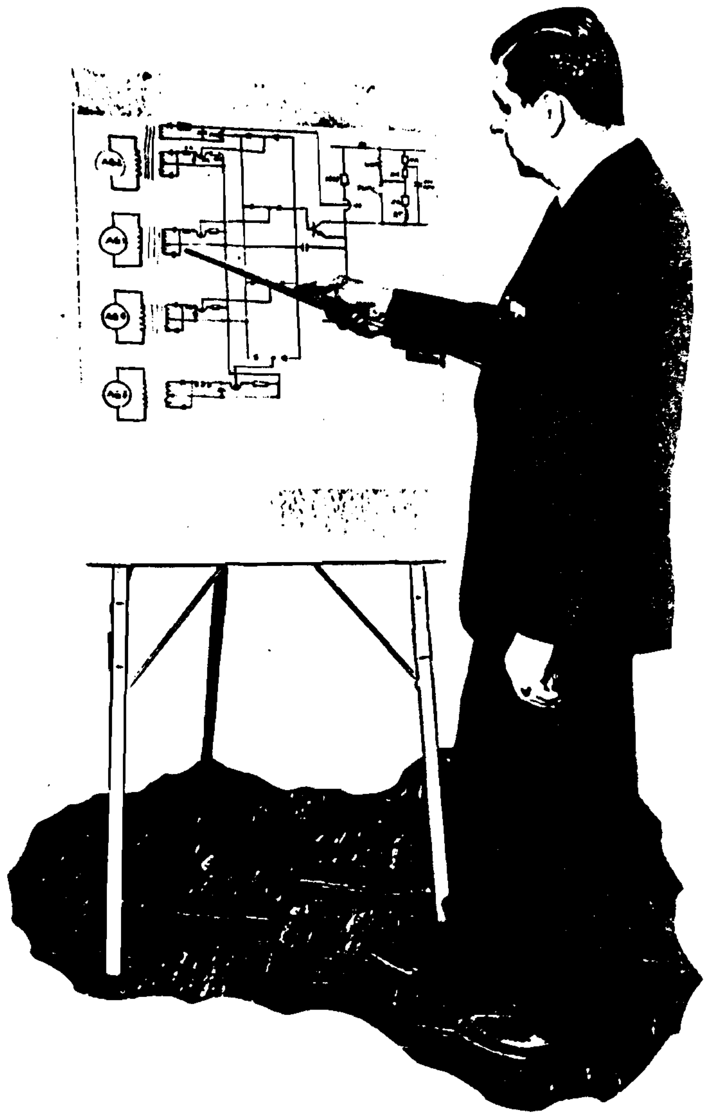
INSTRUCTIONS

GET-2857

CIRCUIT DESCRIPTION FOR 11,000 VOLT COMMUTER CARS



E-10876

GENERAL ELECTRIC

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INTRODUCTION

The purpose of this circuit description is to familiarize maintenance personnel with the schematic wiring diagram. This publication explains schematic fundamentals, circuit function and car operation. The publication is also intended to familiarize the reader with the 11,000 volt a-c, 25 cycle, single-phase commuter system.

An 11,000 KX a-c single-phase overhead fixed voltage supplies and controls four d-c series-field traction motors. The traction motors are supplied with regulated current at one level by varying their voltage supply. Car acceleration is accomplished by regulating current until full voltage is reached, and then continues on fixed voltage and decreasing current on the series motor characteristic. Speed control is maintained by four steps of voltage limit under control of the trainlines set up by the master controller.

The 11,000 KV single-phase a-c is fed through a three secondary transformer. This provides three voltage steps of 637, 546, and 572 volts respectively. One step is phase controlled by back-to-back ignitron tubes. Voltage addition is at the output of silicon-bridge rectifiers. Traction motor voltage is controllable from 0 volts to full volts at regulated motor current.

Semiconductor components are used for phase control, step switching signal, ignitron tube firing and main power rectification.

The system provides stable operation and properly controlled current buildup rates. System advantages over a full-phase control single-stage system are:

1. Permits simple non-grid type ignitron tubes.

2. Improvement in transformer primary current wave shape at partial load volts.

3. Improvement in rectified a-c voltage wave shape to the load smoothing reactor and reduction in required reactor size.

4. Permits use of silicon-rectifier bridges, improving rectifying function from the cost, size, complexity and reliability standpoint.

5. Provides partial power-operation with shorted (the usual manner of silicon cell failures) bridge legs in rectifiers 2 and/or 3 connected to 2nd and/or 3rd secondaries of the main transformer.

6. Silicon rectifier (bridges) and tube failures caused by shorted conditions can be cleared by overload relay operation of the A1, A2, and A3 contactors.

7. Cutout of a defective traction motor by opening an M1, M2, M3, or M4 contactor permits correct operation of remaining pair of traction motors at full control and motor power.

