0%, 20%, 60%

1/ Calibration curve points for channels 1, 4, P-1, shall be checked for each calibration standard run. Calibration curve points for channels P2, P3, P4. P5 and P6 only need to be checked when those curves are necessary for evaluation.

Data Screening / Analysis (Recommended)			
ET Analysis 32 Bit			
L/Strip Chart	**R/Strip Chart**	**L/Lissajous**	**R/Lissajous**
P1	**4**	**Ch-1**	**P-1 or 4**

1. Report all detectable wall loss indications equal to or greater then 20%.
2. Verify tube trace includes ITSIOT-ITSRT and all TSPs and trace pull speed is consistent.
3. Review strip chart (Ch-P1) for localized pitting/thinning signals and other abnormal conditions at normal (calibration) strip chart length.
4. Review strip chart (Ch-4) for localized/general thinning signals and other abnormal conditions at normal (calibration) strip chart length.
5. Set the appropriate channel in the L/R Lissajous to measure the depth of indications.
6. Zooming-in (expanding) L/R Strip Charts may be performed when deemed necessary for increased visibility of indications.

Definition of Detectable Discontinuity

A detectable discontinuity is defined as a discontinuity which can be ordinarily identified by an analyst, as opposed to a signal barely discernable and difficult to re-identify. Some conditions to consider are: 1) signals with 3-to-1 or greater signal-to-noise ratio, 2) all differential channel signals with a voltage greater than 0.5 volts peak-to-peak, 3) absolute channel signals greater than or equal to 4%, 4) a combination of these approaches, or 5) other comparable strategies or signal levels selected by the Level III Test Examiner.

Figure 6-8. Sample Eddy Current Technique Sheet – Continued.

6. REPORTING REQUIREMENTS			
Condition/region	Report 1/, 2/	CH	Comments
Inside diameter pitting	IDP	1	ID pitting indications in free span area
		P1	ID pitting indications under/near tube supports
Outside diameter pitting	ODP	1	OD pitting indications in free span area
		P1	OD pitting indications under/near tube supports
Inside diameter non-uniform thinning	INT	P5	ID localized non-uniform thinning indications in free span area
Outside diameter non-uniform thinning	ONT	1 & 4	OD localized non-uniform thinning indications in free span area
		P1 & P3	OD localized non-uniform thinning under/near tube supports
Inside diameter uniform thinning	IUT 3/	P6	ID uniform thinning indications in free span area
Outside diameter uniform thinning	OUT 3/	P4	OD uniform thinning indications in free span area
		P2	OD uniform thinning under/near tube supports
Dents	DNT 4/	1	Dent indications in free span area measuring 8 volts and greater
		P1	Dent indications under/near tube supports measuring 8 volts and greater

1/ Indications measuring greater than the maximum wall loss allowed shall be re-evaluated by an independent inspector prior to plugging.
2/ Report Volts, Degrees, (except for thinning) Percent, Ind, Channel, Location and Extent.
3/ Unless there is a strong differential signal, thinning indications shall be measured initially with the Milled Flat curve until the indication reaches the maximum wall loss allowed. At that point, data shall be acquired with a MRPC probe. If the indication is uniform then evaluate the bobbin data with the 360° Machined Ring curve. If the indication is not uniform report the measurement using the Milled Flat curve.
4/ Report Volts, Degrees, Ind, Channel, Location and Extent.

Sizing Techniques	
Condition	Technique
IDP, ODP	Volts P-P (Vp-p) & Max Rate (MaxR) are the primary methods to make phase angle measurements. Guess Angle (GAng) and 180 may be used with discretion on distorted signals only.
ONT, OUT, INT, IUT	Vert Max (VMax) & Vert Max "Shifted" are the primary methods to make voltage (amplitude) measurements. **NOTE**: Volts P-P & Max Rate should be used when there is a strong differential signal and reported with a phase angle measurement in Ch1 or P1. 1. Measurements should only be taken of clearly distinguishable thinning signals similar to that of the thinning standards. 2. Use the start and the stop of the indication as the null points and record the largest percentage of wall loss between the two points. 3. The size of the expanded strip chart can be adjusted in the operator selectables. 4. Do not range across tube support plate locations unless using a mix channel. Ensure that "absolute drift" is not included in the measurements.
DNT	Volts P-P (Vp-p)

Figure 6-8. Sample Eddy Current Technique Sheet – Continued.

