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Instruments

MASTER

INSTRUMENTATION FOR DYNAMIC MEASUREMENTS
OF RESISTANCE WELDING CURRENT AND
ELECTRODE FORCE

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UNION CARBIDE CORPORATION
NUCLEAR DIVISION
OAK RIDGE Y-12 PLANT

operated for the ATOMIC ENERGY COMMISSION under U. S. GOVERNMENT Contract W-7405 eng 26

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ABSTRACT

Instrumentation has been designed that can dynamically determine the current and electrode-force changes during a resistance welding cycle. Since the information obtained can be recorded and studied, resistance welds can be more accurately reproduced.

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SUMMARY

Instrumentation has been designed by personnel at the Oak Ridge Y-12 Plant that can dynamically determine and record the welding current and electrode force for a resistance welding cycle. Strain gages were applied to an aluminum rod located under the electrode arm of the welder. The strain measurements obtained when force was applied to the electrode arm were calibrated in terms of the welding electrode force.

A toroidal current meter was used to determine the welding current and it, together with the strain indicator, was connected to separate channels of an oscilloscope.

The information obtained by the use of these instruments can be recorded, studied, and analyzed, thus facilitating an accurate reproduction of any weld.

INTRODUCTION

In recent years the Welding Laboratory Group of the Y-12 Metallurgical Development Department has been concerned with upgrading and improving their resistance welding program. As a part of this work, instrumentation has been prepared which could dynamically determine the welding current and electrode force during a welding cycle.

This report presents details concerning the way the instrumentation was wired, calibrated, and operated. Also, an analysis of the information that was obtained is included.

This information is presented, primarily, to serve as a possible guide for setting up and operating this or similar equipment.

OPERATION AND USE OF THE INSTRUMENTATION

PRINCIPAL COMPONENTS

The instrumentation, shown in Figure 1, consists of the following components:

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Figure 1. INSTRUMENTATION USED TO DYNAMICALLY DETERMINE CURRENT AND ELECTRODE FORCE IN RESISTANCE WELDING.

1. An aluminum rod which is fabricated to fit under the lower electrode arm of the resistance welder and to which strain gages were applied.

2. A strain indicator^(a) used to determine how much strain was transmitted to the gages when pressure was applied to the electrode arm.
3. A current meter^(b) to determine the amperage through the electrodes during the welding cycle.
4. An oscilloscope^(c) to display and record the information.

DESCRIPTION OF THE EQUIPMENT^(d)

Strain Gage Rod and Indicator

General - A 3/8-inch aluminum rod, fabricated per drawings C-M-32374 and C-M-32375 (Figures A-1 and A-2, Appendix A), was attached under the lower electrode arm and also to the base of the Sciaky welder^(e), as shown in Figure 2. Care should be taken to insulate this aluminum rod to prevent current from shunting through it during welding. When current passes through the rod, a voltage is induced in the strain gage causing an erratic reading. This effect will be shown and discussed in the section on "Curve Interpretation". To prevent the erratic readings, the clevis pin holding one end of the rod was wrapped with fiber glass tape. A 120-ohm full-bridge-transducer strain-gage hookup was applied to the upper rod, as shown in Figure 3.

Hookup - After the strain gage rod had been installed to the welder, the bridge circuit was connected to the strain indicator according to the following procedure (also refer to Figure 4⁽¹⁾):

1. Open the jumper connection between the two binding posts and Terminal R.
2. Connect the power input (excitation) terminals (Wires 5 and 7) to Binding Posts B and G.
3. Connect one bridge output (signal) terminal (Wire 6) to Binding Post W.
4. Connect the other output terminal (Wire 8) to Binding Post R.

-
- (a) Model 100P, Manufactured by BLH Electronics, Baldwin-Lima-Hamilton Corporation, Waltham, Massachusetts.
 - (b) Model 270D, Manufactured by Duffers Associates, Inc, Troy, New York.
 - (c) Type 564 Oscilloscope with a Type 3B3 Plug-In Unit and Type 3A1 Dual-Trace Amplifier and Oscilloscope Camera, Model C-27. Manufactured by Tektronix, Inc, Beaverton, Oregon.
 - (d) The wiring diagrams and explanations describe wiring color schemes and numbering codes which are characteristic of this specific application only and may be arbitrary in other similar setups.
 - (e) Manufactured by Sciaky Brothers, Inc, Chicago, Illinois.

