ELECTRICAL SERVICE MANUAL
FOR THE

**Linde**
Trade-Mark

**FSM-1**
(SERIES 3)

MACHINE FOR
SIGMA WELDING

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**ELECTRICAL MANUAL**

**FSM-1**
(SERIES 3)

**FORM 9260-A**

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Be Sure this Booklet Reaches the Operator. You Can Get Extra Copies Through Any LINDE Office.
I. GENERAL DESCRIPTION OF THE FSM-1 CONTROL

A. Operating Features

   The FSM-1 Sigma Welding Control Unit provides a wide range, highly flexible, rod feed control for arc welding processes such as sigma welding. This unit has the following features:

1. The unit is semi-automatic and is easy to use.

2. The welding arc can be started manually, or by automatic rod retraction.

3. The rate of rod feed can be controlled by manual adjustment or automatically by the arc voltage to maintain a constant arc length. For further information refer to the supplement in the appendix.

4. Under proper operating conditions it will maintain the arc voltage to within ±0.1 volt.

5. The electrical system is completely interlocked so that the equipment will not be damaged by improper operation of the controls.

6. The electrical equipment is adequately protected by means of fuses and overload relays.

7. With a few unavoidable exceptions, all parts are standard and are readily available, thus simplifying service problems.

B. Equipment Components

   The FSM-1 Sigma Welding Control is made up of a number of units:

1. Main Control Box

   The main control box which contains all of the electronic equipment, the motor field supply, and the protective equipment. It supplies the necessary power to all of the other units. (See Figure 30 in Form 9136.)

2. Auxiliary Control Box

   The auxiliary control box contains the relays that control the sequence of events, the arc voltage voltmeter, the arc current ammeter, the carriage speed indicator, the rod feed motor braking resistor, and the governor contact resistor and condenser for the oscillating motor. It also contains the parts for the automatic rod-retract circuit. This unit is usually mounted on an OM-48 or CM-37 Carriage. (See Figure 24 in Form 9136.)

3. Operating Control Hand Box (Hand Box No. 1)

   This hand box contains the controls necessary for operation of the machine and includes the ready switch, the feed and retract push-buttons, and the potentiometer for adjusting the arc voltage when operating with automatic arc voltage control. This unit can be mounted in a clip on the side of the auxiliary box or the operator can place it wherever it is most convenient. (See Figure 26 in Form 9136.)
4. Constant Speed Control Hand Box (Hand Box No. 2)

This hand box contains the potentiometer for adjustment of rod feed when operating with manual control of the rate of rod feed. This hand box need not be plugged into the circuit except when the machine is to be operated with manual control. (See Figure 27 in Form 9136.)

5. Welding Generator Control Box

The welding generator control box contains the current relay, the welding contactor auxiliary relay and the ammeter shunt. (See Figure 34 in Form 9136.)

6. Junction Boxes

Junction boxes are provided to supply power to the water and gas solenoid valves and to the rod feed motor. (See 25 and 26 in Form 9136.)

7. Drive Head

A revised UNIONMELT drive head is used to feed the welding rod at a controlled rate of speed.

8. Welding Current Contactor

This contactor is used to provide the automatic on-off control of welding current. It is not supplied as part of the FSM-1 but must be purchased separately.

C. Theory of Operation

1. Basic Theory

The FSM-1 Control can be used as the so-called "arc voltage control type" wherein the rate of rod feed is automatically adjusted so as to maintain a constant arc voltage. The control also permits the rate of rod feed to be kept constant and regulated manually during machine operation.

The following explanation covers operation of the control circuit when set for automatic arc voltage control (switch SW-4 on the main control box set in "Aut" position, and the "ready weld" switch on the operating control hand box turned to "On"). Refer to block diagram E-6300 at the rear of this booklet for clarification.

a. The rate of feed is determined by the speed of the rod feed motor.

b. The speed of the rod feed motor is controlled by the speed control circuit.

c. The speed control circuit is responsive to the combined outputs of:

(1) A base speed selector, which is set by the operator to give approximately the correct rod feed motor speed necessary to maintain the desired arc voltage.

(2) An error voltage which is proportional to the difference between the desired arc voltage and the actual arc voltage at any instant.
d. The effect of these two voltages on the speed control circuit causes the rod feed motor to feed the rod at a speed which maintains the desired arc voltage.

e. The error voltage is obtained in the following manner:

(1) The operator adjusts the arc voltage selector to deliver a voltage approximately equal to the desired arc voltage. This voltage will hereafter be referred to as the reference voltage.

(2) The reference voltage is fed into a circuit which compares it with the arc voltage. This circuit will be referred to as the comparing circuit.

(3) If the arc voltage does not equal the reference voltage the comparing circuit feeds an error voltage proportional to the difference between these two voltages, to an amplifier.

(4) The amplifier amplifies the error voltage and feeds it into the speed control circuit.

f. As previously explained, the speed control circuit is responsive to the combined outputs of the base speed selector and the amplified error voltage. The base speed selector supplies a rough setting of the rod speed and the amplified error voltage serves as a vernier adjustment to bring the rod speed to the exact speed required to maintain the voltage.

2. Theory Based on Simplified Schematic Diagram

The next logical step in this explanation is to go from the block diagram to a simplified schematic diagram of the circuit. Drawing E-6299 shows a simplified schematic diagram which contains the parts necessary to explain the operation of the circuit. The various components shown on this drawing bear the same identifying symbols as the corresponding parts shown on the complete schematic Drawing No. A-264034 (for FSM-1 with CM-48 carriage) or A-262441 (for FSM-1 with CM-37 carriage) at the rear of this booklet.

a. A direct current voltage is supplied to the arc voltage selector potentiometer, Pot 1. This is adjusted to deliver a reference voltage roughly equal to the desired arc voltage.

b. The arc voltage appears across resistor R1. The arc voltage and the reference voltage are connected in series bucking and the difference between these voltages appears across the comparing circuit consisting of C2, R4 as the error voltage. This error voltage is amplified by the 6SF5 tube and the amplified voltage appears across C3, R6. The current through R6 is indicated by the operating range meter, M2.