7. OTHER INFORMATION		
Landmark Name	**Elevation**	**Type**
EOTRT	255.125	END
ITSRT	244.625	TTS
TSP-9	220.81	TSP
TSP-8	197.87	TSP
TSP-7	173.93	TSP
TSP-6	150.62	TSP
TSP-5	127.06	TSP
TSP-4	103.75	TSP
TSP-3	80.43	TSP
TSP-2	56.25	TSP
TSP-1	33.56	TSP
ITSIOT	10.500	TTS
EOTIOT	0.000	END

Figure 6-8. Sample Eddy Current Technique Sheet – Continued.

APPENDIX A
CONTENT AND FORMAT FOR REPORTING EDDY CURRENT INSPECTION DATA

A.1 SCOPE.

Appendix A provides the requirements for reporting eddy current inspection data. Other formats may be used provided all required fields and associated contents are captured. These requirements are applicable to eddy current signals generated using various inspection probes such as the standard dual bobbin, magnetic bias bobbin, shielded bobbin, beaded joint flex, crosswound, and single and multiple coil pancake probes.

A.2 REQUIREMENTS.

A.2.1 REQUIREMENTS FOR REPORTING EVALUATED EDDY CURRENT INSPECTION DATA.

The following describes the required content and suggested format for reporting evaluated eddy current data. Table A-I provides a summary of the permissible entries in the various fields.

Table A-I. Summary of Permissible Entries in the Various Fields.

Field #1 Tube Row/ Column Indicator	Field #2 Tube Number Indicator	Field #3 Signal Amplitude (volts)	Field #4 Signal Phase Angle (degrees)	Field #5 Defect Depth (percent)	Field #6 Eddy Current Indication Code Descriptor	Field #7 Channel Number/ Coil Number	Field #8 Reference Location	Field #9 Distance from Reference Location to Indication or Start of Indication (inches)	Field #10 Probing Extent Indicator
999 1: 998 or A: ZZZ or A1: 998	999 9SR 1: 998 or A: ZZZ	nn.nn	nnn	nn%	CAL	1	ITSIOT	±nn.n to + nn.n	FI
					NDD	2	ITSRT		FO
					NRD	3	TSP1: TSP-N		P
					ODP	4	ASME-type nn%		N
					IDP	5	Milled flat nn%		T
					OUT	6	360 ring nn%		O
					IUT	7			U
					ONT	8			SI
					INT	P1 (M1)			SO
					DNT	P2 (M2)			
					PVN	P3 (M3)			
					NDA	P4 (M4)			
					OCC				
					ICC				
					OAC				
					IAC				
					OTH				
					BLG				
					DEP				
					RBD				

Comments (for example, to identify the beginning or end of a data storage set, to identify a change of probes or a change in probe positioner, to elaborate on any tube, probe, defect condition, etc.) are permissible and are encouraged. The tube row and column fields should be completed if the comment is specific to a particular tube. If the data set is judged to require a re-pull, then a comment to that effect should be entered. The list of tubes reported should also include all obstructed and plugged tubes.

The entries identified for the various fields shall be used exclusively. If these entries are inadequate to describe a given condition, additional information should be incorporated by the use of comments (see preceding paragraph).

Field #1. Tube Row/Column Indicator.

Character	Definition
999	Calibration standard pull
1 : 998 or	Tube row indicator
A : ZZZ or	Tube row indicator
A1 : 998	Tube row indicator

Field #2. Tube Number Indicator.

