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METALS AND CERAMICS DIVISION

ULTRASONIC EXAMINATION OF JBK-75 STRIP MATERIAL

K. V. Cook, R. A. Cunningham, Jr., J. C. Lewis, and R. W. McClung

NOTICE: This document contains information of a preliminary nature. It is subject to revision or correction and therefore does not represent a final report.

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CONTENTS

ULTRASONIC EXAMINATION OF JBK-75 STRIP MATERIAL

K. V. Cook, R. A. Cunningham, Jr.,
J. C. Lewis,* and R. W. McClung

ABSTRACT

An ultrasonic inspection system was assembled to inspect the JBK-75 stainless steel sheath material (for the Large Coil Project) for the Westinghouse-Airco superconducting magnet program. The mechanical system provided for handling the 180-kg (400-lb) coils of strip material [1.6 mm thick by 78 mm wide by 90–120 m long (0.064 by 3.07 in. by 300–400 ft)], feeding the strip through the ultrasonic inspection and cleaning stations, and respooling the coils. We inspected 54 coils of strip for both longitudinal and laminar flaws. Simulated flaws were used to calibrate both inspections. Saw-cut notches [0.28 mm deep (0.011 in., about 17% of the strip thickness)] were used to calibrate the longitudinal flaw inspections; 1.59-mm-diam (0.063-in.) flat-bottom holes drilled halfway through a calibration strip were used to calibrate the laminar flaw tests.

INTRODUCTION

This report was prepared to describe chronologically the successful effort to establish and use an ultrasonic test system to evaluate large coils of strip material for planar and laminar flaws. In early 1981, the Nondestructive Testing Group of ORNL was asked to assess the quality control possibilities for sheath material for superconducting cable for the Westinghouse-Airco superconducting magnet project. Specifically, ORNL was asked to review inspection procedures and to provide a recommendation of a "best" examination technique for nondestructively examining JBK-75 sheathing material supplied by the Carpenter Technology Corporation. This material is a modification of A-286 precipitation-hardening stainless steel, containing nominally (wt %) 30 Ni, 14 Cr, 1 Mo, 2 Ti, and 0.02 C.

*Y-12 Development Division.

On March 19, 1981, a letter on the subject of "Nondestructive Examination of JBK-75 Material for Westinghouse-Airco Superconducting Magnet" was drafted (see Appendix A). Part of this response introduced the possibility of performing an ultrasonic examination on the sheath material while in the strip form. In a subsequent letter to the Fusion Energy Division management of the Large Coil Project (LCP), a formal recommendation was made that an ultrasonic examination of the strip be made before forming and welding. The basic reason for this recommendation was to ensure that the JBK-75 strip before forming into sheath is free of discontinuities (laps, cracks, etc.) that could lead to sheath failure (leakage). Consideration of several options[1] indicated that shear wave ultrasonic techniques offered the potential for performing this examination. Initial industry surveys (by telephone) of ultrasonic practices for examination of metal strip resulted in an overly optimistic view that systems using rubber-tired wheel search units for strip and sheet examination were in regular use. After further investigation to get necessary details from equipment manufacturers and users, we recognized that the wheel search units would not perform adequately for the examination of the 78-mm-wide (3.07-in.) strip. However, brief laboratory investigations demonstrated the feasibility of using immersion ultrasonic techniques to perform the needed examination. In addition, a brief investigation determined a feasible approach for assembling the necessary mechanical fixturing for handling the rolls of strip, driving the strip through an immersion ultrasonic tank, and rewinding on a take-up reel.

A scope of work, schedule, and cost for nondestructive examination of JBK-75 sheath material was provided to the Fusion Energy Division on July 7, 1981. Management of LCP formally accepted the proposal on August 21, 1981.

INSPECTION SYSTEM

MECHANICAL HANDLING

The mechanical system needed for the ultrasonic immersion testing of large coils of strip required sturdy drive and take-up fixtures. Each coil weighs around 180 kg (400 lb) and has an inner coil diameter of about

400 mm (16 in.) and an outer diameter of about 700 mm (28 in.). The strip dimensions are nominally 78 mm wide by 1.6 mm thick by a maximum of 120 m long (3.07 in. by 0.063 in. by 400 ft). Figure 1 shows one of the first coils received (after ultrasonic inspection) on the shipping pallet as it is being lifted by a portable hydraulic lift (necessary for local handling). This coil of strip and others like it were placed on a rotating head of a welding fixture (model UWL-10 of Reed Corporation) in the horizontal position and then moved to the vertical plane. Figure 2 shows the loading turntable (in the lower right) in the vertical operating plane. Note that the inspection is very nearly complete since only a partial turn of coil is left on the head. A spindle on the turntable

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Fig. 1. Coil of JBK-75 strip being placed on shipping pallet by a small hydraulic hoist.

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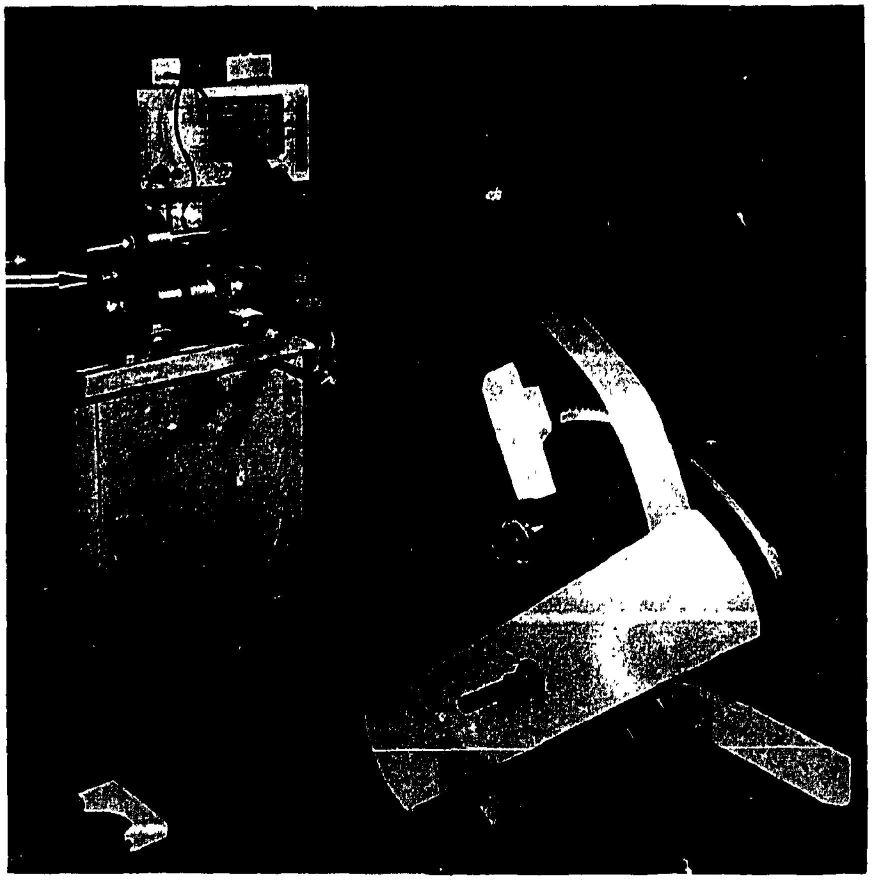

