HOW TO MAINTAIN INDUSTRIAL CONTROL

REPRINTED FROM THE MANUAL "HOW TO MAINTAIN ELECTRIC EQUIPMENT" (PRICE $3.00)

GENERAL INFORMATION

ELECTRIC control equipment upon which industry depends for continuity of service is no exception to the rule that periodic inspection and maintenance are important in helping to keep plants running at peak capacity. Control often operates thousands of times a day, and it is therefore important that it be inspected regularly so that replacements or repairs can be made before a breakdown occurs.

Many progressive operators realize that there are three good rules for the maintenance man to follow:

1. Prepare a productive-maintenance program consisting of a list of the items to be checked at each inspection.

2. Keep on hand a few renewal and repair parts. If you do not have a recommended list, such as is supplied in the instruction book accompanying the equipment, The General Electric Co. will gladly furnish recommendations on G-E equipment.

3. Much time and trouble can be saved by buying renewal parts made by the manufacturer who originally supplied the equipment. You then are sure that the renewal parts will comply with all the specifications of the original parts.

Productive Maintenance Inspection Schedule

The suggested frequency of inspection recommended below is based on average conditions. The actual frequency should be adjusted for each application as experience dictates.

	WHAT TO INSPECT	WHAT TO INSPECT FOR
MONTHLY	**Magnet-operated Devices** Contactors, Relays, Solenoids, Brakes, both A-c and D-c	Control-circuit voltage.
		Collections of dirt or gum.
		Excess heating of parts—evidenced by discoloration of metal parts, charred insulation, or odor.
		Freedom of moving parts (no binding or sticking).
		Corrosion of metal parts.
		Remaining wear allowance on contacts.
		Excess slam on pickup.
		Proper contact pressure.
		Loose connections.
		Condition of flexible shunts.
		Condition of arc chutes or barriers.
		Worn or broken mechanical parts.
		Excessive arcing in opening circuits.
		Condition and level of oil (if oil-immersed). Check for presence of sludge.
		Condition of gaskets (for oil-immersed, dust-tight or watertight units).
		Excessive noise in a-c magnets.
		Evidence of dripping water or liquids falling on control.
		Operation—including proper functioning of timing devices, sequencing of devices, etc.
		Condition of wheels and linings (on brakes).

Thermally Operated Devices Overload Relays, Temperature Relays, Thermostats, etc.	Collections of dirt or gum. Excess heating of parts---evidenced by discoloration of metal parts, charred insulation, or odor. Freedom of moving parts (no binding or sticking). Corrosion of metal parts. Proper contact pressure. Loose connections. Condition of flexible shunts. Worn or broken mechanical parts. Excessive arcing in opening circuits. Evidence of dripping water or liquids falling on control. Condition of heating element. Condition of control-circuit contacts. See that contacts open when latching mechanism trips.
Motor-operated Devices Motor-operated Timers, Thrustor Mechanisms, Valves, Brakes, Rheostats	Control-circuit voltage. Collections of dirt or gum. Excess heating of parts—evidenced by discoloration of metal parts, charred insulation, or odor. Freedom of moving parts (no binding or sticking). Corrosion of metal parts. Proper contact pressure. Loose connections. Condition of flexible shunts. Worn or broken mechanical parts. Excessive arcing in opening circuit. Condition and level of oil (if oil-immersed). Check for presence of sludge. Condition of gaskets (for oil-immersed, dust-tight or watertight units). Evidence of dripping water or liquids falling on control. Operation—including proper functioning of timing devices, sequencing of devices, etc. Excess vibration or noise in operation. Wear or roughness on sliding contacts. Condition of gearing and lubricate where recommended.

EVERY 6 MONTHS

Static Accessories Resistors, Rectifiers, Capacitors, Transformers, Fuses, Wiring, and Bus and Cable Work	Collections of dirt or gum. Excessive heating of parts---evidenced by discoloration of metal parts, charred insulation, or odor. Corrosion of metal parts. Loose connections.
Mechanically Operated Devices Master Switches, Drum Controllers, Push Buttons, Selector Switches, Knife Switches, Manual Starters, Rheostats, Limit Switches, Speed-sensitive Switches, Flow Switches, Float Switches, Pressure Switches	Collections of dirt or gum. Excessive heating of parts—evidenced by discoloration of metal parts, charred insulation, or odor. Freedom of moving parts (no binding or sticking). Corrosion of metal parts. Remaining wear allowance on contacts. Proper contact pressure. Loose connections. Condition of flexible shunts. Condition of arc chutes or barriers. Worn or broken mechanical parts. Excessive arcing in opening circuits. Condition and level of oil (if oil-immersed). Check for presence of sludge. Condition of gaskets (for oil-immersed, dust-tight or watertight units).

EVERY 6 MONTHS (Cont.)

	Evidence of dripping water or of liquids falling on control.
	Condition of control-circuit contacts.
	Wear or roughness on sliding contacts.
	Lubricate contacts where recommended.
Arc Chutes or Barriers	If they are almost burned through, replace. This will prevent the heat of the arc from burning out pole pieces or shorting the next phase.
Flexible Shunts	Corrosion.
	Damage from wear.
	Flex or twist slightly to make sure that they are in good condition.
Interlocks	Make sure they are adjusted as described in the manufacturer's instruction book.
Push Button, Overload Relay, Contacts, Etc.	Make sure they function freely enough to provide protection if an emergency arises.
Gaskets	Corrosion.
	Torn or damaged so that they do not make tight joints.

HOW TO REMOVE DUST, DIRT, AND GREASE

If heavy dust or grease has accumulated on any part of the control, it should be removed with a heavy brush or wooden scraper. Dry dust and dirt should be blown off, using dry compressed air. This is important, as dust may not only prevent the control devices from operating normally, but also may contain conducting material which will ultimately form a path between points of different potentials, resulting in a short circuit. Dust on the surfaces of interlocks may prevent a circuit from being completed, even when the contacts are in the closed position. Grease, oil, or sticky dirt is removed by applying a cleaning fluid, such as carbon tetrachloride. Do not soak the parts, particularly the coils with the cleaner, but use just enough to loosen the grease so that it can be wiped off. For cleaning small parts, a small paint brush, dipped into the cleaning solution, is good for getting into corners and crevices.

HOW TO CARE FOR FUSE CLIPS AND FERRULES

While most fuse clips and fuse ferrules are plated to resist corrosion, it is well occasionally to remove the fuse from the clip and polish the contact surfaces. (This statement does not apply to silver-plated clips and ferrules.) In replacing the fuses, be sure that they fit snugly into the clips.

HOW TO CARE FOR SILVER CONTACTS

Many contactors, up to 150-ampere capacity, as well as small relays, utilize fine-silver contacts, which oxidize more slowly than copper contacts. When silver oxide is formed on the contact, the oxide is self-reducing. Therefore, it is not necessary nor recommended that fine-silver contacts be filed to remove the oxide. It does not take much filing to destroy the contact's usefulness completely.

If sulphur gas is present in the atmosphere in any quantity, a sulphide may form on the silver. If the contact pressures are light and the voltage low, this condition may prevent the current from flowing when the contacts close. The sulphide is darker in color than the oxide, and should be removed by cleaning if it causes trouble.

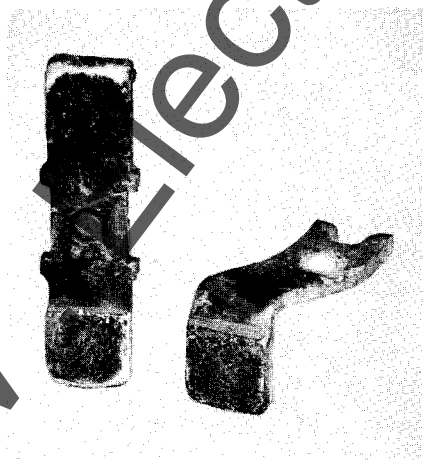
HOW TO CARE FOR COPPER CONTACTS

A contactor has several bolted or spring-closed contacts. If excessive heating is apparent, the most likely point of high resistance (and resultant heating) is where the movable contacts make contact with the stationary contact. It is very easy to inspect these contacts weekly or monthly, and if the temperature is unduly high, to give them a few strokes with a file. Copper contacts oxidize rapidly at elevated temperatures, and slowly at room temperatures. The copper oxide which is formed has a very high resistance. A few strokes with a file will remove the oxide and reduce the resistance to low value again. It is usually unnecessary to file copper contacts if the device is operated fairly often. The slight abrasion produced by the ordinary closing operation is sufficient to keep the oxide cleaned off. However, if corrosive gases are present, or if the contact controls a highly inductive circuit (such as a d-c machine field), the oxidation may progress more rapidly, and it is usually better to substitute a special type of contact, for which information may be obtained from the Company.

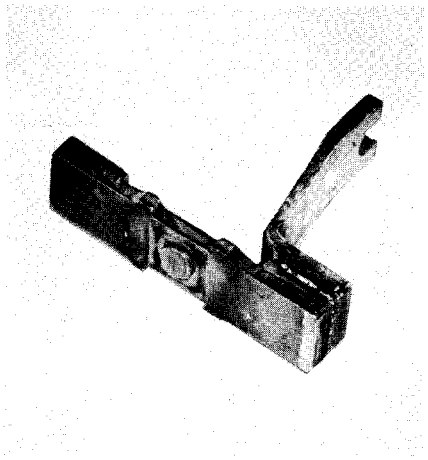
A fairly common erroneous impression is that contacts which have been roughened by service should be kept smoothed so that they will carry the load. A roughened contact will carry current just as well as a smooth contact. Of course, if a large projection should appear on a contact, because of unusual arcing, it should be removed. However, a contact that has been roughened by ordinary arcing need not be serviced. If a copper contact becomes overheated, this condition indicates that oxide has developed, and the oxide should be removed.

Do not lubricate the contact face, because the burning of the lubricant on circuit interruption increases the heating of the contact and shortens the life of the contact.

As the contact wears, pressure is maintained by the wiping spring which presses the movable contact against the stationary contact when the contact is closed. Check this spring at intervals, since contact heating may draw the temper of the spring and reduce the pressure of the contacts. The correct spring pressure is usually indicated on the instruction sheet accompanying the controller. Also, the contact spring pressure on one pole of a contactor can be compared with the contacts pressure on the other poles of the same contactor. The spring pressure on all poles should be approximately the same, and if one is considerably lower than the others, the spring should be replaced.