c. The base speed selector potentiometer, Pot 2, is in series with R6 across a source of d.c. voltage indicated as B+ , B- in the sketch. Any desired fraction of the voltage across B+ , B- can be selected by means of the Pot 2 for use as the basic speed voltage.

d. Potentiometer, Pot 4, supplies an adjustable d.c. bias voltage to the grid of the thyatron tube, C3J.
e. A phase shifted a.c. voltage which lags the a.c. plate voltage of the C3J by 90 deg. is placed in the grid circuit of the C3J tube.

f. When the armature of the direct-current shunt motor, used for the rod feed, is rotated, it develops a counter emf proportional to its speed. This voltage appears across Pot 6. A part of this voltage, selected by means of the slide on Pot 6 is fed back into the grid circuit of the C3J tube.

g. From the above, it is evident that the grid circuit of the C3J has the following voltages impressed upon it.

(1) The amplified error voltage appearing across R6.

(2) The base speed selector voltage appearing across Pot 2.

(3) The d.c. bias voltage appearing across Pot 4.

(4) An a.c. phase shift voltage lagging the plate voltage by 90 degrees.

(5) A feed back voltage proportional to the armature speed of the rod feed motor.

The net effect of the above voltages is such that the rod feed motor armature rotates at a speed at which the feed back voltage approximately equals the sum of the amplified differential voltage plus the base speed voltage.

3. Theory Based on Complete Circuit

Drawing No. A-264034 (or A-262441) shows a complete schematic of the control. This schematic is essentially the same as the simplified schematic circuit No. E-6299 with the addition of circuit refinements and switch gear, relays, etc. required to obtain automatic operation. These schematic diagrams, and the wiring diagrams discussed below, are shown with the control connected for reverse polarity welding.

For ease of servicing, the components are covered by a three-way cross reference:

a. Drawing No. 2A-264035 (or 2A-262442) shows a complete wiring diagram of the unit together with all cables, plugs, terminal strips, etc. and it also shows in which unit the various parts are located.

b. Form 9136 gives a listing and the description and location of parts.

c. Form 9136 contains a set of photographs showing the various assemblies and sub-assemblies with the individual parts identified.

D. Circuit Functions

The following is a more detailed description of the function of the various parts of the completed circuit, shown on the drawings listed above.
1. Reference Voltage

Rectifier SR1 rectifies the a.c. output voltage of transformer TR5. The d.c. output of SR1 is filtered by means of condenser C1 and is fed to the voltage regulator system consisting of R2, R3 and voltage regulator tube OA3-VR75. The voltage regulator system serves to supply to the arc voltage selector potentiometer, Pot 1, a constant voltage of approximately 50 volts regardless of line voltage variations and transients.

2. Arc Voltage

The arc voltage is fed to resistor R1 through choke Ch1 which serves to filter out the instantaneous variations which are constantly occurring in an arc. Thus, the arc voltage appearing across R1 is actually the average of arc voltage over a very short period of time. This averaging time is made small enough not to interfere with rapid operation.

3. Comparing Circuit

The reference voltage and the arc voltage are connected in series bucking relation and the difference appears across resistor R4 as the error voltage. In practice, the arc voltage is slightly greater than the reference voltage so that the error voltage is applied as a small positive voltage on the grid of the 6SF5 amplifier tube.

4. Amplifier Circuit

The 6SF5 tube is connected as a cathode-coupled amplifier and the amplified output of the error voltage appears across the resistor R6. The operating range meter M2 is connected in series with the resistor R6 and serves to indicate the relative voltage appearing across R6.

5. Base Speed Selector

The output voltage of the base speed selector potentiometer, Pot 2, is connected in series with the voltage across R6.

6. Bias Supply for Thyatron

The bias supply for the C3J tube consists of transformer TR4 which steps up the voltage, rectifier SR2 which rectifies the output of TR4, condenser C4 which filters the rectified output of SR2 and bias voltage adjusting potentiometer, Pot 4, which provides an adjustment for the bias voltage. This voltage is in series with the output of the base speed selector voltage and the amplified differential voltage through the normally open relay contact RSS.

7. Phase Shift Voltage

The phase shift voltage is supplied by means of transformer TR3, resistor R8 and condenser C5. This voltage is also in series with the other above mentioned grid voltages.
8. **Inching Circuit**

The above circuit description covers the components used when the unit operates as an arc voltage control. For inching, the unit operates as a straight electronic governor as it does also for constant speed control. The inching speed is determined by the setting of the potentiometer, Pot 3. When inching, the output of Pot 3 is connected to the grid of the C3J through the normally closed contact of relay R8S. Thus, for inching, the output of Pot 3 is used in place of the outputs of the base speed selector Pot 2 and the amplified error voltage.

9. **Rod Feed Motor Armature Circuit**

A direct-current shunt-wound motor is used to drive the rod. The motor armature is connected into the thyatron circuit by means of relays RF and RR. These relays, in effect, act as a reversing switch to control the direction of rotation.

10. **Armature Control Relays**

Relay RF is the rod feed relay. When it is energized, contacts RF1 and RF2 are closed, connecting the armature to run in the feed direction. Relay RR is the rod retract relay. When it is energized, contacts RR1 and RR2 are closed, connecting the armature to run in the retract direction. When neither the RF or RR relays are energized, contacts RF3 and RR3 are closed, connecting the dynamic braking resistor RL0 across the armature and thus serving to limit the over-travel.

11. **Rod Feed Motor Field Supply**

The rod feed motor field is energized by direct current obtained from the rectifier system consisting of transformer TR1, the 8J rectifier tube and filter condenser C7. Resistor RL4 is connected in series with the field so that the current can be adjusted to deliver 230 volts across the field winding.

12. **Amplifier and Base Speed Selector Supply**

The above rectifier circuit is also equipped with a voltage regulator system consisting of resistor R11 and voltage regulator tube OD3YR150. The voltage regulator supplies a constant voltage, regardless of line voltage variations, to the plate of the 6SF5 tube and to Pot 2 and Pot 3 through the contacts TD of the time delay relay. The time delay relay TD is energized by the secondary of the C3J tube filament transformer TR7. This time delay relay prevents the operation of the C3J thyatron until it is properly warmed up.