Fig. 2. Welding fixture (lower right) used to unwind JBK-75 strip for feeding through ultrasonic immersion inspection tank (upper left) facility. Arrow indicates one of pair of skate wheels used to control lateral movement of the strip.

consists of three polyurethane-tread wheels mounted on sections of Unistrut. A split bolt, with set screws and a nut, locks the end of the coil in place. The white nylon pieces (shown in Fig. 2 on the turntable) were used in an attempt to minimize lateral movement as the coil unwound. After initial runs, these nylon pieces had to be replaced with rigid plywood sections, as shown in Fig. 3, where the turntable has obviously been turned 180°. The operating position of the loading turntable (that is, loading the inspection unit but unloading the coil) is reversed from Fig. 2; Airco preferred that the sheared edge of the strip face upward on

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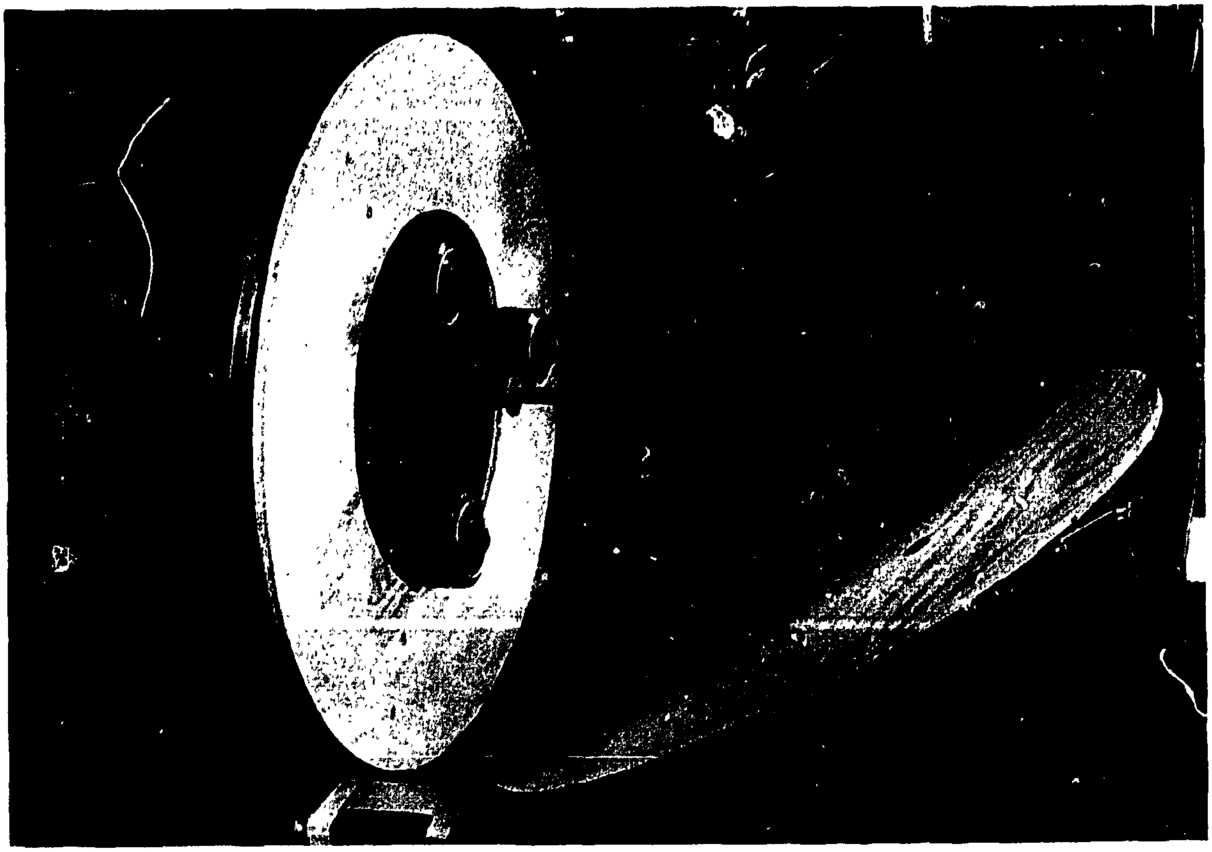

Fig. 3. Altered loading turntable (with wooden restraining pieces to prevent excessive lateral motion of the coil of strip as it unwinds) for JBK-75 inspection with ultrasonics.

the loading pallet to simplify handling. Also note in Fig. 2 that the strip arches into the long immersion tank (left center of the photograph) and is fed through three additional polyurethane-tread guide wheels, which are mounted on Unistrut and pillow block structures. Also, two steel skate wheels are mounted to the left and right of the pinch point between the guide wheels to control the lateral movement of the strip and to ensure proper feed into the immersion tank. Only one of these skate wheels is visible in Fig. 2. Figure 4, of the total system, shows the loading fixture at the left center of the picture and the unloading (strip respooling) fixture at the lower right. The loading fixture is braked

Y-181120

Fig. 4. Ultrasonic immersion inspection system used to inspect strips of JBK-75 sheath material.

with a friction drag, and the unloading or drive fixture pulls the strip through the long water-filled tank. (Here "loading" and "unloading" refer to the inspection system.)

Details of the respooling (unloading) turntable are shown in Figs. 5 and 6. Figure 5 is the original respooling method that used nylon pieces and urethane-coated wheels identical with those used on the initial loading turntable (Fig. 2). Figure 6 details the changes needed to provide smoother respooling operation and handling. The three small nylon pieces were replaced with a wooden doughnut section (see Fig. 6 in a nonoperating position for clarity of turntable changes) that was coated with nylon except for two strapping openings (near the top and bottom of the photograph). Also note that a metal ring (split ring) was added to keep the first turns of the coil from bending as they were forcibly wrapped (respooled) around the urethane three-wheel spindle. The outside

Y-181123

Fig. 5. Respooling turntable as used for the initial respooling operation in the ultrasonic inspection system for JBK-75 strip.

nylon retainer shown in Fig. 5 was again used to form a reel-type control of the respooling by tying to the centering rod shown in both Figs. 5 and 6. Also note at the bottom center of Fig. 5 the roll of paper that is interleaved into the respooled coil. The strip is also cleaned at a station that is visible near the top of Fig. 5. Figure 7 is a close-up of this cleaning station. Two forced-air drying units are shown on the