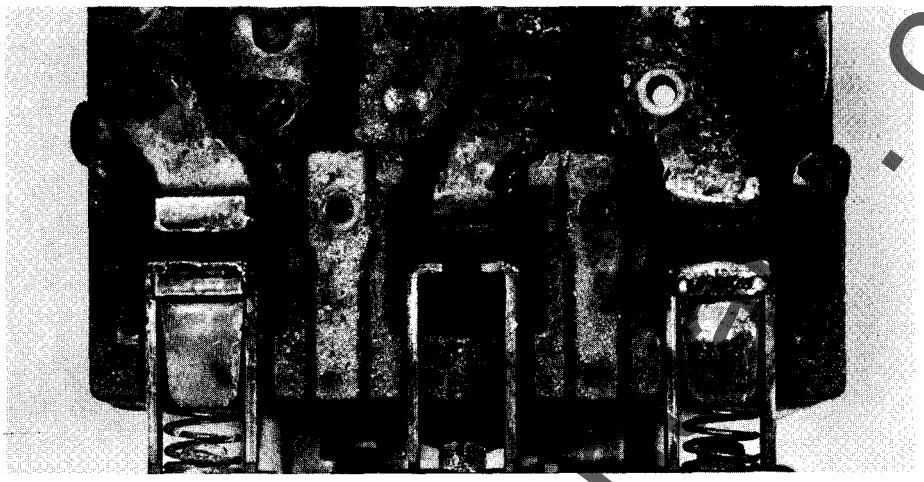


Normal service will sometimes make contacts look like this. When inspection is made, the surfaces of contacts having this appearance should be left alone. DO NOT FILE THEM.

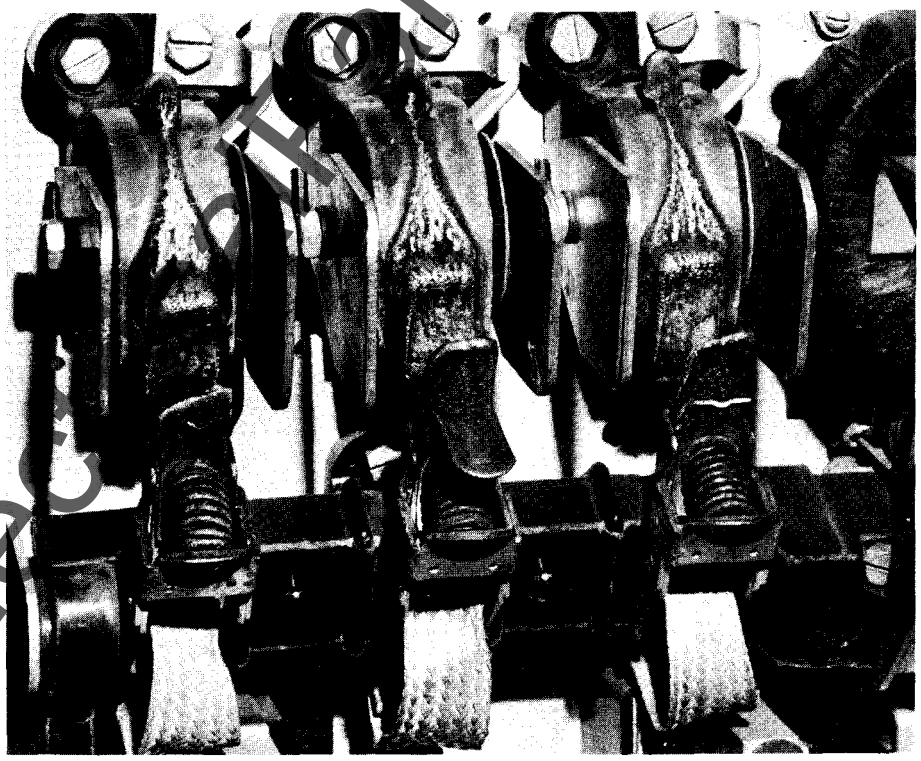


When the contacts close, they will have good contact and alignment.

How to Judge by Appearance



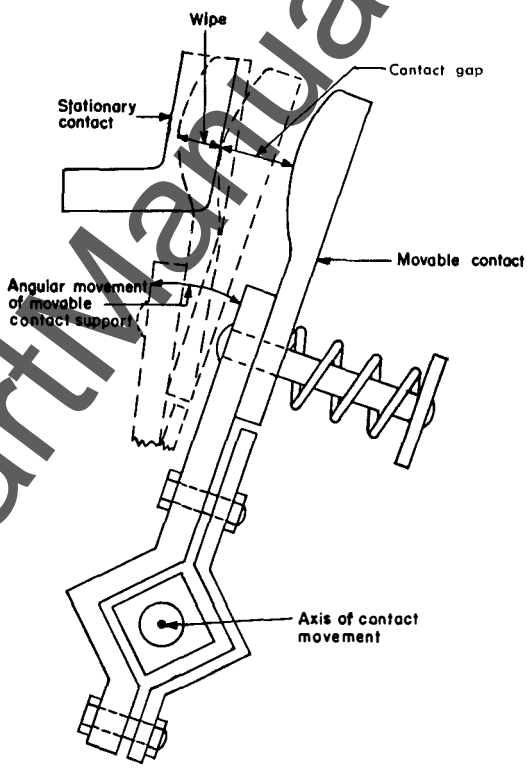
Never allow contacts to stay in service until they do not work. Note damage to other parts of the control which could have been avoided.



When contacts have this appearance they should be replaced. Wear of other parts of the control caused poor alignment. When replacing contacts, make sure poor alignment is corrected.

CLAPPER-TYPE CONTACTORS

A term commonly used, though in many cases incorrectly, is "wipe." Wipe can best be defined as the total depth of contact material that can be worn away before the contacts fail to make contact when the device is closed. It does not pertain to the sliding or rolling of any of the parts. By virtue of this "wipe," the total pressure exerted by the movable contact builds up in accordance with the pressure of the contact spring. When the contact materials have been worn away, reducing this contact pressure to the minimum safe value, it is recommended that contacts be replaced. *Wear allowance* and *wipe* are entirely different, although often used synonymously. Perhaps there may be 50-per-cent wipe remaining when the maximum wear allowance has been reached. In practice, wear allowance is not directly computed from contact dimensions and armature travel. Usually, the instruction sheet for a given device shows how to measure wear allowance between two points which are readily accessible, and also which dimension is proportional to the wipe. When the wipe has been reduced to a specified minimum, the wear allowance will already be used up, and it is then advisable to replace the contacts.



Sketch illustrating contact gap, wipe or wear allowance

VERTICAL-LIFT CONTACTORS

If, for any reason, the stationary contact support of a vertical-lift contactor is removed from the contactor base plate, the contactor must be carefully reassembled for proper contact wipe and thereby correct contact gap. Refer to the instruction sheet furnished with device for specific directions for reassembling in the correct position.

HOW TO CARE FOR MAGNET COILS

The coils of a-c contactors are designed to operate satisfactorily over a range of 85 to 110 per cent of rated voltage, and on d-c contactors from 80 to 110 per cent. The temperature rise of standard coils should not exceed 85 C by resistance. This is a permissible temperature rise for use in ambients up to 40 C. With a rise of 85 C by resistance, the rise measured by thermometer on the coil surface will be about 65 C, depending upon the design of the coil.

How to Handle Coils

Never use the leads on coils as carrying handles. Although the leads are strong enough to support the weight of the coil, this practice may cause a complete or partial fracture of the lead wire or joint, resulting in either an open-circuited coil or one that may open-circuit shortly after being installed.

Careless handling of coils bends the connections and often makes a coil worthless, although the coil may be new.

How Coils Work

The current on a-c shunt coils is at minimum value when the armature seals properly with the stationary frame. Any excessive gap in the magnetic circuit lowers the impedance of the coil, and this will allow the coil to draw more current. If the magnet is accidentally blocked open, or if the voltage is so low that the magnet cannot close, the current is likely to be several times greater than the minimum gap current; and if this condition occurs, the coil may be damaged in a short time.

How to Store Coils

D-c shunt coils are particularly subject to failures caused by absorption of moisture from the air. When a d-c coil absorbs only a very slight amount of moisture, the next time the coil is energized electrolytic action may be initiated between coil and guard, which will quickly cause an open circuit. Therefore, it is extremely important to store coils in a dry place and to keep the air reasonably dry where control is installed. For special high-humidity conditions (as in the tropics), coils that have been given special treatment are available.

How to Dry Coils

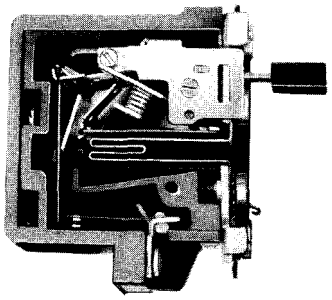
If coils have become wet, they should be thoroughly baked as soon as possible in an oven at a temperature of 110 C to 125 C. This should also be done if coils have been soaked in carbon tetrachloride to remove grease or oil.

How to Varnish Coils

If it is necessary to varnish coils, only an approved insulating paint or varnish should be used. (G-E No. 458 black or G-E No. 1225 clear is recommended.) Some paints or varnishes contain thinners that will rapidly attack coil and wire insulations. Apply paint while the coils are still warm from baking.

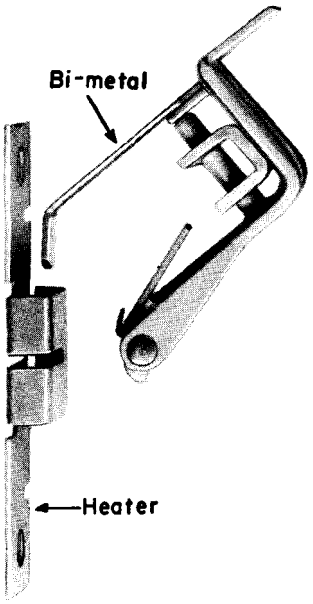
How to Assemble Coils

When coils are assembled on the magnet frame, make sure to fasten them securely because when the coils are energized, a mechanical force is developed which will tend to cause them to slip back and forth on the frame. This would in time cause excessive wear on the coil insulation or spool.



