INSTRUCTIONS

GENERAL ELECTRIC

maxspeed*

CRANE DRIVE

MG SET CONVERSION

SPEED VARIATOR DEPARTMENT

GENERAL ELECTRIC

ERIE, PENNSYLVANIA

CONTENTS

TABLE OF CONTENTS (CONT.)

SECTION 1, INTRODUCTION

1-1 GENERAL

This Instruction Book is intended to give helpful suggestions for the installation, start up, and maintenance of Maxspeed Crane Drive Equipment to go into service. It contains inspection and maintenance information to help attain long, trouble-free life. The applicable sections of this Instruction Book should be studied in advance of performing any work on the system.

SECTION 2, RECEIVING, HANDLING, AND STORAGE

2-1 RECEIVING

The equipment should be placed under adequate cover immediately upon receipt, as packing cases are not suitable for out-of-doors or unprotected storage. Each shipment should be carefully examined upon arrival and checked with the packing list. Any shortage or damage should be reported promptly to the carrier and to the nearest office of the General Electric Company.

2-2 HANDLING

All power units have lifting lugs, or holes for lifting bars, so that crane hooks may be used to pick up the unit. Spreader bars should be used as required.

2-3 STORAGE

If the equipment is not to be installed immediately, it should be stored in a clean, dry location. Precautions should be taken to prevent moisture from accumulating in the equipment. The entrance of moisture, dust, or dirt during storage or installation is detrimental to component insulation and life of the equipment.

SECTION 3, PRINCIPLES OF OPERATION

3-1 MAXSPEED CRANE DRIVE DESCRIPTION

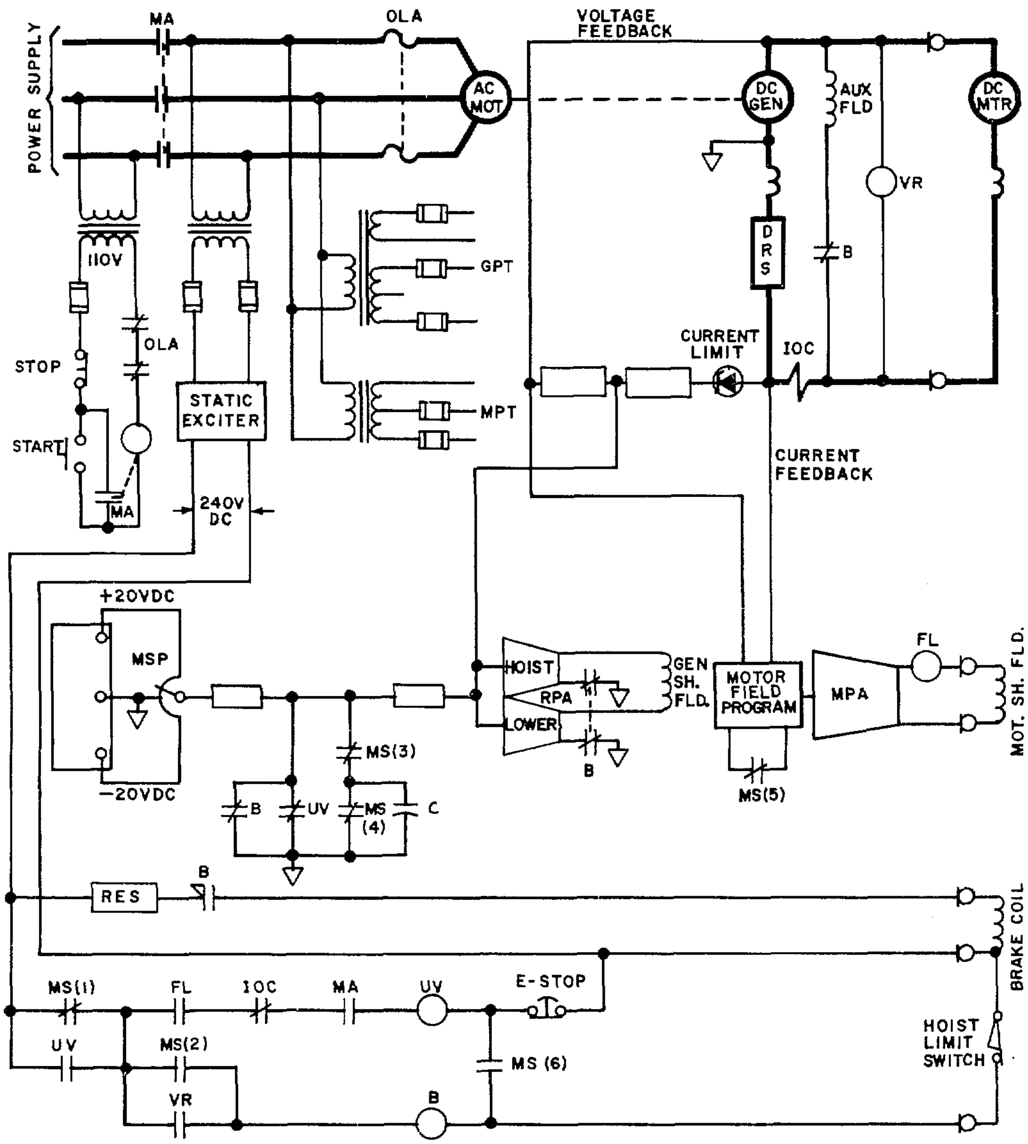
The Maxspeed Crane Drive System is a D-C adjustable-voltage drive operating from an A-C power source. The basic drive consists of a D-C shunt wound motor, a motor-generator set operating on A-C power and supplying adjustable voltage D-C power to the D-C motor, an A-C/D-C control panel, a start-stop pushbutton for the MG set, and a master switch or pendant station for controlling direction of rotation and speed. In addition, the drive includes provision for a brake, normally magnetic shunt wound and spring-set, and limit switches. The MG set and control panel are furnished as a packaged unit complete with internal wiring and interconnections, plus terminals for external power and control leads. The enclosure doors are removable for increased accessibility. See Fig. 3 - 1 for simplified crane drive elementary diagram.

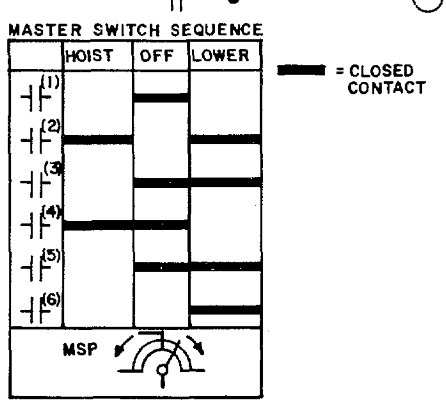
The Maxspeed Drive is a speed control drive providing programmed speed versus load characteristics and smooth acceleration and deceleration regardless of how rapidly the operator manipulates the controller. The Maxspeed Drive 'number' refers to the programmed speed characteristic selected for the drive and is the percent of full load hoist speed at which the drive will operate in the hoisting direction at no-load. For example, the no-load hoisting speed of a Maxspeed 250 is 250 percent of full load hoist speed.

In the Maxspeed Drive no armature loop or field reversing contactors are required because reversing is accomplished statically. The generator field is controlled by a static reversing power amplifier, and the motor field is controlled by a static unidirectional power amplifier.

To stop from a fast speed, the Maxspeed Drive decelerates the motor by regenerative braking before the mechanical brake is set. This saves wear on the brake and lessens the the strain on the machinery.

CRANE DRIVE SYSTEM





NOMENCLATURE

B - BRAKE CONTACTOR
DRS - DROPPING RESISTOR
FL - FIELD LOSS RELAY
GPT - GENERATOR POWER TRANSFORMER
IOC - OVERCURRENT RELAY
MA - AC STARTER
MPT - MOTOR FIELD POWER TRANSFORMER
MS - MASTER SWITCH
MSP - MASTER SWITCH POTENTIOMETER
RES - RESISTOR
UV - UNDERVOLTAGE RELAY
VR - VOLTAGE RELAY
REGULATOR-MPA - MOTOR FIELD POWER AMPLIFIER
RPA - GENERATOR FIELD REVERSING POWER AMPLIFIER

Fig. 3-1 Simplified Crane Drive Elementary Diagram

3-1-1 MAXSPEED 100 DRIVE

The Maxspeed 100 Drive is a regulated speed control drive using the inherent characteristics of an adjustable voltage shunt wound motor drive. The maximum no-load hoisting speed is approximately the same as full-load hoisting speed (see Fig. 3-2) with the generator voltage being regulated. The throw of the master switch determines the direction and speed. Since the maximum speed is rated speed, no field weakening is required; therefore, there may be no motor field programer in the Maxspeed 100, and the D-C motor field may be connected to a static exciter. The lowering speeds are approximately those shown in Fig. 3-2.

3-1-2 MAXSPEED 175, 250, AND 320 DRIVES

The Maxspeed 175, 250, and 320 Drive are common speed versus load characteristics (see Fig. 3-2); however, intermediate characteristics are provided to meet various applications. The curves on Fig. 3-2 show the range of speeds from minimum throw of the master switch to full throw for each characteristic where speed is a function of hook load. The particular characteristic selected for a drive is determined by the application requirements and the capability of the D-C motor. How this characteristic is set-up in the regulator is covered in later sections.

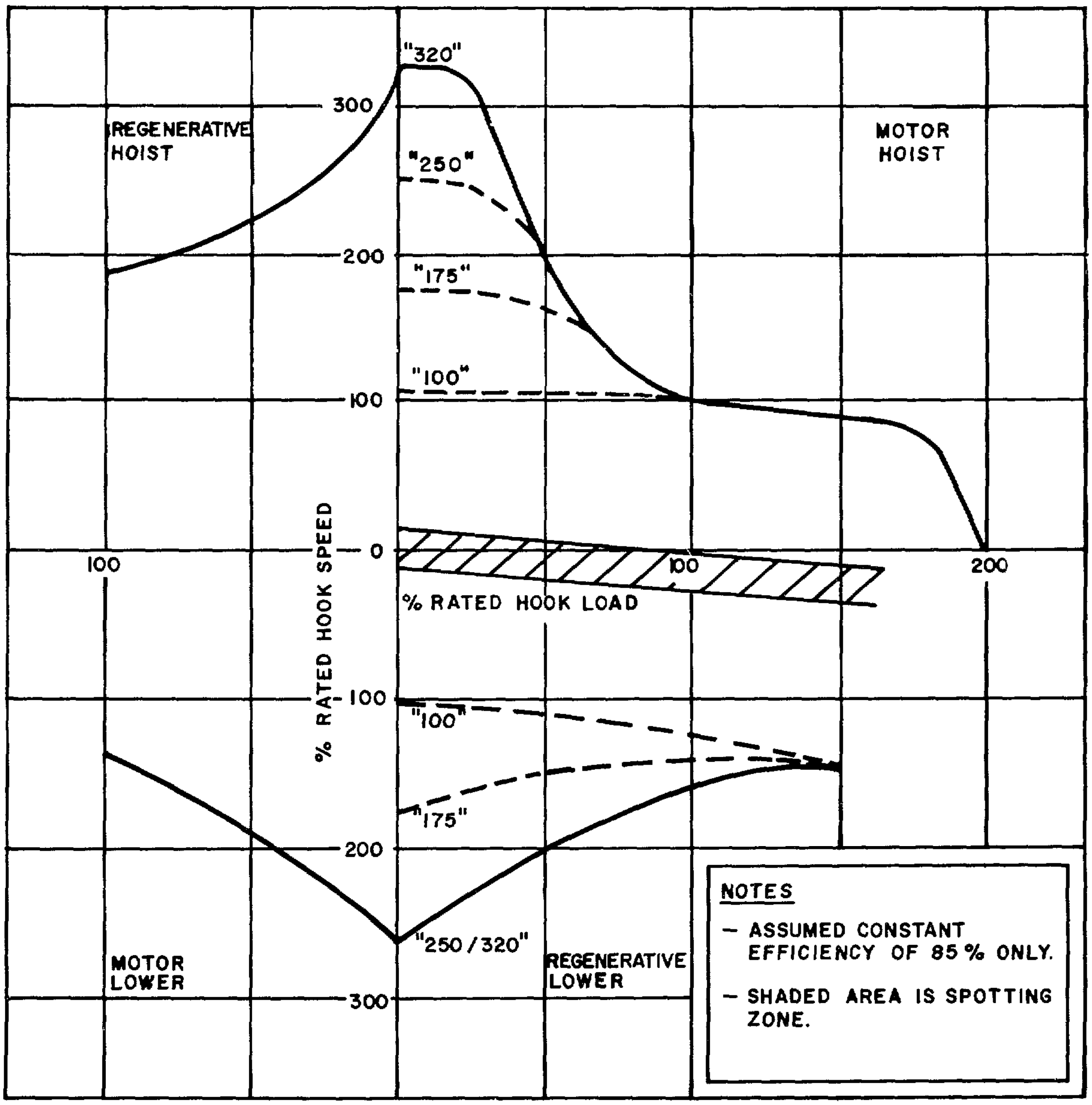


Fig. 3-2 Typical Speed-load Curves For Maxspeed Hoist Drives

3-2 REGULATOR

The regulator consists of a reversing driver card, an SCR Bridge Card, a SCR power amplifier card* for the motor field, a coordination card* for motor field programming, plus reference, feedback, field weakening*, and current limit circuits.

The components making up the reversing driver, SCR bridge, power amplifier, and coordination circuitry are mounted on printed circuit cards or boards. The cards are inserted in guides and are mated with receptacles which are properly spaced on a rack assembly. A handle on each card provides a convenient means of removing the card for individual inspection.

Functional adjustments can be made by potentiometers located on the regulator pot bracket. Some cards, having variable potentiometers, are provided with screwdriver adjustments on the card cover. Adjustments are clearly identified.

3-2-1 REGULATOR WIRING

Interconnections of the cards are made either directly by wiring from card receptacle to card receptacle, or indirectly through an auxiliary terminal board, usually mounted adjacent to the card receptacles. All external connections are wired to the regulator assembly's main terminal board. Occasionally, auxiliary terminal boards (near receptacles) are not used, and point-to-point sequence wiring is employed. Here, both sides of the receptacle are used; one side for the "in" wire and the other side for the "out" wire. A jumper spring is used to connect the sides of the receptacle together. Access to the receptacle wiring is provided by loosening the catches on the regulator rack, and rotating the rack forward approximately 90 degrees to a mechanical stop.

All receptacle wires are terminated in leaf terminals which lock in the receptacle cavities. The tabs on the printed circuit cards make direct contact with the leaf terminals. Care must be exercised in handling, and in inserting and removing the leaf terminals from the receptacle, in order to maintain proper contact pressure between card tabs and leaf terminals. Complete and detailed instructions concerning the correct receptacle wiring practices are a part of the regulator "Maintenance Kit" shipped with each regulator. In addition to the instructions (refer to Fig. 6-2), the maintenance kit includes a release tool for removing receptacle wires, jumper springs for use when both sides of a receptacle cavity are used for "in and out" sequence wiring, retaining springs for holding the cards in place and spare leaf-terminated wires.

Be sure to refer to and understand the instructions in the "Maintenance Kit" before attempting any receptacle wiring.

* May not be required for Maxspeed 100 Drives.