Character	Definition
999	Calibration standard pull
9SR	Calibration standard pull with tube support simulation ring over the required discontinuity
1 : 998 or	Tube number indicator
A : ZZZ	Tube number indicator

Field #3. Signal Amplitude (Volts).

Character	Definition
nn.nn	Peak-to-peak amplitude of eddy current signal in volts

Field #4. Signal Phase Angle (Degrees).

Character	Definition
nnn	Angle of the eddy current signal in degrees

Field #5. Defect Depth (Percent).

Character	Definition
nn%	Depth of discontinuity in percent of wall thickness

Field #6. Eddy Current Indication Code Descriptor.

Character	Definition
CAL	Calibration standard
NDD	No detectable discontinuities (for titanium only)
NRD	No recordable discontinuities
ODP	Outside diameter pitting
IDP	Inside diameter pitting
OUT	Outside diameter uniform thinning
IUT	Inside diameter uniform thinning

Field #6. Eddy Current Indication Code Descriptor – Continued.

Character	Definition
ONT	Outside diameter non-uniform thinning
INT	Inside diameter non-uniform thinning
DNT	Dent indication
PVN	Permeability variation signal
NDA	Non-damage anomaly (unique to titanium tubes)
OCC	Outside diameter circumferential crack
ICC	Inside diameter circumferential crack
OAC	Outside diameter axial (longitudinal) crack
IAC	Inside diameter axial (longitudinal) crack
OTH	Other type of indication – provide description in comments section
BLG	Bulge indication
DEP	Conductive deposit indication
RBD	Retest – bad data

Field #7. Channel Number/Coil Number.

Typical Channel Numbers (Dual Coil Bobbin Probe Data).

Character	Definition
1	Primary frequency differential channel
2	Absolute channel
3	Differential channel
4	Primary frequency absolute channel
5	Differential channel
6	Absolute channel
7	Differential channel
8	Absolute channel
P1 (M1)	Mix channel #1
P2 (M2)	Mix channel #2
P3 (M3)	Mix or copy channel #3
P4 (M4)	Mix or copy channel #4

Field #8. Reference Location.

Character	Definition
ITSIOT	Inner surface of inner tube sheet inlet/outlet or inlet end
ITSRT	Inner surface of inner tube sheet return or outlet end
TSP-1 : TSP-N	Tube support number (tube supports shall be numbered starting with TSP-1 from the inlet/outlet or inlet end)
ASME-type nn% (actual)	ASME standard where nn% is the actual depth of the discontinuity
Milled flat nn% (actual)	Milled flat standard where nn% is the actual depth of the discontinuity
360 ring nn% (actual)	360-degree ring standard where nn% is the actual depth of the discontinuity

Field #9a. Distance from Reference Location to Indication or Start of Indication (Inches).

Character	Definition
±nn.n	Distance from center of reference location to center of indication in inches. Designate as positive or negative, with the positive direction being from the inlet/outlet or inlet end toward the return or outlet end. For the reporting of an area of tube length with a continuous discontinuity (thinning), this number would be the location of the start of the discontinuity.

Field #9b. Distance from Reference: Location to End of Indication (Inches).

Character	Definition
To + nn.n	Distance from center of reference location to the end of a discontinuity, which is being reported as having a length along the tube length. Always designate as positive. For the reporting of a single discontinuity with no length along the tube, there is no need to record the “to” extent.

Field #10. Probing Extent Indicator.

Character	Definition
FI	Full tube length pulled, probe inserted from inlet/outlet or inlet end
FO	Full tube length pulled, probe inserted from return or outlet end
P	Permanently plugged tube (plugged prior to current inspection)
N	Newly installed permanent plug (plugged during this inspection)
T	Temporarily plugged tube (temporarily plugged during this inspection)
O	Obstructed tube
U	Data collected only in U-bend section of tube
SI	Data collected in the straight section only on the inlet side of a U-bend tube
SO	Data collected in the straight section only on the outlet side of a U-bend tube

APPENDIX B
EDDY CURRENT INSPECTION SUPPLEMENTAL REQUIREMENTS

B.1. SCOPE.