The equipment necessary for control of the acceleration of the car through its full range is contained in the main control group (17KG206A1); the equipment to control the auxiliary equipment and voltage conuol of the motor alternator and blower motor alternator is contained in the auxiliary control group (17KG208A1). The main transformer (MT) is mounted under the car (11,000 volt, 25 cycle, 735 KVA). A third control group (17KG205A1) contains the rectifiers and equipment necessary for the power circuits.

In addition to the relays, contactors, and other mechanical devices contained in the main control group (17KG206A1) there are two panels mounted on one end of the group which contain the plug-in type semiconductor cards. The semiconductors mounted on the cards conuol the operation of the car automatically after the operator has selected the desired operation position of the operating handle on the master controller. The auxiliary control group (17KG208A1) contains a similar panel to control the voltage of the motor alternator set and the blower-motor alternator set.

The main conuol group panels are identified as the 17FL2F1 panel which contains 12 cards, and the 17FL2L1 panel which contains 10 cards. The 17FL2K1 panel contains eight cards and is in the auxiliary control group. The following table lists the card identification letters, function, panel number, control group location, and catalog number of the cards. Where two cards of the same type are used (CM), the panel identification letters will have a small number 1 or 2 between the letters to indicate its particular circuit. The identification C1M will indicate the axle card number two axle circuit. Number one axle circuit and C2M will indicate the axle two card for the number two axle circuit. However, cards with the same letter symbol are interchangeable. The number between the letter symbol on the panel is only to identify the circuit application of the particular card when inserted into the panel.

The key to effective maintenance of electrical systems and equipment is the schematic diagram.

Familiarity with the schematic diagram and understanding of the circuits which it covers will help to minimize the time required to locate and correct electrical troubles.

The reader should understand the application and basic operation of the semiconductors ueed in the system before tracing the circuits described in the following text. To help gain a basic knowledge of semiconductor operation and characteristics it is suggested that the reader consult GET-2848, APPLICATION OF SEMICONDUCTORS, before tracing the circuits. This publication explains the operation of semiconductors ae they are used by the Locomotive and Car Equipment Department of the General Electric Company.

CARD IDENTIFICATION TABLE

CARD SYMBOL	FUNCTION(S)	PART OF PANEL	PANEL LOCATION	CATALOG NUMBER
A1L	Regulates voltage of blower motor alternator (BMA).	17FL2K1	Auxiliary group 17KG208A1	17FC100D1
A1V	Controls field current to maintain BMA voltage output at 220 volts.	17FL2K1	Auxiliary group 17KG208A1	17FC101B1
BC	Removes power in case of traction motor overspeed.	17FL2L1	Main control group 17KG206A1	17FC141A1
B1D	Provides full-wave rectification of BMA.	17FL2K1	Auxiliary group 17KG208A1	17FC145A1
BJ	Provides pickup time delay for auxiliary motor starting.	17FL2K1	Auxiliary group 17KG208A1	17FC148A1
BM	Provides dropout time delay for auxiliary motor starting.	17FL2K1	Auxiliary group 17KG208A1	17FC150A1
CA	Amplifies pilot unijunction signal for pilot ignitron firing SCR's.	17FL2F1	Main control group 17KG206A1	17FC122A1
CB	Controls initial firing. Limits C12 capacitor voltage. Regulates firing current.	17FL2F1	Main control group 17KG206A1	17FC123A1
CC	Controls tube firing by providing firing Lock, notching de-fire and end of cycle dumping.	17FL2F1	Main control group 17KG206A1	17FC124A1
CD	(1) Stabilizes high-starting motor currents. (2) Filters bleed line currents.	17FL2F1	Main control group 17KG206A1	17FC125A1
CE	Controls current limit & wide range stabilization.	17FL2F1	Main control group 17KG206A1	17FC126A1
CF	Maintains 20 volt reference in firing circuit,	17FL2F1	Main control group 17KG206A1	17FC127A1
CG	Rectifies and filters current limit signal.	17FL2F1	Main control group 17KG206A1	17FC128A1

TABLE (Cont'd.)

CARD SYMBOL	FUNCTION(S)	PART OF PANEL	PANEL LOCATION	CATALOG NUMBER
CH	Converts d-c to a-c (300 cycles/sec.) for current limit reactor.	17FL2L1	Main control group 17KG206A1	17FC129A1
CJ	Rectifies tube volts. Sends signal to first stage SCR (CJSC1).	17FL2F1	Main control group 17KG206A1	17FC130A1
CK	(1) Maintains 20 volt reference in notching circuit. (2) Initiates pickup of A contactors by turning on notching uni-junction transistor (CKT1).	17FL2F1	Main control group 17KG206A1	17FC131A1
CL	Energizes A contactor when notching SCR's turn on. Suppresses voltage spikes by means of diodes.	17FL2F1	Main control group 17KG206A1	17FC132A1
C1M	Rectifies No. 1 axle alternator output and compares voltage between alternators.	17FL2L1	Main control group 17KG206A1	17FC139A1
C2M	Rectifies No. 2 axle alternator output and compares voltage between alternators.	17FL2L1	Main control group 17KG206A1	17FC139A1
CN	Rectifies Nos. 3 and 4 axle alternator output and compares voltage between alternators.	17FL2L1	Main control group 17KG206A1	17FC138A1
CP	Senses wheel slip.	17FL2L1	Main control group 17KG206A1	17FC137A1
CR	(1) Rectifies output of No. 3 axle alternator to obtain d-c signal proportional to motor rpm. (2) Provides voltage division by means of resistofs to set application of power removal when overspeed occurs.	17FL2L1	Main control group 17KG206A1	17FC135A1
CS	Divides voltage by means of resistors to set application of service brake if overspeed continues after power removal.	17FL2L1	Main cmtrol group 17KG206A1	17FC142A1
CT	Senses motor overspeed during acceleration.	17FL2L1	Main control group 17KG206A1	17FC136A1