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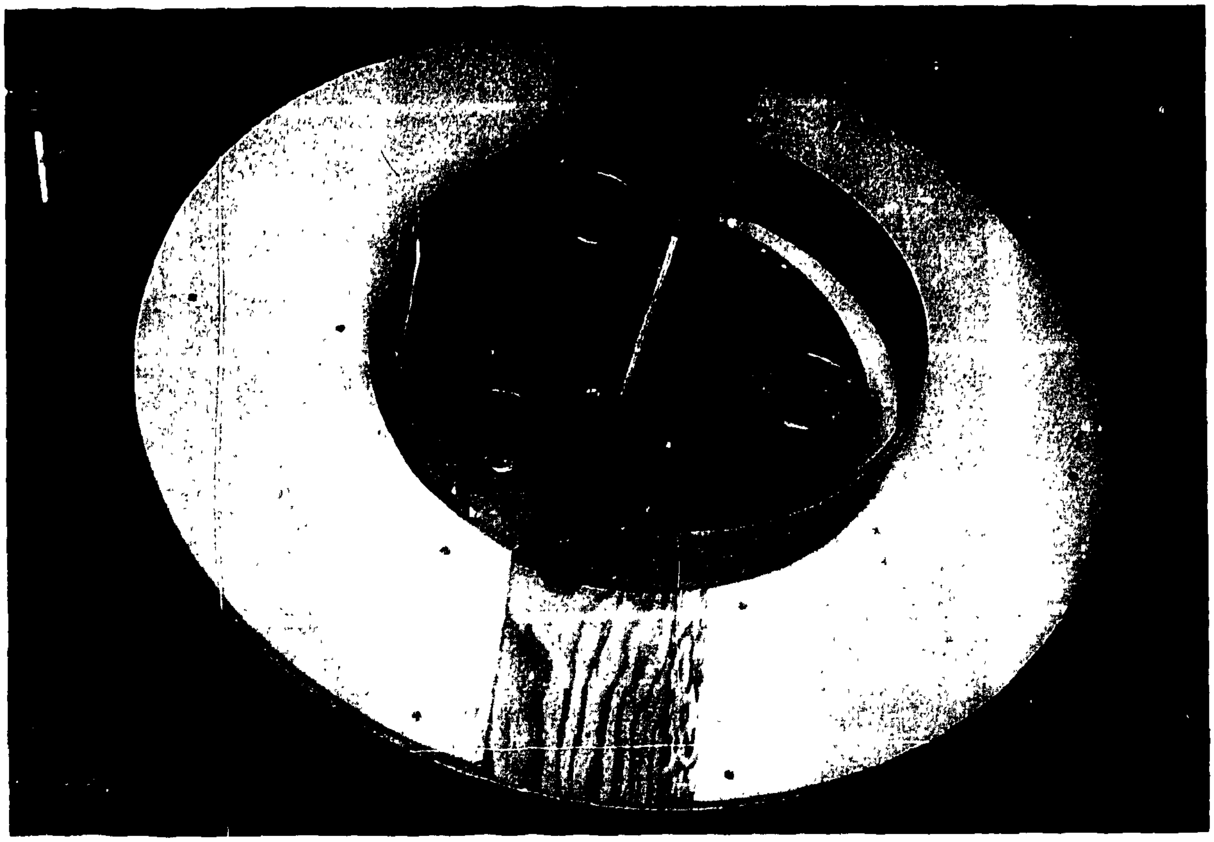

Fig. 6. Modifications made to turntable mechanism for improved control of the respooling of JBK-75 strip.

right. One is located above and one below the strip (not shown) as it feeds through the two sets of gauze-wrapped rollers. The first gauze rollers (top and bottom) are saturated with alcohol before the strip is drawn between them. The top one is then constantly flooded with dripping alcohol from the glass buret shown in the upper portion of Fig. 7. The second set of gauze-wrapped rollers (nearest the center of the photograph) is used to further clean the strip before the cool-air dry. The cleaning station is also seen in the upper right-hand side of Fig. 8. Note the sponges used to remove excess water before the cleaning operation.

The urethane guide wheels, the skate wheels, and the Unistrut assembly, also evident just to the right of where the strip is drawn out of the

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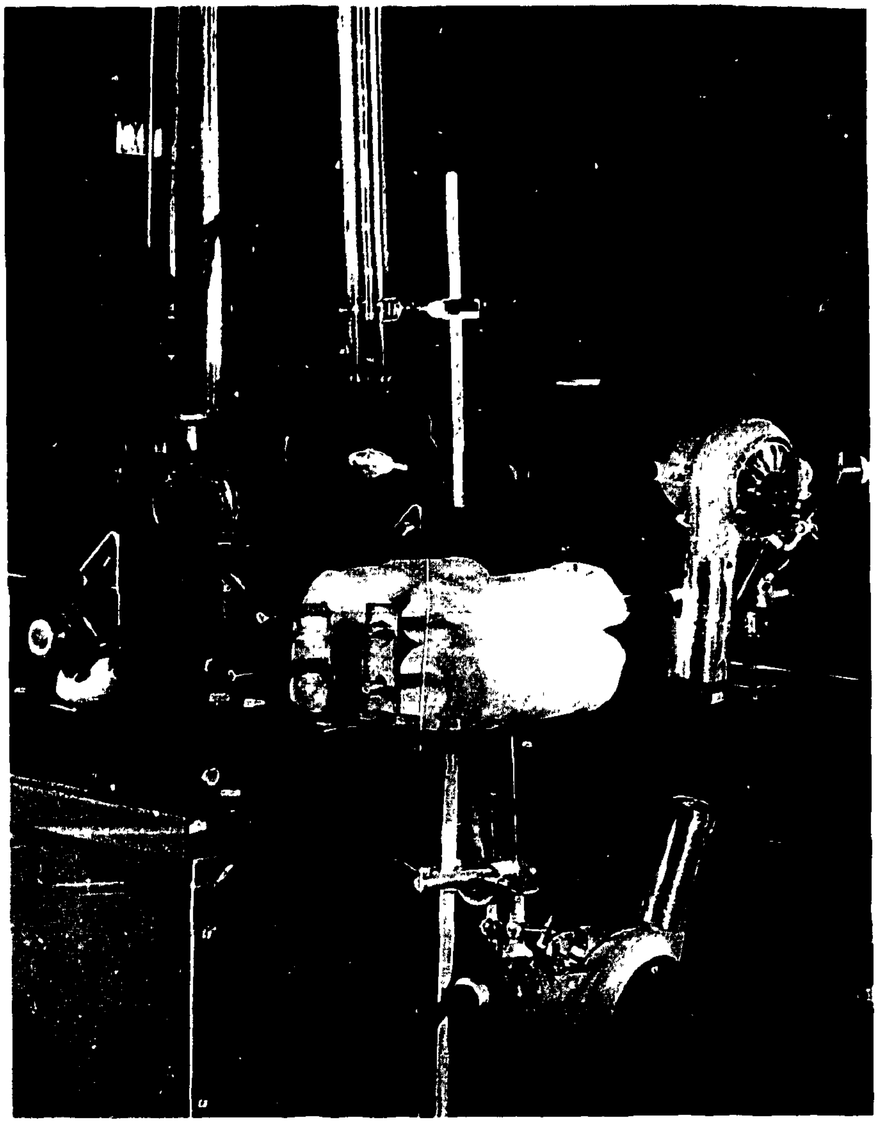

Fig. 7. Close-up of the cleaning station portion of the ultrasonic inspection system for sheath material.

water (Fig. 8), are identical with the ones described earlier and located near the coil unloading device. The two sets of wheels on the end of the tanks and additional ones located at intervals in the immersion tank are used to ensure the alignment of the material at the three key locations (i.e., the center inspection area and both ends of the mechanical system).