3-2-2 REVERSING POWER AMPLIFIER FOR GENERATOR FIELD

This amplifier is a full wave, polarity reversible power amplifier designed to handle highly inductive loads such as the generator shunt field

Four SCR's connected in a back to back, full wave, center tapped configuration form the SCR bridge card. An all semiconductor firing circuit with coordination functions for both directions are packaged on a single printed circuit card called "Reversing Driver".

OPERATION:

Fig. 3 - 3 shows a functional block diagram of the complete Reversing Power Amplifier. Refer to 36C761416-CA or Fig. 3-4 (for 193X730 series card) for details of the Reversing Driver.

The input signal applied to the error differential amplifier may either be a direct reference signal indicative of desired output or an amplifier error signal from an universal amplifier. The input requirement is approximately 2 MA (10 volts on Tab 5) for rated power amplifier output. The 193X730-G02 driver has an internal jumper removed (Tab 4 to Tab 6) deleting the field current feedback circuit. Under these circumstances, the reference signal is dropped to 2 MA with approximately 2 MA voltage feedback, and a RC stability circuit from Tab 9 to 3 may be required.

Depending on the polarity, the input signal to the error differential amplifier is applied to either the forward or reverse Gate Pulse Generator. With positive inputs, the forward gate pulse generator is turned "on" while the reverse is turned "off".

Exciting the gate pulse generator causes the unijunction firing circuit to operate, sending pulses to the gates of the card mounted SCR's. This excitation of firing pulses will occur if the lock-out circuits are not in operation.

The current feedback signal from the forward and reverse SCR's serves a dual purpose. It acts as a negative feedback to the error differential amplifier linearizing the gain, (193X730-G01 drivers only) and operates the lock out circuits. The circuit is arranged such that if current is flowing in the forward SCR's, the reverse SCR's are "locked out" from firing. Conversely, if the reverse SCR's are conducting the forward SCR's are "locked out".

The driver has a regenerative function which allows pumping the inductive field energy back into the A-C line. This makes polarity reversals faster, effectively reducing the systems time constant. An input change in polarity commands a change in power amplifier output. Due to the highly inductive load, the output current flow cannot instantaneously change direction. Until the forward current is zero, the reverse current SCR's are locked out and the forward SCR's are pulsed at zero degrees by the current feedback. This causes the on SCR's to keep commutating between each other, applying the negative half waves of the A-C to the load voltage, actually forcing the field to zero.

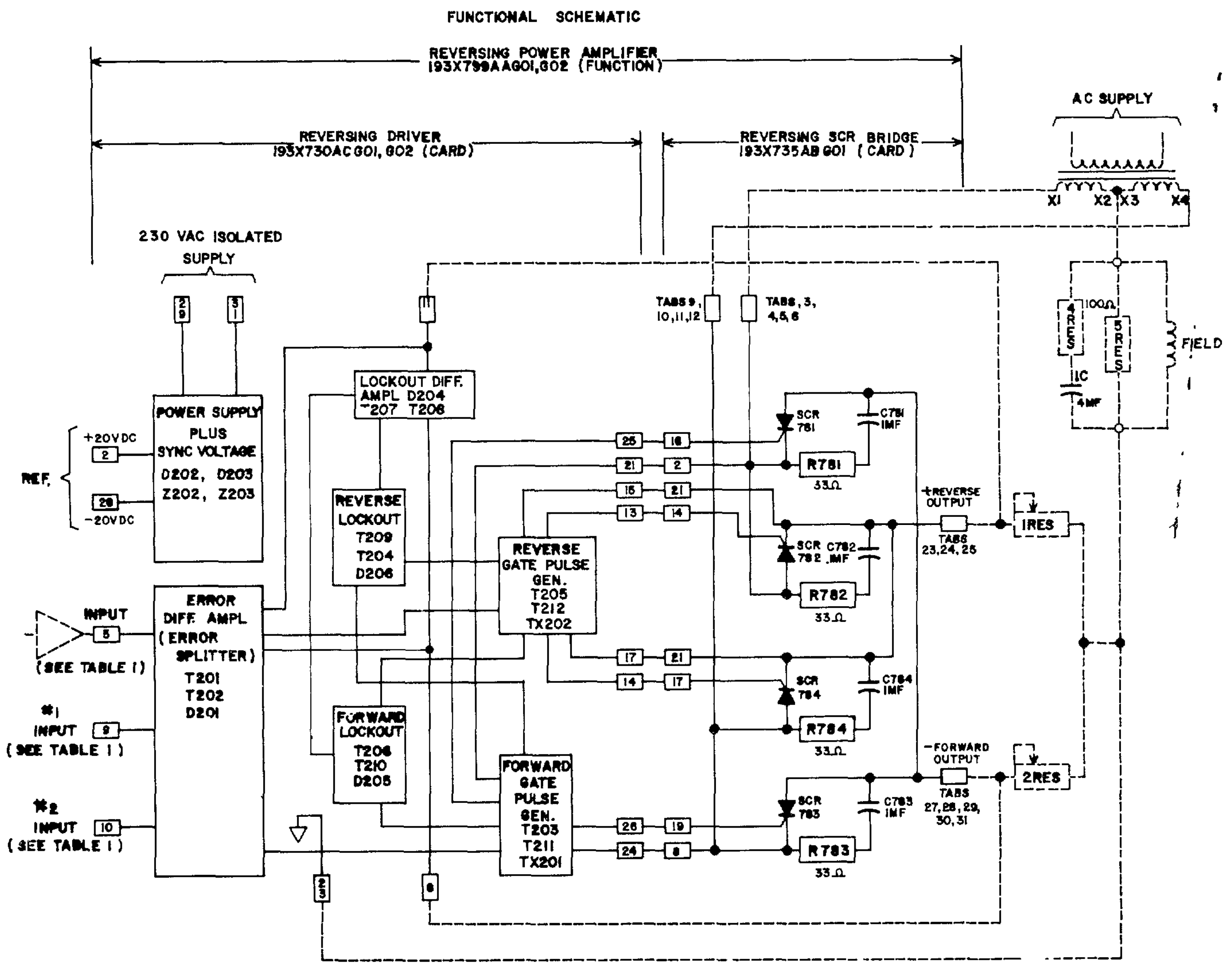
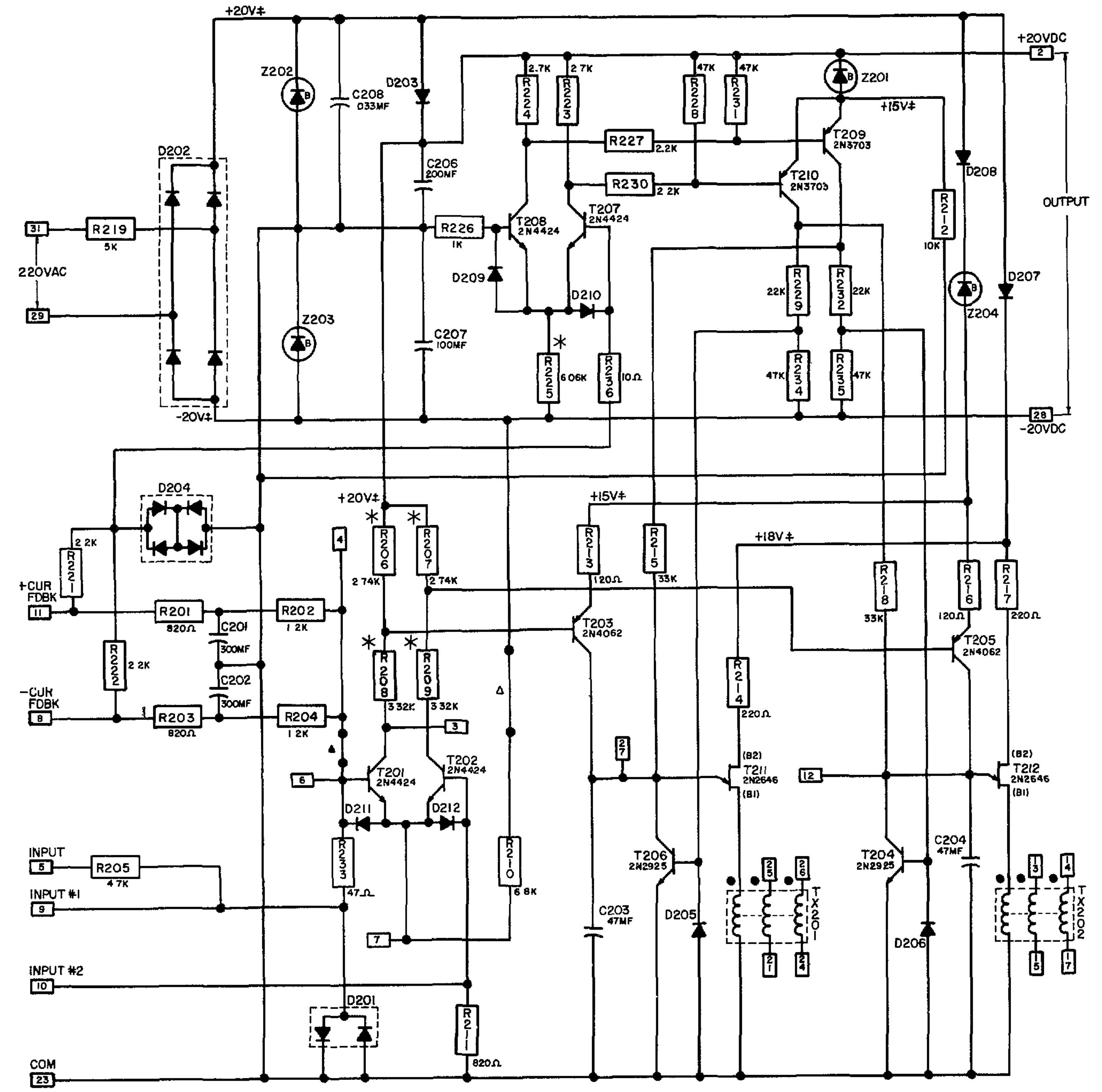


Fig. 3-3 Functional Schematic Of Reversing Power Amplifier

A positive reference voltage applied to the input of the reversing driver (Tab 5 or 9, Fig. 3-4) will turn on transistor T201 of the differential amplifier causing current to flow through resistors R206 and R208. This current flow will drop the voltage between these resistors by the IR drop across R206 from 20 volts. Transistor T203 is turned on by this voltage drop and its current charges capacitor C203. This charging voltage builds up until the firing point of the unijunction T211 is reached, sending a pulse through the gate pulse transformer TX201 which applies the pulse to the gates of SCR781 and SCR783 (Fig. 3-3). The higher the reference, the higher the current through transistors T201 and T203, and thus the faster C203 will be charged to fire the unijunction sending more pulses to the SCR's. These pulses, caused by the charging of the capacitor and firing of the unijunction, are in the shape of sawtooths (Fig. 3-5b).



NOTES

I NUMBERS INSIDE SMALL RECTANGLES INDICATE TAB NUMBERS WHICH CORRESPOND TO MATCHING RECEPTACLE NUMBERS
II RESISTORS MARKED WITH ✱ ARE 1% TOLERANCE TEMPERATURE COMPENSATED TO ±50 PPM/C
III ● – TO TURN THE SILICON CONTROLLED RECTIFIERS ON, THE DOTTED LEAD MUST BE CONNECTED TO THE GATE
IV ‡ – VOLTAGE INDICATED IS ONLY APPROXIMATE
V ▲ – JUMPER IS REMOVED FOR 193X730ABG02, ELIMINATING CURRENT FEEDBACK CIRCUIT
VI IF INPUT TAB 5 OR 9 IS MADE POSITIVE, FIRING PULSES WILL APPEAR ON TX201 NEGATIVE INPUT ON THE SAME TABS WILL PRODUCE PULSES ON TX202

Fig. 3-4 Schematic Diagram Of Reversing Driver

A positive voltage applied to the gate (projection from the arrow) of the SCR with respect to the cathode (head of the arrow), during the half cycle when the anode (tail of the arrow) voltage is positive, causes the SCR to fire, and allows current to flow. This is the inherent characteristic of the SCR. So even though gate pulses are being applied to both SCR781 and SCR783, SCR781 will only fire during the half cycle when its anode is positive with respect to its cathode, and SCR783 will fire during the other half cycle. Thus these two SCR's give a full-wave output (Fig. 3-5c).

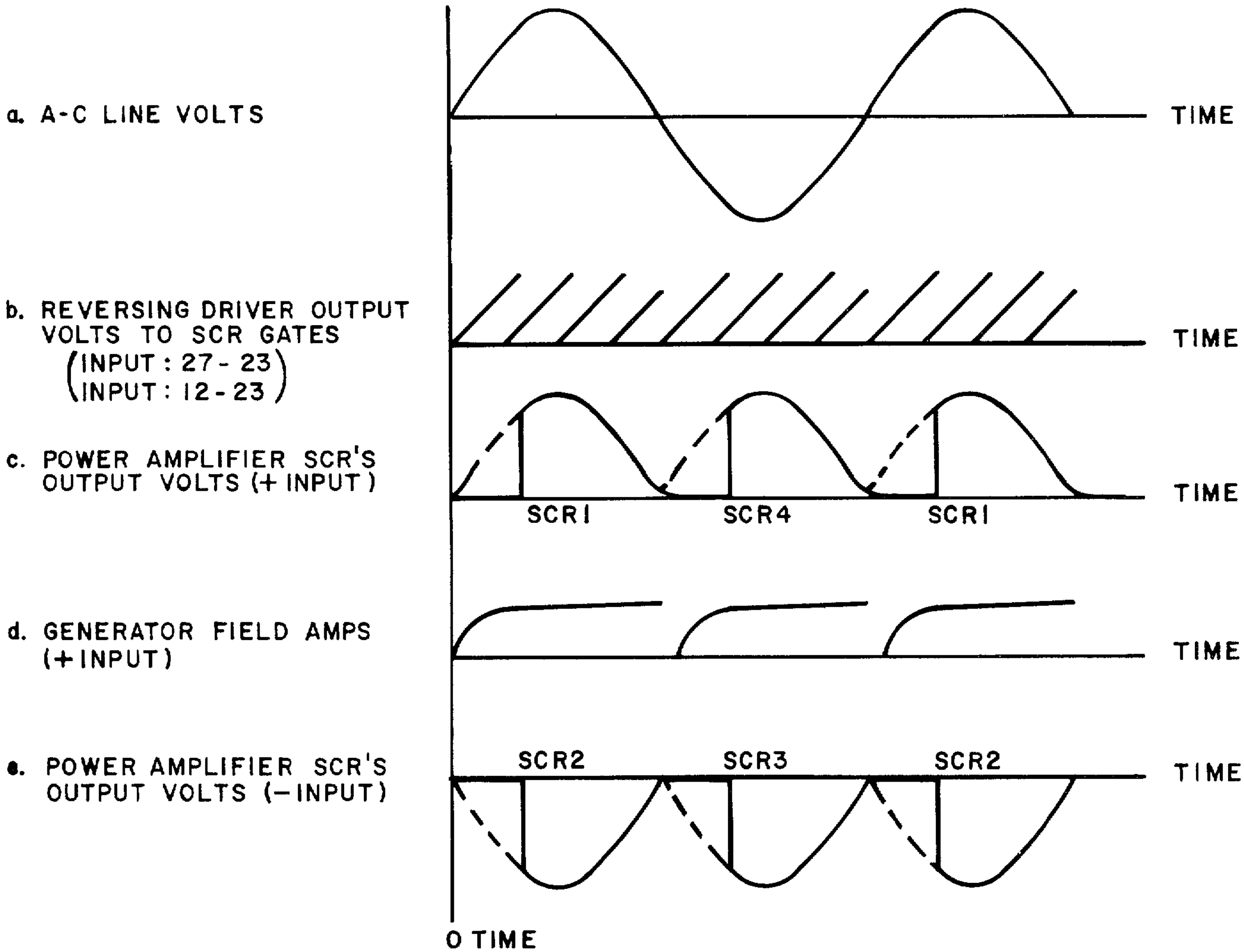


Fig. 3-5 Reversing Power Amplifier Waveforms

The lockout circuit of the reversing driver is controlled by the current feedback from the generator field resistor. With SCR781 and SCR783 firing, generator field current is flowing across 2 RES (Fig. 3-3) giving a negative voltage feedback into Tab 8 (Fig. 3-4). This negative signal, applied to a differential amplifier through resistors R222 and R236, turns on transistor T208, allowing current to flow through resistor R224. This IR drop subtracts from 20 volts to drop the voltage applied to the base of transistor T209, turning it on, which puts current through resistor R232. The resulting voltage above resistor R232 is applied through resistor R215 to the collector of transistor T206, assuring that it remains off and keeps this unijunction operating. The net positive voltage between R232 and R235 is applied to the base of transistor T204, turning it on, shorting the capacitor and unijunction to common and "locking out" the reverse gate pulse generator.