This Appendix establishes minimum requirements in addition to those in the body of this publication for the acquisition and analysis of data for the eddy current inspection of nonferromagnetic tubing in heat exchangers. All requirements in the body of this publication are applicable unless otherwise revised or addressed in this Appendix. This Appendix shall be used only when specifically identified in the contract or job order.

B.2 GENERAL REQUIREMENTS.

a. Multi-Frequency Eddy Current Instrument. A Zetec MIZ-18, MIZ-27, or MIZ-43 eddy current data acquisition system shall be used. Other equipment may be used with NAVSEA approval. There are new features in the MIZ-27 and MIZ-43, not in the MIZ-18, that could affect the recorded data by potentially saturating high-amplitude absolute signals. The "probe drive" and "gain" settings on the newer MIZ systems must be set with caution. The settings must be high enough such that there is still a good signal-to-noise ratio, but large amplitude absolute signals must be scrutinized during calibration to ensure that no signal saturation occurs. To date, signal saturation has only been observed in the 360-degree machined ring standard. If saturation occurs, retest the affected tubes at a lower gain setting that prevents saturation.

b. Probes. For the detection of pitting and thinning, the probes shall be selected from Table B-I. Other probes may be used with NAVSEA approval. Any of the listed Zetec probe models may be used for a particular tube material/size/wall thickness (for example, the BS, CBS, or magnetic bias versions of these probes). For tubes not listed in Table B-I, contact NAVSEA's Materials Branch, SEA 05P2. For the detection of other types of discontinuities (for example, circumferential cracking), the choice of inspection probe(s) shall be made on the basis of inspection to be performed, type of defect suspected, and ID of the tube. The diameter of the probe shall be as near the ID of the tube as practical, and as specified in 4.1.5.

c. Reference Standards. Calibration standards shall be fabricated in accordance with 4.1.6 and shall be obtained from ZETEC or another NAVSEA-approved source.

Table B-I. Required Probes for the Detection of Pitting and Thinning.

Material	Tube Diameter (inch)	Wall Thickness (inch)	Allowable Probes [1/] (Zetec Probe Models)	
			Primary Probes	**Secondary Probes**
70-30 CuNi	5/8	0.049	A-490-BS	A-480-BS
			A-490-CBS	A-480-CBS
			A-490-MBS	A-480-MBS
			A-490-MCBS	A-480-MCBS
		0.065	A-460-BS/LF	A-450-BS/LF
			A-460-CBS/LF	A-450-CBS/LF
			A-460-MBS/LF	A-450-MBS/LF
			A-460-MCBS/LF	A-450-MCBS/LF
80-20 CuNi	5/8	0.065	A-460-BS/LF	A-450-BS/LF
			A-460-CBS/LF	A-450-CBS/LF
			A-460-MBS/LF	A-450-MBS/LF
			A-460-MCBS/LF	A-450-MCBS/LF
90-10 CuNi	5/8	0.049	A-490-BS/LF	A-480-BS/LF
			A-490-CBS/LF	A-480-CBS/LF
			A-490-MBS/LF	A-480-MBS/LF
			A-490-MCBS/LF	A-480-MCBS/LF
Titanium	9/16	0.035	A-460-BS	A-450-BS
			A-460-CBS	A-450-CBS
			A-460-MBS	A-450-MBS
			A-460-MCBS	A-450-MCBS
	5/8	0.049	A-490-BS	A-480-BS
			A-490-CBS	A-480-CBS
			A-490-MBS	A-480-MBS
			A-490-MCBS	A-480-MCBS

NOTE:

[1/] One of the “primary” probes listed for a particular tube shall be used, if it will pass through the tubes after cleaning. If the tube has been adequately cleaned (in the Level III Examiner’s opinion) and the primary probe will not pass through the tubes, then the “secondary” size probe shall be used. If the secondary size probe will not pass through the tubes, the Level III Examiner shall select the probe size, but must still meet the requirements of B.2.b.