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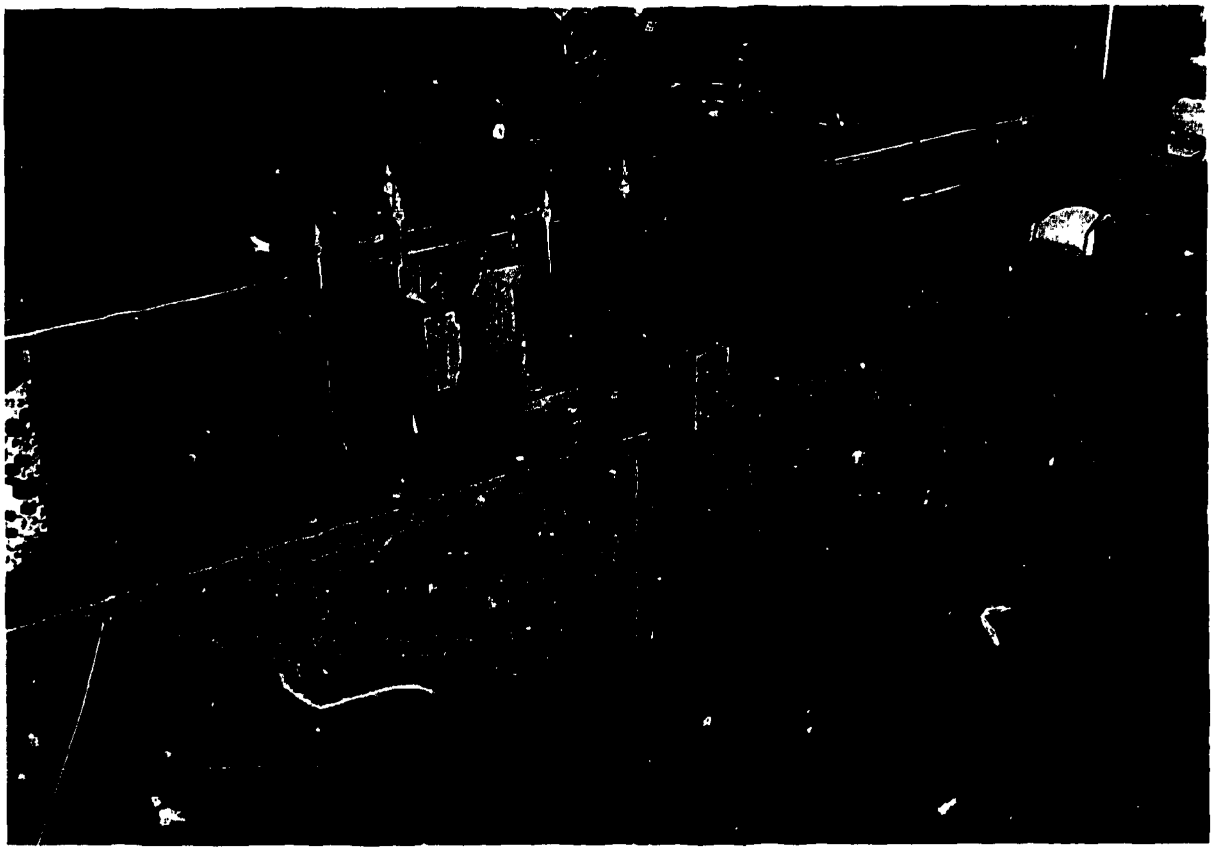

Fig. 8. Ultrasonic immersion tank facility used to inspect sheath in strip form.

ULTRASONIC TECHNIQUES

Pulse-echo immersion ultrasonic techniques with demineralized water as the couplant were used. Both longitudinal planar flaws (i.e., flaws perpendicular to the strip thickness with their major length parallel to the strip length) and delamination flaws (i.e., areas of separation within the strip thickness lying near one edge or the other) could be detected by the ultrasonic tests that we developed. The original goals were to detect the longitudinal flaws with two ultrasonic search units where a little more than one-half the strip width could be interrogated from each direction (from slightly beyond the strip center to the opposite edge). Our initial feasibility experiments attempted to use a 5-MHz ultrasonic search unit to generate in the strip shear waves that would scan at least one-half the 78-mm-wide strip for longitudinal flaws; however, the attenuation (at both 5 and 2.25 MHz) was too great to allow adequate examination across the half width. Thus, the interrogating frequency had to be reduced to 1 MHz to provide the necessary coverage. The lower frequency provided the necessary detection for flaws in the center zone of the strip, but it did not allow adequate resolution of planar flaw indications that occurred within the large reflected signal from the edge. Thus, we added a higher frequency (2.25-MHz) test to provide better resolution for flaws located near the edge. In fact, we included a transducer for each edge, so the strip had to be drawn through the inspection station only once to detect longitudinally oriented flaws near both edges. Simple sketches illustrating the three-search-unit scheme for detecting longitudinal flaw is shown in Fig. 9(*a*).

The laminar flaw tests on each edge were added to our original test plans because this type flaw could cause welding problems and it would be fairly simple to test for during the same inspection. The laminar flaw

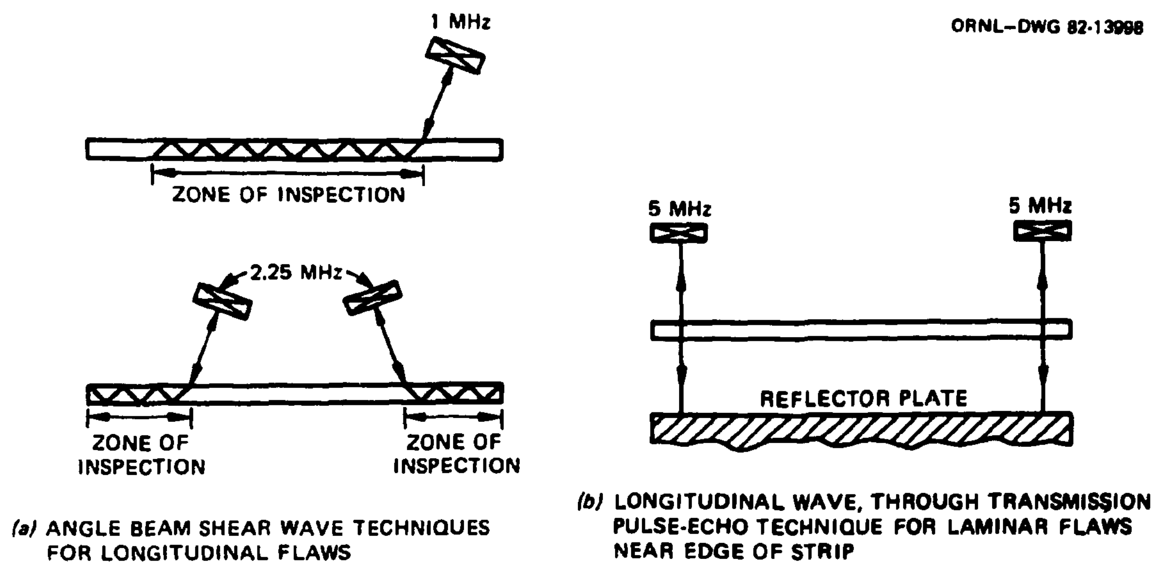

Fig. 9. Ultrasonic techniques for JBK-75 strip.

tests used two 5-MHz search units [see sketch in Fig. 9(*b*)] located perpendicular to the strip (one over each edge) and a reflector steel plate located underneath the strip to simply reflect the ultrasound that is passed through the strip back to the search unit. Sound passes through the strip twice, and the transmitted signal intensity is decreased both times if a laminar flaw is present. Thus, the amplitude of the reflected signal is monitored for flaw detection. Smaller flaws were resolved by masking the search unit with 3.18-mm (0.125-in.) lead masks.