13. **Inching Control**

The rod feed relay RF is energized by the feed push button and the rod retract relay RR is energized by the retract push button. These push buttons are cross-connected so that no damage can be caused by energizing both push buttons simultaneously.

The "Manual Carriage" switch SW3 energizes the carriage drive motor (and the oscillating motor when used) for positioning and test purposes.

15. "Ready Weld" Switch

The "Ready Weld" switch is closed just prior to starting a weld. When this switch is closed, it energizes the relay RWR. Contact RWR1 takes control of the rod feed motor away from the push buttons and puts it under the control of the automatic welding circuit as will be explained later. Contact RWR2 energizes the water and argon solenoid valves and the welding contactor auxiliary relay which in turn energizes the welding contactor and causes the arc voltage meter to indicate the open circuit voltage of the generator. Contact RWR3 energizes the speed selector relay RSS and its contacts RSS swing the grid circuit of the C3J tube from the inching Pot 3 to the base speed Pot 2, thus switching the speed of the rod feed motor from inching to automatic arc control.

16. Welding Circuit Controls

Starting a weld energizes the welding current relay RW1. Contact RW1 of this relay energizes the auxiliary welding current relay, RAW, contact RAW1 energizes the carriage motor (and the oscillator motor), contact RAW2 energizes the rod feed relay RF, thus causing the rod feed motor to start.

17. Automatic Retract-Starting Circuit

The over-voltage relay ROV energizes on the high open-circuit voltage of the welding circuit and de-energizes when the welding circuit voltage drops appreciably below the open-circuit value. As the machine leaves the factory, the adjustable resistor R-19, in series with the operating coil of ROV, is adjusted so that ROV will energize at about 60 volts. See Section III-H for instructions on adjusting this resistor.

The under-voltage relay RUV cannot be energized when ROV is energized because its operating coil circuit is interrupted by one set of contacts of ROV. When ROV is not energized, RUV will energize on a welding circuit voltage of about 20 volts.

At open-circuit voltage, ROV will be energized and RUV de-energized. At zero or near zero welding circuit voltage, RUV and ROV will both be de-energized. At welding voltage, RUV will be energized and ROV de-energized.

The operating coil of the welding contactor WC is energized by relay RAW when the "ready-weld" switch SW-2 on the operating control hand box (No. 1) is turned on.

To operate retract starting, SW-5 on the auxiliary control box is turned to "R" and the generator is turned on. Switch SW-2 on the operating control hand box is then turned on. This turns on the welding contactor WC and starts the welding services (argon flow, water flow, etc.).
The following sequence then occurs:

(a) Relay ROV is energized by the open-circuit voltage when WC closes.

(b) This causes the rod feed motor to feed* until the rod contacts the workpiece.

(c) This contact causes a dead shorted welding circuit with zero voltage so that both ROV and RUV are de-energized.

(d) With both relays de-energized, the feed motor reverses and the rod draws away from the workpiece, drawing an arc.

(e) As the length of the arc increases, the welding voltage increases and RUV becomes energized at about 20 volts.

(f) When RUV is energized (ROV remaining de-energized) the speed selector relay RSS becomes energized. This shifts control of the rod feed from the retract start circuit to the selected method of rod feed speed control (automatic arc voltage control or constant speed manual control). Rod then starts to feed into the weld at a speed to meet the conditions for which the controls are adjusted. Relay RUV remains energized during the welding operation. Relay ROV remains de-energized until the next starting cycle.

* Speed of rod feed at this stage is the same as the inching speed. See Section III-C of Form 9260 for instructions for adjustment of the inching speed.

E. **Constant Speed Rod Feed Operation**

1. **General Description**

   The FSM-1 machine can be set to feed rod to the welding zone at a constant rate of speed. The rate of rod feed is then controlled manually and can be changed during the welding operation.

2. **Constant Speed Control Hand Box (No. 2) (Fig. 27 in Form-9136)**

   This remote control hand box contains a potentiometer to control the rate of rod feed manually when the FSM-1 machine is under constant speed rod feed operation.

3. **Electrical Operation**

   a. **Arc Voltage "Manual-Automatic" Selector Switch (Fig. 29 in Form-9136)**

      This switch is used to select the proper control circuit for either arc-controlled rod feed speed ("Automatic") or manually-controlled rod feed speed ("Manual"). When the switch is placed in the "Manual" position, the amplifier tube, base speed selector, and arc voltage selector are removed from the arc-controlled welding circuit. The potentiometer in the constant speed control hand box (Pot. 5) is placed in the circuit and is used to regulate the rod feed speed. In this case the circuit and operation is similar to the standard LINDE
(9)

electronic governor (see Form-9161).

b. **Rod Feed Speed Selector** (Fig. 27 in Form-9136)

   This is a potentiometer (Pot.5) located in the constant speed control hand box and used to regulate the speed of the rod feed motor when the FSM-l machine is under constant speed rod feed operation. It does this by varying the voltage applied to the grid of the thyatron tube.

F. **HW-11 Sigma Hand-Welding Torch Adaptor Assembly, Part No. D-246048** (Fig. 28 in Form-9136).

1. **General Description**

   This adaptor assembly consists of the parts required to connect a sigma hand-welding torch, such as the HW-11, to the FSM-1 machine. The hand torch can then receive its continuous supply of welding rod, argon, power, and cooling water from the mechanized setup. The adaptor assembly also permits the hand torch to use the welding circuit used in a mechanized setup.

   a. **Relay Box**

      This box contains the electrical apparatus required to connect the FSM-1 machine welding circuit controls so they can be used for hand torch operation.

   b. **Welding Cable Connector and Water Inlet Block**

      This assembly consists of the parts required to connect the hand torch water and welding cable connections to the welding cable and the water outlet hose at the FSM-1 machine. The connections are provided with an insulating mounting block.

   c. **Conduit Adaptor**

      This assembly permits the torch flexible conduit to be connected to the FSM-1 welding head so that welding rod can be fed from the welding head to the hand torch.