In a similar manner, a negative reference input and a positive current feedback will operate through gate pulse transformer TX202 which fires SCR782 and SCR784 and locks out TX201. The SCR output is now reversed and the resulting waveform is flipped over (Fig. 3-5c). Thus the polarity of the reference determines the direction of output, and its amplitude determines the amount of output.

3-2-3 POWER AMPLIFIER FOR MOTOR FIELD

The device responsible for controlling the field of the motor is the 193X803 series power amplifier for half-wave operation. If the motor field power requirements call for a full-wave power amplifier, see GEI-95518 (included if used) for description of operation.

The power amplifier furnishes excitation for the motor field. This amplifier is connected for half-wave operation. The circuit employs a silicon-controlled rectifier (SCR) with a magnetic amplifier firing device. The SCR and free-wheeling diode are mounted on a finned heat sink on one side of the card. The magnetic amplifier and associated components are mounted on the reverse side.

The SCR operates on one half-cycle of the A-C source and is phase controlled by a magnetic amplifier (REAC). An increase in error signal causes the magnetic amplifier to saturate, passing a pulse of current every cycle of the A-C source into the gate lead in the SCR. This control pulse triggers the SCR into the conducting mode (fire), allowing current to flow through the load. When the A-C source reverses polarity, the magnetic amplifier comes out of saturation, removing the control signal to the SCR. The A-C reversal also turns off the SCR. The circuit is ready for another pulse of current when the A-C source again reverses. Variable D-C output is therefore provided by turning on the SCR at various times during the conductible half cycle. This is shown in the curves, Fig. 3-6.

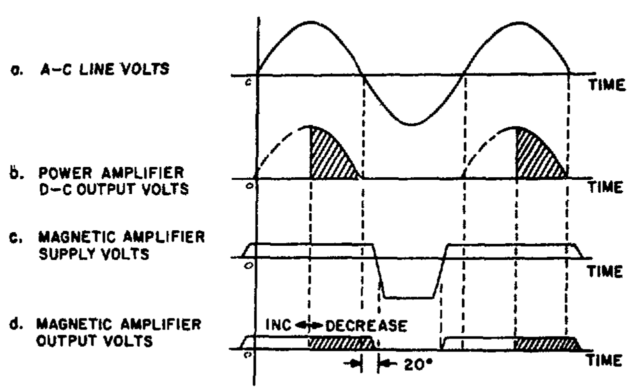


Fig. 3-6 Power Amplifier Wave Forms

A positive voltage is applied to the gate (projection from the arrow) of the SCR with respect to the cathode (head of the arrow), during the half cycle when the anode (tail of the arrow) voltage is also positive, causing the SCR to allow current to flow (fire). This is the inherent characteristic of the SCR. The 115-volts A-C input and the 134 volts A-C (or 268 volts) must be connected in the proper phase relationship to assure the above SCR phase relationship.

In the 193X803 series "Power Amplifier and Supply", see Fig. 3-7, diode (D601) provides a half-wave rectified A-C for the bias circuit and gate supply circuit. This half wave is clipped by a zener (Z601) to form an unsymmetrical square wave.

The magnetic amplifier bias circuit consists of potentiometer (P606) and a choke (L603). The choke holds the current through the bias circuit constant at about 20 milliamperes (depending on the bias requirement of the particular core). The choke absorbs energy during the time when Tab Group 8-12 is positive relative to Tab 31, and then "free wheels" through the zener (Z601) when the line voltage reverses and diode (D601) blocks.

Capacitor (C601) couples the voltage across the zener (Z601) to the transformer (TX601), blocking the D-C component, and coupling only the A-C portion of fire voltage. The A-C portion is a square wave, with one side lower in amplitude and 220 degrees wide, and the other side higher in amplitude and 140 degrees wide, see Fig. 3-6c. The voltage is stepped down 4.1 in the transformer (TX601) to Section No. 1 of the secondary. This voltage is then applied to the magnetic amplifier gate winding circuit. The high-magnitude narrow portion is used in the reset direction of the magnetic amplifier; reverse current being blocked by the diode (D602). The wider portion is applied in the forward direction Fig. 3-6c. This allows the magnetic amplifier to be controlled over a full 180 degrees because of the 20-degree margin provided at each end. This allows SCR D604 to be controlled from all the way off to all the way on.

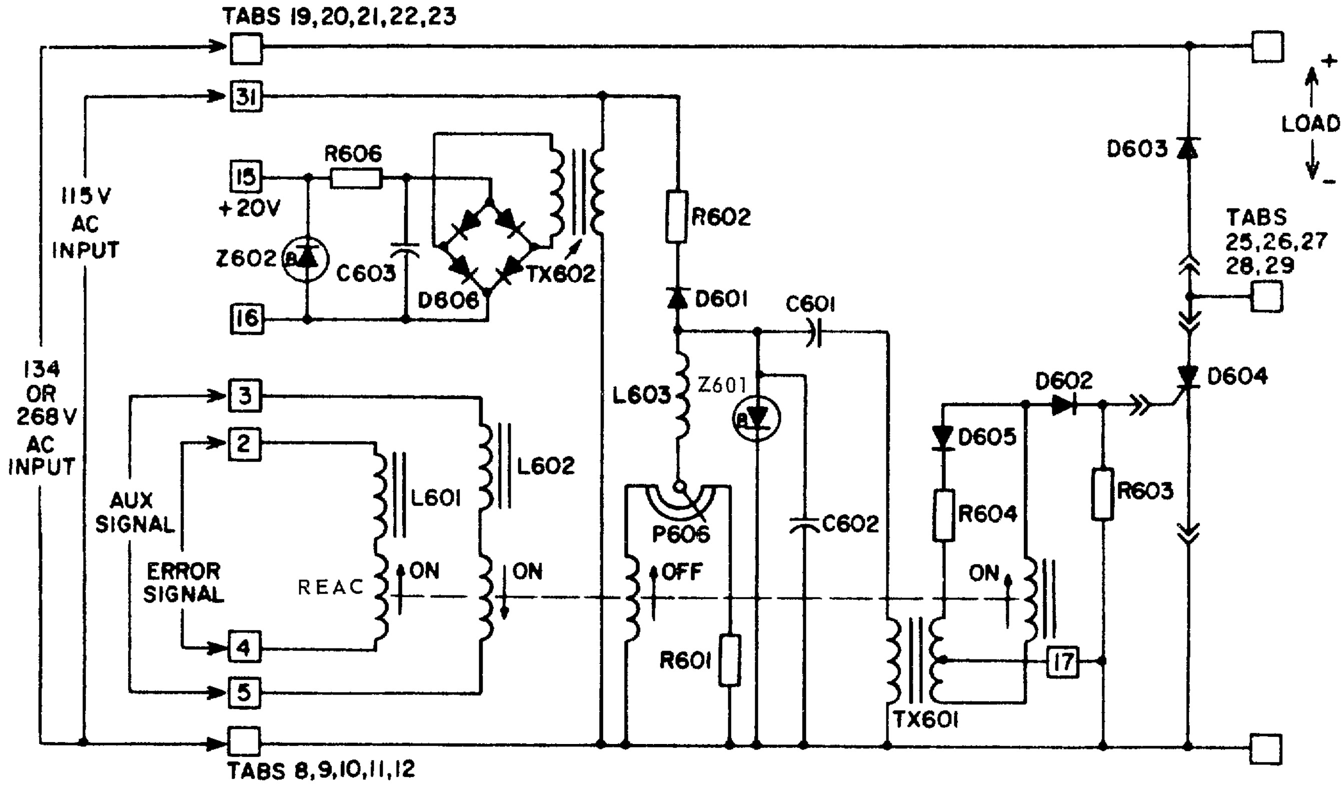


Fig. 3-7 Simplified Diagram Of The Series 193X803 Power Amplifier

Capacitor (C602) compensates for the excitation current of the transformer (TX601), so that no phase shift is introduced between the line A-C and the firing wave by this exciting current dropping through R602. Section No. 2 of the transformer secondary, resistor (R604), and diode (D605) provide an auxiliary loading circuit on the magnetic amplifier, to divert the magnetic amplifier exciting current prior to the point of firing. This prevents accidental pre-firing of unusually sensitive SCR's. The choke in series with the control windings makes the magnetic amplifier gain higher and less sensitive to external resistance. When the magnetic amplifier fires, primary current must be drawn by transformer (TX601). This energy is supplied by capacitor (C601) discharging back through the zener (Z601). The zener is held in conduction by the inductive current of the choke (L603).

Amplifier (REAC) saturates at a point during the application of the supply voltage dependent upon its bias and control windings conditions. With zero control signal, potentiometer (P606) is usually adjusted to bias the magnetic amplifier to saturate near the end of the wave. This fires the SCR at the very end of the anode-to-cathode forward voltage of the SCR, producing a very small output. If a positive control signal is applied to the magnetic amplifier, saturation occurs earlier in the cycle. This is called "phase control". The magnetic amplifier phases "on" with increasing control current, to cause saturation to occur near the beginning of the flat-topped portion of the wave.

Saturation of the magnetic amplifier reduces its high impedance to a low impedance. The resulting current flows in the gate-cathode circuit of the SCR (D604). The firing point of the SCR is therefore controlled by the saturation point of the magnetic amplifier.

3-3 GENERATOR VOLTAGE REGULATOR

The generator voltage regulator consists of a reversing driver which operates from the net input resulting from the summation of the reference voltage signal, generator voltage feedback signal, and current limit signal.

3-3-1 COMPARISON CIRCUIT

The comparison circuit, shown on the simplified elementary diagram (Circuit 1, Fig. 3-8) contains the reversing driver with its reference and voltage feedback circuits for speed control.

The reference voltage is obtained from the +20 volts and -20 volts D-C power supply, located on the reversing driver card, which is connected to the speed potentiometer

3-3-1 COMPARISON continued:

(MSP) mounted in the master switch (MS). The center tap on the speed control potentiometer is tied to regulator common with one side connected to +20 volts and the other to -20 volts. The potentiometer wiper arm then provides the reference polarity and magnitude which in turn determines the direction and speed of the drive. A minus reference to the reversing driver is hoist and a plus reference is lower. The maximum reference in each direction is determined by the setting of the maximum voltage pots in Circuit 1.

A time delay is provided in the reference circuit by capacitor 1C for the lower direction. In Hoist, the parallel MS contact remains closed, while the series MS contact opens; and in Lower, the parallel MS contact opens and the series MS contact remains closed to put 1C into the circuit. Therefore, on a fast operation of the speed pot in Lower, this circuit provides a time delay before the reference current builds up in the driver, thus giving smooth acceleration and deceleration of the motor. There is no time delay in Hoist to prevent the load from falling before the reference current builds up in the driver.

The generator armature voltage is used as the feedback voltage. One side is tied to regulator common such that the voltage feedback is the opposite polarity of the reference at the summing point.

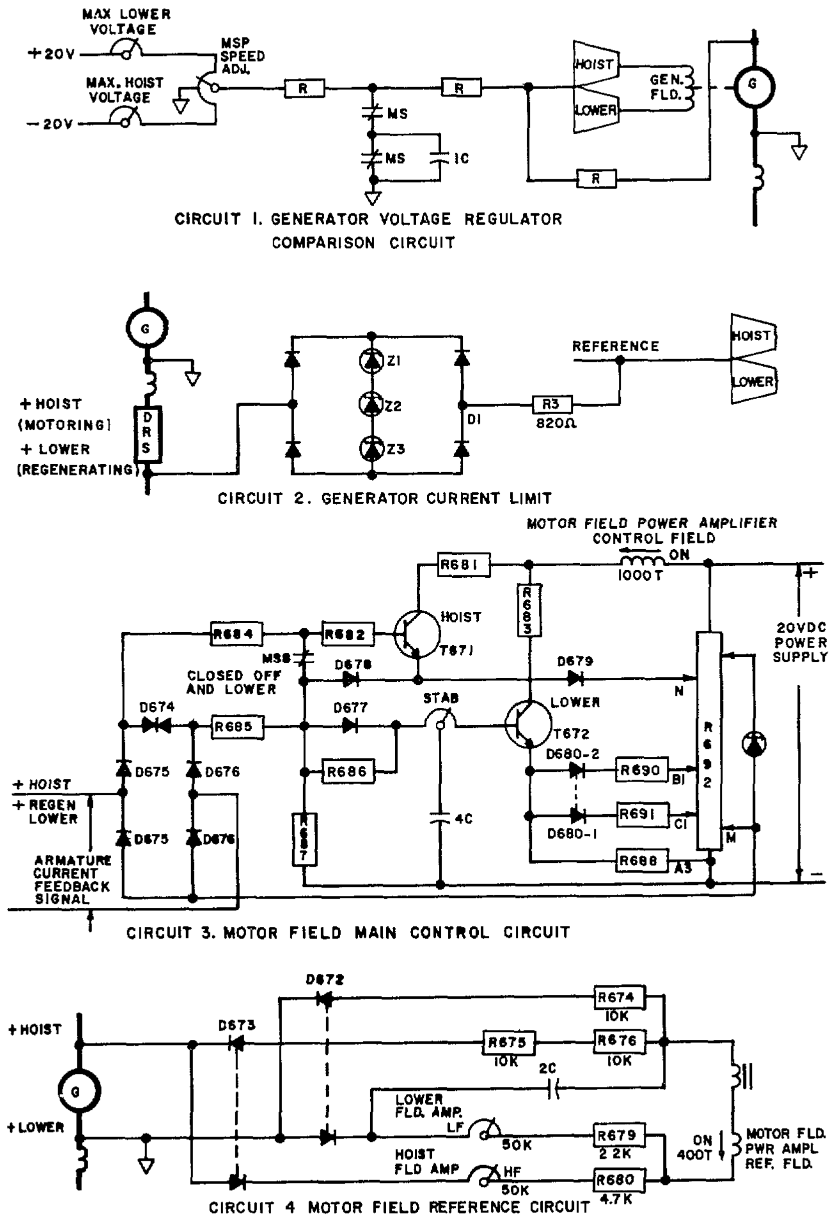


Fig. 3-8 Simplified Elementary Diagram

Although the actual reference and feedback signals are voltages, the comparison circuit compares current which operates the reversing driver. The actual summing junction is Input No. 1, Tab 9, (see Fig. 3-4) on the driver which operates on the net current resulting from the summation of the reference and feedback currents. The reference current tries to turn the driver on, while the feedback current tries to turn it off, and their difference is the error signal to the driver which determines its output.