ULTRASONIC INSPECTION STATION

Figure 8 includes a general view of the ultrasonic inspection fixturing. Close-up views of two sets of ultrasonic inspection fixtures are shown in Figs. 10 and 11. Figure 10 is the left side, and Fig. 11 is the right side of the inspection station shown in Fig. 8. Note the cleaning wipe (roll of gauze) at the lower center of Fig. 10 to keep the strip free of bubbles and so forth as it enters the tank. Just above the cleaning wipe are sets of skate wheels that control lateral strip motion. The long guide urethane roller just above the skate wheels keeps the strip flat in the inspection zone. Another long guide roller directly under this one provides another pinch point on the strip. Additional long two-roller guide systems are located at key positions along the immersion tank (another set is evident in Fig. 11). Three minimanipulators (goniometer devices with knurl knobs) provide the incident angles for the three longitudinal flaw detection tests using three ultrasonic search units. The three search units (see the arrows in Fig. 10) are located just above the strip and are angled to introduce ultrasonic shear waves by mode conversion at the water-steel interface. The search unit and minimanipulator nearest the urethane roller (Fig. 10) are used to inspect most of the strip width (i.e., the center section) for longitudinally oriented flaws. The search unit operates at 1.0 MHz and is about 13 mm in diameter (0.5 in.). The next two search units (located down the axis of the strip) are 2.25-MHz units of the same nominal diameter. They monitor small edge zones on each side and can detect longitudinally oriented flaws as close

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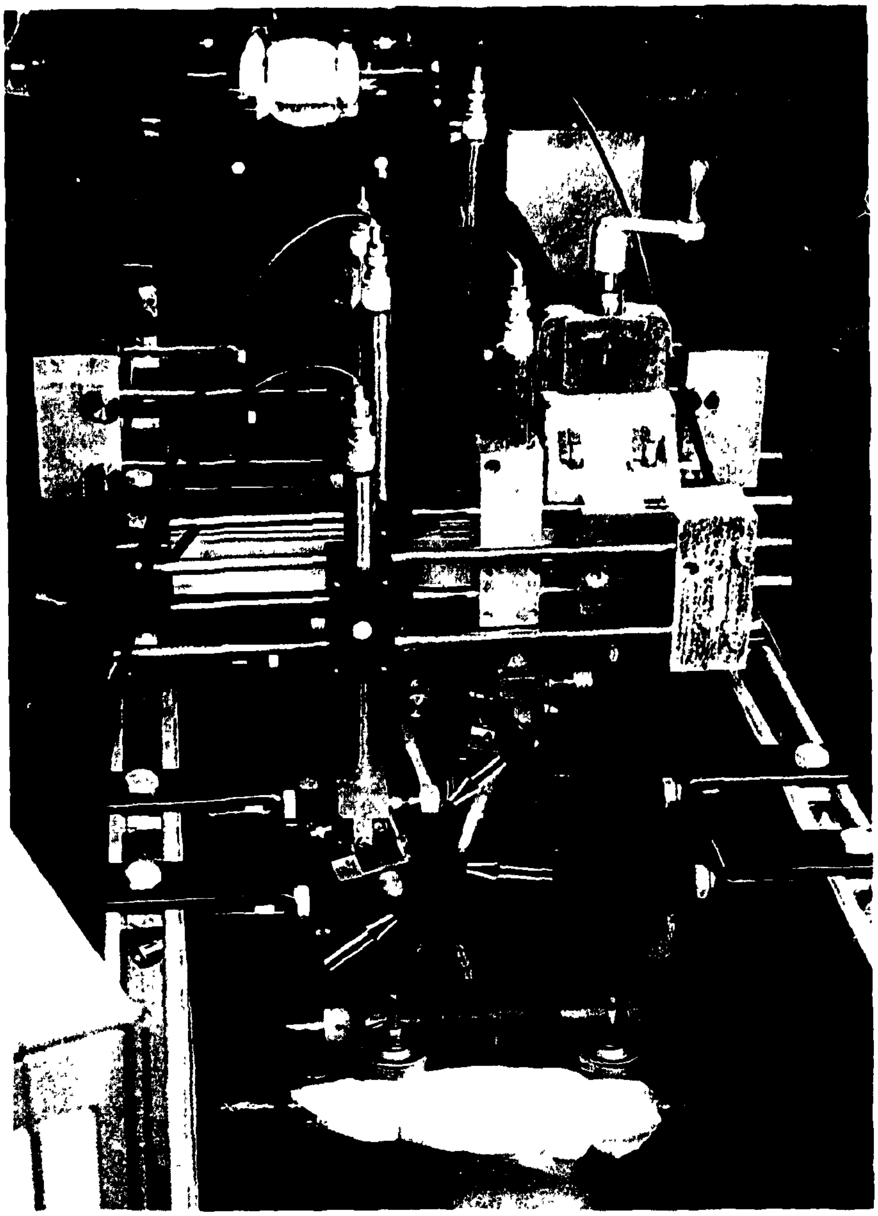

Fig. 10. Ultrasonic fixturing used to inspect strip for longitudinally oriented flaws. Arrows indicate search units.

as 3 mm (0.12 in.) to the edges. The long vertical round [19-mm-diam (0.75-in.)] tubes (on which the minimanipulators are mounted) are ultrasonic search tubes, and they provide the electrical contact (along with coaxial cables) between the flaw detectors and the search units. In

ORNL-PHOTO 1082-82

Fig. 11. Ultrasonic fixturing used to inspect strip for edge delaminations.

addition to the three search tubes used in the longitudinal flaw detection system (Fig. 10), note the two near the center of Fig. 11. These two search tubes provide the electrical connection, mechanical support, and stability for the search units used to test for laminar flaws or voids near the edges of the strip. Two search units [5 MHz, 13 mm (0.5 in.) in diameter] are used with minimanipulators to provide the test. Each search unit has its response confined with lead masks to a 3.18-mm-diam (0.125-in.) area for the laminar edge tests.

STRIP CLEANLINESS

Because it was extremely important that the JBK-75 strip be clean for Airco's welding operation, we used contacting materials that were considered to be safe by Airco and ORNL personnel. Contact materials that were used to maintain proper alignment included polyurethane guides, wood and nylon spooling and respooling fixtures, and steel skate wheels. A cleaning station (also mutually agreed to) was established at the coil takeoff end of the immersion tank. This cleaning station (described earlier and shown in Fig. 7) is located just above the roll of inter-leaving paper and consists of a series of gauze-wrapped rolls, an alcohol drip station, and cool-air blowers.

ELECTRONICS

Figure 4 includes electronic equipment used for the strip inspection. Two ultrasonic inspection instruments are on a portable table near the left end of the immersion tank. Two others are shown beside the portable table; however, they rest on the immersion tank near the left end. These four units are commercial flaw detectors. Unit 1 (the top or upper unit on the immersion tank) monitors the center portion of the strip for longitudinal flaws [i.e., a zone located 15.9 mm (0.6 in.) from one edge to 15.9 mm from the other edge]. A constant response over this large zone (strip width) is maintained with a built-in electronic distance-amplitude correction circuit. Unit 2 (located under unit 1) is a dual-channel instrument that monitors for longitudinal flaws near each edge of the strip (an overlap is maintained with the examination zone of unit 1). Units 3 and 4 (on the portable table, one sitting on the other) monitor for laminar flaws near the edge. All flaw detector units have audible alarms for monitoring flaw detection. These alarms were used (along with a visual observation of the flaw detector displays) by a certified ultrasonic inspector to determine the acceptability of the strip as compared with a reference calibration strip.