2. **Electrical Operation**

   a. **The Relay Box and HW-11 Torch Trigger**

      The purpose of the relay box of the adaptor assembly is to provide a means for making the torch trigger serve the same purpose as the "Ready" switch (toggle switch) on the operating control hand box of the FSM-1 machine. A transformer in the relay box provides 6.3 volts for the low-voltage switch circuit. When the torch trigger switch is closed by pulling the trigger, the relay in the relay box is energized. This relay closes a circuit to energize relay RWR in the auxiliary control box. The operation of the FSM-1 control circuits are then the same as in mechanized welding when the relay RWR is energized by setting the hand box "Ready" switch to the "On" position.
II. INSTALLATION

A. Power Supply

The control unit receives its power from a source of 115-volt, 60-cycle alternating current. The supply line should be free from surges and should deliver a reasonably constant voltage in a range between 110 and 120 volts. In general, it is desirable to secure this power from a lighting circuit rather than a power circuit.

B. Interconnections Between Units

All interconnections between the various units are made with prepared cables. These connections are straightforward, and can be identified by means of the photographs and wiring drawing.

C. Arc Voltage Considerations

Since the unit is controlled by the voltage across the arc, it is important that this voltage reach the control circuit without change, the positive side of the arc voltage is taken from the drive head through cable No. 13, through the auxiliary box to the control circuits in the main box. It would be possible to pick off the negative side of the arc voltage from the work cable at the ammeter shunt. However, the connection between the work cable and the work is usually through a clamp, and frequently the heavy currents through the clamp produce contact voltage variations which could affect the operation of the unit. Therefore, to avoid these spurious voltage variations, a separate cable, No. 10, is used with a separate clamp to the work. Since the current through this separate clamp is negligible, there are no spurious voltage variations to disturb the operation of the machine.

D. Arc Voltage Meter

The arc voltage meter M1 has its positive side connected to the drive head through Cable No. 13. Its negative side is connected to the workpiece by a separate ground clamp.

E. Welding Current Contactor

A solenoid-operated welding current is used to close the welding current circuit. The ready-weld switch SW-2 controls the power to the operating solenoid through the auxiliary welding current relay RAWC. Cable 12 contains the connecting leads from relay RAWC to the coil of the contactor WC.

F. Connections for Straight Polarity Welding

Most materials welded with the FSM-1 machine require the use of reverse polarity welding current. The schematic diagrams (Drawing Nos. A-264034 and A-262441) and the wiring diagrams (Drawing Nos. 2A-264035 and 2A-262442) are therefore shown with the control connected for reverse polarity welding. However, some applications may require straight polarity welding. To change from reverse to straight polarity welding, change the setting of the polarity switch on the generator. Then interchange the two conductors of Cable.
No. 13, and connect Cable No. 10 to the welding head instead of the work-piece.

III. ADJUSTMENTS

The internal adjustments of the FEM-1 control are normally made at the factory. However, it is sometimes necessary to make field adjustments in order to secure optimum performance. This section describes how these adjustments can be made.

A. Arc Length Adjustment

The arc voltage adjustment, Pot.1, located in the operating control hand box (Hand Box No. 1) is used to control the arc length when operating with automatic arc voltage control. It is adjusted by the operator to give the desired arc length or arc voltage. Turning the knob clockwise will increase the arc length and turning it counter-clockwise will decrease the arc length. This knob is equipped with an arbitrary calibration for ease of resetting.

B. Base Speed Adjustment

Note: The base speed adjustment is required only for automatic arc voltage operation. When the selection switch SW4, on the main control box, is set for "Man" (constant speed) operation, there may be a reading on the meter M2, but it has no significance, and no attempt should be made to vary or adjust the meter reading.

When the base speed selector potentiometer, Pot.2, is properly adjusted, the operating range meter M2, located on the front of the main control box should read somewhere in the range between 0.5 and 1.0 ma and should behave as indicated below. (Note: The following conditions pertain to operation with automatic arc voltage control only.)

1. Straight Line Welding

For straight line welding without oscillating the head, the operating range meter reading should remain fairly constant with a small quivering movement. This constant reading should be somewhere between 0.5 and 1 ma.

2. Oscillating Welding

When the welding head is oscillated while welding, the operating range meter reading will rise and fall in step with the head oscillations. The average rise and fall of the operating range meter should be within the range between 0.5 and 1 ma but occasionally it may rise or fall outside of this range.

3. Poor Welding Conditions

When, for any of the reasons given under the heading of "Test Procedure," sub-heading "Proper Welding Conditions," a poor weld is being produced as evidenced by violent weld puddle agitation, the range meter needle may oscillate rapidly from a reading of zero to as much as 2 ma. When this occurs the unit is probably still in the proper operating range but is trying to follow a disturbed puddle. This is a process problem and not one of control.

In checking the performance of the control, avoid using the machine on a new application, or with a rod previously untried. Unsatisfactory operation under such circumstances may be the result of a process problem rather than one of control. Checking should be done on material, and with a rod known to work well under established welding conditions.
4. **Welding With Unstable Rod**

Some stainless steel welding rods will not give arc stability when meter M-2 is in the range of 0.5 to 1.0 ma. These are rods that tend to deposit metal in large visible drops rather than in a fine spray. If trouble of this kind is encountered, potentiometer P-2 may be adjusted to give arc stability so that M-2 reads higher than 1.0 ma. However, M-2 should never read higher than 1.35 ma. If this value is exceeded, the control will lose its sensitivity and will not respond to changes in voltage.

5. **Machine out of Proper Operating Range**

If meter M2 shows consistently below 0.5 or above 1 ma, the unit is out of operating range. If this occurs, proceed to make the adjustments described below to get the machine back into the operating range.

If the reading of meter M2 is too high, increase the setting (by turning it clockwise) of base speed selector Pot. 2 (located on the front of the main control box) until the meter drops back into the proper range.