B.3 DETAILED REQUIREMENTS.

B.3.1 TUBE IDENTIFICATION.

Each heat exchanger tube is identified by a unique letter or number grid system. The tube numbering system for submarines shall be as defined in 9254-SMMS-HBK, Eddy Current Inspection Tube Numbering Guide, Submarine Main Condensers. For aircraft carriers, contact the NAVSEA Heat Exchanger Branch, SEA 05Z, for the latest drawings or information on tube numbering.

B.3.2 PREVIOUS INSPECTION RESULTS.

Reports from the previous inspection shall be reviewed for applicable equipment, calibration data, and any special considerations of the inspection prior to inspection. Obtaining the previous inspection reports shall be coordinated through the NAVSEA Heat Exchanger Branch.

B.3.3 DATA ACQUISITION.

a. Equipment Setup. Local procedures, guides, and operation manuals specific to the particular activity's hardware and software shall be used for connection and setup of the system, software, probe pusher/puller, and accessories. Inspection equipment selected shall be based on the type of discontinuity to be detected. Digital data recordings shall be made of all data acquisition inspections and channels along with a recording of all the variables used during evaluation (for example, span settings (or volts per division for some MIZ systems), rotation settings, mix parameters, and any additional settings or information needed to re-create the setup at the time of data analysis). The probe pull speed by the puller shall be limited to a minimum data sample rate of 350 samples per foot of probe travel (samples/second ÷ probe speed in feet/second). In addition, it shall be demonstrated and documented by the Level III Examiner that the signal amplitude of the calibration notches between static probe and maximum pull speed does not vary by more than 10 percent for each inspection frequency being used. Calibrations, recalibrations, and calibration verifications shall be recorded on the same removable media storage device as the inspection data.

b. Test Calibration. The inspection shall be performed with four separate frequencies, each operating in both the differential and absolute mode, at the following frequencies: primary frequency, ½ primary frequency, ¼ primary frequency, and 2× primary frequency.

c. Detection of Cracks. When specific supplemental inspections are called out to perform an inspection for crack detection, contact SEA 05P2 for direction and approval of the inspection techniques to be used.

d. Calibration Standard Sequence. Standards, as required, shall be oriented such that the calibration discontinuities are positioned in the upward (12 o'clock) position during calibration, and shall be placed in a sequence such that as the probe is withdrawn, they will appear from bottom (earliest in time) to top of the strip charts in the following order:

   (1) ASME-type (100 percent to 20 percent).

   (2) Milled flat (smallest to largest).

   (3) 360-degree machined ring (smallest to largest).

   (4) Slotted (smallest to largest) – when specifically required.

e. Tubes shall be inspected using a mechanical puller when possible. Manual pulling shall only be used when local tube access restrictions preclude the use of mechanical pullers. Manual pulling requires approval of the eddy current Level III Examiner. A message shall be entered to identify all tubes manually pulled.

f. Tubes shall be scanned for the full length of the tube between the inner surfaces of the innermost tube sheets, including under the tube supports.

g. A calibration message shall be entered prior to any inspection. This message shall be recorded at the beginning of all removable media storage devices. Whenever calibration, calibration verification, or recalibration of the test system is required, a message indicating the reason (configuration change, standardization verification, probe change, instrument change, etc.) shall be typed and written to the removable media storage device in the form of a message. The calibration message shall be completed such that all information the analyst will need for the generation of final reports will be recorded (for example, probe model, probe S/N, operator name, procedure).

h. Perform the following steps to record the calibration standards:

(1) With the probe in a defect-free portion of the standard(s) and the calibration discontinuities in the upward position (12 o'clock), balance and center the displayed data and then advance the probe to the end of the standard.