CALIBRATION PROCEDURES

Figure 12 is a sketch of the part of the calibration strip that contains electrodischarge-machined (EDM) notches and saw cuts for establishing calibration. This figure documents the number of notches, the notch locations, and the notch depths. Notches 3, 6, 7, 7A, 8, 9, and 9A were used to calibrate the center zone inspection for longitudinal flaws. The notches (either 3, 2, and 1 or 6, 5, and 4) located at 15.9,

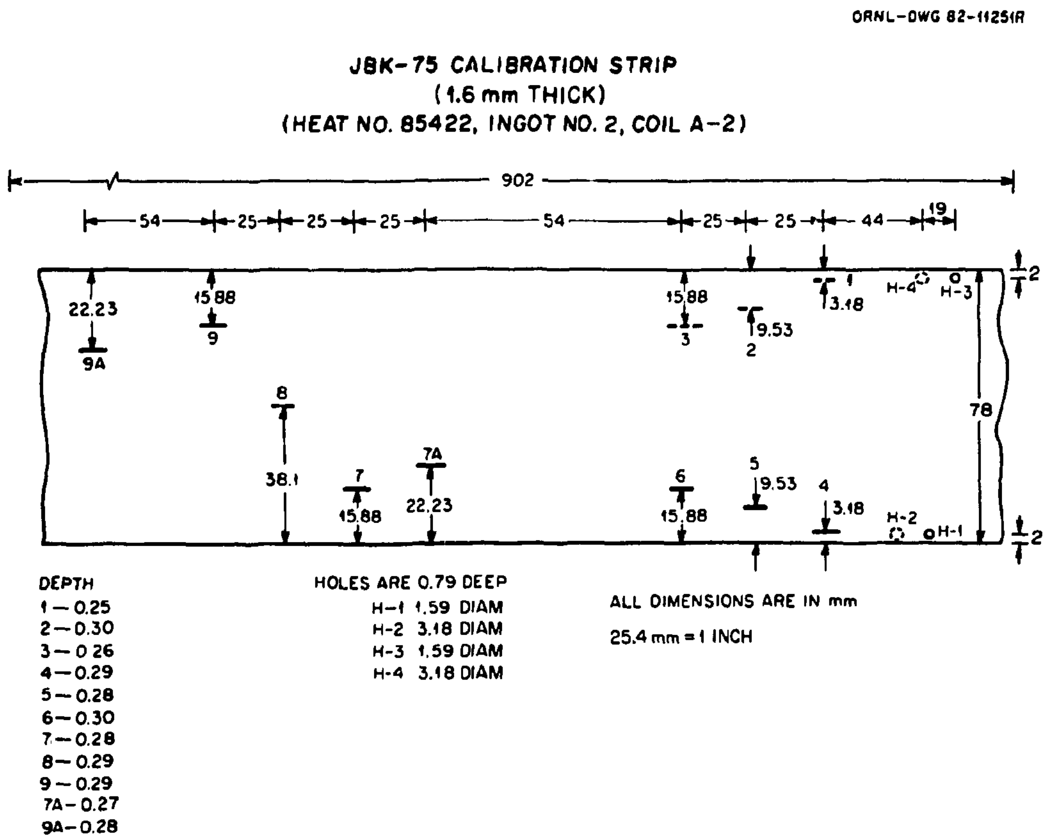

Fig. 12. Nominal locations of reference flaws in JBK-75 calibration strip.

9.53, and 3.2 mm (0.625, 0.375, and 0.125 in.) from the edge are used to calibrate each edge monitoring system for longitudinal edge flaws. Each is calibrated with notches on first the top surface and then the bottom surface (i.e., the calibration strips' top and bottom surfaces are switched for setup as needed). Notches 7A and 9A (Fig. 12) were also used in the edge tests to ensure overlap into the center zone. The primary references for the laminar edge flaws are the 1.59-mm-diam (1/16-in.) holes (one on each edge), although 3.18-mm-diam (1/8-in.) holes are also used (evident beside the primary calibrators in the figure) to aid in the initial adjustment. In addition to the primary 1.59-mm hole, a supplementary method for dynamically checking the detectability and sensitivity for laminar flaws was used. This supplementary calibration check used a 1.59-mm-diam by 1.09-mm-thick (1/16- by 0.043-in.) brass disk (cut from a rod) soldered to a 0.33-mm-diam by 51-mm-long (0.013- by 2-in.) stainless steel wire, which was in turn soldered to a brass handle [3.18-mm-diam (1/8-in.) rod]. The handle was then used to insert the disk into the sound path. Inserting the brass disk reflector into the through-transmission ultrasonic sound path at intervals provided the same response as the drilled hole and activated audible alarms to ensure that proper setup was being maintained.

INSPECTION RESULTS

We inspected 54 coils of JBK-75 strip material for longitudinal and laminar flaws. Four of the coils (the first received) were from a preproduction run of strip and were extremely useful for establishing the production test inspection details (both ultrasonic and mechanical). The ultrasonic inspection details were not altered for the 50 production coils that followed. In fact, the inspection for longitudinal flaws (the only inspection proposed initially by us) proceeded with a more sensitive calibration scheme than that originally proposed. Instead of the 0.38-mm-deep (0.015-in.) notch calibrators, we used 0.28-mm-deep (0.011-in.) notches.

The four preproduction coils were inspected in spite of some mechanical difficulty, which was not surprising for the initial use of the mechanical system. However, after adding hold-down and alignment devices to our original inspection station and by adding a brake to the idler coil, we were able to inspect the coils and establish an adequate mechanical handling system for the production coils. The inspections detected no discontinuities comparable in size to our calibration notches or holes. However, surface scratches were evident on the ends of each of the four coils. Thus, we recommended that the ends not be used to fabricate sheaths, and we understand that the first and last 6 m of the coil are normally not used in fabrication. Other problems noted on the first four coils concerned (1) local bends in the strip, which were again near the ends and affected the ultrasonic entry angle into the strip, and (2) the respooling operation, which produced looser coils than desirable. Although no discontinuities were found in the bend areas, we cannot be certain that none existed. A good respooling operation was developed and used for 90% of the 50 production coil tests (i.e., the first five coils were not respooled with the final system). The production coil inspection results were nearly identical to the preproduction coil results (i.e., no indications that compared to the reference notches or holes were detected in any of the 54 coils except at the ends). Results of the tests were documented through informal letter reports to Airco and are attached as Appendix B.

SUMMARY

Immersion ultrasonic flaw detection techniques were developed for the continuous detection of longitudinal and laminar flaws in long lengths of stainless steel strip. A mechanical system was designed and assembled for handling a roll of strip, feeding the strip through the ultrasonic inspection station in a carefully controlled manner, cleaning and drying the inspected strip, and interleaving with paper as the strip was rewound into a coil for reshipment. The inspection capability for detecting laminar flaws along the edge of the strip was in addition to the originally proposed detection of longitudinal flaws. Five ultrasonic transducers

and four ultrasonic instruments were used to perform five concurrent (independent but correlatable) examinations as the strip was fed through the multiple sets of rollers of the inspection system.