3-3-2 CURRENT LIMIT

The current limit circuit consists of one rectifier bridge (D1), zener diodes (Z1, Z2, Z3), and resistor (R3) connected to the reversing driver (Circuit 2, Fig. 3-8). A voltage signal proportional to armature current is taken across the generator commutating field and a dropping resistor with one side tied to regulator common for correct polarity. The armature current signal is fed through the rectifier bridge to the zener diodes. No current flows from the current limit circuit until the voltage across the zeners exceeds their zener voltage. Current then flows through the bridge and zeners causing a current to flow to the summing junction of the reversing driver in a direction to prevent further increase in armature current. Thus motoring and regenerating current limit is set by the same circuit.

By looking at a plot of armature voltage versus armature current (see Fig. 3-9a), it is apparent that armature voltage stays constant until motoring current limit action takes place. At such time as this happens, the voltage versus current follows a constant resistance curve to a stall condition. The point of current limit can be varied by jumpering one zener or adjusting current limit potentiometer, if available.

3-4 MOTOR FIELD PROGRAMER

The purpose of the motor field programer is to control motor field current, as a function of armature current, to obtain a constant horsepower characteristic. From no load to some small load, depending upon the characteristic, the motor shunt field is held constant; from that point to approximately 100 percent rated load, armature current is constant, and the field is varied to change speed and torque to give a constant horsepower characteristic. At 100 percent rated load, the motor field SCR reaches maximum voltage, and the motor field is held essentially constant for further increases in load.

The motor field programer consists of a power amplifier and a coordination card. The motor field is programed by the master switch off position bias, main control circuit, reference circuit, and feedback circuit.

3-4-1 OFF POSITION BIAS

In the OFF position of the master switch, the motor field is biased at 65 percent of rated motor field by adjusting the bias potentiometer on the regulator pot bracket and the power amplifier bias on the card. This OFF position bias provides field economy.

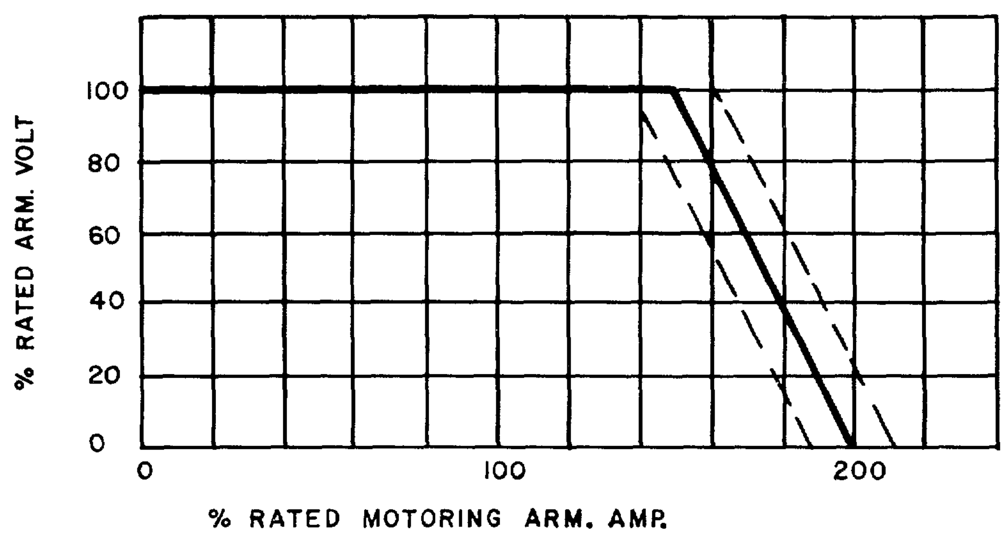


Fig. 3-9a Armature Volts Versus Armature Current Signal

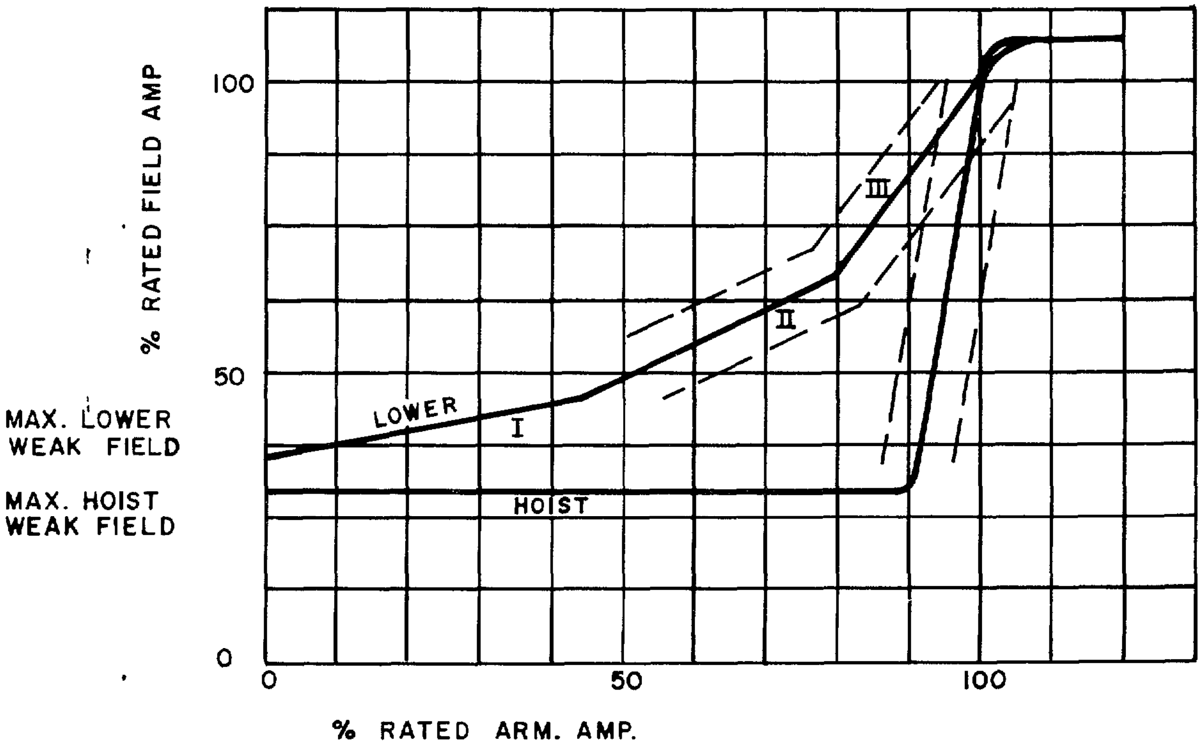


Fig. 3-9b Motor Field Versus Armature Current Signal (Typical Curve)

3-4-2 MAIN CONTROL CIRCUIT

The main control circuit (see Circuit 3, Fig. 3-8), during hoist, consists of diodes (D675, D676 and D679), resistors (R684, R682 and R692), and hoist transistor (T671). The current feedback voltage, which is proportional to armature current, is applied to the base of the transistor (T671) and compared to a preset reference voltage at point N on resistor (R692). When the voltage of the current feedback signal exceeds the reference voltage, diode (D679) will conduct, and a current flows through the base of transistor (T671), causing it to conduct. This conduction will turn on the power amplifier control winding and increase the motor field current. The transistor increases the gain of the circuit, so that the motor field changes from its weak field value to rated, with a change in armature current equal to approximately 10 percent of rated. Fig 3-9b shows a plot of motor field amperes versus armature hoisting amps. The point at which the transistor conducts can be changed by changing Jumper W.*

During lower, master switch contact MS 8 is closed, which shorts the base of the hoist transistor (T671) to its emitter, thus making it inoperative. The feedback signal is now applied to the base of the lower transistor (T672), and it will conduct through resistor (R688), as soon as armature current creates a feedback voltage. The gain of the transistor circuit or the rate of change of the motor field depends on the value of R688 which is determined by the Z to A jumper setting. Field excitation will increase at a constant rate until the feedback signal exceeds the preset reference voltage at jumper Y on resistor (R692). Then, the diode (D680-1) starts conducting, the over-all impedance of the circuit is reduced by paralleling R688 and R691. The rate of change of motor field excitation versus armature amperes will be increased as determined by the value selected for R691 and will remain constant until the feedback signal causes diode (D680-2) to conduct. This conduction point depends upon the setting of the X jumper on R692 and the gain or rate of change of the motor field depends upon the value of R690 selected for the X jumper. * Fig. 3-9b shows lowering motor field excitation characteristic. Capacitor (4C), which is connected to the base of the lower transistor through the stability potentiometer (STAB), slows the rate of change of the motor field for a change in armature current.

3-4-3 REFERENCE CIRCUIT

The reference circuit consists of the power amplifier control winding and includes hoist and lower field ampere adjusting potentiometers (Circuit No. 4, Fig. 3-8). Since this circuit is connected across generator armature voltage, the no-load motor field excitation will vary inversely as a function of generator voltage. This allows slow speed operation at a strong motor field, with relatively small changes in speed resulting from changes in load. The maximum weak field condition occurs at maximum gener-

* See Appendix 6-5 for selecting jumper taps and Fig. 6-1 for coordination card schematic.

3-4.3 REFERENCE CIRCUIT

ator voltage, and provides the no-load hoisting and lowering speed.

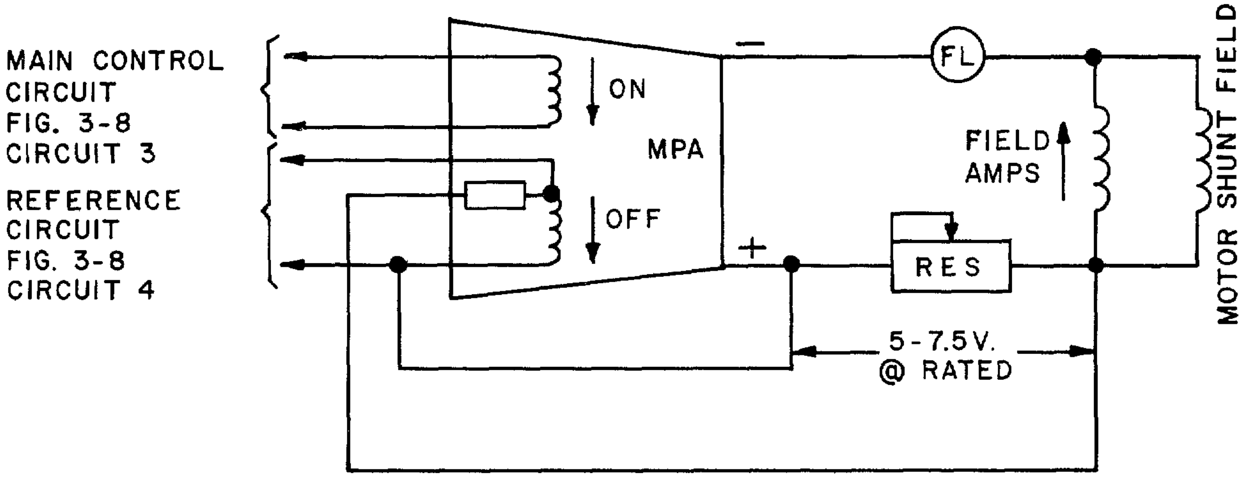


Fig. 3-10 Motor Field Current Feedback Circuit

In Hoist, diodes (D673) of the coordination card are positive, and a control current, which is adjusted by hoist field amp potentiometer, flows through the reference winding in an off direction, thus controlling the weak field excitation level for maximum hoist speed. Diodes (D672) are positive during lowering, and the control current flowing is determined by the setting of lower field amp potentiometer.

3-4.4 FEEDBACK CIRCUIT

Operating on the same control winding of the power amplifier as the reference is the motor field current feedback which is 5-7.5 volts at rated field current across the resistor in series with the motor field (see Fig. 3-10). The purpose of this current feedback is to regulate the motor field current and thus compensate for motor field heating and line voltage changes.

3-5 STATIC EXCITER

The static exciter is a full-wave, single phase bridge supplying constant-potential, direct-current power supply, employing static components. It consists of a transformer, rectifiers, and protective components. See GEI 43710.

3-6 DECELERATION CIRCUIT

When the master switch is moved rapidly from a high-speed position to the OFF position, the system is designed to decelerate by regenerative braking until the generator voltage decays to approximately 30 percent generator volts. At this point, the brake contactor (B) is designed to drop out, removing the reference, suiciding the generator and setting the mechanical brake. This deceleration characteristic, which reduces wear of the brake lining, is accomplished by a voltage relay connected across the generator armature. The voltage relay is set to pickup at 60 percent generator volts and drop out at 30 percent volts. The brake is picked up as a function of the master switch operating, but for a stop the brake contactor is held by a voltage relay interlock until the generator regenerates to the 30 percent volts. Then the voltage relay drops out, setting the brake (see Fig. 3-1). However, with the operation of a protective device, limit switch, or emergency stop, this delaying action is bypassed, setting the brake immediately.

3-7 UNDERVOLTAGE PROTECTION

Undervoltage protection (see Fig. 3-1) is provided by the undervoltage relay (UV), which drops out if the control voltage is lost. The undervoltage relay (UV) is picked up through a master switch contact, which is closed in the OFF position, and is sealed in by one of its own normally open contacts. Therefore, if the master switch is in one of the running positions when the motor-generator set is started, the drive will not operate until the master switch is returned to the OFF position, picking up the undervoltage relay. Likewise, if a protective function, the emergency stop switch, or the MG set starter is opened while the system is operating, the undervoltage relay is designed to drop out and set the brake immediately. Upon restarting the motor-generator set, the master switch must again be returned to the OFF position to pick up the undervoltage relay before resuming operation.

3-8 FIELD LOSS PROTECTION

The field loss relay (FL) is in series with the motor field (see Fig. 3-1) and picks up at approximately 50 to 55 percent of rated field amps and drops out if the motor field drops below a minimum value. A normally open contact of FL is connected in series with the undervoltage relay; thus, if FL drops out due to low or loss of motor field, the undervoltage relay is de-energized and the drive is stopped. Note: The relay must pick up at less than the 65 percent motor field bias.

3-9 OVERCURRENT RELAY (IOC)

An instantaneous overcurrent relay (IOC) is provided in the D-C motor loop. This relay is normally set at 250 percent or higher of rated current to back up current limit with a normally closed contact in the undervoltage relay (UV) circuit such that if the IOC picks up, the undervoltage relay is dropped out, causing the brake contactor to suicide the generator and set the brake.

3-10 PROTECTIVE FEATURES

Besides the FL and IOC relays operating in the undervoltage circuit, an emergency stop switch is recommended to open a contact in the UV circuit, dropping out the UV relay and stopping the drive.