If the reading of meter M2 is too low, decrease the setting of the base speed selector Pot. 2 until the meter comes up to the proper reading.

In some cases it may not be possible to bring the meter M2 into the proper range by adjusting Pot. 2 from one extreme to the other. In such a case, reset the adjustment of the potentiometer (Pot.6). Pot.6 acts as a rough setting while Pot. 2 acts as a vernier setting.

No such settings are necessary when under constant speed rod feed operation. The controls may be switched from automatic arc voltage control to constant speed operation and back without disturbing the base speed adjustment setting as set for automatic operation.

C. **Inching Speed and Retract-Starting Speed Adjustment**

Potentiometer P-3, located in the rear top side of the main control box (Fig. 30 in Form-9136) controls the rod speed when either of the inching buttons is depressed. When retract-starting is used, the speed at which the rod approaches the work to make the start is the same as the inching speed, and is governed by the same adjustment. Increasing the setting by turning P-3 in a clockwise direction will increase the inching speed; turning in a counterclockwise direction will decrease the inching speed. For retract starting operation, the inching speed should not be so great as to cause the rod to glance off or jam into the workpiece. Excessive speed in retract starting can also result in "sticking" (welding of the rod tip to the work).

D. **Braking Speed Adjustment**

The rod feed motor is provided with a dynamic brake to prevent overtravel of the rod when the rod feed motor is stopped. The degree of braking is controlled by the adjustment of resistor R10 located in the auxiliary control box. (See Figure 24 in Form 9136.) When this resistor is properly adjusted, the rod will stop in a position ready for the next weld without the necessity of using the inching push button. This resistor is normally set for 2 ohms. If the rod tends to overtravel, reduce the value of this resistor slightly so as to provide faster braking action. If the rod stops too far from the work reduce the braking action by increasing the value of this resistor.
Large changes in the size of welding rod or welding current may necessitate a change in the setting of this resistor.

E. Thyratron Bias Voltage Adjustment

Potentiometer, Pot.4, located on the bias and phase shift sub-assembly (see Figure 32 in Form 9136) adjusts the thyratron bias voltage. This bias voltage is adjusted at the factory and it should not be necessary to make readjustments in the field. However, if parts or the entire sub-assembly are replaced, it may be necessary to readjust this setting. The following is the correct procedure for adjusting the bias voltage:

1. The inching adjustment, Pot.3, should be set for the minimum setting (i.e., all the way counter-clockwise).

2. Keep either the feed or the retract inching button in a depressed position while making the next adjustment.

3. Turn Pot.4 in a counter-clockwise direction until the thyratron, C3J, tube fires. This will be indicated by a blue glow in the tube elements. Then slowly turn Pot.4 in a clockwise direction to the point where the thyratron stops firing. This will be indicated by the blue glow disappearing. At this point the adjustment is completed.

F. Rod Feed Motor Field Voltage Adjustment

Resistor R14 located in the rear top side of the main control box (see Figure 30 in Form 9136) controls the voltage on the field winding of the rod feed motor. This resistor is adjusted at the factory to deliver 230 volts direct current to the motor and it should not be necessary to readjust this resistor unless the resistor is damaged or a different type of motor is used. If, for any reason, this setting is to be checked, the field voltage can be measured between the metal case of condenser C7 and the resistor R14. (See Figure 30 in Form 9136.)

G. Tachometer Adjustment

Meter M4 indicates the speed of the CM-37 Carriage in inches per minute. This meter is equipped with a resistor located on the back side of the meter for adjusting the meter reading to agree with the actual carriage speed. If the carriage speed does not agree with the meter reading within +10 per cent, readjust the resistance so that they do agree.

When the FSM-1 is used with the OM-48 Side-Beam Carriage, meter M4 is inoperative. Carriage Speed is indicated by the speedometer in the electronic governor on the OM-48.

H. Adjustment of Over-Voltage Relay (ROV)

The welding voltage required to energize the over-voltage relay depends on the setting of the adjustable resistor R-19. Increasing the effective value of this resistor causes the relay to energize at a higher welding circuit voltage; decreasing the effective resistance causes the relay to energize at a lower welding circuit voltage.

The resistor should be set so that ROV will energize at a voltage
slightly below the open-circuit voltage of the generator (see note below).

If ROV does not energize on open-circuit voltage, the rod will immediately retract when switch SW-2 on the control hand box is turned on. (Note: This will also happen if the generator is not turned on, or if the voltage pickup leads are not properly connected.)

If ROV energizes at a voltage considerably below the open-circuit voltage, its operating coil will be subjected to excessive voltage. If, for any reason, the relay should remain energized for an appreciable period of time with the generator voltage remaining at open-circuit value, the relay operating coil would probably burn out.

As the machine is shipped from the factory, resistor R-19 is set to cause ROV to energize at about 60 volts. This will provide satisfactory operation with a generator open-circuit voltage of about 65 to 75 volts.

To adjust the resistor for operation on open-circuit voltages outside of this range, proceed as follows:

1. Turn on the generator and set the open-circuit voltage at the desired value.

2. If there is rod in the drive head, remove it so that the drive may be operated without feeding rod.

3. Press the retract inching button and observe that the end of a shaft in the left-hand side of the head turns when the drive is operating. Note the direction of rotation of this shaft while operating on retract.

4. Release the retract button and turn on the toggle switch SW-2 (on the same hand box). Note the direction in which the shaft rotates.

5. If the shaft rotates in the forward direction, adjust the resistor R-19 to increase its effective resistance, in gradual steps, until a point is reached where the shaft rotates in the retract direction. See note below before adjusting the relay.

6. With the resistor set so that the shaft rotates in the retract direction, readjust the resistor in gradual steps, as described in the note below, to decrease the resistance until the first point is reached where the shaft rotates in the forward direction. Then shift the resistor slide slightly further (about 1/16 in.) in the direction to decrease the effective resistance, and tighten the slide in this location.

