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EDDY CURRENT NONDESTRUCTIVE TEST
TUBING CROSS-SECTION DISPLAY DEVICE

August 1969

AEC RESEARCH &
DEVELOPMENT REPORT

ROUTE TO	DATE	LOCATION	FILE NO. DATE

BNWL-1158

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BNWL-1158
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Printed in the United States of America
Available from
Clearinghouse for Federal Scientific and Technical Information
National Bureau of Standards, U.S. Department of Commerce
Springfield, Virginia 22151
Price: Printed Copy \$3.00; Microfiche \$0.65

EDDY CURRENT NONDESTRUCTIVE TUBING
CROSS-SECTION DISPLAY DEVICE

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ABSTRACT

Additional test results of an eddy current tubing cross-section display device described in an earlier report are given. The tubing cross-section display device gives a cathode ray tube presentation showing the approximate location of tubing flaws detected by the eddy current method. A multi-parameter eddy current tester is used to provide the needed variety and separation of signals, and the method of display is similar to that used in a radar system plan position indicator. Signals resulting from artificial flaws within the tube wall have now been displayed. A composite photograph of the display shows the relative location of outer wall, within the wall, and inner wall artificial flaws in 0.080 in. wall, 3-7/16 in. O.D. type 304 stainless tube. Display circuitry for handling six signal channels has been built.

DISCUSSION

The principles used are the same as previously reported and by whose application artificial flaws in the outer and inner walls of a section of tubing were displayed in their relative locations.⁽¹⁾ The technique has now been demonstrated to be capable of displaying artificial flaws located within the tubing wall. This was done by obtaining the information about the within-the-wall flaws from a third channel of the multiparameter eddy current tester. A block diagram of the circuit is shown in Figure 1.

The tube rotation position information is transferred to a cathode ray tube display in a way similar to that used in radar system plan position indicators.

Test object information is transferred to the display by unblanking the cathode ray beam by means of a multiplexed signal derived from the output of the multiparameter eddy current tester.

In the test described a section of tubing mounted in a metal lathe is rotated so that the surface of the tubing is effectively scanned by a tangent coil mounted in a quasi-fixed position in a lathe tool holder.

In principle the method is also applicable for the inspection of stationary tubing by using a rotating and translating test coil assembly. Rotating test coils are in use in the metals industry and the technique should be adaptable to the display method described here. The coupling of the rotating coil to the eddy current instrument presents some specialized problems. These have been solved in the industry by use of rotating transformers or by use of conducting slip rings.

BEAM DEFLECTION SHOWS TUBING POSITION

The section of tubing to be inspected is mounted in a lathe and rotated past a tangent test coil whose diameter is $\frac{1}{2}$ in. The lathe also mechanically drives the rotor of a resolver which furnishes tube rotation (angular position) information for the display.

Still referring to Figure 1, the resolver is driven by a 5 kHz electrical signal from an oscillator and provides ac signals related to shaft position to a phase detector. The phase detector provides tube rotation information to the modulator sweep generator. This modulator, in turn, provides beam deflection signals for the cathode ray tube display which cause the cathode ray beam to produce a radial motion at a 5 kHz rate and a slower rotary motion in synchronism with the tube rotation. The radial deflection direction is denoted by the arrow labeled *r* on the cathode ray tube pattern in Figure 1. The rotary motion is denoted by the arrow labeled *C* in the same diagram. The circuits are so designed that the direction of the radial deflection or sweep of the beam depends upon the angular position of the tubing being inspected. If the tubing is stationary the radial sweep direction remains constant, the beam being swept from its center position to its extreme position at the 5 kHz rate. When the tubing is rotated to a new angular position, the direction of the radial sweep of the beam changes accordingly. During constant rotation of the tubing at a 300 rpm rate, the beam makes 1000 radial sweeps per revolution of the tubing. Thus there are about 3 sweeps per degree rotation of the tube.

TEST OBJECT INFORMATION TRANSFERRED TO DISPLAY BY A BEAM UNBLANKING FUNCTION

The tangent test coil, mentioned above, is excited simultaneously with 70 kHz and 250 kHz sinusoidal currents by a multiparameter eddy current tester

shown in Figure 1. This eddy current tester is shown in more detail in block diagram Figure 2. Its operation and adjustment will be described later. For the present we will return to Figure 1 and assume that the eddy current tester has been adjusted so that outer surface tubing irregularities and inside wall irregularities produce signals on output channels p_1 , p_2 , and p_3 , respectively. These output signals are next applied to the amplitude-to-pulse position modulator. The function of this modulator is to produce a multiplexed signal containing the test object irregularity information which is used to unblank the cathode ray display beam. For example, the two circular base lines shown on the display in Figure 1 represent the outer and inner surface of the tubing. These are obtained by the unblanking of the beam at the appropriate times during each radial sweep.

MULTIPARAMETER EDDY CURRENT TESTER

This portion of the equipment, shown by the block diagram in Figure 2, consists of two main channels. One operates at 70 kHz and the other at 250 kHz. These function simultaneously and each has associated filters, amplifiers and two amplitude-phase detectors. The outputs of the phase detectors are combined in different proportions in the transformation circuit to separate the signals caused by the selected types of irregularities. Adjustments of the transformation circuits are made manually to give the desired separation of signals.