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Figure 2. ALUMINUM STRAIN GAGE ROD IN POSITION UNDER THE WELDER ELECTRODE ARM.

To connect the strain indicator box to the oscilloscope, simply make the proper connections between the scope jack plug and the oscilloscope: (1) connect the sleeve side of the plug (gray wire) to the sleeve side of the connecting wire (red wire); and (2) connect the lead wires (white and black wires) together and then connect these wires to the oscilloscope through Channel 2. The general wiring diagram is shown in Figure A-3, Appendix A.

Figure 3. STRAIN GAGE WIRING.

Figure 4. HOOKUP FOR THE STRAIN INDICATOR.

Operation of the Strain Indicator - Instructions for operating the strain indicator are found in Appendix B.

Calibration of the Strain Rod - To use the strain gage rod to determine electrode force changes, the strain gages must be calibrated and the following steps taken:

1. Make sure the rod is clamped tight and secured to prevent any slippage; then tighten the turnbuckle of the rod attachment so that the rod will always remain in tension. It is very important that the rod be kept in tension. If any slack occurs or if the rod goes from tension to compression during the weld cycle, erroneous strain-gage readings will occur.
2. Test the tension and slippage of the rod by applying pressure to the electrodes several times. The meter pointer should return to the initial reading each time if the rod is tight enough. If it does not return to that reading, check for slippage. If there is none, then increase the tension in the rod.
3. Place a force gage between the electrodes to measure the force applied. Take several readings of strain and force while varying the electrode force over as wide a range as possible.
4. Plot the values of the electrode force and strain, as shown in Figure 5.

If the rod is in enough tension and there is no slipping, the points will plot a straight line. The slope of this line gives the relation between the pressure applied and the strain in the gages. For the curve shown in Figure 5, the relation is: 1 microinch per inch strain equals 2.2 pounds of electrode force. The slope of this line should never change. However, due to thermal changes in the rod or battery drift in the strain indicator, the curve may move parallel to the original, but it should always maintain the same slope.

In similar setups to the one described, the strain-gage bridge will have a characteristic curve similar to the one in Figure 5, but it may or may not have the same slope. Thus, even though the same strain-gage hookup may be used, as shown in Figure 3, the rod must be calibrated individually.

With a strain relationship of $\mu\text{in/in}=2.2 \text{ lbs}$ and oscilloscope setting of 0.02 volts/div, a one-centimeter-oscilloscope screen division would equal 250 pounds. This value was determined empirically.

Current Meter⁽²⁾

Hookup - The toroidal pickup should be connected to the input jack at the right rear of the meter case. The hookup sequence of the meter to the oscilloscope is as follows:

1. Connect a lead from Channel 1 to Output Connection 5, which is the AC signal proportional to the current signal connection, located at the right rear of the meter case.

Figure 5. CALIBRATION CURVE FOR THE STRAIN GAGE ROD.

2. Connect a second lead from the ground connection of the time base unit (connection below EXT TRIG connection in lower-right-hand corner of unit, Figure 6) to a pin that "jumps" both Output Connections 1 and 11 (which are the common and case ground connections, respectively).

The general wiring diagram is shown in Figure A-3, Appendix A.

Operation - Instructions for operating the portable current meter are contained in Appendix B.

Calibration - The calibration factors are presented in Table 1. These are for an oscilloscope setting of 0.2 volt/div.