**NOTE ON METHOD OF ADJUSTING RESISTOR R-19**

Adjustable resistor R-19 is in the auxiliary control box, mounted on the inner panel, just above the meters. It stands perpendicular to the panel on which it is mounted (see Fig. 24 in Form-9136).

The welding generator and the power supply to the FSM-1 controls should be shut off each time that an adjustment is made on this resistor. In order to secure an accurate final adjustment, the setting should be made in gradual steps, shifting the
slide not over 1/16 inch each time, then turning on the power supply, the welding generator and the ready-weld switch to observe the results of the adjustment.

The slide is connected to one end of the resistor by a short lead. Thus the slide and lead form a short circuit across that end of the resistor. The remaining length of the resistor, which is not shorted, is the effective portion of the resistor. To increase the effective resistance, move the slide toward the end to which the short lead is attached. To decrease the effective resistance, move the slide away from that end.

IV. TEST PROCEDURE

If a machine which has been working in a satisfactory manner stops working properly, there is a certain logical procedure which can be followed in order to locate the source of trouble.

A. Sources of Trouble

There are two general sources of trouble:

1. Improper operating conditions may cause the machine to lose control of the arc even though the controls are in good working order.

2. A defect in the controls may cause the machine to lose control of the arc or it may stop the machine entirely.

B. Proper Welding Conditions

If the machine feeds rod but does not properly control the arc, the welding conditions should be checked. The following is a check list.

1. Check gas flow.

2. Check cup size and height from work.

3. Check the sealing "O" ring outside the water-cooled gas cup.

4. Check the sealing "O" ring inside the lower drive head which seals the outside of the guide tube.

5. Check drive roll pressure to make sure that the wire is not slipping. Also be sure it is not too tight. With proper rod adjustment the armature current of the rod feed motor should be .5 ampere d.c. or less.

6. Check the setting of the welding generator and see that it is delivering the correct current as indicated by welding current meter M3.

7. Check the welding polarity by means of arc voltage meter M1. If the meter reads backwards the polarity is wrong.

8. Check the welding wire size, analysis and preparation. Be sure that no oil is leaking from the drive head onto the drive rolls and thus contaminating the wire.

9. Check the preparation and cleanliness of the weld zone of the work.
10. Check the traverse speed of the CM-37 Carriage.

11. Check the setting of the arc voltage selector potentiometer, Pot.1. (See paragraph on arc length adjustment.)

12. Check the setting of the base speed selector potentiometer, Pot.2. (See paragraph on base speed adjustment.)

13. If the oscillating motor is being used, be sure that the rate of oscillation is not too fast.

If the above tests indicate that the welding conditions are satisfactory, then proceed with the following tests. Complete each test before going to the next test and do not skip any tests.

1. Be sure that all of the controls, switches, and adjustments are properly set in accordance with the instructions.

2. Be sure that all of the cables are properly plugged in and connected, and that none of the cables are damaged.

3. Check the pilot light to see that it is lighted. If it is not lighted and fuses F1 and F2 are O.K., check the incoming power line which feeds cable No. 1.

4. Check the fuses in accordance with the information given below under the heading of "Fuses".

5. Check the tubes and timer in accordance with the information given below under the heading of " Tubes and Timer".

6. Check the operation of the relays, switches and push buttons to make sure that they are in good operating order and that they are actuated at the proper time. The section entitled "Theory Based on Complete Circuit" explains the proper operation of the relays.

7. If another FSM-1 of the same series and in good working order is available, an easy way to determine which unit is causing the trouble is to exchange units one at a time on the good machine. A logical order for exchanging units would be as follows:

   a. Use the hand box of the unit which is not working in place of the hand box of the unit which is working and run a test bead to determine if the performance of the machine is still satisfactory. Obviously, if the machine still works the hand box is in good order.

   b. Test the auxiliary box in a similar manner.

   c. Test the main control box in a similar manner. (Be sure to properly set the base speed adjustments in this test.)

   d. Test the drive head in a similar manner.

   e. Test the generator box in a similar manner.

8. Test the "Reference Voltage Sub-Assembly" as described under that heading.
9. Test the "Bias and Phase Shift Voltage Sub-Assembly" as described under that heading.

10. Check all voltages shown on Drawing No. 2A-264035 (or 2A-262442) for transformer TR1 and the rectifier filter system following it and check voltages of TR2.

11. Check all resistors and condensers not already tested.

If the above tests have been carried out, all working parts of this control will have been tested.

V. SERVICING - GENERAL

A. Test Meter

The type of test meter used in making tests on this unit will influence the results obtained. The readings given herein are based on the use of a 1000-ohms per volt instrument, such as the Weston Model 697 Analyzer. This meter has a built-in ohmmeter which can be used for resistance measurements in testing resistors, condensers and the selenium rectifiers.

B. Fuses

The electrical equipment is protected by means of six fuses located in the main control box. Figure 29 in Form 9136 shows the physical location of these fuses. The use of this rather large number of fuses serves to isolate the various circuits and permits quick tracking down of the trouble caused by shorts or grounds. In replacing any of these fuses use only Type 3AG "Littlefuses" of the recommended size. These Littlefuses can be obtained from the factory or from radio supply houses. Fuses of another make or ampere rating may not give adequate protection.

Fuses F1 and F2 (normally 15-ampere fuses) are the main line fuses. Failure of these fuses will be indicated by the pilot light going out. Since these fuses are back-up protection for the other fuses, one or more of the other fuses will usually blow when either F1 or F2 blows.

Fuse F3 (normally a 5-ampere fuse) supplies the auxiliary box. Failure of this fuse indicates a short or ground in one or more of the following pieces of equipment: the switch gear located in the auxiliary box, the push buttons located in the operating control hand box, the water or gas solenoid valves, the carriage relay, or the oscillating drive motor. Since several of the above pieces of equipment plug into the auxiliary box they can be checked as a source of trouble by unplugging them from the rear of the auxiliary box. (See Figure 23 in Form 9136.)