ASSEMBLING THERMAL OVERLOAD-RELAY HEATERS

If it is necessary to remove a relay heater, notice carefully how it is mounted on the relay; and when remounting it, be sure it is placed in the same position as it was originally. If incorrectly installed the heater may, by touching the thermostatic strip, make the relay inoperative. The screws holding the heater in place should be tight; otherwise, heating, which will affect the calibration of the relay, will develop.



If the relay trips frequently, first compare the rating of the heater with that recommended in the heater label. If the heater rating is correct, measure the current taken by the motor. If the current is higher than that shown on the motor nameplate (plus the service factor), the relay is doing a protective service and the mechanical load should be inspected to determine the cause of the overload. If the line voltage is low, it will cause the current to be high, and the relay will trip. Low voltage may be caused by inadequate power leads running to the controller from the power supply.

Thermal overload relays cannot protect a motor against damage due to faults (grounds), internal or external, nor against burn-outs in case a bearing failure allows the rotor to rub on the stator; nor can they protect themselves, or the motors which they are designed to protect, against short-circuit conditions. This has to be done by fuses or circuit breakers of proper rating. This does not indicate any weakness in the design of such relays — it is due to the inherent characteristics of overload relays.

ADJUSTING MECHANICAL INTERLOCKS

The mechanical interlock between two contactors of a reversing controller prevents both contactors from closing at the same time. This mechanism is carefully adjusted at the factory, but it may be re-adjusted quite readily by following the directions given on the instruction sheet that is furnished with the controller.

TROUBLE SHOOTING

Three tips which will help the operator get inoperative control back into service in a hurry:

1. Become familiar with each circuit and the operation of each new controller as it is installed in the plant.

2. Keep the elementary diagram handy. This is the *most valuable tool* that the control manufacturer can furnish for use in trouble shooting. In many plants these diagrams are framed and kept near the controllers to which they refer.

3. Keep portable instruments handy for checking voltage, current, resistance, etc.

What to Do if Trouble Becomes Chronic

Send to the manufacturer at least one sample of broken or damaged parts and give him as much of the following information as possible:

1. Complete nameplate data on controller.
2. Nameplate data, and function of equipment on which the controller is used.
3. Manufacturer's requisition or order number, if available.
4. Duty cycle and details of operation.
5. Length of time equipment has been in service, and estimated total number of operations.
6. Voltage and frequency conditions at the panel, and other pertinent electrical data.
7. Complete description of manner in which failure occurred.
8. Complete information on any unusual service conditions.

It is also advisable to send along the user's opinion as to why the failure occurred, and any suggestions which he may have for preventing its recurrence.

Although, as a general rule, control equipment is designed to require the least possible maintenance, there are many cases which may require particular attention. Very often modification of the equipment which might help overcome the difficulty can be suggested.

UNUSUAL CONDITIONS

Unusual operating conditions should be called to the manufacturer's attention, as apparatus for use in such cases may require special construction or protection. The following are unusual conditions that are similar to the NEMA Industrial Control Standards covering unusual conditions.

1. Exposure to damaging fumes.
2. Operation in damp places.
3. Exposure to excessive dust.
4. Exposure to gritty or abrasive dust.
5. Exposure to steam.
6. Exposure to excessive oil vapor.
7. Exposure to salt air.
8. Exposure to vibration, shocks, and tilting.
9. Exposure to explosive dust or gases.
10. Exposure to the weather or to dripping water.
11. Apparatus in cooling mediums having temperature higher than 40 C or installed at altitudes greater than 6000 feet.

TROUBLE-SHOOTING CHART

GENERAL

TROUBLE	CAUSE	REMEDY
CONTACTS		
Contact Chatter	Poor contact in control pickup circuit.	Improve the contact or use holding interlock.
	Excessive jogging.	Find out whether device is recommended for jogging service. If it is not, caution operator.
	Broken pole shader.	Replace, or order new magnet assembly.
	Contactor slams, thus opening interlock in coil circuit.	Increase wipe, also pressure on interlock.
Overheating of Contacts	Copper oxide on contacts.	Install silver-faced contacts.
		If copper contacts—file with a fine file. (Caution: excess filing wears out the contacts. Never file silver-faced contacts.)
	Carrying load continuously for a long time.	Install silver-faced contacts.
	High inductive loads, such as d-c fields.	Install silver-faced contacts.
	Sustained overload.	Reduce current or install a larger device.
	Insufficient contact pressure.	Clean, adjust.
	Loose connection.	Clean and tighten.
		(Measurement of the millivolt drop across the current-carrying connections will indicate where excessive heating originated.)
Short-circuit Currents on Contacts	Feeder fuses too large.	Eliminate short circuits or use smaller fuses in feeder.
Short Contact Life	Interrupting high currents.	Install special contacts designed to withstand arcing better than copper. (There are cases where these cannot be used because of their high resistance and lower rating.) Install larger device designed for jogging service.
	(Note: Contact life varies approximately inversely as the square of the current interrupted. Therefore, jogging may wear contacts more than 30 times as fast as an equal number of straight starts, with stops from full speed.)	
	Excessive filing or dressing.	Never file silver contacts. The rough spots will not hurt them.
	Oil-immersed device is a misapplication. (Note: Oil-immersed contacts burn away from 20 to 40 times as fast as similar contacts breaking the same current in air.)	Change to air-break device if oil is not essential.
	Mechanical rebound on drop-out, causing contacts to touch.	Reduce rebound, or report trouble to manufacturer.
Weak Contact Pressure	Wear allowance gone.	Replace and adjust.
	Poor contact adjustment.	Adjust gap and "wipe."
	Low voltage which prevents magnet sealing.	Correct voltage condition (possible line regulation).
Welding or Freezing	Abnormal inrush of currents of more or less than 10 times continuous rating. (This will vary, depending on the type of device.)	Reduce currents.
		Substitute special nonweld contacts.
		See pages 80 and 81.
		Install larger device.
		Install copper contacts. (Caution: overheating of copper contacts should be considered.)
	Rapid jogging.	Install copper contacts if otherwise suitable.

TROUBLE	CAUSE	REMEDY
COILS		
COIL FAILURE	Moisture, corrosive atmosphere.	Relocate coils or use special resistant coils.
Open Circuit		
Not Roasted	Mechanical damage.	*Do not handle coils by the leads.*
	Excess vibration or shock; coil movement causing insulation failure or broken wire.	Relocate and provide a special mounting. Coils should be held firmly in place.
Overheated	Overvoltage or high ambient.	Check application and circuit
Roasted		See *How to Care for Coils,* page 82.
	Wrong coil, short-time-rated coil energized too long.	Check manufacturer.
	Shorted turns, caused by mechanical damage, corrosion, or conducting dust.	Replace coil and correct conditions if practical to do so.
	Too-frequent operation (very rapid jogging of a-c coils).	Check application.
	Undervoltage, failure of magnet to seal in.	Check circuit interlock.
SERIES COILS		
Includes Blowout Coils		
Overheated	Used above current rating.	Install larger coil, or reduce current.
	High ambient.	Relocate, or regulate temperature.
	Loose connection, corrosion, oxidation on connection surfaces.	If connection is hot, clean before tightening.
FLEXIBLE SHUNT FAILURE	Improper installation.	See manufacturer's instructions
	Large number of operations—worn out mechanically.	Replace shunt.
	Corrosive atmosphere or moisture.	Incorrect application.
	Burned by arcing; oxidized connection.	Check application and system voltage.
MAGNETS AND OTHER MECHANICAL PARTS		
Worn or Broken Parts	Heavy slamming caused by: overvoltage, underload, wrong coil. Chattering caused by: broken pole shader or poor contact in control circuit. Heavy-duty cycle. Too much jogging. Abrasive dusts, mechanical abuse.	Replace part and correct cause of damage. *Note: The expected mechanical life should be measured in number of operations.*
Noisy Magnet	Broken pole shader, magnet faces not true—result of wear or mounting strains.	Replace. (For locations where a very slight hum is objectionable, use d-c magnets. Hum can be reduced by mounting on rubber or springs to eliminate sounding-board effect.)
	Dirt or rust on magnet faces.	Clean.
	Low voltage.	Check system voltage.
	Improper adjustment—magnet overloaded.	Check manufacturer's instruction sheet.
Broken Pole Shader	Heavy slamming caused by: overvoltage, magnet underloaded, weak tip pressure, wrong coil.	Replace and correct the cause.

TROUBLE	CAUSE	REMEDY
MAGNETS AND OTHER MECHANICAL PARTS (Cont.)		
Failure to Pick Up	Low voltage on coil.	Check system voltage.
	Coil open, wiring of coil or shorted turns.	Replace.
	Wrong coil.	Ask manufacturer for recommendations.
	Excessive magnet gap, magnet overloaded.	Check instruction sheet.
Failure to Drop Out Magnet-operated Device	Mechanical binding.	Check instruction sheet, and adjust.
	Gummy substance on magnet faces.	Clean.
	Worn bearings.	Replace the part.
	Nonmagnetic gap in magnetic circuit destroyed.	Replace magnet.
	Voltage not removed.	Check coil voltage.
	Not enough mechanical load on magnet, improper adjustment.	Check instruction sheet, and adjust.
SLIDING CONTACTS **DRUM SWITCHES, RHEOSTATS, KNIFE SWITCHES**		
Overheating	Overcurrent; weak contact pressure; oxidation; high ambient; rough contacts.	See page 77 on *Copper Contacts*. For very heavy service, use special alloy contacts. Lubricate periodically as manufacturer recommends.
Abrasion Roughening of Contacts	Lack of maintenance and lubrication; very heavy service; arcing; oxidation; abrasive dirt.	Sliding contacts usually require lubrication. (Use lubricant recommended by manufacturer.) Special alloy contacts should be specified for extra-heavy service.
Arc Chutes Pitted, Worn, or Broken	Abnormal interrupting duty (inductive loads), excess vibration or shock.	Check application. *Note: On severe-duty applications, arc chutes wear out and must be replaced periodically.*
	Moisture.	Eliminate presence of moisture or keep several chutes on hand for replacement.
	Improper assembly.	See manufacturer's instruction sheet.
	Rough handling.	
Insulation Failure	Overvoltage, voltage transients, high induced voltages.	Correct system voltage. Use G-E *Thyrite discharge resistors where needed.
	Mechanical damage.	Replace damaged parts.
	Moisture, dirt and fumes, overheating (carbonizing).	Keep controls clean and dry. Get special coil for application.