Table 1
OSCILLOSCOPE CALIBRATION FACTORS
FOR USE WITH DUFFERS CURRENT METER

Current Meter Range Scale (ac peak kiloamperes)	Amps per 1-Cm-Oscilloscope Screen Division (0.2 volts/div.)
1	320
2.5	800
5	1,600
10	3,200
25	8,000
50	16,000
100	32,000

Oscilloscope Operation (3, 4, 5)

The oscilloscope control settings are shown in Figure 6. Some of the settings are as follows:

Amplifier Unit

CH 1:

AC-DC-GND Switch	DC
VOLTS/DIV Switch	0.2

CH 2:

AC-DC-GND Switch	DC
VOLTS/DIV Switch	0.02

MODE

CHOP

Type 3B3 Time-Base Unit

MODE

NORM

TIME/DIV

0.5 sec

NORMAL or DELAYING
SWEEP TRIGGERING:

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Figure 6. SETTINGS OF THE OSCILLOSCOPE CONTROLS FOR RECORDING CURRENT AND ELECTRODE FORCE TRACE.

SLOPE	NEGATIVE
COUPLING	AUTO
NORMAL-SINGLE	
SWEEP-RESET	SINGLE-SWEEP

To take a reading:

1. Erase both screens and place the oscilloscope in the STORE position.
2. Make sure that both sweeps are positioned well and that the beams are focused with moderately bright intensity.
3. With the oscilloscope instrument controls set as just outlined, a push of the NORM-SINGLE SWEEP-RESET switch to RESET will trigger the sweeps. The weld cycle should be initiated at the same time in order to capture the whole cycle trace on the screen.

CURVE INTERPRETATION

Figure 7 shows one of the curves traced with the use of the instruments connected as explained previously. The top curve shows the current impulses applied during the weld cycle. In this particular case, there were 12 impulses of approximately 13,000 amperes each. The bottom curve shows the pressure cycle which consists of four main parts. The first portion shows the force buildup to a precompression force of 500 pounds. The weld cycle is then initiated and, with the machine set for variable pressure, the electrode force drops off to a welding force of 250 pounds. The forge delay time, which is the elapsed time before the forging force is applied, begins after the last current impulse. The fourth and last portion of the curve shows the forging force. Figure 8 shows curves made using welding conditions similar to those used for Figure 7. In this case, however, the clevis pin was not insulated as described on Page 8 of this report. The result is a distorted pressure trace due to the voltage induced into the strain gage.

The width of the pressure trace is noticeably wider than that of the amperage trace in each photograph. This condition is due to the pickup of the exciting voltage of the strain indicator which has a built in oscillator that produces a 1,800 cy/sec current. Figure 9 shows a portion of a pressure trace at an oscilloscope sweep rate of 0.1 millisecond/centimeter. At the slow sweep rate used during a weld, this frequency would show up as a wide line.

Figures 10 through 13 show several curves with variations in some of the welding parameters.

Figure 7. CURRENT AND FORCE TRACE.

Figure 8. CURRENT AND FORCE TRACE SHOWING THE EFFECT OF CURRENT SHUNTING THROUGH THE STRAIN ROD.

Figure 9. OSCILLOSCOPE TRACE OF A PORTION OF THE PRESSURE CYCLE AT A SWEEP RATE OF 1.0 MILLISECOND/CENTIMETER SHOWING THE STRAIN GAGE EXCITATION VOLTAGE AT 1,800 CYCLES/SECOND. (Y-Axis: 1 cm = 0.02 Volt)

Scale: Applies to All Figures (7 through 13),
Except Figure 9.

X Axis: 1 cm = 0.5 seconds.

Y Axis: Current Trace (upper) -
1 cm = 0.2 volt = 8,000 amperes

Force Trace (lower) -
1 cm = 0.02 volt = 250 pounds

Figure 10. WELD AT CONSTANT FORCE. (5 Impulses, 15,000 Amps)

Figure 11. WELD WITH NO FORGE DELAY TIME. (6 Impulses, 12,500 Amps)

Figure 12. WELD WITH LONG CURRENT DECAY TIME. (5 Impulses, 10,000 Amps)

Figure 13. WELD WITH LONG FORGE DELAY TIME. (6 Impulses, 12,500 Amps)

CONCLUSIONS

The curves and information obtained from the instrumentation can aid in many ways, namely:

1. The information obtained permits the weld setting to be recorded and reproduced accurately. Also, the information can be used to reproduce the weld on different welders.
2. It can be easily determined if both the electrode force and current cycles are in phase and if both phases are functioning properly throughout the cycle.
3. Both the electrode force and weld current can be set at the exact values desired.
4. The dynamic happenings, which occur during each welding cycle, can be studied, and the effects of changes in welding parameters can be determined.