Remove plug P6 to isolate the operating control hand box (Hand Box No. 1)
Remove plug P8 to isolate the solenoid valves
Remove Plug P10 to isolate the CM-37 motor
Remove plug P11 to isolate the oscillating motor

If fuse F3 still blows after all of the above plugs have been removed, then the short or ground must be in the switch gear or receptacles contained in the auxiliary box. If plugging in one of the above mentioned plugs causes
F3 to blow, it is likely that the defect is in equipment connected to that plug.

Fuse No. 4 (normally a 2-ampere fuse) supplies transformers TR1, TR3 and TR7. TR1 supplies the power for the 83 rectifier tube which in turn supplies the direct current for the rod feed motor field, plate voltage to the 63F5 amplifier tube and voltage to potentiometers Pot.2 and Pot.3, and it also energizes TR4 and TR5. TR3 supplies the phase shift voltage for the C3J tube. TR7 supplies filament current for the C3J and it also energizes the time delay tube 2N030. Burning out of fuse No. 4 could be caused by one of the following:

1. Defective 83 tube.
2. Condenser C7 shorted or leaky.
3. A short or ground in the rod feed motor field winding or in the cables or plugs leading to the motor.
4. Transformers TR1, TR3, TR4, TR5 or TR7 defective. These can be checked by checking the voltage of all windings to see if they agree with the voltages shown on the master wiring diagrams. If winding 3-4-5 of transformer TR1 does not deliver the proper voltage, the trouble may be due to an overload caused by the troubles listed in "1", "2", "3" above.

If the transformers TR4 and TR5 do not deliver proper voltages to their respective rectifiers, check condensers C4 and C2 for leakage or shorts.

Fuse F5 (normally 10 amperes rating) supplies the plate transformer TR2 of the C3J thyratron tube. Normally this fuse will not blow unless transformer TR2 is defective or the C3J thyratron is defective. However, if the motor fuse F6 is larger than specified, overloads on the rod feed motor may cause F5 to blow.

Fuse F6 (normally 2 ampere rating) protects the rod feed motor armature from overloading. This fuse will blow for one of the following reasons:

1. Drive head too tight or binding. The normal armature current driving 1/8-in. 61S-T wire is usually in the order of 0.3 to 0.5 ampere as measured on a direct-current ammeter. (Do not use an alternating-current meter, a rectifier type meter, or a so-called "ac-dc" with an iron vane movement. Use only a direct current D'Arsonval type meter for this measurement.)
2. No field voltage or too low a field voltage on the rod feed motor will cause armature current to be abnormally high and thus blow F6.
3. Shorts or grounds in the wiring between the thyratron and the armature of the rod feed motor. Check the RF and RR relays, plugs and cables.

A thermal overload relay, O.L., is connected with its heater in the armature circuit and its contacts in series with the primary of transformer TR2. This overload relay is located on the rear top side of the main control box chassis. (Figure 30 in Form 9136.) This overload relay serves to back up fuse F6 particularly on long overloads which are not great enough to blow fuse F6. When this overload trips, the reset button jumps up and opens its contacts. The relay is reset by depressing the reset button, but this
cannot be done until the relay cools down. This cooling down period permits the motor to cool down to a safe operating temperature before being put back into service.

C. Tubes and Rectifiers

The tubes in this unit are used very conservatively so that they will not require frequent replacement. It is recommended that a spare set of tubes be kept on hand at all times so as not to tie up a machine in the event of a tube failure. The following tubes can be tested in a tube tester such as can be found in a good radio supply house or, in an emergency, they can be tested by substituting a new tube: 6SF5, 83, OA3-VR75, OD3-VR150. Since conventional tube testers will not test thyratrons the C3J thyratron tube can be tested only in a special thyratron tester. If there is any question regarding this tube it can be tested by substituting another C3J tube in its place.

The OA3-VR75 and the OD3-VR150 are voltage regulator tubes which serve to make the operation of the unit independent of line voltage variations and surges. In general, if the tubes show their characteristic glow in operation they are in good working order. A definite test on these tubes is to measure voltage across tube socket terminals 2 and 5. For the OA3-VR75, the voltage across these terminals should be 75 volts and for the OD3-VR150 the voltage across these terminals should be 150 volts.

The 2-N0-30 is not actually a tube but is a thermal time delay relay mounted in a tube base. The heater terminals are connected across terminals 2 and 3 of its socket and are energized by TR7. The heat developed in the heater causes the thermal elements to flex and make contact across socket terminals 5 and 7. This timer takes approximately 30 seconds to operate. Closing of the timer contacts is indicated by a change from 0 to approximately 0.2 ma in the reading of the operating range meter M2. If this meter does not show approximately 0.2 ma reading after the unit has been turned on for a minute, replace the timer. If this does not clear the trouble, remove the 6SF5 and check the voltage between pins 5 and 2. This should be approximately 120 volts direct current as measured on a 1000 ohm per volt voltmeter. Also check the 33,000 ohm resistor R6 (see Figure 31 in Form 9136) and the meter M2.

D. Relays

If a relay coil is receiving its rated voltage, it should operate its contacting mechanism; therefore, if a relay does not operate, check the coil voltage first of all.

Check the operation of the mechanical parts for excessive friction or jamming.

Check the contacts to make sure they are opening and closing properly. These relays are equipped with silver contacts which should not be filed or cleaned unless the contact has been very badly burned by a short or by defective equipment.

If the relay is in good mechanical condition and it still does not operate when rated voltage is applied to its coil, the difficulty may be due to an open coil or to a partly shorted coil. An open coil can be found by
means of an ohmmeter. A partly shorted coil will generally overheat.

Overheating of an alternating current relay coil can also be caused by failure of the operating mechanism to close all the way when the coil is energized since excessive currents will flow through the coil unless the mechanism goes through its full normal movement.

E. Reference Voltage Sub-Assembly

As indicated by the master wiring diagrams and Figure 33 in Form 9136, the parts required for the reference voltage are mounted on a sub-assembly panel which is connected into the main control box by means of terminal strip T4. Segregating these parts in a sub-assembly makes it easy to check the performance of this part of the circuit and also makes it possible to quickly repair or replace a unit if trouble is found.