(2) With the recorder on, withdraw the probe through the calibration standards to record the calibration data.

(3) A second pull of the calibration standards is required with the tube support simulation ring positioned over the applicable discontinuity of the particular standard. However, for the milled flat and 360-degree ring standards, the tube support simulation ring is centered over the edge of the notch and the notch is long enough where the opposite end of the notch is not affected by the support ring. In these instances, a second pull of the standard is not required. Similarly, a second set of 20-percent holes may be added to the ASME standard to preclude the need to pull the ASME standard twice.

(4) Calibration standards may also be recorded individually, if desired, using a standard identification scheme selected by the individual inspection activity.

B.4 EDDY CURRENT DATA ANALYSIS.

B.4.1 EQUIPMENT REQUIREMENTS.

Data shall be evaluated utilizing one of the following Zetec software packages: DDA-4 Data Analysis Software or ET Analysis for Windows. Other software may be used with NAVSEA approval.

B.4.2 MESSAGE REVIEW.

The analyst shall read all messages recorded on the removable media storage device prior to evaluation. The analyst may also find that a printout of all the messages is useful. This could prevent either:

a. Analyzing data indicated in a MESSAGE to be invalid.

b. Analyzing data indicated to be incorrectly identified on the recorded data.

B.4.3 DATA REVIEW.

Review the data stored on the recorded media for acceptability as specified in 5.3.8.

B.4.4 CALIBRATION.

When establishing calibration curves, use actual depth values provided with the standards and not nominal values (20 percent, 40 percent, etc.). Use caution that only unsaturated signals are used. Measuring the phase angle of a saturated signal will result in an erroneous measurement.

B.4.5 VOLT SETTING.

Locate the 20-percent OD flaw (ASME standard) in the lissajous display with the primary differential channel displayed. Measure the peak-to-peak amplitude of this signal. Set the voltage scale so that the peak-to-peak voltage is 4.00. Set all channels to the same voltage scale.

B.4.6 MIX CHANNEL ESTABLISHMENT.

Mixing of the support plate signals shall be accomplished using the tube support simulation ring. Alternatively, the mix shall be based on actual tube data when the tube support simulation ring does not result in an acceptable mix. However, the calibration must still be checked with the tube support simulation ring on the calibration standard. As is required for the differential and absolute channels, the mix channel must also meet the calibration requirements.

B.4.7 ESTABLISHING AXIAL LOCATION/LENGTH OF FLAW SIGNALS.

a. The location names ITSIOT, ITSRT, TSP-1, TSP-2, … TSP-10, etc., shall be used exclusively as reference points for reporting the location of a flaw. These acronyms are listed and explained in Appendix A. The tube support plates shall always be numbered from the inlet/outlet end on the condenser, regardless of whether the tubes have been pulled from the inlet/outlet or return end.

b. Set up a scale in inches. Once the scale is set, zero can be moved to any named location, and plus or minus measurements from that location can be made. A scale can only be established for known dimensions and a constant probe pull speed.

B.4.8 DEFECT EVALUATION.

Defect evaluation shall be performed as specified in 5.3.9.

B.5 RECORDING AND REPORTING.

Reporting and record requirements shall be as specified in 5.4 and 5.5 and the following: All tubes shall be reviewed for pitting, thinning, and conditions such as dents (above the threshold), deposits, bulges, cracks, distorted signals, or any other unusual condition shall also be reported. If several reportable conditions are detected in a tube, such as several pits or an area of pitting and an area of thinning, separate line entries with the same tube number are required in the report and on the removable media storage device.

Ref: NAVSEAINST 4160.3 NAVSEA S0005-AA-GYD-030/TMMP

NAVSEA/SPAWAR TECHNICAL MANUAL DEFICIENCY/EVALUATION REPORT (TMDER)

INSTRUCTIONS: Continue on 8 ½” x 11” on page if additional space is needed.
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