A-C motor overload relays (OLA) protect the A-C motor against damage from excessive currents resulting from overload, a locked rotor, or attempted single-phase starts. If the overloads trip, the MG set is shut down by dropping out the AC motor starter.

After an emergency stop, or stops due to overcurrents, overloads, undervoltage or loss of motor field, correct the fault and return the master switch to the OFF position.

3-11 MODIFICATION FEATURES

With the various types of crane drive applications, there are many special features required which differ from one crane drive system to another. Below are listed some of the more frequently used features which may be found in a particular crane drive.

3-11-1 LIMIT SWITCHES

There are various functions of limit switches. An "operating" limit switch may bring the drive to a stop or slowdown the drive as part of normal operation. The stop is by regenerative braking before setting the brake, and the slowdown may simply recalibrate the regulator reference for a slow speed.

A "back-up" or "overtravel" limit switch is designed to initiate an immediate stop by setting the brake and suiciding the generator. Such a limit switch may be an overhoist or *end-of-travel limit switch.*

A "power" limit switch is sometimes required as an overhoist limit switch which actually interrupts the power loop of the D-C motor and generator and connects a dynamic braking resistor across the motor armature (Fig. 3-11). A contact on the power limit switch (PLS) de-energizes the brake directly. When backing out of the limit switch, the master switch picks up the lower contactor (L) which bypasses PLS energizing the brake.

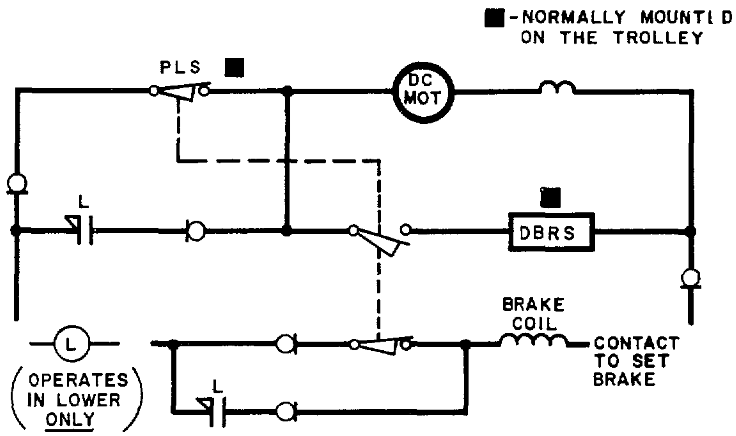


Fig. 3-11 Power Limit Switch Circuit

3-11-2 PENDANT STATION

A pendant station may be substituted for the master switch for a floor-operated crane. On a pendant station, the speed potentiometer is operated by depressing the hoist or lower pushbutton proportional to the speed required. While a master switch can have twelve contacts (standard maximum) for interlocking, the interlocking must be performed by relays for a pendant station control. Other functions supplied in an operator's cab, such as MG set start-stop pushbuttons, are supplied on the pendant station.

3-11-3 EMERGENCY DYNAMIC BRAKING

This safety modification is designed to prevent the free fall of an overhauling load under the condition of simultaneous failure of the power supply and the holding brake. This is accomplished by a contactor which drops out due to loss of power, inserting a motor series field (special) into the D-C power loop which is designed to allow the motor to lower self-excited at a safe controlled speed by current flowing through the motor and generator armatures. Another method is to connect a resistor across the motor armature. The voltage across this resistor is then fed through a rectifier bridge, for the correct polarity, to the motor shunt field to self-excite the motor for a controlled lowering speed.

3-11-4 TRAVEL MOTIONS

Many crane drives require bridge, trolley, gantry, or a combination of motions to be incorporated in one crane drive system. Depending on the application and duty cycle, the travel motions may be operated simultaneously with the hoist, in which case separate generators are used for each function; or the travel motions may be operated with the hoist on a first-come, first-serve basis powered by the same generator. In this case the hoist or travel motion is chosen by a selector switch or by whichever master switch is operated first, locking out the other functions.

Each travel motion then has the same protective devices, brake circuitry, and provisions for limit switches as described previously for the hoist function. Two differences for travel motions are that (1) the torque or current limit function is normally set for 150 percent of rated torque, and (2) the drive is allowed to regenerate to 10 percent generator volts before setting the brake on a stop. These lower settings prevent skidding of wheels and make braking less severe. Also the pick-up of the travel voltage relay is set lower (20 percent of generator volts), so that the brakes are set immediately only for stops from 20 percent volts or less.

3-11-5 TORQUE PROVING RELAY

The torque proving relay is used to prevent load driftback, on steel mill "MD" drives, and on first-come, first-serve crane drives where a contactor must close the D-C motor and generator loop. The purpose of this relay is to sense hoist motor loop current to be certain that hoist motor torque is available before allowing the hoist brake to be released. The torque proving relay coil is connected across the armature loop dropping resistor, set to pick up at approximately 20-30 percent of rated current; and a normally open interlock is in series with the hoist brake contactor, so the brake is not energized until this relay is picked up.

3-11-6 LOAD FLOAT

The load float or spotting zone control is to enable the operator to hold or spot the load without the use of the holding brake. Load float control is initiated by depressing the master switch thumb latch or a pushbutton which releases the brake and recalibrates the drive speed relationship. Top drive speed now becomes 20 to 25 percent of normal speed.

NOTE: The motor capability limits the time of stalling at absolute zero speed.

3-11-7 TRAVEL DRIFT

The travel drift modification is to enable the operator to "coast" the crane drive for a travel motion. Drift control is initiated by depressing the master switch thumb latch or pushbutton which releases the travel brake and recalibrates torque or current limit. The current limit now becomes 50 percent instead of 150 percent of rated current, thus reducing the braking torque during the regeneration to a low value.

3-11-8 TRANSFER SWITCHING

For some crane drive systems the same crane drive may be operated from different control locations, in which case it is necessary to transfer the crane drive control from one master switch to another. This transfer may be accomplished by SB type switches or relays.

3-11-9 RADIO REMOTE CONTROL

Radio control can be substituted for the master switch for remote operation. By the nature of radio control, all speed control is stepped and all functions and interlocking must be performed by relays.

SECTION 4 INSTALLATION

4-1 CHECK LIST

Experience gained during many startups has indicated that following certain practices will result in a more trouble-free and less expensive installation. Some of these are listed below. They should not be considered, nor should they be interpreted as a General Electric Company recommendation. Responsibility for proper installation practices belongs to the installing contractor.

1. Have spare parts on hand at time of initial start-up.
2. Provide adequate ventilation or air flow for any external resistors, and adequate spacing between resistor boxes.
3. Use thermally suitable cable where subjected to higher than normal ambient.
4. Use cable size corresponding at least to name-plate ratings of motors.
5. Color code, wire number, or otherwise identify all interconnecting wire and cable.
6. Include a few extra control wires between devices and panels in case of grounding, or where additional control functions might later be considered.
7. Protect all interconnecting wire and cable from abrading on sharp or rough edges.
8. For ease in trouble shooting, use of the control panel as a junction point for all interconnecting control wires will reduce the downtime required to locate trouble if it occurs.
9. Use of stranded wire is to be preferred on materials handling equipments.
10. Sufficient terminal board points should be provided and used so as not to require more than two control wires at any given terminal point.
11. Keep system free of unintentional grounds.
12. Collectors, where required, should be thoroughly reliable and their design should take into consideration ambient conditions (e.g. excessive dust or dirt, vibration, oxide producing fumes, corrosive element). Spring loaded, double shoe collectors give optimum performance.
13. Establish effective communication means between the control panel and the operator's station. Sound powered telephones are excellent.
14. Connect to a stiff power supply.
15. Keep wiring and components accessible.
16. Locate power components as near each other as practical.
17. Provide adequate bracing of equipment to eliminate "whipping" under vibration or rapid acceleration and deceleration of the drive.
18. Maintain adequate electrical and thermal clearances.
19. If equipment is to be stored before use, provide adequate protection against the elements.
20. If the equipment has been stored or unused for prolonged periods, be sure all equipment is dry and clean before energizing.
21. Check for frayed or loose connections.
22. After all equipment is installed and running, clean-up the area and remove accumulated debris.
23. Provide means to prevent unauthorized "tinkering".
24. Have three or four test weights or loads available at time of initial startup.
25. Have knowledgeable service available should trouble occur.
26. Before applying power, all contactors and relays should be checked by hand to insure that mechanical motion is not impeded by packing or other foreign material.
27. Interconnecting control wiring should be run in separate conduit from power wiring.

4-2 LOCATION

The power unit should be placed such that there is sufficient clearance in front and back, if there are rear panel devices, of the units to allow access for maintenance or repair. The power unit outline indicates the clearance required.

4-3 AIR SUPPLY

If the control enclosure is ventilated by the motor-generator set, there are various combinations of screened openings and louvered openings for the different types of cases. Make sure that these areas do not become obstructed, thereby restricting air flow.

Prior to shipping, openings of the MG set and enclosure are often masked closed to prevent dirt and dust from entering the equipment during shipping, storage, and installation.

CAUTION: REMOVE ALL TEMPORARY MASKING FROM OPENINGS OF MG SET BEFORE STARTING UP THE EQUIPMENT.

4-4 MOUNTING

See power unit outline, "Certified for Installation", for the number of supports and maximum deflection or twist of case base requirements for customer mounting.

4-5 CONNECTIONS

All internal electrical connections between components in the controller power units were made at the General Electric factory.

When installing the drive, all connections should be checked for tightness, since connections may become loose during shipping or storage.

Refer to the electrical diagrams which show all connections between the power unit and related components. All terminals to which external connections are to be made are numbered on the equipment as indicated on the connection diagrams.

The standard conduit entrance is through the bottom of the case; other entries may be furnished as required. A removeable cable entrance plate is provided over the conduit entries. All external wiring connects to terminal boards located near these entries. Care should be taken that all connections between the panels, master switches, limit switches, motors and brakes are made as shown on the interconnection diagrams, although the routing may differ from the diagrams.

CAUTION: MAKE CERTAIN THE INPUT VOLTAGE FREQUENCY, AND PHASE ON THE POWER UNIT NAMEPLATE ARE THOSE REQUIRED FOR THE INSTALLATION.

4-6 PRELIMINARY TESTS

This equipment was tested and adjusted by the General Electric Company prior to shipment. However, it is recommended that the following procedure be followed for initial start-up. If trouble is encountered, refer to the Trouble Shooting Chart in Section 6, Maintenance.

1. After the power unit, master switches, motors, and brakes have been interconnected in accordance with the electrical diagrams, check for grounds and shorts before applying power. It is recommended that the proper sequence of control operation be checked with the motor and brake disconnected before actually attempting to operate the motor.

CAUTION: DO NOT ATTEMPT TO APPLY ANY HIGH POTENTIAL ELECTRIC SOURCE TO THE ELECTRONIC DEVICES OF THE CONTROLLER.

2. Disconnect and temporarily insulate one of the armature leads of the motor and brake.

3. Remove all regulator power fuses.

4. Disconnect the wires connecting the generator suicide field to the control (generally F5 & F6 or F9 & F10, depending upon the generator field connection).

5. To apply A-C power to the controller with an A-C motor starter (MA), close any A-C disconnect switch (which may be remote). The motor can then be started by pushing the START button.

6. Start the motor-generator set, and check the motor-generator set fan or coupling for the correct rotation. Rotation should be according to the rotational nameplate on the MG set. If not, interchange any two of the A-C wires (L1, L2, L3) at the incoming A-C power terminals. A strong flow of air should be felt emanating from the exhaust holes in the rear of the case. If not, check for an obstruction in the air flow.

7. With the master switch in the OFF position, any emergency stop switch closed, all limit switches (if used) closed, and the motor generator set running, check the suicide circuit by connecting a voltmeter across the generator armature at power points connected to A1 & A2 of the generator. Observe the voltage when momentarily making contact with suicide field at connection points per connection diagram. For proper suiciding, the voltmeter should indicate one or two volts. If the voltmeter indicates that the voltage starts to build up, remove connection immediately, (the suicide field is connected incorrectly and the generator is building up self-excited). To correct, interchange the suicide field leads. Restart the motor-generator set, and check for correct suiciding.

8. Return the regulator power fuses, and check the OFF position motor-field current with the voltmeter connected across the resistor in series with the motor field. By checking the ohmic value of the resistor and any portion jumpered, calculate the motor-field current. The OFF position motor-field current should be approximately 65 percent of rated current*.

9. Determine operation of the devices under the following conditions. When the motor-generator set is started, the field loss relay (FL) should pick up and cause the undervoltage relay (UV) to pick up. Move the master switch to a HOIST position and then to a LOWER position. In both positions, the brake contactor (B) should pick up. Check generator polarity to see that it agrees with the elementary diagram.

10. With the master switch in the maximum HOIST position, measure the generator armature voltage at points A2 (positive) and A1, * and motor field current.

11. Move the master switch to the maximum LOWER position, and observe both the generator volts and the motor field current. *

* Refer to Test Data, inside case door of Fig 6-3 (if available).

12. Check the dropout of the brake contactor (B) by moving the master switch rapidly from the maximum HOIST or maximum LOWER position to the OFF position. The brake contactor will drop out after a short delay. If the master switch is moved from a slow-speed position to OFF, the contactor will drop out immediately.

13. The proper functioning of any emergency stop circuit can be checked by moving the master switch to a slow-speed position in HOIST or LOWER, and then tripping the emergency stop switch or any protective device. The undervoltage relay (UV) and the brake contactor (B) should drop out immediately. Reset the emergency stop switch or protective device, and return the master switch to the OFF position. The undervoltage relay (UV) should not pick up until the master switch reaches the OFF position.

With the master switch in a slow-speed HOIST or LOWER position, stop the motor-generator set by pushing the MG set STOP button. All devices (UV, B, and FL) should drop out immediately. Upon restarting the motor-generator set, the field loss relay (FL) should pick up; however, the undervoltage relay (UV) should not pick up until the master switch is returned to the OFF position.

4-7 POWER OPERATION

After satisfactorily completing the above preliminary start-up procedure, reconnect the motor armature and brake leads, and check the operation under empty hook conditions. If it is necessary to change the direction of rotation of the motor, interchange the motor shunt field leads.

* Refer to Test Data, inside case door or Fig. 6-3 (if available).

SECTION 5, ADJUSTMENTS

5-1 GENERAL

The following adjustment should be necessary, only after replacement of components, or disassembly of either control or the motor-generator set for servicing. Before attempting the adjustments, complete Steps 1 thru 6 listed under Preliminary Tests in Section 4. It is recommended that the section covering Principles of Operation be reviewed before making adjustments.

5-2 REGULATOR

The adjustments which follow cover the steps necessary to adjust a regulator which has not previously been adjusted or tested, or one which has been completely disassembled and rewired. During test at the factory, all potentiometers were adjusted and locked in position. In addition, the knobs were marked with permanent ink to allow readjustment to the original factory setting in case unauthorized persons tamper with the settings. For the following adjustments, disconnect the motor armature and brake leads.

1. Adjust the current feedback resistors, in series with the generator field, for 4 volts feedback at rated generator field current.

2. Set the current limit with an auxiliary D-C power supply or battery by setting generator voltage* and applying D-C voltage to the input of current limit circuit (see Sec. 3-3-2). A voltage signal* (drop across generator comm. field and dropping resistor), which corresponds to 200 percent current in the armature loop, should force the generator voltage to zero (actual voltage at stall would read about 40 volts for the IR drop at 200 percent current).