SPECIFIC DEVICES

TROUBLE	CAUSE	REMEDY
OVERLOAD RELAYS **MAGNET-OPERATED INSTANTANEOUS TYPE**		
High Trip or Low Trip	Wrong coil.	Install coil with correct rating.
	Shorted turns (on high trip).	Test coil and replace with new coil if found defective.

*Reg. U. S. Pat. Off.

TROUBLE	CAUSE	REMEDY
OVERLOAD RELAYS (Cont.)		
High trip or low trip (Cont.)	Mechanical binding; dirt, corrosion, etc.	Clean parts with carbon tetrachloride.
	Assembled incorrectly.	See manufacturer's instruction sheet.
	Wrong calibration.	Refer to manufacturer.
MAGNET-OPERATED INVERSE-TIME TYPE		
Slow Trip	Fluid too heavy, vent too small, or temperature too low.	Change fluid and open vent slightly, or regulate temperature.
	Mechanical binding; dirt, corrosion, etc.	Clean parts with carbon tetrachloride.
	Worn parts.	Replace and adjust.
Fast trip	Worn or broken parts.	Replace.
	Same as above, except fluid (fluid dry or too light). Vent too large or temperature too high.	Use heavier fluid or close vent slightly or regulate temperature. Dashpots should be cleaned periodically and refilled with new oil.
THERMAL TYPE	Wrong size of heater.	Check rating with recommendations on instruction sheet.
Failure to Trip Causing Motor Burnout	Mechanical binding; dirt, corrosion, etc.	Clean and adjust.
	Relay previously damaged by short circuit.	Replace relay.
	Motor and relay in different ambient temperatures.	Install motor and control near to each other, or make temperature uniform for both.
Trips at Too Low Temperature	Wrong heater.	Check rating with recommendations on instruction sheet.
	Assembled wrong.	See instruction sheet.
	Relay in high ambient temperature.	Install controls closer to each other, or make temperature uniform.
	Wrong calibration.	Consult manufacturer.
Failure to Reset	Broken mechanism; worn parts; corrosion, dirt.	Replace broken parts, clean and adjust.
Burning or Welding of Control Contacts and Shunts	Short circuits on control circuit with too large protecting fuses.	In general, install fuses of not over 10-ampere rating.
	Severe vibration.	Re-mount control.
	Dirt, corrosion.	Clean and adjust.
	Misapplication, handling too heavy currents.	Reduce current or get manufacturer's recommendations.
TIMING RELAYS		
MECHANICAL ESCAPEMENT TYPE		
Mechanical Wear or Broken Parts	Abrasive dirt.	Clean and replace worn parts.
	Misapplication.	Get manufacturer's recommendations.
	Very heavy duty cycle.	In general, not designed for continuous cycling.
Jamming or Sticking	Dirt; corrosion; lack of lubrication; worn or broken parts (see above).	Clean and lubricate moving parts; replace worn or broken parts.
FLUX-DECAY TYPE		
Too Short Time	Dirt in air gap.	Clean.
	Shim too thick.	Replace with thinner shim.
	Excess spring and contact pressure.	See instruction book.

TROUBLE	CAUSE	REMEDY
TIMING RELAYS (Cont.)		
FLUX-DECAY (Cont.)	Misalignment.	Correct alignment and remedy the cause.
Too Long Time	Shim worn or too thin.	Replace with heavier shim. (Use brass screws with steel-backed shims.)
	Weak spring and contact pressure.	See instruction book.
	Gummy substance on magnet faces, or mechanical binding.	Clean and adjust.
MAGNET-OPERATED CAPACITOR TYPE		
Too Short Time	Dirt in air gaps.	Clean.
	Excess spring and contact pressure.	See instruction book.
	Misalignment.	Correct alignment.
	Not enough capacitance or not enough resistance in discharge circuit.	Check with manufacturer to see if capacitor and resistor are correct.
Too Long Time	Mechanical binding or sticking.	Clean and adjust.
	Worn shim.	Replace.
	Weak spring and contact pressure.	See instruction book.
	Too much capacitance or resistance.	Check manufacturer.
MOTOR-OPERATED TYPE	Worn or broken parts.	Replace parts and adjust them.
Failure to Time Out	Corrosion, dirt.	Clean.
	Motor damaged.	Check condition of motor electrically and mechanically.
	No voltage on motor.	Check circuit.
Failure to Reset	Worn or broken parts; corrosion dirt.	Same as for *Failure to Time Out*.
BRAKES		
MAGNET-OPERATED OR THRUSTOR OPERATED		
Worn or Broken Parts	See magnets and other mechanical parts (above).	
	Heavy duty cycle, high-inertia loads, excess temperature, rough surface of wheels, misapplication.	Check application. Perhaps a larger or different-type brake is needed.
Failure to Hold Load	Worn parts, out of adjustment, wrong friction material used for replacement.	Use renewal parts recommended by the manufacturer.
	Grease or oil on brake wheel.	Clean thoroughly.
Failure to Set	Out of adjustment; worn parts, mechanical binding.	Replace worn parts and adjust them.
	Coil not de-energized.	Examine break and check circuit to make sure current is cut off.
Failure to Release	Out of adjustment.	See manufacturer's instructions.
	Coil not energized—low voltage or current.	See *How to Care for Coils,* page 80
	Wrong coil.	Check with manufacturer, or see *How to Care for Coils,* page 80.
	Shorted turns or coil open.	See manufactuer's instructions.
	Coil not energized; low voltage or current.	Check to see if coil is getting correct voltage or current and see *How to Care for Coils,* page 80.
	Open coil or shorted turns.	Replace coil.

TROUBLE	CAUSE	REMEDY
VALVES		
ELECTRICALLY OPERATED, SOLENOID, THRUSTOR, OR MOTOR OPERATED		
Leaks and Mechanical Failure	Worn valve seal.	Replace seal or valve.
	Abrasive matter in fluid.	Check application; use strainer ahead of each valve.
	Corrosion.	Remove corrosive elements from fluid or get manufacturer's recommendations.
Noise	Same as for *Noisy Magnet*, page 86.	See *Noisy Magnet*, page 84.
	Water hammer.	Install surge tank.
THRUSTOR MECHANISMS		
Short Life	Abrasive dust or water in the oil.	Change oil more frequently.
	Mechanical damage.	Replace broken parts and assemble with care.
Failure to Move Load	Worn parts.	Replace worn parts.
	No voltage on motor.	Check circuit.
	Misapplication.	Get manufacturer's recommendations.
THERMOSTATS		
BULB AND BELLOWS TYPE WITH EXPANDING FLUID		
Bellows Distorted	Mechanical binding.	Clean and adjust.
	Temperature too far above normal.	Replace bellows.
Bulb Distorted	Liquid frozen in capillary tube, or tube stopped up.	Replace bulb and bellows assembly.
RESISTORS		
Insulation Failure	See *Insulation Failure*, page 87.	
Overheating	Rating too low.	Install larger resistor.
	Running on starting resistor.	Check the timer to make sure it operates.
	Restricted ventilation.	Relocate.
Open Circuit	Burned out from overheating.	Replace resistor, and see above.
	Corrosion, moisture, acid fumes.	Relocate or correct atmospheric conditions.
	Mechanical damage.	Replace worn or broken parts.
RECTIFIERS		
DRY TYPE		
Overheating	Overvoltage.	Correct system voltage.
	Overcurrent intermittent-rated unit left on continuously.	Check operation of circuit.
	High ambient.	Relocate unit or correct condition.
	Misapplication.	Get manufacturer's recommendation.
Failure	Overheating, corrosive atmosphere, overvoltage, mechanical damage.	Same as for *overheating*.
Burnout or Breakdown		

TROUBLE	CAUSE	REMEDY
CAPACITORS		
Breakdown or Failure of Dielectric	Overvoltage.	Check system voltage.
	Voltages surges caused by switching or lightning.	Install protective equipment.
	Some type not usable on a-c.	Check application.
	Moisture, corrosion, or high temperature.	Correct condition, or install special unit.
	Continuous voltage on intermittent-rated unit.	Install proper unit.
	Mechanical damage.	Replace capacitor.
	Wrong polarity on d-c unit.	Replace capacitor and reconnect, changing polarity.
FUSES		
Premature Blowing	Fuse too small.	
	Heating at ferrule contacts, corrosion or oxidation of ferrules and clips.	Keep ferrules and clips clean. Use plated clips and ferrules; replace annealed clips.
	Weak contact pressure.	Provide adequate pressure.
Too Slow Blowing	Wrong size of fuse for application.	
AIR CIRCUIT BREAKERS		
Premature tripping	Setting too low for motor starting current.	If adjustable type trip coil, slightly increase tip setting.
	Repetitive closing or jogging of motor starting currents.	Check type of load and current peaks vs trip setting.
	Undervoltage device control circuit, when used, and auxiliary pilot devices affected by open circuit or loss of voltage.	
	Incorrect trip rating.	
Failure to latch-in or to open or reset	Incorrect adjustment of trip mechanism.	Refer to breaker instructions and adjust.
	Worn parts as pins, links, or broken springs etc.	Check and adjust all operating parts and control circuits.
	Excessive currents causing contact wear.	
	Fault in remote control circuit.	
	Door mechanism, when used, out of adjustment.	
	Trip element or mechanism damaged due to excessive current.	
	Excessive corrosion or accumulation of foreign material.	
	Arc chutes damaged due to excessive currents.	
Short contact life	Corrosion of contacts.	Check motor starting current.
	Excesive currents and frequent closing and opening of circuit.	Reduce duty cycle.
	Short circuits, loose connections.	Refer to Mfr. See page 82.
	Mis-application.	Do not file silver contacts.
	Excessive filing or dressing.	
WELDING OF CONTACTS	Abnormal inrush motor starting currents.	Reduce currents.
	Rapid jogging.	Use suitable contactor to switch circuit to normal duty.
	Incomplete manual closure.	Frequent inspection of contacts.
	Inadequate maintenance for renewal of contacts.	Renew contacts.