REFERENCES

- (1) Instruction Manual, Model 100P Strain Indicator, Section 2.8; BLH Electronics; Baldwin-Lima-Hamilton Corporation, Waltham, Massachusetts.
- (2) General Maintenance Manual, Model 270 Series Current Meters and Accessories, pp 2-4; Duffers Associates, Inc, Troy, New York.
- (3) Instruction Manual, Type 564 Oscilloscope, pp 2-1 through 2-12; Tektronix, Inc, Beaverton, Oregon (1963).
- (4) Instruction Manual, Type 3B3 Plug-In Unit, pp 2-1 through 2-5; Tektronix, Inc, Beaverton, Oregon (1963).
- (5) Instruction Manual, Type 3A1 Dual-Trace Amplifier, pp 2-1 through 2-3; Tektronix, Inc, Beaverton, Oregon (1963).

APPENDIX A

STRAIN GAGE ATTACHMENT DRAWINGS AND WIRING DIAGRAM

Figure A-1. ALUMINUM STRAIN GAGE ROD. (Drawing C-M-32374)

APPENDIX B

OPERATION OF THE BLH SR-4 STRAIN INDICATOR, MODEL 100P

Preliminary Adjustments

1. Check batteries prior to using by pushing the CHECK button in the lower right-hand corner of the panel. If the meter pointer shows beyond the red line, the batteries are satisfactory. If the pointer does not show, replace the batteries. Repeat the check hourly if the indicator is used continuously. To conserve batteries, always turn the power off when not taking readings.
2. Push the ON button located above the CHECK button on the panel.
3. Set the gage factor dial in the upper right corner to exactly the value required by the gages or the external bridge circuit, and make a record of this setting. In order to be able to reproduce strain readings at some later date, it is essential that the gage factor dial be set precisely at the same value as before. (For the circuit described in the text, the gage factor is 2.06).

Strain Measurements

The strain in the rod is the difference between the initial and the final instrument readings made up of the dial reading as well as the RANGE switch reading.

The initial reading is obtained as follows (before applying strain):

1. Push the 0 (zero) button located on the left side of the panel.
2. Rotate the balancing dial in the direction that will bring the meter pointer to zero. If the meter pointer cannot be brought to zero, leave the balancing dial at the end to which it has been turned (set exactly at 0 or 2000).
3. Rotate the THOUSANDS switch (left side of panel) until the meter pointer kicks across the scale and stops.
4. Rotate the balancing dial to bring the meter pointer to zero.
5. Record the dial and switch readings.

Final reading is obtained as follows (after applying strain):

1. Repeat steps 2 - 5 for the initial reading.

2. Record all dial and switch readings with the meter pointer at zero and strain applied.

Computation of strain is accomplished as shown in the following example:

Initial Reading: Thousands Switch - 10

Dial Reading - 890

Total Reading - 10,890

Final Reading: Thousands Switch - 8

Dial Reading - 1,350

Total Reading - 9,350

Strain: $10,890 - 9,350 = 1540 \mu \text{ in/in.}$

OPERATION OF THE DUFFERS MODEL 270D CURRENT METER

The procedure for operating the current meter consists of the following steps:

1. Place the power switch in the ON position. Allow one minute for the circuits to stabilize.
2. Set the RANGE switch located to the right of the meter to a value corresponding to the maximum expected current. Since the accuracy of the instrument is ± 3 percent of full scale, the most accurate readings will be obtained when a range is selected which provides the maximum practical upscale reading. For example, a better accuracy results from using the 10-kiloampere scale to read a current of 9 kiloamperes than from using the 25-kiloampere scale to read the same current.
3. Place the BLANK switch in the OUT position. Place the METER switch in the PEAK position. The meter switch allows the user to select either the positive (+) half cycle or the negative (-) half cycle, or both.
4. Depress the RESET button to the left momentarily to reset the meter.
5. Place toroid around the electrical conductor.
6. Initiate the pulse and read the current on the meter.
7. Reset the meter to zero by depressing the RESET button to the left.