3. Adjust the OFF position motor field amperes, with the motor field bias potentiometer in the center on the regulator potentiometer bracket and adjust with (P606) on the motor field power amplifier card for 65 percent of rated current*.

4. With the master switch in the maximum HOIST position, adjust the maximum hoist voltage potentiometer to obtain rated hoist generator armature voltage.*

5. Using the hoist motor field amps potentiometer on the regulator bracket, adjust hoist weak field amperes.* The master switch is still in the maximum HOIST position.

6. Move the master switch to the maximum LOWER position. Adjust the maximum lower voltage potentiometer to obtain rated lower generator armature voltage of the correct value.* Adjust the lower motor field amps potentiometer.

* Refer to Test Data, inside case door or Fig. 6-3 (if available).

5-3 MOTOR SPEED

Motor speed is a function of load, and it is affected by the crane mechanical efficiency. To check speed for a specific hook load, the efficiency must be considered. The mechanical efficiency is generally figured at approximately 85 percent.

If all the regulator no-load adjustments were made properly, the motor speeds should be correct. However, if the speeds vary excessively from the line speed-hook load curve, recheck the regulator adjustments and refer to the Trouble Shooting Chart in Section 6 (see Appendix 6-5).

5-4 UNDERVOLTAGE RELAY (UV)

The undervoltage relay should pick up when the exciter is energized. There is no adjustment necessary.

5-5 VOLTAGE RELAY (HVR or VR)

The voltage relay is factory adjusted to pick up at approximately 60 percent generator volts and drop out at 30 percent generator volts. Any adjustments must be made by the adjustment screw or changing shim sizes.

5-6 BRAKE CONTACTOR (B)

The brake contactor has only a single control coil with no adjustment possible (see voltage relay).

5-7 FIELD LOSS RELAY (FL)

The field loss relay (FL) is set to pick up at 50-60 percent of rated amperes or less.* There should be no adjustment required. If necessary, any adjustment must be made by the adjustment screw or changing shim sizes.

5-8 INSULATION TEST

The insulation to ground of the motor armature, motor field circuit, brake solenoid, and heater circuits may be checked by use of a 500 volt, D-C megger. For acceptable megger readings, check the device Instruction Book.

Before attempting to apply any hi-potential source to the system, the fuses must be removed from all of the transformers in the control cabinet. The regulator cards must also be removed from their receptacle, and must have at least a one-inch clearance with their receptacle.

SECTION 6, MAINTENANCE

6-1 GENERAL

Refer to the manufacturer's instruction publications contained in later Section for a detailed maintenance procedure on devices, the d-c motor, and the motor-generator set.

If it is necessary to disassemble the control or motor-generator set to service or repair the equipment, the preliminary tests and adjustments procedure should be followed in putting the equipment back in operation.

6-2 GENERAL TROUBLE SHOOTING

The following is a general procedure to follow when trouble shooting, after a shutdown due to suspected failure of components or circuits. Attempt to isolate the trouble to a general area and then refer to the Trouble Shooting Chart for the specific types of malfunction and the recommended solution.

1. Make a visual check of the control for broken wires or loose connections, also look for damaged contactors or relays, as indicated by burned or welded tips. Observe resistors, capacitors, chokes, and reactors for evidence of overheating such as discoloration, smoking, or dripping insulation.

2. Make sure there are no open control fuses. Measure all a-c and d-c control power voltages and compare with reference values given on the Elementary Diagram and Test Data inside case door or Fig. 6-3 (if available).

3. Observe all relays and contactors to determine that they pick up and drop out in the proper sequence.

The following is the normal sequence of operation of relays with the motor-generator set running.

Device	Condition
Field Loss Relay (FL)	Always picked up
Undervoltage Relay (UV)	Always picked up with master switch in the OFF position.
Brake Contactor (B)	Picked up when master switch is in operating position. Drops out when master switch is returned to OFF position

4. Ring out the circuitry in the suspected area, opening connections as necessary to isolate series circuits that may be checked in their entirety. Contactors and relays should be operated manually where necessary, to establish continuity through the selected and now isolated series circuits. An ohmmeter will allow checking continuity through all resistors, potentiometers, coils, etc., in the isolated series circuit. After establishing continuity or finding the fault in the circuitry, make sure that all connections removed for purposes of circuit isolation are reconnected.

When a rectifier failure is suspected, the following procedure may be used to check either a bridge or a single cell. In the case of a bridge, each individual leg must be checked. Disconnect all leads to the rectifier, and measure the forward and reverse resistance of each cell, using a multimeter with the selector on the X1K or X100K scale. The resistance should be very low in the forward direction and practically infinite in the reverse direction. If the rectifier or one leg (in the case of a bridge) measures zero resistance in both directions or infinite resistance in both directions,

* Refer to Test Data, inside case door or Fig. 6-3 (if available).

the rectifier has been damaged and must be replaced.

If failure of a capacitor is suspected, isolate the capacitor from the circuit. Discharge the capacitor by shorting the output terminals, and measure the resistance using a multimeter with its selector and the X100K scale. A normal capacitor will indicate a low resistance initially; as the capacitor charges, the resistance will increase until, at full charge, the meter will indicate infinite resistance. Capacitors with larger values of capacitance will require longer charging times. If the capacitor does not indicate a charging current (delay of the meter in reaching infinite resistance), or indicates zero or low resistance, the capacitor should be replaced. Also, if a capacitor shows evidence of leakage of electrolytic, it should be replaced.

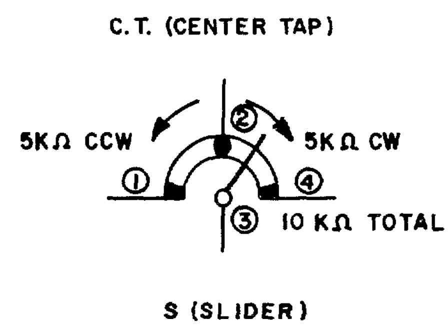
5. If it is impossible to obtain generator voltage or motor field current, the reversing driver, power amplifier, or coordination card may be defective. Select a spare card. Insert the known good cards into the malfunctioning regulator, after adjusting and checking card connections (coordination), and check the operation. If operation is normal, then the original cards were defective.

6. When a SCR is suspected of malfunctioning, first check the wiring connections and suppression circuits around the SCR's. If an oscilloscope is available, check the SCR firing per Section 6-4-13 of Trouble Shooting Chart. Then if the SCR's themselves are suspected as faulty, disconnect two of the three leads to an SCR so as not to introduce false readings. Using a multimeter on the 1000X ohms scale, a good SCR should read 100K to infinity ohms in the forward direction and 30K to 50K ohms in the reverse direction. A shorted or inoperative SCR will give very low readings in one or both directions, but an open SCR will give the same readings as a good SCR. To check for an open SCR, connect the ohmmeter across the SCR with plus at the anode; the reading should be high as already mentioned. Then touch the gate to the anode and the SCR should conduct to give a low reading; if not, the SCR is open. Ideally the SCR should remain conducting until it is disconnected from the ohmmeter, but the ohmmeter only puts a small voltage across the SCR, so it may turn off when the gate is removed from the anode.

Once a faulty SCR is located, remove the cell from the heatsink and recheck to be sure the SCR was isolated from the circuitry and a fault in another cell was not producing false readings. When replacing SCR's, be careful not to damage adjacent SCR's or overheat the SCR if it is necessary to solder leads.

7. When the Hoist and Lower references are not equal for equal throws of the master switch, or if there is a "zero spot" in the reference, the master switch potentiometer may be faulty or off center, or the stop screws for the master switch handle may be set wrong. To check the master switch pot, disconnect all its connections to prevent false resistance readings. With an ohmmeter check the resistance of the pot on both sides of the center-tap (1-2 & 4-2 on pot below) which should be 5K ohms or 10K ohms total. To center the pot, first loosen the set screw holding the coupling of the master switch shaft to the potentiometer shaft. With the master switch in the OFF position and the ohmmeter connected across the center-tap and wiper arm of the pot (2-3 on pot), center the pot shaft for a null reading (ideally zero, but actually about 100 ohms). Tighten the set screw and recheck the null reading to be certain the pot did not move while tightening the set screw.

Then adjust the master switch handle stop screws to assure that full reference is reached with the full throw of the master switch Set these screws to the lowest point, connect the ohmmeter across the center-tap and wiper arm of the pot (3-2 on pot), and move the master switch slowly to its maximum position. The meter reading should increase to a maximum of 5K ohms in each direction, and at the end of travel there is a shorted segment of approximately 10 degrees rotation (indicated by blackened portions at the ends of the pot below) which can be observed on the ohmmeter. Now adjust the stop screws to stop the master switch handle approximately in the center of these shorted segments.



Sketch of Master Switch Potentiometer Connections

6-3 CHANGING REGULATOR CARDS

CAUTION: NEVER PULL OUT A REGULATOR CARD IF THE EQUIPMENT IS ENERGIZED.

6-3-1 GENERATOR FIELD

With the power off, replace the reversing driver card and open the loop between the d-c motor and generator. Recheck the generator field resistors' setting for approximately 4 volts feedback, plus and minus, for rated generator field current.* The card is now adjusted, and a quick check of the generator armature voltage should be taken. With master switch (MSP) full on, adjust the maximum speed control potentiometers with the armature loop open.*

6-3-2 MOTOR FIELD

With the power off, replace the power amplifier card, and connect a voltmeter across resistor in series with the motor field. By checking the ohmic value of the resistor and any jumpered portion, calculate the motor field current or use ammeter. Check test data sheet.* Access may be gained to the bias adjust potentiometer (P606) by removing the plug in the face of the card. A Philips head screwdriver is ideal for adjustment.

There are two controls for motor field current; potentiometer (P606) on the card itself, and motor field bias potentiometer on the regulator potentiometer panel. Clockwise rotation of these potentiometers increases the motor field current.

With the power on and master switch (MSP) in the OFF position, adjust these two potentiometers.* A check of motor field amps in the maximum HOIST and LOWER positions should be taken. With the armature loop open and master switch (MSP) in full HOIST, adjust the Hoist field amp potentiometer.* With master switch (MSP) in full LOWER, adjust the Lower field amp potentiometer.

6-3-3 COORDINATION CARD

The coordination card is directly replaceable, with no adjustments necessary. However, the jumper locations on the card should be noted to be sure that it corresponds with the replaced card. See Appendix 6-5 if it is necessary to check the drive's speed versus load characteristic.

* Refer to Test Data, inside case door or Fig. 6-3 (if available).

6-4 DETAILED TROUBLE SHOOTING

For information on Trouble Shooting, refer to the Following Trouble Shooting Chart

TROUBLE SHOOTING CHART

TROUBLE	POSSIBLE CAUSE	COMMENT
1. A-c motor will not start	1. Open line fuses or open breaker	
	2. Overload system tripped	2. Overloads normally automatic rest, check relays. Reset if necessary.
	3. Low line voltage	3. Motor nameplate voltage should agree with that of the power supply. Dual-voltage motors should be reconnected as necessary, to agree with power supply voltage.
	4. Open circuit in stator windings	4. See instructions for motor.
	5. Faulty control	5. Check the a-c motor-starting controller for proper operation. Replace any badly worn or broken control elements.
2. A-c motor noisy	1. Motor running single phase	1. Stop the motor; then try to start. It will not start on single phase. Check for an "open" in one of the lines.
	2. Unbalanced power supply voltage.	2. Check the voltage and current balance on all three lines.
	3. Vibration	3. Check the motor-generator set alignment.
	4. Noisy Ball Bearings	4. Check lubrication; also check for overgreasing. Check the bearing outer race surface for evidence of turning in the housing. Replace the bearings if the noise is persistent and excessive.
	5. Cramped bearings and/or rotor rubbing on stator	5. Check for proper reassembly of all rabbetted parts of the motor or motor-generator set.
3. A-c motor temperature excessive, possibly smoking	1. Incorrect power source voltage and/or frequency.	
	2. Motor running single phase	2. Refer to same subject under "AC motor noise".
	3. Insufficient ventilation	3. Remove any obstructions to the free flow of intake or exhaust air.
	4. Stator winding shorted and/or grounded	
	5. Overload	
4. Bearings (motors and generator)	1. Machine mechanical parts not reassembled properly	1. All rabbetted machine parts should be fitted squarely and properly tightened.
	2. Too much grease	2. Remove the relief plugs and let the machine run to expel any excess grease.
	3. Insufficient grease	
	4. Wrong grade of grease	
	5. Bearing damaged	

TROUBLE SHOOTING CHART (CONT'D)

For information on Trouble Shooting, refer to the Following Trouble Shooting Chart

TROUBLE	POSSIBLE CAUSE	COMMENT
5. Brushes sparking (d-c motors and generator)	1. Poor brush fit	1. Sand the brushes to a proper fit, or stone the commutator with the brushes down.
	2. Commutator rough or pitted.	2. Stone the commutator with the brushes up.
	3. Foreign material on commutator.	
	4. High mica	4. Undercut the mica.
	5. Commutator extremely rough, and/or eccentric	5. Turn down the commutator and undercut the mica.
	6. Excessive vibration	
	7. Insufficient or excessive brush pressure	7. A nominal acceptable brush pressure value is 2 to 2-1/2 pounds. All brushes should ride freely in their holders.
	8. Brushes too short	
	9. Brushes off neutral	9. Generator reset to inductive neutral. Motors reset, usually to full-load speed neutral.
	10. Short circuit in armature	10. Check the commutator and remove any metallic particles between segments. Check for short circuits between adjacent commutator risers.
	11. Incorrect brushes for the service	11. Obtain recommendations from the General Electric Company.
	12. Poor atmospheric conditions	
	13. Overload	
6. Field coils overheat (d-c motors and generator)	1. Short circuit between turns or layers of the field coil	
	2. Excessive shunt field voltage	
7. "Jerky" stops	1. Voltage relay not delaying setting of brake	1. Check voltage relay and continuity of circuit.
	2. Too high tension on brake spring	2. Check the brake spring adjustment.
8. Excessively high speed, both hoist and lower	1. High generator voltage	1. See Section 5, "Adjustments". Check feedback circuit.
	2. Low motor field	2. See Section 5, "Adjustments". Check field strengthening circuit.
9. Normal speed in in hoist, high speed in lower with load	1. Capacitor 4C failed (capacitor off STAB pot)	1. Replace the capacitor.
10. High speed empty hook lower (normal speed hoist)	1. Capacitor 4C failed (capacitor off STAB pot)	1. Replace the capacitor.