A total of 54 coils of strip material were inspected and shipped to Airco, along with informal letter reports that document the inspection r ts (Appendix B). Figure 13 shows five skids (5 coils per skid) af-er inspection and repackaging for shipment to Airco. The scheduled shipments originally planned were not rigidly followed because delays in other project tasks provided ORNL the flexibility to schedule the inspections and shipments for maximum efficiency and minimum cost. We

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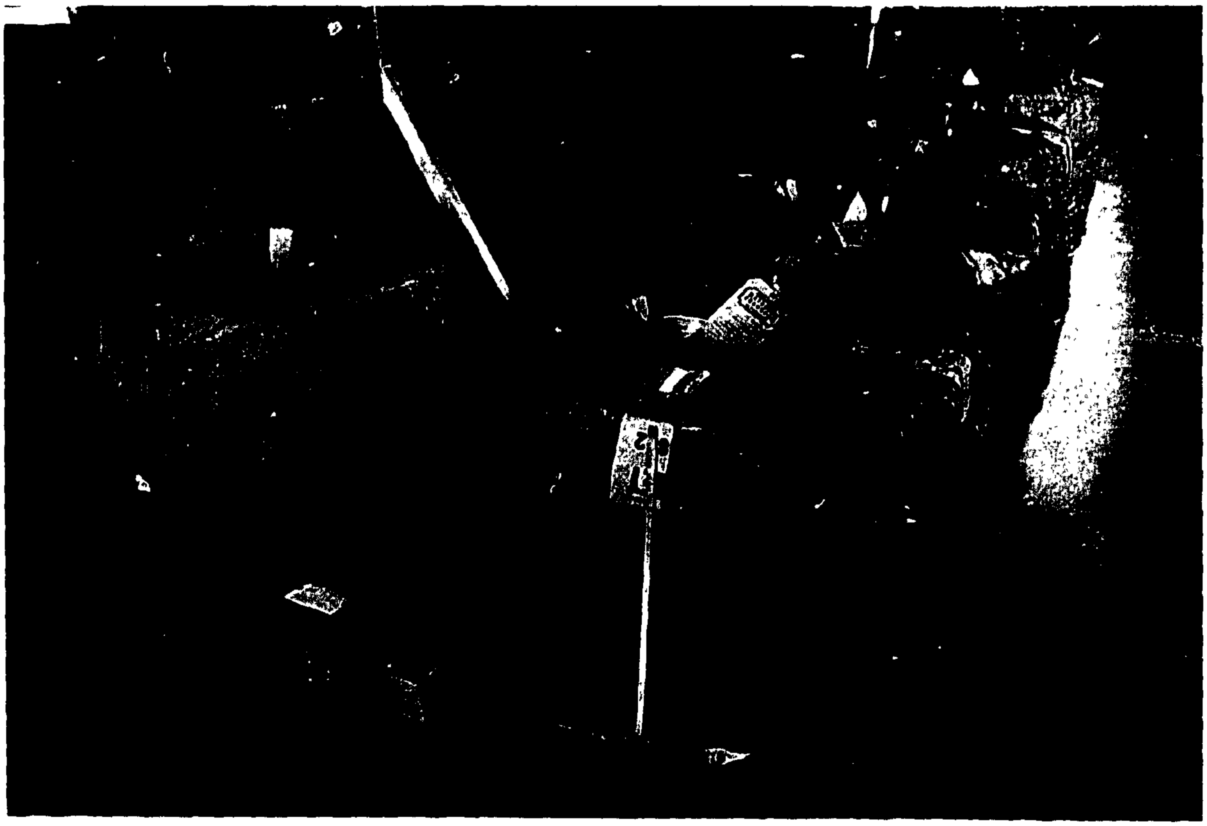

Fig. 13. Twenty-five coils of JBK-75 strip are packaged on the five skids or pallets shown. Five coils are on each pallet and are not visible because of the brown wrapping paper used along with a plastic undercoating to keep them clean.

shipped the final 30 coils (five of the six skids are shown in Fig. 13) on March 15, 1982, or about two weeks later than the original plan had predicted.

ACKNOWLEDGMENTS

The authors thank E. J. Walker, H. T. Murrin, A. J. Moorhead, V. T. Houchin, and W. A. Simpson, Jr., for major contributions on this project. The generosity, cooperation, and patience of D. R. Frizzell and W. O. Wilson, who loaned us the welding fixtures, are very much appreciated, as is the diligent editing by S. Peterson. We also are indebted to Julia Bishop and Denise Sammons for the preparation of this report.

REFERENCE

1. T. L. Mansfield, "Lamb Wave Inspection of Aluminum Sheet," *Mater. Eval.* **33**(4), 96–100 (April 1975).

Appendix A

RECOMMENDATIONS FOR INSPECTION OF AIRCO SUPERCONDUCTING MAGNET

Letter No. 0319-32-81

INTRA-LABORATORY CORRESPONDENCE

OAK RIDGE NATIONAL LABORATORY

March 19, 1981

To: A. J. Moorhead

From: R. W. McClung

Subject: Nondestructive Examination of JBK-75 Material for Westinghouse-Airco Superconducting Magnet

Your memo on the above subject requested my opinions on the examination being provided for JBK-75 material that is being fabricated into strip for sheathing of superconducting cable. I have reviewed the two Carpenter Technology ultrasonic procedures (R-UT-C-4 and S-UT-C-392) for examining bars or forgings. The latter will be used on the ~~4~~-6-in. billets in the rough ground condition. The procedure is intended to provide a screening of faulty material to minimize the possibility of putting expensive work into material destined for scrap. The qualitative comparisons of loss of back-reflection or amplitude of discontinuities as a function of the back-surface reflection assists in eliminating bars that may have large centerline bursts, inclusions, or other discontinuities. As such, it should serve as a useful process control for the manufacturer. However, it should not be used to infer the quality of the finished strip to be made from the bar. The extensive working to produce the strip could introduce objectionable discontinuities such as seams, laps, cracks, laminations, or other flaws. The generally accepted examination philosophy for critical materials (i.e., those for which failure could have expensive consequences of safety, cost, etc.) is to examine at the last reasonable stage of fabrication (including heat treatment) to assure that any objectionable condition that my be introduced has a good probability of detection.

To supplement my knowledge and opinions and in an attempt to avoid personal bias, I conducted a quick telephone survey of knowledgable colleagues around the country, including steel fabricators, an inspection equipment manufacturer, inspection standards specialists, and a military materials development laboratory. Other than obtaining confirmation of some of the commercial practices, no new technical information was gained. One of the most common nondestructive testing methods for sheet and strip is the angle-beam ultrasonic technique. Normally this is applied in the sheet condition before slitting into the strip. Use of the technique is reflected in paragraph 5.1.1(b) of the DOE RDT Standard F3-37T, Special Requirements for Metal Products. Admittedly not everyone performs the examination at the strip stage, since this is still an intermediate product form that undergoes further fabrication. So it is also common to wait until the final form is produced before conducting the examination. (Unless it seems economical to also examine the strip as a part of process control, or it is impossible or impractical to examine the final product. In the latter case there is a calculated risk that unknown flaws will be introduced at the last fabrication stage.) An example of performing the critical examination of the final product is in weld-drawn tubing produced from strip. Depending on the criticality of use, the finished tubing may receive extensive examination (e.g., ultrasonics, penetrant, eddy current, or other) to assure that no defects are present in the body of the tube.

