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**A SEMIAUTOMATIC LVDT DISPLACEMENT
TRANSDUCER TESTING SYSTEM**

L. E. Bearden, Jr

MASTER

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OAK RIDGE Y-12 PLANT
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A SEMIAUTOMATIC LVDT DISPLACEMENT TRANSDUCER TESTING SYSTEM

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ABSTRACT

A semiautomatic system has been built to test the electrical and mechanical properties of linear variable differential transformer (LVDT) transducers. From these measurements, the transducer pretravel, overtravel, maximum percent nonlinearity, null voltage, and half-range output voltage are calculated and outputted in a report format. Displacement measurements are made with a laser interferometer; output/input voltage ratio measurements are made using an AC bridge circuit. The system accuracy is better than $\pm 0.02\%$ at a frequency of 5 kHz.

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SUMMARY

A fully manual system for testing the electrical and mechanical properties of linear variable differential transformer (LVDT) transducers was updated to a semiautomatic status. The new system consists of a minicomputer and an interface which control and/or take data from a programmable ratio transformer, a laser interferometer, and a digital-phase-angle voltmeter to make the measurements which are necessary to test an LVDT. Software was also written to provide the necessary program control and data analysis.

The system was tested using a "quasi-LVDT" which is comprised of a phase-reversal switch, a ratio transformer, and an isolation transformer. Results of this testing show that the system has a nonlinearity of 0.006% at 2.5 kHz, 0.02% at 5 kHz, and 0.08% at 10 kHz. The system is routinely used to certify LVDTs by the Physical and Electrical Standards Laboratory of the Oak Ridge Y-12 Plant.

INTRODUCTION

Linear variable differential transformer (LVDT) transducers are used extensively throughout the Oak Ridge Y-12 Plant^(a) for displacement measurements. These transducers have electrical and mechanical properties which must be tested before use. A fully manual testing system in a standards laboratory was updated to a semiautomatic status by the addition of a minicomputer, interface, and software to control the instruments which make the measurements necessary for LVDT testing. The system (Figure 1) is now operating as part of the transducer linearity certification program of the Physical and Electrical standards laboratory at the Y-12 Plant.

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Figure 1. LVDT TRANSDUCER TESTING SYSTEM.

(a) Operated by the Union Carbide Corporation's Nuclear Division for the US Atomic Energy Commission.

LVDT CERTIFICATION SYSTEM

HARDWARE

A block diagram of the semiautomatic testing system is presented in Figure 2. The oscillator, power amplifier, and LVDT settings and connections are performed by the operator. Appendix A contains the operating procedure. The computer interface (schematics and logic diagrams are provided in Appendix B) for the project performs four major functions, the first of which is to control the ratio transformer. This control is accomplished by energizing or deenergizing 25 relays in the ratio transformer. Twenty four of the relays are controlled by loading six binary-coded-decimal (BCD) digits into flip flops. These digits are the transfer ratio of the transformer. The 25th relay is used to set the phase shift introduced by the transformer. When this relay is deenergized, the phase shift is zero radian; when the relay is energized, the phase shift is π radians.

The second function of the computer interface is to make the displacement measurements necessary in the test procedure. This function is accomplished via digital outputs on the laser interferometer. The interferometer continually updates its position registers; and, after each update, a "ready" signal is generated. When the computer requests data, the interface monitors the "data ready" signal; when it is posted, the interface causes an interrupt. The computer acknowledges this interrupt, and nine BCD digits are transferred from the interferometer through the interface and into the computer memory.

Figure 2. PRINCIPAL COMPONENTS OF THE SEMIAUTOMATIC TESTING SYSTEM.

The third function of the interface is to control and read the digital-phase-angle voltmeter (PAV). Two measurement modes of the PAV are used in the test. These modes are selected by the interface by asserting voltage levels on the PAV control lines. The interface is also used to read the PAV. When the computer is ready for a PAV reading, a "data request" pulse is sent from the interface to the PAV which, in turn, makes the requested measurement and signals the interface when completed. The interface then interrupts the computer which acknowledges the interrupt, and 4 1/2 BCD digits are read from the PAV through the interface and into the computer's memory.

The final function of the computer interface is to monitor the "operator-signal" button to allow the operator to signal the computer when the LVDT is properly positioned for a data acquisition cycle. A two-position, push-button contact is enabled by the interface. When it is depressed, the interface then generates a computer interrupt.

SOFTWARE

To enable the computer to issue the proper control pulses and receive the desired data through the interface, software was written. A flow chart for the program is given in Appendix C. To collect the proper data, the following sequence is necessary: First, the PAV is set to "in phase" and the ratio transformer is set to "zero". The operator then searches for the null position of the LVDT. When this point is located, the signal button is pressed. The computer switches the PAV to "fundamental" and reads the null voltage. Next, the operator moves the stylus of the LVDT to its innermost position and takes a reading. The PAV is then set to "in phase", and the operator positions the LVDT to 16 points which encompass its specified linear range. At each point, the program switches the ratio transformer until the PAV reading is minimized. Both the ratio and position are stored for each point. The stylus is then fully extended, and the position is read. Pretravel and overtravel are calculated from the displacement measurements, and a straight line is fit through the 16 ratio/position doublets. Using the two lines shown in Figure 3, the nonlinearity for each point is calculated, based on the best-fit line and on the zero-intercept line. A table of the test data is then outputted, as given in Appendix D, which serves as the calibration record.