TROUBLE SHOOTING CHART (CONT'D)

For information on Trouble Shooting, refer to the Following Trouble Shooting Chart

TROUBLE	POSSIBLE CAUSE	COMMENT
11. Normal speed with empty hook; high speed full load (both hoist and lower)	1. Loss of armature current feedback	1. See Section 5, "Adjustments". Check field strengthening circuit.
	2. Failure of component on card 193X715	2. Replace the card.
12. Excessively low speed both in hoist and in lower	1. Low generator voltage	1. See Section 5, "Adjustments". Check reference adjustment.
	2. High motor field voltage	
13. Impossible to obtain generator voltage	1. Generator field fuses blown	1. Replace the fuse. If the fuse fails repeatedly, check to determine that MS closes in the OFF position Check SCR for failure. Replace the generator card 193X730. Replace SCR bridge card 193X735.
	2. Loss of reference	2. Check fuse in 230 vac supply from GPT. Check for shorts. Replace generator card 193X730. Check master switch pot.
	3. Undervoltage relay (UV) interlock shorted closed	3. Fix relay.
	4. SCR's failed	4. Check per Section 6-2-6. Replace SCR bridge card 193X735.
	5. BX relay failed	5. BX relay should be picked up with B contactor to allow reversing driver to operate, may be pulled for emergency operation.
	6. Loss of field current feedback.	6. Check adjustment per Section 6-3-1. Check polarities for lockout circuits.
	7. SCR's misfiring	7. The use of an oscilloscope is necessary to observe whether the generator SCR's are firing correctly by connecting it directly across the field. The plus and minus output should be per Fig. 3-5 c & e. If not, check gate pulse signals. With a positive voltage input to the reversing driver, a scope from Tab 27 to 23 should indicate a series of sawtooths (Fig. 3-5 b) and Tab 12 to 23 should have no signal. With a negative input, reverse readings to the above should occur. Replace driver card 193X730. Replace SCR bridge card 193X735.
14. Low generator volts	1. Low reference voltage	1. Measure voltage 2 to 28 should be 40 volts d-c. (+20 VDC to −20 VDC)
15.Low generator volts in LOWER	1. Timing capacitor in reference circuit has high leakage	1. Replace the capacitor.
16. High generator voltage	1. Failure of generator field current feedback	1. Check circuit. Replace rev. driver 193X730
	2. Failure of generator voltage feedback resistor	2. Replace the resistor.
17. Impossible to obtain generator volts in HOIST	1. Master switch contact in reference circuit failed to open.	1. Inspect and replace if necessary.
	2. Hoist SCR's bad	2. See 13-4 & 7 – Trouble Shooting Chart.

TROUBLE SHOOTING CHART (CONT'D)

For information on Trouble Shooting, refer to the Following Trouble Shooting Chart

TROUBLE	POSSIBLE CAUSE	COMMENT
17. Impossible to obtain generator volts in HOIST (cont'd)	3. Hoist reference bad.	3. See Section 6-2-7.
18. Impossible to obtain generator volts in LOWER	1. Master switch contact in reference circuit failed to open	1. Inspect and replace if necessary.
	2. Timing capacitor failed in reference circuit	2. Replace capacitor
	3. Lower SCR's bad	3. See 13 - 4 & 7 – Trouble Shooting Chart.
	4. Lower reference bad	4. See Section 6-2-7.
19. High motor field amperes with master switch in OFF position	1. Loss of motor field current feedback	1. Check voltage across motor field resistor. Check the continuity of the feedback circuit.
	2. OFF position bias	2. Check per Section 5-2.
	3. Bad coordination card	3. Replace coordination card 193X715 after checking jumper settings.
20. Excessive armature amperes	1. Loss of armature current feedback	1. Check the continuity of the feedback circuit.
	2. Low Motor Field	2. Check adjustments Section 5-2.
	3. Loss of current limit	3. Check circuit. Check rectifier bridge (D1). Check Zener voltage (Z1, Z2, Z3).
	4. Bad capacitor around hoist transistor (coord.)	4. Replace capacitor
21. Undervoltage relay (UV) won't pick up	1. Field loss relay (FL) not picked up or interlocks are open	1. Observe and inspect FL.
	2. Emergency stop switch open	2. Close and check circuit continuity.
	3. OFF position master switch contact in UV circuit open.	3. Return the master switch to the OFF position and check circuit continuity.
	4. Control voltage is low	4. Measure the voltage. It should be 240 volts d-c.
22. Undervoltage relay (UV) drops out when master switch is moved to operating position	1. UV sealing interlock open	1. Check with an ohmmeter, replace if necessary.
23. Brake contactor (B) won't pick up	1. Master switch contacts in brake contactor circuit	1. Check the continuity of the circuit.
	2. UV interlock open	2. Check undervoltage relay (UV) interlocks with an ohmmeter, replace if necessary.
24. Brake contactor (B) picks up and drops out, chatters (MS in OFF position)	1. Generator suicide field connected backwards	1. Check the generator for correct suiciding.

TROUBLE SHOOTING CHART (CONT'D)

For information on Trouble Shooting, refer to the Following Trouble Shooting Chart

TROUBLE	POSSIBLE CAUSE	COMMENTS
25. Field Loss relay (FL) won't pick up	1. Motor field current low	1. See the regulator adjustments.
	2. Loss of motor field	2. Check the continuity of the field circuit. Regulator a-c power fuse blown.
26. Brake sets in light hook speeds	1. FL drops out	1. Motor field too weak, refer to motor field adjust Section 6-3-2.

6-5 APPENDIX CONCERNING SETUP INSTRUCTIONS FOR MAXSPEED CRANE DRIVE CURVES

6-5-1 CHECK ON CHARACTERISTIC CURVES

Generally it is not recommended that someone attempt to set up these Maxspeed Crane Drive characteristic curves in the field, mainly because of the difficulty of loading and measuring speeds as accurately as necessary. These instructions are included mainly to give a better understanding of the regulator setup and how minor adjustments can be made. These cards have been set up as accurately as possible at the factory; and, although no two cards are exactly identical because of tolerances, differences between cards are usually negligible, and when replacing cards it should only be necessary to connect the coordination card jumpers per the Test Data sheet* connections. Of course, there will always be those cases where the drive characteristic must be changed for one reason or another. First, record original tap settings of jumpers.

The Test Data sheet* gives the speed and motor field amps versus load data. One fact that should be noted when comparing the test data and actual performance is that it is impractical for the factory to regenerate the motor to set up the Lower characteristic. Since the motor is motoring in the Hoist direction for both Hoist and Lower characteristic setups, the actual speeds in Lower will be higher than the test data shows. For example, at rated load the factory set speed in Lower is 1.2 X base speed, but the actual Lower speed with rated load will be about 1.4 X base speed because now the load is overhauling rather than being driven.

Because of the loading and measuring problem already mentioned, one way to check the characteristic is to disconnect the motor armature and brake from the power loop, insulate the leads, and run the generator open loop. Essentially the characteristic curve is a program of the motor field current according to the load or armature amps, which the regulator sees as a voltage drop across the generator commutating field and a dropping resistor. With the open loop system, feed a dummy d-c voltage into the regulator corresponding to some load* and record the motor field amps. In this way check motor field amps versus armature amps over the full range of loading and compare to the test data*.

If the check does not approximate the test data or characteristic curve, read the following section which gives a step-by-step setup procedure for the coordination card as would be followed at the factory. These instructions should give an idea as to which connections should be changed and where in order to make the drive meet the desired curve. In other words, this is a trial-and-error procedure for the inexperienced, and, for this reason, tampering with the coordination card jumpers should be avoided unless absolutely necessary.

6-5-2 SETUP INSTRUCTIONS APPENDIX FOR MAXSPEED CURVES

(Setting Coordination Card Jumpers)

Preliminary Adjustments.

1. Check generator field current feedback to reversing driver - 4 volts at rated field current.*
2. Set motor field bias pot on regulator to give motor field current of 65 percent of rated.*
3. Set the maximum voltage pots to give rated volts for full throw of master switch in both directions.*

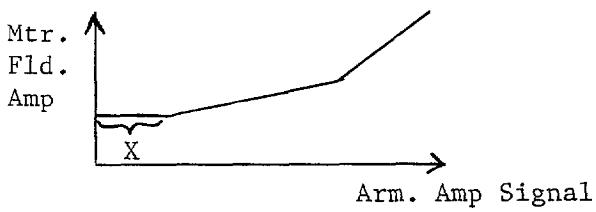
Again because of the difficulty of measuring speeds and loads accurately, it is necessary to plot motor field amps versus armature amps and compare to Test Data Sheet* which also gives the test jumper settings. To do

* Refer to Test Data, inside case door or Fig. 6-3 (if available).

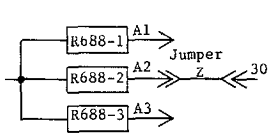
this requires that the motor armature and brake coil be disconnected and use a dummy d-c signal to simulate load as in Section 6-5-1.

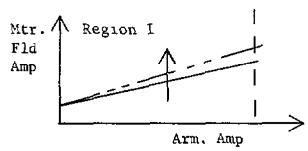
To check the Lower characteristic, first adjust the lower field amp pot to give maximum lower RPM field amps with rated generator volts. Then plot motor field amps versus armature amps (load signal).

Below is a sketch of a lower characteristic with a flat portion, denoted as X, as a result of improper bias on the lower diodes. Adjust jumper V (see Fig. 6-1 for coordination card) on R692 for proper bias and eliminate the flat portion of curve. This jumper is normally set at point 27 and should not be necessary to change it.

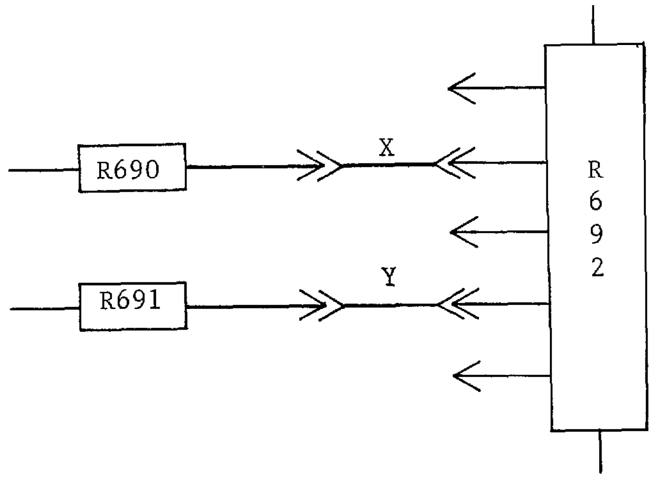


The lower characteristic is divided into three Regions I, II, and III. (See Fig. 3-9b). R688 controls Region I, and since it also affects the other regions, it must be adjusted first. Shifting Jumper Z to a lower value of R688 tends to raise the curve as shown. Likewise, a higher value of R688 will lower the curve. The other side of Jumper Z must stay at point 30 on R692.





R691 controls Region II and affects Region III, but not Region I. Shifting Jumper Y in a similar manner to Z will raise or lower the curve accordingly. Finally, R690 controls Region III only, and again Jumper X will raise or lower the curve as R690 is lowered or raised. The value of R690 or R691 determines the rate of change or slope of the region they govern while the tab selected on R692 determines where on the characteristic curve this slope takes effect.



Another way to look at jumper adjustments.

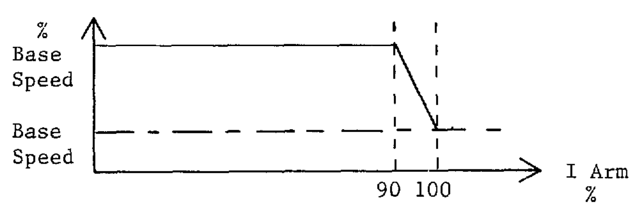
To move curve up (less rpm @ a particular load):

(R688 - Z (A) Region I
Decrease (R691 - Y (C) Region II or Move Jumper Z, Y, or X
(R690 - X (B) Region III R692 (1-31) Toward 31.

and vice-versa to move curve down.

The lower characteristic should now check with test data. To check the hoist characteristic, adjust hoist field amp pot to give maximum rpm* motor field amps with rated generator volts for hoist.

Below is a sketch of the hoist characteristic. The hoist Jumper W will control the knee of the hoist characteristic.* See Fig. 3-9b for motor field amp curve.



* Refer to Test Data, inside case door of Fig. 6-3 (if available).

Final Checks:

1. 4 volts feedback to reversing driver from generator field resistors.
2. Motor field bias pot set for 65 percent rated current.*
3. Max. voltage pots set to give rated volts* in both directions for full throw of master switch.
4. Hoist field amp pot set to give max. rpm* with rated arm. volts.
5. Lower field amp pot set to give max. rpm* with rated arm. volts.

Check commutation for fast slowdowns, stops, and motor reversals from both Hoist and Lower directions. Also check current limit by observing voltage across comm. field and dropping resistor during motor reversals, using voltage drop at rated current* for reference. If possible, a brush recorder is helpful, recording arm. amps versus time.

Normally the stability potentiometer (STAB), located on regulator pot bracket, is set at position 3.

* Refer to Test Data inside case door of Fig. 6-3 (if available).

6-6 REGULATOR MAINTENANCE KIT

CAUTION: READ AND THOROUGHLY UNDERSTAND THESE INSTRUCTIONS BEFORE ATTEMPTING ANY ADJUSTMENT OR MAINTENANCE OF THE RECEPTACLE WIRING OR LEAF TERMINALS.

GENERAL

A maintenance kit is furnished with each regulator. The kit includes a release tool, jumper springs, wire jumpers, and retaining springs. A card extender is available as a modification and therefore, supplied only when ordered. The kit is normally stored in the speed variator case bookholder.

MAINTENANCE KIT USAGE

A. Instructions for Changing Wires in the Printed Circuit Receptacle.

1. Remove printed card or cards from receptacle or receptacles that are to be rewired.

2. Open regulator case by releasing the two latches on regulator support and rotate case forward until the stop supports the case in the open position.

3. Locate wire point or points to be changed.

   NOTE: The numbers on the receptacles correspond to numbers in the wire table and also to the tab numbers on the printed circuit card schematic diagram.

4. Remove jumper springs (if present) from connections which are to be changed before removing or adding wires. See Figure No. 4.

5. Removing wires from receptacle:

   Insert the release tool as shown on Figure No. 2 or No. 5.

   Remove wire, which has a crimped on leaf terminal, as the release tool depresses the leaf terminal holding latch. See Figure No. 2 or No. 5.

6. Adding wires to the receptacle.

   Check each leaf terminal for damaged leaf, before inserting into receptacle. See Figure No. 3.

   Insert leaf terminal in desired location and push until the holding latch snaps into place. See Figure No. 4.

   Add jumper springs, where necessary, to complete the wire sequence.

   IMPORTANT: Jumper springs must be added only after wires are inserted.

   NOTE: Insert jumper spring on center web only (horizontally adjacent to terminals) and push with a screwdriver or similar tool until spring is seated on receptacle shoulder. See Figure No. 4. Too much pressure will either damage the spring or push the spring over the receptacle shoulder, causing a malfunction.

7. When making wire changes,

   Check the entire wire run for each wire being changed to make certain the wire sequence is maintained and continuous, according to the wire table.

   Work only to an original or marked-up wire table when making changes to regulator wiring.

B. Instructions for Removing or Adding Retaining Springs

1. Remove retaining spring (See Figure No. 6).

   Insert the release tool prong between the center web and the retaining spring on the wire side of the receptacle.

   Using a small screwdriver, push the retaining spring through the receptacle and out of the card side.

2. Add retaining spring:

   Check each retaining spring for damage before inserting into receptacle. See Figure No. 7.

   Insert retaining spring into the selected slot in the card side of the receptacle.

   Push until the spring snaps into place.

C. Instructions for Use of a "Card Extender" (If Furnished)

The card extender is designed to enable trouble shooting and testing of a printed circuit card with power on. When a printed circuit card is inserted in the card extender, any point on the card becomes accessible for probing.