TROUBLE	CAUSE	REMEDY
TRANSFORMERS		
Overheating	Overcurrent or overvoltage.	Check load on transformer and system voltage.
	Intermittent-rated unit left on continuously.	Failure of other devices to operate properly.
	High ambient.	Relocate transformer or reduce load.
	Shorted turns.	Replace coil.
Insulation Failure	See *Insulation Failure*, page 85.	
MASTER SWITCHES **PUSH BUTTONS** **SELECTOR SWITCHES** **MANUAL CONTACTORS** **LIMIT SWITCHES** **SPEED SWITCHES** **FLOAT SWITCHES** **FLOW SWITCHES** **PRESSURE SWITCHES** **KNIFE SWITCHES** **RHEOSTATS** **DRUM SWITCHES**	See *Contacts*, page 83. See *Mechanical Parts*, pages 84 and 85. See *Insulation Failure*, page 85.	
MANUAL STARTERS	See *Contacts*, page 83. See *Sliding Contacts*, page 85. See *Mechanical Parts*, pages 84 and 85. See *Insulation Failure*, page 85. See *Thermal Overload Relays*, page 86.	

GENERAL INFORMATION

ONE of the advantages of electronic control is the small number of moving and wearing parts. Because of the nature of the components—such as resistors, reactors, transformers, and capacitors, this type of G-E control requires very little maintenance. The electron tubes themselves, while replaceable items, require inspection and testing at comparatively long intervals.

Many parts of electronic control are similar to those used in magnetic control: the enclosing cases, bases, and terminal, wiring, and conduit devices. Standard magnetic control devices such as fuses, switches, overload relays, and both instantaneous and time-delay relays will be found on many electronic panels. These devices usually perform starting or protective functions and operate infrequently. This infrequent operation sometimes leads to special maintenance problems.

EQUIPMENT FOR TESTING CIRCUITS

Since many circuits on electronic panels have a very high impedance, in order to properly service this equipment, meters having high impedance are required. The radio-service multimeter, having a resistance of 1000 ohms per volt or higher, is a useful tool, but some circuits can be tested only with electronic instruments such as the vacuum-tube voltmeter (Volt Ohmyst or similar), or the cathode-ray oscilloscope. The cathode-ray oscilloscope, particularly when modified to read d-c potentials, is an extremely useful device because it combines a very high impedance voltmeter with a time axis, thus voltage changes that are much too rapid for the ordinary instrument to follow are made visible. Instantaneous thyratron grid and plate potentials can be observed easily, and any incorrect operation can be quickly detected.

TROUBLE-SHOOTING CHART

GENERAL ITEMS FOR ALL TYPES OF ELECTRONIC CONTROL

Loose connection, or leads breaking	Excessive vibration.	Install extra-flexible connections.
Reduced tube life, or tube failure	Vibration or mechanical abuse.	Shock-mount the control panel and use extra-flexible leads. Prevent objects from striking tube holders and sockets. Elements may be jarred out of position or the weld on leads may be broken.
WARNING: Tube filament or heater circuits may be at high voltage above ground. Use extreme care in making measurements and adjustments.	Natural deterioration. Usually failure is due to gradual loss of electron emission as the active cathode material is used up or flakes off.	Be sure deterioration is at a rate consistent with expected life for each type of tube in its particular service. If the tube life seems too short, see following recommendations.
	Incorrect voltage on filament or heater.	Check voltage at tube terminals frequently to determine nature of error. Do this with tube in socket both with and without anode load connected.
	If voltage is: Fluctuating (more than plus or minus 5 per cent from rating)	Install voltage regulating transformer.
	Consistently high or Consistently low	Adjust taps (if any) on transformer, or install new heater transformer, or install auto or booster transformer to correct voltage.
	Poor contact between socket and tube base pins.	Tighten socket contact springs or replace socket if springs are discolored due to overheating.

TROUBLE	CAUSE	REMEDY
Reduced tube life, or tube failure (cont.)	If voltage is: Erratic---on and off.	Check wiring from heater supply to tube sockets for loose connection or break.
	Ambient temperature too low or too high.	Provide extra heat or forced air cooling to hold temperature within limits specified in tube instructions. Ambient temperature should be measured *at the tube*. Consult tube instruction sheet before applying cooling means.
	Excessive loading.	Tube should not be operated at outputs greater than those for which it has been designed.
	Too frequent operation.	When equipment is used intermittently, tube life may be increased by leaving cathodes heated during unloaded periods. This prevents strains caused by too frequent heating and cooling.
	Defective tube.	Replace tube.
Mercury-vapor tubes don't 'fire'	Ambient temperature too low.	Measure air temperature next to tube; provide heat to bring temperature up to value specified in tube instructions. Manually or thermostatically controlled strip heaters are recommended.
Arc-backs after tubes have warmed up	Ambient temperature too high.	Provide forced-air cooling according to instruction sheet on tubes. (Mercury-vapor tubes are rated on the basis of "condensed mercury temperature.")
Arc-backs when tube is first placed in service	Mercury vapor splashed on elements during shipment or handling of tube. Tube not kept in upright position.	Heat the tube cathode to distill this mercury before anode power is applied. Make sure cathode is heated for the length of time stipulated in instructions furnished with tube.
Failure of tubes to operate when starting equipment	Interlocks or protective control devices not operating properly.	Check contacts to see that they close and that they are clean.
	Cathode protective timer has not completed its timing cycle.	Wait until timing cycle is completed before attempting to operate equipment.
	No voltage at control panel terminals.	Check external connections to be sure they are correct. Check fuses. Check panel connections to be sure they are right.
	Incorrect power.	Check the terminal voltage to make sure it corresponds with nameplate rating.
	Missing connection.	Recheck the circuit with wiring diagram.
	Tubes will not heat up.	Check with wiring diagram to make sure tubes are in the right places. The thyratron tube will be warm when cathode is heated. *Do not touch metal power tubes while power is on the panel.*
	Tubes may have been damaged internally through shipment.	Replace tube.
Overheated transformer or reactor	Overload.	Check cause of overload and remove
	Defective unit.	Warning is usually given by the odor of excessive heating melting of the sealing compound, smoking or charring of the insulating paper. Replace transformer.

INSPECTION SCHEDULE

ELECTRONIC CONTROL FOR RESISTANCE WELDING

	WHAT TO INSPECT	WHAT TO INSPECT FOR
MONTHLY	**Over-all mechanical inspection with power-supply and control voltage disconnected but water supply turned on.**	
	Water-supply system	Leaks or corrosion at fittings. See that there are no kinks in hose connections. Water-flow switch should not allow control to be operated on less than required water flow. Mechanical-type flow switch should be tested at this time. Thermal-type flow switch, which requires control voltage, should be tested later. Water should flow upward through power tubes. If solenoid valve is used for water saver, its operation should be checked later when the control power is applied.
	Tube sockets and anode and grid connectors	Remove anode and grid connectors and remove tubes from sockets. Remove dust (especially any metallic dust) from top of socket. Replace tubes, making sure that each tube is replaced in the same socket from which it was removed, replace anode and grid caps, and inspect tightness of tube connections.
	Relays	Should be in de-energized position. Inspect tip condition and wipe.
	Adjustable parts	Knobs should be tight.
		Slider brushes should make good contact with resistor windings. Tapped rheostats should be clean.
	Wiring and connections	Inspect for loose connections at screw terminals and soldered joints, loose sliders on adjustable resistors, and clearance between exposed wires (capacitor and resistor leads), and live parts. Inspect power-tube connections to insure they are tight. Inspect plugs and sockets to assure that connections are tight and that wiring has not been pulled loose.
	Ignitor fuses	Be sure ignitor fuses of correct size are being used.
	Control operation inspection	
	Cathode heater timer; first apply control voltage only.	Check for correct time interval as specified in structions for tubes.
	During time delay for cathode heating	Thyratons should not glow except for small grid-current glow in tubes having self-rectified grid bias.
		Firing-tube-anode protective relay should not respond to water flow.
		If thermal-type flow switch is used, be sure correct voltage is applied to heating element.
	After cathode heating time	Thyratron for rectified d-c supply should glow. Firing-tube-anode protective relay should respond to operation of water-flow switch. Do not touch metal power tubes. All hot-cathode tubes should show evidence of heating. Interior surface of glass tubes should be free of condensed mercury except near lower part of glass bulb. Mercury adhering to glass walls in upper part of bulb indicates improper ventilation or air leak in tube.
	Operation of control circuit	In most cases the operation of control timing circuits may be inspected without applying power to the welder. During operation, mercury thyratrons should have a deep blue glow. Greenish or very light blue glow indicates presence of foreign gas for mercury tubes but is characteristic of gas filled types.
		Check control adjustments (dial settings, switch positions, etc.)
	Over-all operation	
	Apply control voltage, power-supply voltage, and water. Make welds on scrap metal.	During operation both firing tubes should have somewhat uniform flicker. Flaring of firing tubes indicates hard-starting ignitrons or insufficient load current for starting ignitrons. See *Trouble-shooting Chart*, page 95.

TROUBLE-SHOOTING CHART

ELECTRONIC CONTROL FOR RESISTANCE WELDING

Note: Be sure that the control was correctly installed and is being operated in accordance with its nameplate ratings. Consult instruction book, if available.

Safety Notes: Remove all power from the control circuit and welder before replacing tubes, connecting in meters, or doing any work on the control.

The water jacket of the ignitron power tube is at cathode potential. Therefore, do not touch these tubes unless power switch and control switch are both open.