SYSTEM EVALUATION

The major error component in this system is the nonlinearity introduced by the transfer ratio measuring circuit. To determine this component, a quasi-LVDT was built. (b) (Figure 4 provides a diagram of this unit.) Using this quasi-LVDT, a set of 62 accurate voltage ratios were measured at three frequencies. To ensure accuracy, the quasi-LVDT was certified by the Y-12 Physical and Electrical Standards Laboratory using a precision ratio transformer which is traceable to the National Bureau of Standards. The 62 certified ratios were selected to encompass all values that the measuring circuit would encounter during operation. A linear least-squares curve fit of the measured ratio versus the actual ratio was

(b) Turner, P. C.; *A Phase-Sensitive LVDT Transducer Testing System*, Y-1936; Union Carbide Corporation - Nuclear Division, Oak Ridge Y-12 Plant, Oak Ridge, Tennessee; April 4, 1974.

Figure 3. NONLINEARITY OF A TYPICAL LVDT.

Figure 4. ELECTRICAL DIAGRAM OF THE QUASI-LVDT.

calculated for each run. Using a technique previously devised at Y-12^(b) and the fitting coefficients, the maximum nonlinearity of the system was found to be 0.006% at 2.5 kHz, 0.02% at 5 kHz, and 0.98% at 10 kHz. The increasing error seems to result from stray capacitances which increase as the frequency increases.

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APPENDIX A

SEMI-AUTOMATIC LVDT TESTING SYSTEM OPERATING PROCEDURE

1. If system is on and running, proceed to Step 3; if not, turn line corrector on. Turn PAV on, turn computer on, turn power amplifier on, turn interferometer on.
2. Depress the REM button on the PAV, set the switch registers to 0200, press LOAD ADD, and then START on the computer.
3. Depress the X-10 button on the interferometer, set the proper frequency on the oscillator. Type "G" followed by a carriage return on the Teletype. Input the proper frequency followed by a space on the Teletype.
4. Using the shorting plug provided, set up the proper input voltage on the power amplifier.
5. Plug in the LVDT which is to be tested.
6. Input the identifying information which is requested (follow each input by a space).
7. After the LVDT has been plugged in about one minute, move it until the PAV reading is minimized. Press the RESET button on the interferometer. Depress the OPERATOR SIGNAL button.
8. When the bell rings, move the stylus until it is fully extended and press the SIGNAL button.
9. When the bell rings, move the stylus to the 100% position and depress the SIGNAL button.
10. Repeat Step 9 for the 80%, 60%, 40%, 20%, 10%, 5%, 2%, -2%, -5%, -10%, -20%, -40%, -60%, -80%, and -100% positions.
11. After the -100% position is finished, move the stylus until it is fully retracted. Press the SIGNAL button.
12. Wait for the printout to terminate.

Figure B-3. SEMIAUTOMATIC LVDT TESTING SYSTEM. (Pushbutton and Interferometer)

Figure B-4. SEMIAUTOMATIC LVDT TESTING SYSTEM. (Phase Angle Voltmeter Interface)

APPENDIX C

SOFTWARE FLOW CHART

APPENDIX D

TYPICAL LVDT CERTIFICATION RESULTS OUTPUT

G

OSCILLATOR FREQUENCY =: 5000 BEGIN CALIBRATION

LVDT-: M27286

DATE : 5-: 21-: 74

SN-: 1021

RANGE=: .040 MILS

FREQUENCY= 5000 HZ

EXC VOLTS= 2.9810 VOLTS

NULL VOLTAGE= 0.117700E-02

PRETRAVEL = 0.841500E-02 HALF RANGE VOLTAGE= 0.187200E+00

OVER TRAVEL= 0.691590E-01

BEST FIT LINE

Y= 0.562856E+03*X+ 0.914397E+02

% RANGE	OUTPUT	% LIN.	% LIN. (BEST FIT)
100	56281	-0.423344E-02	-0.854681E-01
80	45204	0.130189E+00	0.489601E-01
60	33999	0.197729E+00	0.116501E+00
40	22726	0.187625E+00	0.106396E+00
20	11409	0.108055E+00	0.268266E-01
10	5722	0.982548E-01	0.170263E-01
5	2884	0.593084E-01	-0.219200E-01
2	1194	0.660819E-01	-0.151465E-01
- 2	- 1111	0.305701E-01	-0.506583E-01
- 5	- 2767	0.190856E-01	-0.621428E-01
- 10	- 5613	0.359209E-01	-0.453075E-01
- 20	- 11225	0.254336E-01	-0.557948E-01
- 40	- 22527	0.450063E-02	-0.767278E-01
- 60	- 33775	0.187867E-01	-0.624417E-01
- 80	- 44933	0.810807E-01	-0.147707E-03
- 100	- 44997	0.241306E+00	0.160077E+00

MAX NON LINEARITY= 0.241306E+00 % (ZERO INTERCEPT)

MAX NON LINEARITY= 0.160077E+00 % (BEST FIT)

INTERCEPT= 0.812284E-01%

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