Each printed circuit card has an anti-tarnish protective coating on the etched side of the card. When probing on the etched side of the card, the probe must penetrate the protective coating in order to make satisfactory contact.

The card extender may also be used to extend the test points to the front of the regulator.

1. Extending a card for trouble shooting:

   Locate defective card by checking each test point per voltage check list on the speed variator elementary diagram.

   Turn power off and remove defective card.

   Insert card extender in place of defective card.

   Insert defective card in receptacle of card extender and clamp card with means provided.

   Check card per instructions for that particular function or card.

2. Extending the test points:

   Remove the spacer card from the test point receptacle.

   Insert the card extender into the test point receptacle.

   CAUTION: DO NOT INSERT ANY FUNCTION CARD IN RECEPTACLE OF CARD EXTENDER WHEN CARD EXTENDER IS IN THE TEST POINT RECEPTACLE POSITION.

   Probe the test points from the card extender receptacle at the front of the regulator.

   NOTE: The receptacle is not designed to hold a test probe; therefore, clip one lead of the instrument to "common" on the regulator terminal board and with the other lead, which should have a phono-needle tip type test probe, probe points for readings.

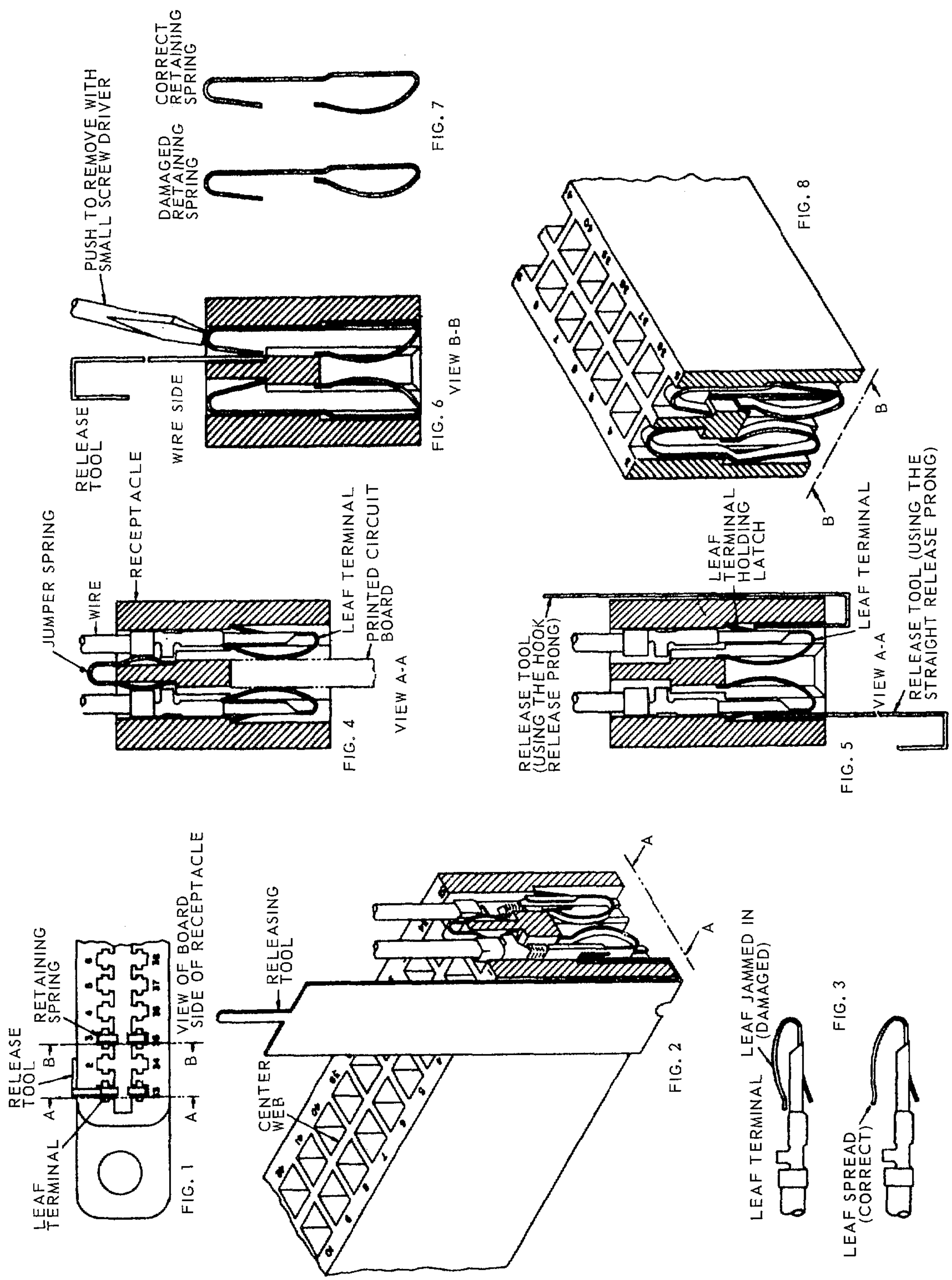


Figure 6-2 Maintenance Kit Instructions (Sheet 2)

MAX SPEED______________ CRANE DRIVE
Hoist, Bridge, Trolley or Gantry Function

Reqn.__________________
S/N __________________

Coordination Card Connections

Wire	From	To
U		
V		
W		
X		
Y		
Z		

Pot Settings

1P	
2P	
3P	
4P	
5P	

Current Limit

Arm A	Arm V

______HP; ______/______ RPM Base Speed/Max Speed
______Current Feedback Volts Equals________ rated armature amps
______Rated Motor Field Amps for______ volt connection
Volts Across Motor Field Resistor Equals________ (OFF Position) Amps (65%)

Lower or Reverse

% Load	0	25	50	75	100	125
RPM						
Arm A						
Fld A						
Arm V						

______ Ref. Volts = ______ Hoist Volts
______ Ref. Volts = ______ Lower Volts

______ Generator Field Feedback Volts

Hoist or Forward

% Load	0	25	75	90	95	100	125
RPM							
Arm A							
Fld A							
Arm V							

DEVICE CHECK

	P.U.	D.O.
HVR (or B)	________	________
FL	________	________
IOC	________	________
BSR	________	________
UV	________	________
Limit Switches	________	________
Pots Marked	________	________
Pots Locked	________	________

NOTE: These test values are given for rated a-c input voltage and with the equipment at operating temperature. Variation of a-c input voltage and heating of the equipment will result in readings varying from the values indicated. Approximately 5 percent would be normal.

Tested By ____________________

Date ____________________

Figure 6-3 Test Data Sheet

GENERAL ELECTRIC SALES OFFICES

READY TO ASSIST YOU . . When You Have Electrical Problems . . . Need Further Information . . Require Ordering Instructions

SALES OFFICE CODE KEY
- * Industrial Equipment (including Agent and Distributor) Sales
- † Electric Utility Equipment Sales
- § Marine and Defense Equipment Sales
- ‡ Component Sales Operation

ALABAMA
- * † ‡ Birmingham 35205 — 2151 Highland Ave.
- * Mobile 36602 — 704 Government St

ARIZONA
- * † ‡ Phoenix 85012 — 3550 N Central Ave
- * † Tucson 85711 — 151 S Tucson Blvd

ARKANSAS
- * ‡ North Little Rock 72114 — 1900 E Washington
- † Pine Bluff 71602 — P. O Box 1033

CALIFORNIA
- * Fresno 93728 — 1532 N West Ave
- * † § Los Angeles 90054 — 212 N Vignes St
- ‡ § Los Angeles 90005 — 3325 Wilshire Blvd
- * Oakland 94612 — 409 Thirteenth St
- * Redwood City 94063 — 55 Veterans Blvd.
- * † Sacramento 95816 — 2407 "J" St
- * † § San Diego 92103 — 2560 First Ave
- * † ‡ § San Francisco 94106 — 235 Montgomery St
- * San Jose 95128 — 2155 So First St

COLORADO
- * † ‡ § Denver 80201 — 201 University Blvd

CONNECTICUT
- * † Hamden 06518 — 2905-2921 Dixwell Ave
- * † ‡ Hartford 06105 — 764 Asylum Ave

DISTRICT OF COLUMBIA
- * † § Washington 20005 — 777—14th St, N W

FLORIDA
- § Cocoa Beach (Cape Canaveral Office) — 1325 N. Atlantic Ave.
- * Coral Gables 33146 — 250 Bird Road
- * † Jacksonville 32202 — 1901 Hill St.
- † Miami 33134 — 4100 West Flagler St
- † Pensacola 32503 — First Bank Bldg.
- † ‡ Tampa 33609 Henderson Blvd at Lois Ave
- * Tampa 33609 — 2106 S. Lois Ave

GEORGIA
- * † ‡ Atlanta 30309 — 1860 Peachtree Rd, N.W
- * Macon 31202 — 682 Cherry St
- * † Savannah 31405 — 5002 Paulsen St

IDAHO
- * † Boise 83706 — 1524 Idaho St

ILLINOIS
- * † ‡ § Chicago 60680 — 840 S Canal St
- * † Peoria 61603 — 2008 N E. Perry Ave
- * Rockford 61105 — 4223 East State St.
- † Springfield 62701 — 607 E Adams St

INDIANA
- * † ‡ Evansville 47714 — 2709 Washington Ave
- ‡ Fort Wayne 46807 — 1635 Broadway
- * † Fort Wayne 46806 — 3606 S Calhoun St
- * † ‡ Indianapolis 46207 — 3750 N Meridian St
- * ‡ South Bend 46601 — 430 N Michigan St

IOWA
- * † Cedar Rapids 52401 — 210 Second St, S.E
- * † ‡ Davenport 52805 — 1039 State St., Bettendorf, Iowa
- * † Des Moines 50310 — 3839 Merle Hay Rd
- † Sioux City 51101 — 520 Pierce St.

KANSAS
- * † Wichita 67211 — 820 E. Indianapolis Ave.

KENTUCKY
- * † Lexington 40503 — 465 E. High St.
- * † ‡ Louisville 40218 — 2300 Meadow Dr

LOUISIANA
- † Alexandria 71302 — 720 Murray St
- * Baton Rouge 70815 — 633 Oak Villa Blvd
- * Lake Charles — 1424 Ryan St
- † § New Orleans 70112 — 837 Gravier St.
- * New Orleans 70125 — 4747 Earhart Blvd
- * † Shreveport 71101 — 400 Travis St

MAINE
- † Augusta — 152 State St
- * Bangor 04402 — 77 Central St

MARYLAND
- * † ‡ Baltimore 21201 — 1 North Charles
- † Hagerstown — 49 East Franklin St

MASSACHUSETTS
- * † ‡ § Boston 02117 — 31 St James Ave
- * Springfield 01103 — 120 Maple St.
- * Worcester 01605 — 288 Grove St

MICHIGAN
- * † ‡ Detroit 48202 — 700 Antoinette St
- * Flint 48503 — 316½ W Court St
- * ‡ Grand Rapids 49508 — 2821 Madison Ave, S E
- * † Jackson 49201 — 210 W Franklin St
- * Kalamazoo — 927 S Burdick St.
- † Lansing 48901 — 501 Bank of Lansing Bldg
- * Saginaw 48607 — Second National Bank Bldg

MINNESOTA
- * † Duluth 55802 — 14 W Superior St
- † Fergus Falls 56537 — 106 E. Washington St
- * † ‡ Minneapolis 55402 — 12 S. Sixth St

MISSISSIPPI
- † Gulfport 39502 — P O Box 33
- † Jackson 39201 — 210 S Lamar St

MISSOURI
- * Joplin 64802 — 212½ W Fifth St
- * † ‡ Kansas City 64105 — 106 W Fourteenth St
- * ‡ St Louis 63101 — 1015 Locust St

MONTANA
- * † Billings 59101 — 303 N Broadway
- * † Butte 59701 — 103 N Wyoming St

NEBRASKA
- * † Omaha 68102 — 409 S Seventeenth St

NEVADA
- † Las Vegas 89106 — 1711 S 8th St

NEW HAMPSHIRE
- † Manchester 03104 — 1662 Elm St

NEW JERSEY
- * † ‡ East Orange 07017 — 26 Washington St

NEW MEXICO
- * † Albuquerque 87108 — 120 Madeira Drive, N E

NEW YORK
- * † § Albany 12203 — 8 Colvin Ave
- † Binghamton 13902 — 19 Chenango St
- * † ‡ Buffalo 14202 — 625 Delaware Ave
- * † § New York 10022 — 570 Lexington Ave
- * † ‡ Rochester 14604 — 89 East Ave
- * † ‡ Syracuse 13206 — 3532 James St
- * Utica 13501 — 1001 Broad St
- ‡ Waverly 14892 — P O Box 308

NORTH CAROLINA
- * † ‡ Charlotte 28202 — 129 W Trade St
- * Greensboro 27405 — 801 Summit Ave
- * † Raleigh 27602 — 16 W Martin St

NORTH DAKOTA
- † Bismarck 58501 — 418 Rosser Ave

OHIO
- * † Akron 44313 — 2858 W Market St
- * † Canton 44701 — 515 Third St, N.W
- * † ‡ Cincinnati 45206 — 2621 Victory Pkwy
- * † ‡ § Cleveland 44104 — 4966 Woodland Ave
- * † Columbus 43215 — 395 E Broad St
- ‡ Columbus 43212 — 937 Burrell Ave
- * ‡ Dayton 45402 — 11 W Monument Ave
- * † § Dayton 45402 — 118 W First St
- ‡ Mansfield 44906 — 564 Park Ave., West
- * † ‡ Toledo 43606 — 3125 Douglas Rd
- * Youngstown 44507 — 272 E Indianola Ave

OKLAHOMA
- * † Oklahoma City 73106 — 2000 Classen Blvd.
- * † Tulsa 74114 — Columbia Bldg, 2651 E. 21st St

OREGON
- * † Eugene 97401 — 1170 Pearl St.
- * † Medford 97501 — 107 E Main St
- * † ‡ Portland 97210 — 2929 N.W. 29th Ave.

PENNSYLVANIA
- * † Allentown 18102 — 732 North 16th St
- * Erie 16501 — 1001 State St.
- * † Johnstown 15902 — 841 Oak St.
- * † ‡ § Philadelphia 19102 — 3 Penn Center Plaza
- * † ‡ Pittsburgh 15222 The Oliver Bldg, Mellon Sq.
- § Pittsburgh 15228 — 733 Washington Rd.
- * ‡ York 17403 — 56 N. Harrison St.

SOUTH CAROLINA
- * † Columbia 29201 — 1310 Lady St
- * Greenville 29602 — 108 W. Washington St.

TENNESSEE
- * † ‡ § Chattanooga 37402 — 832 Georgia Ave.
- * Kingsport 37662 — 322 Commerce St.
- * † Knoxville 37916 — 1301 Hannah Ave., N.W.
- * † Memphis 38104 — 1420 Union Ave.
- * Murfreesboro — P.O Box 1040
- * ‡ Nashville 37203 — 1717 W. End Bldg.
- § Oak Ridge — 253 Main St., East

TEXAS
- † Abilene 79601 — 442 Cedar St
- * † Amarillo 79101 — 403 Amarillo Blvd.
- * † Beaumont 77701 — 1385 Calder Ave.
- † Corpus Christi 78401 — 205 N Chaparral
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