A-C CONTROLS

TROUBLE	CAUSE	REMEDY
No welding current when weld-initiating switch is closed:		
If both firing tubes operate for normal timing	Secondary circuit of welder open.	Make sure that electrodes fully close on work. Inspect joints in electrodes and electrode holders.
	Welding transformer set on too low heat tap or heat control (phase control) set too low for welding heat.	Compare all time and heat settings with values specified for work to be done.
If neither firing tube operates, but control tubes operate for normal timing	Power supply off.	Close line circuit breaker or replace line fuses.
	Ignitron power tubes have open ignitor circuits:	
	Protective relay de-energized.	Make sure safety switch closes.
		Make sure cathode heating period for firing tubes has elapsed.
	Water-flow switch or temperature control switch on ignitron tripped out.	Make sure cooling water for power tubes is adequate. Be sure cooling water is not too warm. (Also see remedy for ***Power Tubes Too Hot,*** page 96.)
	Ignitorsdisconnected, or firing tube anode or grid caps are off.	Also inspect ignitor leads and be sure ignitrons are mounted vertically with cathode end down.
	Ignitor fuses blown.	Do not increase fuse size, but if replacement fuses also blow, check the following:
	Incorrect protective resistorin ignitor circuit.	When power-supply voltage is less than 250 volts, connect ignitor series resistors for 1 ohm. When power-supply voltage is more than 250 volts, use total resistance of 4 ohms. (Except three-phase frequency changer.)
	Phase-controlled heat setting too low.	When power-supply voltage is less than 250 volts, do not decrease heat control (phase control) below 40 per cent on heat-control dial. (No limit on three-phase frequency changes.) Check initial heat setting if slope control is used.
	Insufficient load current.	If firing tubes flare when ignitor fuses are replaced, make sure that the power-tube load current is sufficient for starting ignitrons (40 amperes reactive load or 25 amperes resistive load). Flash welders require auxiliary load resistor.
	Defective copper-oxide rectifier.	Replace copper-oxide rectifiers in ignitor circuits.
	Copper-oxide rectifier short-circuited to ground.	Replace copper-oxide rectifiers in ignitor circuits.
	Defective ignitron tube.	Install new power tube. When installing new power tubes, also install new firing tubes. If this overcomes trouble, retest old power tubes by reinstalling one at a time.
	Firing-tube cathodes not heated.	Make sure that filament voltage is correct. Substitute new firing tubes.
	Heat-control circuit open.	
	Heat-control potentiometer or rheostat open.	Try full-heat setting, using short timing and low-heat tap on welding transformer, and then try weld on scrap stock.
	Full-heat limit resistor open.	Be sure slider adjustment makes good contact on winding.

TROUBLE	CAUSE	REMEDY
No welding current when weld-initiating switch is closed. (cont.)	Phase-control (heat control) circuit open.	Cathode-ray oscilloscope should be used for checking component voltages in grid circuits of firing tubes.
	Series capacitor for power-factor improvement not charged.	Energize welder at reduced heat (phase) setting to charge series capacitor and then readjust heat dial for desired setting.
If neither firing tube operates, and control tubes do not operate	Refer to remedies for *Protective Relay De-energized* and *Water - flow Switch Tripped Out*, page 95.	
	A-c control-voltage fuse blown.	Be sure correct tap on primary of control transformer is being used. If replacement fuses blow, disconnect load on secondary of control transformer. Then apply control voltage to check transformer for short circuit. If transformer is all right, reconnect load, one item at a time, until short circuit is found.
	No d-c control voltage.	If rectifier tube does not glow, make sure cathode is heated and replace d-c control voltage fuse. If new fuse blows, substitute new rectifier tube. If trouble still persists, check filter capacitors and resistance of d-c voltage-divider circuit by using high-resistance voltmeter.
	Sequence or weld-initiating circuit open.	Make sure initiating contacts close.
	Keying tube does not operate.	Inspect contacts in anode circuit. Substitute a tube known to be good. Be sure anode voltage is applied, and that grid voltages are correct. Complete inspection requires using cathode-ray oscilloscope.
Welder energized when power switch is closed	Initiating circuit already closed.	Check this point if ignitron contactor is being used.
If one or both firing tubes operate, but control tubes do not operate	A-c control voltage reversed or out of phase.	Be sure that phase relation between power and control voltages has not been altered by changes made farther back on lines.
Sequence timer goes through a sequence without initiation	Loss of bias (metallic rectifier or tube rectifier), or shorted filter capacitor.	Replace necessary components.
	Ignitrons fired by a-c, caused by insulation breakdown between grid circuits of firing tubes.	Remove power and control voltage, disconnect both ignitor leads, and test for insulation breakdown between grid circuits of firing tubes, between each grid circuit and main control circuit, and between each grid circuit and ground. If defect is found, clear fault, and repeat test. Replace overheated transformers, but retest circuits before applying control voltage.
If neither firing tube operates	Power tubes too hot. (Also refer to preceding item.)	Make sure cooling water is adequate and not too warm. Make sure operating duty cycle is not too high. Refer to rating curves. Demand current at full-heat (phase-control) setting must be used for selecting size of power tube.
	Defective power tube.	Find which tube is defective by disconnecting and insulating one anode connector at a time.
Electrodes flash when closing on work	Weld-initiating switch being closed too soon.	Retard cam switch or increase squeeze period. If this does not correct trouble, prevent initiating switch from being closed during test for *Welder Energized When Power Switch Is Closed*.
Electrodes flash when separating from work	Weld-initiating switch still closed, and weld time not elapsed.	If ignitron contactor is being used, make sure weld time has elapsed. Make sure hold period is not initiated before end of weld time.
If firing tubes are still on	Electrodes being opened before weld time elapses.	
	Hold period is too short.	Make sure hold period is not initiated before end of weld time.

TROUBLE	CAUSE	REMEDY
Trailing firing tube operates	Power-factor starting adjustment incorrectly set, causing residual transient in welder secondary following weld. When secondary circuit is opened, the interruption of the transient triggers the trailing firing tube.	Readjust synchronous starting adjustment. Magnetic-type oscilloscope or cathode-ray oscilloscope should be used for this purpose. See instruction book for control being used.
	Thyrite discharge resistor not connected across primary of welding transformer.	Discharge resistor may be in control panel but may not be properly connected to primary of welding transformer.
If firing tubes are not still on or do not flash when electrodes separate from work	Power tubes too hot.	Make sure cooling water is adequate and not too hot. Make sure operating duty cycle is not to high. Refer to rating curves. Demand current at full heat (phase control) setting must be used for selecting size of power tube.
Line breaker trips or line fuses blow when welding is attempted		
If both firing tubes operate	Line circuit breaker may be set too low or fuse size may be too small.	Check power-tube ratings before setting line protection higher.
If only one firing tube operates (Causes saturation in welding transformer)	Over load.	Reduce load.
	Heat control (phase control) advanced ahead of power-factor angle.	Reduce heat setting. If both firing tubes then operate, readjust full-heat limit.
	One ignitor disconnected, one firingtube anode cap off, or one of protective-relay contacts not closed.	Inspect ignitor leads and inspect "wipe" on protective-relay contacts.
	Ignitor fuse blown.	If ignitor circuits are fused separately, interchange positions of power tubes. If the fuse blowing follows one power tube, put in a new power tube. Put in new firing tube when power tube is changed. If fuse blowing still persists, refer to remedy for *Ignitor Fuses Blown* page 95.
	One firing tube defective.	If cathodes of both firing tubes are heated, interchange positions of the firing tubes to check tube.
	A-c control voltage reversed or out of phase with power supply.	Be sure that phase relation between power and control voltages has not been altered by changes made farther back on lines.
	Incorrect tap setting on feed-back transformer for trailing firing tube.	Refer to installation notes on wiring diagram.
	Trouble in phase-shifting (heat control) circuit or auxiliary heat regulating controls.	Inspect component parts. Inspect component voltages by using cathode-ray oscilloscope.
Abnormal timing		
	Bouncing weld-initiating switch.	Inspect switch for mechanical wear or loose mounting.
	Excessive voltage variation.	Obtain control voltage from farther back on lines. Do not change phase or polarity.
	Thyrite discharge resistor not connected across primary of welding transformer.	Discharge resistor may be in control panel but may not be properly connected to primary of welding transformer.
	Defective timing tube.	Thyratron having greenish or very light blue glow (instead of deep blue glow) during operation indicates defective tube. Interchange timing and control tubes of same type.
	Defective time adjustment.	Disconnect time adjustment, and test with analyzer.
	Timing or control tubes too hot.	Be sure ventilating windows or screens are not closed.

TROUBLE	CAUSE	REMEDY
Erratic heat control (phase control). Thumping in welding transformer		
If firing tubes and control tubes appear to operate normally	Ignitron arcs back or fires without firing impulse to ignitor.	
	Ignitron too hot.	
	Inadequate cooling water.	Make sure water-flow switch is correctly adjusted.
	Duty cycle too high.	Measure demand current and duty cycle, and refer to rating curves furnished with the tubes or equipment.
	Water flowing down through water jacket.	Refer to installation notes on wiring diagram.
	Defective ignitron.	Substitute new ignitrons and new firing tubes. Then replace old ignitrons one at a time to find which one is defective.
	Firing tube shoots through (fires without signal on grid).	Possibly indicated by mercury condensing on interior surface of a glass bulb in top of tube.
	Ambient temperature too high.	See if opening the enclosing-case doors overcomes trouble.
	Cathode voltage too low.	Firing-tube filament voltages should be within plus or minus 5 per cent of value specified on wiring diagram for *control*. (Tubes used for firing service are in some cases operated at filament voltages above general service rating.)
	Incorrect circulation of cooling air	Forced ventilation must not be applied directly on thyratrons. Air should flow upward along sides of tubes.
	Thyrite not connected across primary of welding transformer.	See if Thyrite is installed in control panel and properly connected to primary of welding transformer.
Thyratron timing tube, control tube, or firing tube fires during time it should not be operating.	Note: Small glow, near cathode is normal condition for tubes having a-c hold-off grid bias. Grid current during positive half cycle of a-c bias builds up self-rectified grid bias and causes light glow.	
	Tube too hot.	Be sure ambient temperature at the tube is not too high.
	Grid-to-cathode capacitor shorted.	Disconnect capacitor, and test for short circuit.
	Grid resistor open.	Disconnect resistor, and check resistance.
	Open in grid circuit.	Look for oxidized lockwashers in grid-circuit connections.
	A-c grid bias not 180 degrees out of phase with a-c anode voltage.	If control voltage and anode voltage are obtained from separate lines, check the phase relation.
	Tube has foreign gas, which is usually indicated by greenish or very light blue glow instead of deep blue glow in mercury tubes.	Substitute a tube known to be good.
	Mercury drops fall between tube electrodes.	Be sure mercury does not condense on interior surface of glass bulb near top of tube. Forced-air ventilation must not be applied directly on tube. Air should flow upward along sides of tube.
	Grid being triggered by other control tubes.	Use cathode-ray oscilloscope for inspecting conditions.