A recommendation for the "best" examination technique to use on the sheath material is not a simple one to make because of the several factors that must be considered: applicability, access, cost, sensitivity, etc. Several options should be considered. For highest assurance of the finished quality (as noted earlier) it would be best performed on the finished square cross section. Although ultrasonic techniques may be applicable for the weld, I doubt that conventional ultrasonic techniques would be practical for the entire wall. In my opinion an eddy-current technique could be devised to perform the examination. Special steps (e.g., multifrequency) may be necessary to overcome potential signal/noise problems from the interior conductor. If, after investigation, the eddy-current option is impractical, the next earlier preferred stage would be in the round welded condition. Preliminary studies by QA&I showed the potential for an ultrasonic technique for the weld. Eddy currents remain a potential candidate for the weld. For the entire body of the tube, either ultrasonic or eddy currents can be considered. The inability to rotate the tube in the fabrication process places a restraint on conventional ultrasonic techniques for tubing. However, commercial scanning equipment is on the market (and in use) that rotates the ultrasonic transducer around the tube as it moves through the inspection station. Such devices are large and expensive. Encircling coil eddy currents at this stage may still be an option worthy of investigation for examination of the tube wall as it moves linearly through the fabrication (and the examination) sequence. As we move the examination earlier in the fabrication process (missing flaws that may be introduced by the fabrication) the next practical stage is the strip (or preslit sheet or double-wide strip). As noted earlier, angle-beam ultrasonic techniques are the most commonly applied. To my knowledge, eddy-current techniques have not been used but have development potential. Less desirable alternatives that may be considered are surface examination techniques such as visual examination, perhaps enhanced by the use of liquid penetrants. My description of "less desirable" is related to the cost of manpower and time and the limited detection capability.

I recognize that this memo has not provided the single desired answer of "the way to do it." However, as noted, there are numerous other factors that must be considered other than the technical application and capability of the nondestructive testing technique. If decisions are (or have been) delayed too long to allow implementation of the best NDT technique, the confidence in the quality of the product will be decreased.

I'll be pleased to discuss any of this further with you.

RWM:jlb

cc: K. V. Cook
C. V. Dodd
R. K. Kibbe
G. M. Slaughter
R. W. McClung/File

Appendix B

INSPECTION REPORTS ON JBK-75 STEEL STRIP

Letter No. 1030-19-81

OAK RIDGE NATIONAL LABORATORY
OPERATED BY
UNION CARBIDE CORPORATION
NUCLEAR DIVISION

POST OFFICE BOX X
OAK RIDGE, TENNESSEE 37830
October 30, 1981

Dr. Phil Sanger
Airco Superconductors
Airco, Inc.
600 Milik Street
Carteret, New Jersey 07008

Dear Mr. Sanger:

Inspection of 15 Production Rolls of JBK-75 Steel Strip

Results:

The inspection of 15 production strips (further identified via the attached xerox copy of the shipping tags) was performed in a similar manner to that for the four strips returned to you by L. D. Chitwood in early October 1981. As was the case for the first four preproduction strips, no discontinuities were detected that were comparable in size to our calibration notches or holes. However, surface scratches were evident on the ends of each strip. Thus, we recommend that about 4 m (12.3 ft) of the strip not be used in the coil fabrication. We understand that normally about 6 m (18.5 ft) of the strip is not used in the fabrication process, therefore, the surface scratches as well as local bend areas (noted in a few of the first strips) should not be a problem. In all cases noted to date, the scratches and bends are located within the 6-m areas on each end of the strips.

Technique:

Four commercial ultrasonic instruments (allowing inspection with five separate channels) were used to monitor the strip for flaws oriented longitudinally (along the length of the strip) and for flaws oriented in a laminar direction (parallel to the strip face). The longitudinal flaw detection system has three separate search units to monitor the width of the strip for flaws [except for about 3 mm (0.120 in.) not resolved on each edge]. The lamination flaw detection system incorporates two search

Dr. Phil Sanger
Page Two
October 30, 1981

units to monitor both edges for flaws. The sensitivity for longitudinal flaws is established with a series of simulated flaws (notches) that are 9.5 mm long (surface only) by 0.28 mm deep by 0.31 mm nominal width (0.375 by 0.011 by 0.012 in.). A total of seven calibration notches are used to calibrate the three test systems for longitudinal flaws. The seven calibration notches were fabricated with a special saw (because they were more easily and quickly fabricated) to provide a preliminary standard. After the evaluation of the first four rolls of strip, two supplementary electrodischarge-machined (EDM) notches were introduced that have dimensions of 6.35 mm long by 0.28 mm deep by 0.10 mm wide (0.250 by 0.011 by 0.004 in.). The response from the two supplementary EDM notches gave near identical ultrasonic response to the special saw cuts; therefore we conclude that a more expensive standard with all EDM notches is unnecessary. Thus, all the production strips will be inspected after calibrating on the saw-cut calibration standard, as was the case for these 15.

Calibration of the lamination flaw detection system was accomplished by using 3.0-mm (0.120-in.) and 1.5-mm-diam (0.060-in.) drilled holes approximately 70% through the 1.5-mm-thick strip. The air-filled holes are permanent calibrators and will also be used for future strip inspections for edge laminations. The sensitivity for delamination detection is based primarily on the 1.5-mm-diam hole response.

Sincerely yours,

K. V. Cook

K. V. Cook
Nondestructive Testing Group
Metals and Ceramics Division

KVC:jlb

Enclosure

cc/enc: R. K. Kibbe
R. W. McClung
A. J. Moorhead
G. M. Slaughter
K. V. Cook/File

Letter No. 1119-21-81

OAK RIDGE NATIONAL LABORATORY
OPERATED BY
UNION CARBIDE CORPORATION
NUCLEAR DIVISION

POST OFFICE BOX X
OAK RIDGE, TENNESSEE 37830

November 19, 1981

Dr. Phil Sanger
Airco Superconductors
Airco, Inc.
600 Milik Street
Carteret, New Jersey 07008

Dear Dr. Sanger:

The inspection of five production strips (further identified via the attached copy of the shipping tag) was performed in a similar manner to that for the previous strips. As has been the case for all previous strips, no discontinuities were detected that were comparable in size to our calibration notches or holes. However, surface scratches were again evident on the ends of each strip, and we suggest, as before, that the ends not be used for coil fabrication.

Sincerely yours,

K. V. Cook

K. V. Cook
Nondestructive Testing Group
Metals and Ceramics Division

KVC:jlb

Enclosure

cc/enc: R. K. Kibbe
R. W. McClung
A. J. Moorhead
G. M. Slaughter
K. V. Cook/File

P.S. These five coils were shipped from ORNL on November 2, 1981. Would you please inform me of the arrival date at Airco.

Letter No. 0323-06-82

OAK RIDGE NATIONAL LABORATORY
OPERATED BY
UNION CARBIDE CORPORATION
NUCLEAR DIVISION

POST OFFICE BOX X
OAK RIDGE, TENNESSEE 37830

March 23, 1982

Dr. Phillip Sanger
Airco Superconductors
Airco, Inc.
600 Milik Street
Carteret, New Jersey 07008

Dear Dr. Sanger:

The inspection of 30 production strips (further identified via the attached copies of the shipping documentation) was performed just like that for the previous strips (K. V. Cook to P. Sanger, November 19, 1981). As has been the case for all previous strips, no discontinuities were detected that were comparable in size to our calibration notches or holes. However, surface scratches, discolorations, and burrs were again evident on the ends of many of the strips. One data sheet (i.e., pallet No. 2 data) denotes areas of special interest (i.e., manufacturer's flags). We again suggest that the 0- to 6-m zones near the ends not be used for coil fabrication.

Sincerely yours,

K. V. Cook

K. V. Cook
Nondestructive Testing Group
Metals and Ceramics Division

KVC:jlb

Enclosure

cc/enc: P. B. Burn
R. K. Kibbe
R. W. McClung
A. J. Moorhead
G. M. Slaughter
K. V. Cook/File