Note that the terminals of terminal strip T4 are numbered 1 through 8. If the unit is in good working order the following voltages can be measured across these terminals (use only a 1000 ohm per volt voltmeter such as the Weston Model 697 or its equivalent for making these measurements). The readings given below also indicate whether an a.c. or d.c. scale of the meter should be used.

1. From T4-1 to T4-2 should read 5.2 volts a.c. If this voltage is not obtained check voltage of windings 8 and 9 of transformer TR-1.

2. From T4-3 to T4-7 should read 45 to 50 volts d.c. If this reading is much higher than 50 volts check voltage regulator tube OA3-VR75. If voltage is lower than 45 volts check TR-5, R13, R3, R2, SR-1 and C1.

3. From T4-5 to T4-6 should read from 1.6 to 1.8 volts d.c. when the unit is energized and 1.4 to 1.6 volts d.c. when main switch SW-1 is turned off. This is actually a measure of the bias battery (Eveready #950) voltage. This battery should be replaced at the end of the expiration date marked on the battery. If the battery is ever left in service so long that it leaks battery fluid, all traces of this fluid must be carefully removed because it may cause electrical leakage which may render the unit inoperative or erratic in operation.

4. From T4-4 to T4-7 should give a reading of from 0 to 45 volts d.c. when the arc voltage selector potentiometer Pot.1 is changed from its minimum to its maximum setting. If this voltage swing is not obtained check Pot.1.

5. Turn the main line switch SW-1 off and check values of all resistors on panel.

F. Bias and Phase Shift Voltage Sub-Assembly

As is indicated by the master wiring diagrams and Figure 10 in Form 9136, the parts required for the bias and phase shift voltages are mounted on a sub-assembly panel which is connected into the main control box by means of terminal strip T-5. Segregating these parts on a sub-assembly makes it easy to check the performance of this part of the circuit and also makes it possible to quickly repair or replace the unit if trouble is found.
The terminals of the terminal strip T-5 are numbered 1 through 6. If the unit is in good working order the following voltages can be measured across these terminals (use only a 1000 ohm per volt voltmeter, such as the Weston Model 697 or its equivalent for making these measurements). The readings below also indicate whether an a.c. or d.c. scale of the meter should be used.

1. From T5-1 to T5-2 should read 5.2 volts a.c. If this voltage is not obtained check voltage of winding 8 and 9 of TR-1.

2. From T5-3 to T5-4 should read 115 volts a.c. If this voltage is not obtained check fuse F-4.

3. From T5-5 to T5-6 should give a reading of 0 to approximately 50 volts d.c. as the bias adjusting potentiometer Pot.4 is changed from its minimum to its maximum setting. If this voltage is not obtained check TR-4, C4 and the voltage across the Pot.4.

4. Turn off main line switch SW-4 and check all resistors, condensers and the selenium rectifier on this assembly.

G. Resistor Tests

The nominal resistance value for all resistors is given in the master wiring diagrams. The resistance values of the BTA type resistances have a tolerance of ±20 per cent. The resistance values of the wire wound resistors and Pot.1 and Pot.4 have a tolerance of ±10 per cent. In checking resistors it should be noted that in some cases other components are connected across the resistor and will affect the reading which is obtained unless the resistor is isolated. A good example of this is Pot.4 which has connected across it in series relation SR2, R16 and a winding of TR4. An ohmmeter connected across Pot.4 will read lower than 15,000 ohms unless it is isolated from the remainder of the components.

Be sure that the unit is disconnected from the power line before attempting to handle any of the components. An ohmmeter, such as is included in the Weston 697 analyzer should be used for resistance measurements.

H. Condenser Tests

It is difficult to test condensers without special test equipment, so all that can be done is to run leakage and short-circuit tests. In order to test condensers at least one side of the condenser will have to be disconnected from the circuit. An ohmmeter can be used for making crude leakage or short-circuit tests. Because of the difficulty of making accurate condenser checks, it is suggested that all other components be tested and eliminated as a source of trouble before testing the condensers.

Condensers C1, C4 and C7 are electrolytic condensers and the reading obtained on the ohmmeter will depend on the polarity of the ohmmeter connection. For example, with the ohmmeter connected across the condenser terminal, a reading of 10,000 to 50,000 ohms may be obtained, then if the ohmmeter leads are reversed a reading of 200,000 ohms may be obtained. The "higher reading" is the significant one. Any of the above condensers showing a "higher reading" of less than 100,000 ohms should be replaced.
The remainder of the condensers are of the so-called "paper condenser" variety and should show resistances of more than 1,000,000 ohms regardless of the ohmmeter polarity. Condensers showing less than this value should be replaced.

I. Selenium Rectifier Tests

The selenium rectifiers SR1 and SR2 can be tested by means of an ohmmeter but at least one side of the rectifier must be disconnected from the circuit to make this test.

In general, the resistance of these rectifiers with one polarity of the ohmmeter will be approximately 2000 to 3000 ohms and with the other polarity of the ohmmeter it will be over 100,000 ohms. Both of these readings are significant. The low reading should not exceed 5000 ohms and the high reading should not be less than 100,000 ohms. Discard any units which do not meet these specifications.

If transformers TR4 and TR5 are delivering the voltages indicated in the diagrams, then the selenium rectifier should deliver the indicated voltage across the condensers. If it does not deliver the indicated voltage to the condenser, it is either defective or it is overloaded. Overload can be caused by leaky or shorted electrolytic condensers.
VI. APPENDIX

Block Diagram of FSM-1 Arc Length Controls
Simplified Schematic Diagram of FSM-1
Schematic Diagram for FSM-1 on OM-48 Side-Beam Carriage
Schematic Diagram for FSM-1 on CM-37 Carriage
Master Wiring Diagram for FSM-1 on OM-48 Side-Beam Carriage
Master Wiring Diagram for FSM-1 on CM-37 Carriage

Sketch E-6300
Sketch E-6299
Drawing A-264034
Drawing A-262441
Drawing 2A-264035
Drawing 2A-262442