TROUBLE	CAUSE	REMEDY
Thyratron timing tube, control tube, or firing tube does not operate when it should	Note: Depending on circuit function, some thyratrons show evidence of operating normally by flashing once or periodically, others by steady glow at intervals, while some glow too little and too quickly to give much indication.	
	Filament may not be energized, or filament voltage may be too low.	Observe whether cathode is heated. Measure filament voltage at tube sockets.
	Tube may be too cold.	Be sure there is no mercury condensing on interior surface of glass bulb near top of tube. Air should flow upward along sides of tube.
	No anode voltage applied.	Make sure that all relay contacts and fuses in anode circuit are closed, and that anode voltage supply switch is closed.
	Grid not being triggered.	If this is not a high-voltage circuit, observe grid voltage with cathode-ray oscilloscope.
	Tube has an air leak, which is usually indicated by patches of mercury adhering to interior of glass bulb.	Substitute a tube known to be good.
	Other associated controls may not be operating correctly.	See instructions for these controls.

MAGNETIC-ENERGY-STORAGE TYPE RESISTANCE-WELDING CONTROLS

Low d-c voltage	Faulty tubes.	Replace tubes at fault. Most probable tube is ignitron. Replace associated firing tube at same time.
Excessive ripple	Open potentiometer.	Replace voltage-control potentiometer.
No d-c output	No cooling water.	Check water supply.
	Control circuit fuses blown.	Replace fuses.
	Doors open.	Close doors for proper operation.

CAPACITOR-ENERGY-STORAGE TYPE RESISTANCE-WELDING CONTROLS

Capacitors fail to charge	Faulty tubes.	Replace tubes.
	Shunting contactor not picked up.	Check circuit for opens.
Excessive capacitor charge	Faulty tubes.	Replace tubes.
	Inadequate cooling.	Close slide gates in air-pressure chamber.
Irregular voltage across capacitor	Failure of bias supply or amplifier components.	Replace faulty parts. The trouble may be caused by tube, capacitor, resistor, or transformer.
Capacitors fail to discharge	Faulty tubes.	Replace tubes.
	Open discharge circuit.	Complete circuit where open.
	Sequence timers not operating.	Recondition defective unit.

THREE-PHASE FREQUENCY-CONVERTER WELDING CONTROLS

Only Phase A firing tubes and ignitrons operate	Phase rotation reversed.	Reverse any two (welding and control) power leads.
Line breaker trips and/or severe transformer thumping	Overload.	Reduce load or duty factor.
	Commutation fault.	Extend interpulse time.
	Transformer saturation.	Operate several times with welding power at low heat.
Others	See troubles and remedies listed above under A-c Controls. Consult instruction book.	

INSPECTION SCHEDULE

PHOTOELECTRIC CONTROL

FREQUENCY	WHAT TO INSPECT	WHAT TO INSPECT FOR
1000 to 3000 hours	**Light-source lamps**	To prevent shutdowns caused by lamp burnouts, replace lamp each 1000 to 3000 hours, depending upon voltage applied. (Refer to instructions with equipment.)
1 to 3 months, depending on frequency of operation	**Contacts of magnetic relay**	Excessive wear, burning, or pitting. Replace contacts if necessary. Contact springs on telephone type relay should not be adjusted or replaced. Replace complete relay, if necessary.
1 to 6 months, depending on local conditions	**All glass or plastic surfaces through which light passes or from which it is reflected, such as lenses, phototubes, windows, and mirrors**	Dust, oily film, or any foreign matter which restricts the passage of light. Clean the surface. If oil film is present, use a suitable solvent. Since plastic surfaces are quite soft, care must be taken not to scratch the surface. Such surfaces should be cleaned with an air supply or dusted lightly with a cloth or brush. If necessary to use water or solvent, rub surface very carefully so as not to cause abrasive action of material being removed from surface. Replace all glass or plastic parts which have become scratched or broken.
1 to 6 months	**Control panel, phototube holders, and other auxiliary electronic equipment**	Presence of dirt, metallic dust, and other foreign material. Because of the high impedance of most electronic circuits, such accumulations may cause trouble. The presence of moisture will make the condition much worse. Particular attention should be given to the phototube portion of the circuit, since the effective impedance of a phototube may be 50 to 500 megohms. Therefore, any leakage in associated cables, sockets, or panel surfaces must be in excess of several thousand megohms.
1 to 3 months	**Light sources, phototube holders, apertures, mirrors, and other parts included in the optical system**	Proper alignment of these parts. Equipment subjected to vibration may develop loose supports, or it may be accidentally struck by some object and knocked out of position.
3 to 6 months	**Connections to terminals and plug connections**	Under conditions of vibration these connections may work loose. Tighten securely.
1 to 3 months, depending upon local conditions	**Air filter**	Air filters on ventilated cases should be cleaned out and replaced. If filter is of a type which cannot be cleaned, replace with new filter.
3 to 6 months	**Mechanical auxiliaries used with photoelectric equipment**	Contact wear, loose parts, proper lubrication, etc.

TROUBLE-SHOOTING CHART

PHOTOELECTRIC CONTROL

TROUBLE	CAUSE	REMEDY
Magnetic relay in photoelectric device does not operate when light to phototube is changed	No light on phototube, or light reduced below that required for operation.	Check light source. Replace lamp if burned out.
	Light source, phototube holder aperture, or surface from which light is reflected may be out of alignment.	Align correctly and check mounting supports for evidence of vibration.
	Dirt on surfaces through which light passes or from which it is reflected.	Clean the surfaces and inspect at regular intervals.
	Line voltage not within the limits specified.	Correct line voltage. Use stabilizing transformer, necessary.
	Defective tubes.	Check tubes, or if unable to do so, try new ones.
	Positioning key in center of tube base (radio-type tubes) may be broken and tube has been placed in socket incorrectly.	Replace tube. If another one is not available, check alignment of tube pins before replacing in socket.
	Excessive light reaching the phototube from some source other than the light source.	Shield phototube from extraneous light or relocate phototube holder. Use lens barrel and aperture.
	Defective circuit components, such as resistors, capacitors, etc.	If circuit voltages have been included with instructions, check these as a means of locating the trouble. Otherwise, make a visual inspection of the panel for defective parts, and check values of components with suitable testing equipment. Particular attention should be given to electrolytic capacitors, since this type of capacitor has a limited life, and failure may occur after several years of operation. When replacing, be sure to observe polarity.
	Excessive leakage in phototube cable or circuit associated with phototube—caused by moisture accumulation or poor insulation.	Check for leakage of phototube cable, phototube socket, and terminals where cable connects to panel. Total leakage resistance should measure at least 2000 megohms.
	Open magnetic relay coil.	Replace coil.
Photoelectric relay operates erratically	Variation in light on phototube resulting from worn lamp contacts or other causes.	Replace lamp. Light source, phototube unit, aperture, or surface from which light is reflected may be moving due to vibration or loose supports.
	Variation in line voltage outside the limits specified for the device.	If possible, use a better regulated power supply, such as is ordinarily used for lighting circuits. Otherwise, install a constant-voltage transformer.
Magnetic relay on the photoelectric unit opens and closes continuously at a rapid rate	Grounded side of power supply on wrong terminal of photoelectric unit.	In photoelectric relays not provided with anode transformer, grounded side of power supply must be connected to terminal as specified in the instructions. If power supply cannot be grounded, a 1-to-1 ratio transformer should be installed and the proper terminal of the relay grounded.
	Capacitor which is connected in parallel with the relay coil may be open.	Replace capacitor.
	Filter capacitor in rectifier may be open.	Replace capacitor.
Contacts on "sensitive"-type relays either stick or do not make good contact	Contacts worn badly.	Replace relay.

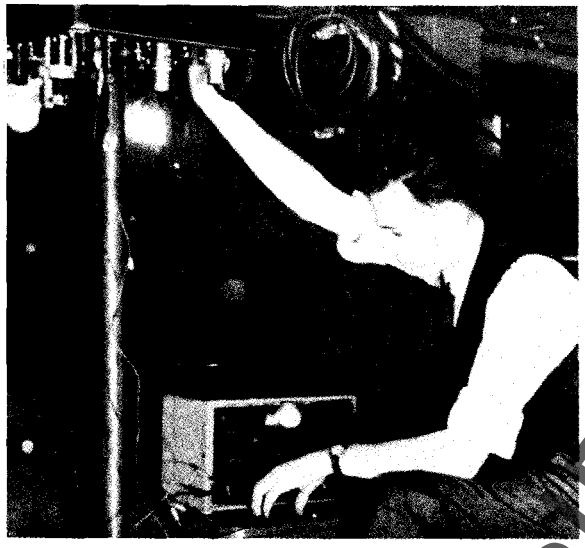
TROUBLE-SHOOTING CHART

PHOTOELECTRIC REGISTER CONTROL

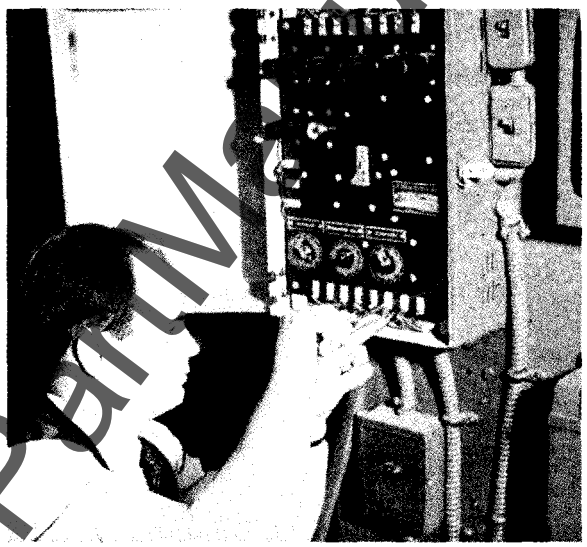
In some of the special types of photoelectric equipment, such as cutoff register and side register control, the electronic equipment is used to provide a signal to a generator and motor. These, in turn, operate a mechanism to effect a correction. Since the proper functioning of the equipment depends upon all units being in working order, it is essential that all auxiliary equipment must be thoroughly inspected in the event of trouble, as well as the electronic portion of the control. Such factors as backlash in gearing and mechanical linkages, loose couplings, and improper lubrication of bearings are some of the factors which prevent electronic control from operating satisfactorily.