TEST RESULTS

The separation of signals caused by three types of artificial irregularities in a section of tubing is shown in Figure 3.

The test specimen used to obtain the display shown in Figure 3 is type 304 stainless steel tube 3-7/16 in. O.D. with 0.080 in. wall. It was faulted as shown with 1/8 in. diameter drill holes on the outer and inner walls, and with four 0.040 in. diameter drill holes drilled from the end of the tube providing simulated or artificial within-the-wall flaws. The multiparameter tester was operated with four parameter separating ability. The test coil was of the tangent type riding on the outer wall of the tube. The multiparameter tester was adjusted to discriminate against probe wobble signals, and to read signals for outer wall flaws, a hole midway between the walls, and inner wall flaws on channel outputs 1, 2 and 3, respectively. The sketch of the tubing showing the location of the various artificial irregularities and the photograph of the cathode ray tube display are shown with the same angular orientation. The display photograph was made as a composite picture because only a two channel multiplexing circuit was available at that time.

First a photographic exposure was made of the outer ring and inner ring showing information obtained from multiparameter output channels 1 and 3, respectively. Then the two display rings were superimposed with diameters adjusted to give a single ring midway between those of the previously exposed outer and inner rings. One of the superimposed rings was modulated (unblanked) with the multiparameter tester output signal from channel 2, and the other with the negative of this same signal. A second exposure was then made resulting in the composite photograph shown in Figure 3. Increased channel display capacity now built makes it possible to display up to 6 rings at a time eliminating the need of composite construction of this kind.

It should be pointed out that the use of two rings to make the central part of the display is not essential. It was done partly because the extra ring was available and because the resulting display more nearly appeared as a hole. No additional information is made available by superimposing the two rings to give the central display as the same modulation information is used in this case for both. However, additional information can be so presented as it becomes available from the multiparameter testers. Modulation (unblanking) due to signals on output channel 2 then resulted in the 4 loops seen on the central ring in Figure 1. The equipment was adjusted, as previously stated, to give maximum reading on channel 2 for the presence of a hole midway between the walls of the tube. This conditions is represented by the display at about 8:30 o'clock. Under the best adjustment some signal effects are noted on the inner and outer wall locations due to the within-the-wall flaws.

For example, a within-the-wall hole closer to the outer surface (at about 7:00 o'clock) results in an appreciable undesired signal on the outer surface ring, and some lesser undesired signal on the inner surface ring. At 10:00 o'clock a within-the-wall hole closer to the inner wall gives the largest indication on the inner wall ring. Thus, for these particular artificial flaws a qualitative estimate of their relative positions within the wall (depth) can be obtained by observing the relative strength of the indications on the three rings. Of course, this appears to reduce the advantage of the system to identify the presence of more than one flaw at a time, as for example, at 3:00 o'clock where we naturally expect to see indications on each ring because of the presence of the three flaws at one radial position. The within-the-wall flaws used are

quite large (diameter equal to one-half of the wall thickness) and the relatively large signals exceed the range in which the signals have sufficient linearity to be readily separable.

It should be emphasized that at the present stage of development of the technique the central ring is fixed in position by instrument adjustment, and the depth of the flaw does not reposition the ring arc element in accordance with depth. Rather, arcs of the central fixed rings are in effect deflected by the inner wall flaw signals to give the loop shown.

Although, as just described, the within-the-wall flaws do give interfering effects on the inner and outer display rings, the flaws used on the outer and inner walls of the tube do not give indication on the central ring. This is probably due to the fact that these flaws give smaller signals and thus more nearly meet the linearity requirements.

The uneven spacing between the central and outer rings in Figure 1 is caused by poor centering of the outer ring. This is easily corrected by adjustment of symmetry controls in the equipment.

ADDITIONAL CHANNELS FOR DISPLAY

A block diagram of the latest display system is shown in Figure 4. The functions are the same as in the original equipment but the circuits have been designed to use solid state components, and the number of display rings available have been increased from 2 to 6. The multiparameter tester being used still has 4 parameter separating capability. Thus, only four connecting circuits from the multiparameter tester to the cross section display are shown by solid lines. The two dotted lines shown connecting the multiparameter tester and the amplitude-to-phase position modulator indicate proposed feed

circuits from two additional channels yet to be added to the multiparameter tester.

The arrangement of circuits for obtaining the radial sweep deflection signals for the cathode ray tube includes a driver amplifier between the 5 kHz oscillator (multivibrator) and the resolver and the ring demodulators.

ACKNOWLEDGEMENT

The assistance of C. R. Wandling who developed the circuits and who performed the experimental phases of this work is acknowledged.

REFERENCE

1. H. L. Libby, "Broadband Electromagnetic Testing Methods. Part IV - Multiparameter Test Principles", BNWL-953, January 1, 1969.

FIGURE 1
Tubing Cross-Section Display Device

FIGURE 2
Multiparameter Eddy Current Nondestructive Test Device. 70 kHz and 250 kHz

FIGURE 3
Multiparameter Eddy Current Tester
Cross Section Display of Simulated Tubing Flaws

FIGURE 4
6-Channel Tube Cross Section Display Device
Block Diagram

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