TROUBLE	CAUSE	REMEDY
Equipment does not provide a signal to correcting motor, as evidenced by failure of motor to respond (side and cutoff register)	No signal being obtained from scanner, as observed on cathode-ray oscilloscope.	Check circuit of scanner for loose connections or defective parts. Test tubes or replace with new ones. Readjust per instructions with equipment when tubes are replaced.
	Light-source lamp burned out	Replace lamp.
	On account of vibration, loose mounting bolts, or other causes, scanner may have been moved out of its correct position.	Readjust position of scanner. Provide lockwashers if necessary.
	Light source or phototube lenses may be out of adjustment.	Readjust according to instructions provided with equipment.
	Register marks or lines do not have sufficient contrast with background.	Improve contrast by using a different color for the marks or lines, or using a different shade of the same color. Try phototube of other color sensitivity.
	Signal obtained from scanner, but no signal from control panel to corrective machines.	Test tubes, or replace with new ones if necessary. Check control panel in accordance with instructions furnished. Check panel adjustments. Try phototube of other color sensitivity.
	Signal being obtained from control panel, but no response from corrective mechanism.	Inspect all motors, generators, contactors, and other parts in the corrective mechanism.
Material is continuously being either advanced or retarded (cutoff register)	Slippage in draw rolls caused by improper or varying tension on the material, causes it to go out of register faster than the control can correct.	Adjust tension so that any slippage that does occur is within the correcting capabilities of the machine.
Material is continuously being alternately advanced and retarded about point of correct register (cutoff register)	"Dead" zone, as determined by selector switch, too narrow or too wide.	Adjust selector switch according to instructions with equipment.
	Correction time may be too great.	Reduce time by adjustment on control panel.
	Incorrect adjustments of electronic or auxiliary equipment.	Adjust according to instructions with equipment.
	Printing adjacent to register marks may interfere and cause false signals.	Decrease "live" zone of selector switch, if possible or change location of register marks on material.
Material is maintained to approximate register, but is not within the accuracy which the equipment is capable of holding (cutoff and side register)	Defective tubes.	Test tubes or replace with new ones. If replaced, readjust system per instructions.
	Incorrect adjustments of electronic equipment.	Adjust according to instructions with equipment.
	Improper operation of auxiliary electric and mechanical equipment.	Inspect and readjust, or correct faulty parts.
	Register marks not spaced accurately on material (cutoff register only).	Accuracy of register-mark spacing must be well within the accuracy that is to be maintained.

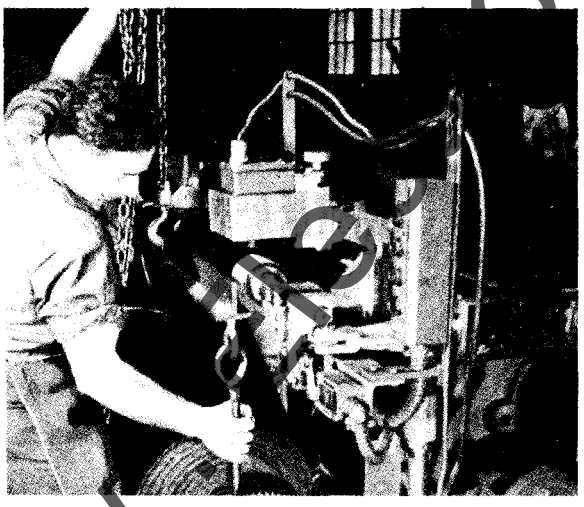
TROUBLE	CAUSE	REMEDY
Material oscillates back and forth about point of correct register (side register)	Rate at which material deviates from correct register may be greater than the ability of machine to correct (side register only).	Change mechanical equipment to provide higher correcting speed, or lower the speed at which the material passes through machine so as to reduce the rate of lateral run-out.
	Sensitivity too high or other controls may be out of adjustment.	Reduce sensitivity and check other adjustments according to instructions.
	Corrective mechanism may have developed excessive backlash in gearing or mechanical linkages.	Inspect machine and correct defects. During machine operations, equivalent backlash of machine elements referred to the web should be far less than the desired accuracy.



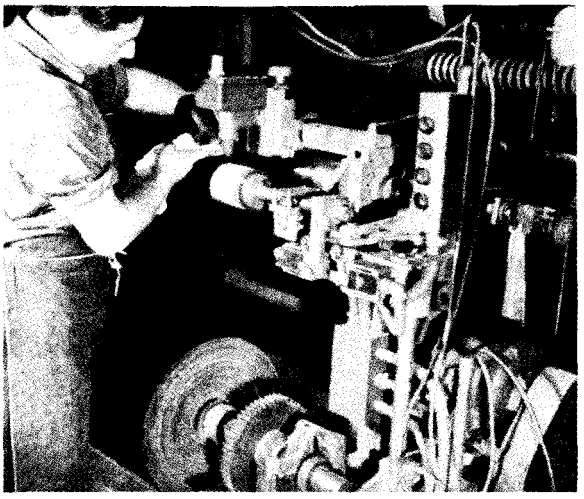
Probably the most useful single instrument for servicing electronic devices is the cathode-ray oscilloscope when modified to register d-c voltages.



Where panel is subject to vibration, regular checks should be made to make sure screws and bolts are tight.



Photoelectric scanning heads and other parts should be protected mechanically from equipment which may disturb their adjustment. Here a guard has been placed around the scanning head to prevent the hoist from striking the head.



Lenses and other parts of the optical system should be wiped off regularly with a clean, soft rag. In this plant, cleaning is done daily to insure accurate register of the material.

GENERAL INFORMATION

THY-MO-TROL* DRIVE

Because of its simplicity, Thy-mo-trol drive requires very little maintenance. The contact tips are the only moving parts and they will last for thousands of operations. The general condition of the panel should be inspected for presence of dirt, oil dripping from machines, or loose nuts or screws which may be caused by the vibration of the machine.

TROUBLE-SHOOTING CHART**

TROUBLE	CAUSE	REMEDY
Motor will not run	A-c line fuses or panel fuses may be blown.	Replace with new fuses of same rating. If these blow in a short time, check wiring for short circuits. Do not replace fuses again until trouble is located.
	Cathode timer has not completed its cycle, or it may be defective.	Wait for timer to cycle. Repair or replace timer.
	Electronic tube may be defective or worn out.	Replace all tubes, one at a time, with tubes known to be good.
	Broken connection in power or control circuit.	Measure anode and control voltage at terminal board. Measure anode voltage at tubes. Measure control voltage at contactor coil or transformer primary. Look for broken lead in motor or control circuit or on panel.
	Tubes will not light because of open filament transformer.	Measure d-c resistance of filament transformer primary. This should be lower than 200 ohms. If primary is OK, check filament voltage at tube socket. If primary is open or if there is no voltage at tube socket, replace filament transformer.
	Open grid or control transformer or saturable reactor.	Measure d-c resistance of all windings. In general, none should be over 10,000 ohms. Replace if open.
	Open-circuited contactor or relay coil. Contactor will not pick up.	Measure voltage across coil. If voltage is present, replace coil.
	Field failure relay drops out.	Check field circuit for continuity. Replace defective units.
	Overload relay has tripped out. Frozen machine bearings.	Reset relay and determine cause of overload. With the power off, turn motor by hand to be sure it is free.
	Temperature too low for mercury tubes to ionize.	Install heaters or some other device for increasing panel temperature.
No control over motor speed	Electronic tube may be defective or worn out.	Replace all tubes, one at a time, with tubes known to be good.
	Open grid transformer or saturable reactor	Measure d-c resistance of all windings. In general, none should be over 10,000 ohms. Replace if open.
	Defective speed-adjusting potentiometer.	Examine potentiometer carefully to see if the internal connections are OK, or, in case of defect, replace with a new unit.
	Broken connection in control circuit.	Look for broken lead on panel and in external potentiometer connections.
	Short-circuited grid-to-cathode capacitor on thyratron tubes.	Measure d-c resistance of capacitor. Replace if under two megohms.
	Temperature too high for mercury power tubes.	Install sufficient ventilation to cool power tubes.

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TROUBLE	CAUSE	REMEDY
Speed erratic	Dirty relay contact tips.	Clean all contact tips in all except power circuits.
	Defective electronic tube.	Replace all tubes, one at a time, with tubes known to be good.
	Loose connections in control circuit.	Tighten all control terminals and check connections for bad solder joints.
	Temperature too high for mercury power tubes.	Install ventilation for power tubes.
Motor will not run above base speed	Defective electronic tube.	Replace all tubes, one at a time, with tubes known to be good.
	Open grid transformer or saturable reactor.	Measure d-c resistance of all windings. Replace if open.
	Broken connection in control circuit or potentiometer.	Look for broken lead on panel and in external potentiometer connections.
	Short-circuited grid-to-cathode capacitor on thyratron tube.	Replace if d-c resistance is below two megohms.
Loss of current or voltage limit or speed regulation	Defective electronic tube. Broken connections in control circuit or potentiometer.	Same remedies as listed above.
Control panel or anode transformer smokes	Excessive load or short circuit on transformer.	Check external transformer leads for heating and short circuits. Replace transformer if it has been badly overheated.
	Internal fault in transformer.	Replace transformer.
	Short-circuited contactor coil or sticky magnet.	Be sure contactor closes firmly. Replace coil.
	Line voltage too high.	Measure line voltage to be sure it agrees with transformer rating. If too high, install voltage regulator or obtain special transformer.
Short tube life	Excessive load.	Measure load with d-c ammeter to be sure it is not greater than panel nameplate rating.
	Line voltage too high or too low.	Measure voltage to be sure taps on filament transformer are set correctly.

GENERAL ELECTRIC

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