TABLE (Cont'd.)

CARD SYMBOL	FUNCTION(S)	PART OF PANEL	PANEL LOCATION	CATALOG NUMBER
CV	Initiates ignitron tube firing by turning on uni-junction transistor. (CVT2)	17FL2F1	Main control group 17KG206A1	17FC143A1
DA	Limits ignitron tube voltage advance in switch position.	17FL2F1	Main control group 17KG206A1	17FC156A1
DB	Reduces power to traction motors on receipt of wheel slip signal.	17FL2L1	Main control group 17KG206A1	17FC157A1
DK	Provides turn-on pulses to DLSCR.	17FL2K1	Auxiliary control group 17KG208A1	17FC165A1
DL	Controls field current to maintain MA voltage output at 220 volts.	17FL2K1	Auxiliary control group 17KG208A1	17FC166A1
DM	Translates MA voltage output into field current requirement.	17FL2K1	Auxiliary control group 17KG208A1	17FC167A1

SCHEMATIC FUNDAMLNTALS

A knowledge of how the schematic diagram is put together is helpful before a circuit description is made. Following is a description of the various functions of the sections of the schematic diagram.

The schematic diagram for a particular commuter car or group of cars is identified by a drawing number such as 41D750600. The complete schematic diagram may be made up of about 30 sheets, each carrying the drawing number. When the sheets are in correct order, sections A1 through 1-22 are in alphabetical order with two sections to a sheet. This arrangement is the equivalent of page numbers and allows the diagram to be prepared in book form.

Each sheet carries a title block with the type of car involved. To the left of the title block is the revision number and date of such revision.

At the top of each section is a description of the information to be found in that section. For example, Sections A and A1 are the index sections; B and B1 are the main power supply sections.

INDEX (SECTIONS A AND A1)

Sections A and A1 are the index pages for the complete schematic diagram. It gives a description of what is found in each section of each sheet, and the latest revision of each sheet. Fig. 1 shows a typical index sheet.

APPARATUS TABLES (1-8 THROUGH 1-22)

The apparatus tables answer three important questions about the electrical devices:

1. What is it?
2. Where is it?
3. What is its function?

Fig. 2 is a partial apparatus table and, in addition to the foregoing the data listed on the table is helpful in testing, correcting, and/or replacing devices or parts of devices.

SCHEMATIC DIAGRAM
MULTIPLE UNIT
COMMUTER CAR
CITY OF PHILADELPHIA
11,000 VOLT AC
4 GE 1252 MOTORS

SECTION	CIRCUIT OR FUNCTION	SHEET NUMBER	CURRENT REVISION
A	INDEX	1	2
A1	INDEX		
B	MAIN POWER SUPPLY	2	1
B1	MAIN POWER SUPPLY		
B2	MAIN POWER PROPULSION	3	1
B3	MAIN POWER PROPULSION (BLANK)		
C	MAIN POWER CONTROL (PROPULSION)	4	1
C1	(PROPULSION)		
C2	(NOTCHING)	5	1
C3	(NOTCHING)		
C4	(CURRENT MEASURING & OSCILLATOR)	6	1
C5	MAIN POWER CONTROL (FIRING & NOTCH BACK)		
C6	MAIN FIRING CONTROL (FIRING)	7	1
C7	MAIN FIRING CONTROL (PILOT FIRING & FIRING)		
C8	MAIN POWER CONTROL (FIRING)	8	1
C9	(FIRING)		
C10	(OVERSPEED)	9	1
C11	(OVERSPEED)		
C12	(BLANK)	10	1
C13	(WHEELSLIP)		
C14	(WHEELSLIP)	11	1
C15	MAIN POWER CONTROL (BLANK)		
D	AUX. POWER (ROTATING EQUIPMENT)	12	1
D1	(BATTERY CHARGING)		
D2	(AIR CONDITIONING)	13	1
D3	AUX. POWER (HEATERS)		
E	AUX. CONTROL (AIR CONDITIONING & HEAT)	14	1
E1	(AIR CONDITIONING & HEAT)		
E2	(VOLTAGE REG. (BMA SET)	15	1
E3	(VOLTAGE REG. (BMA SET)		
E4	(VOLTAGE REG. (MA SET)	16	1
E5	(VOLTAGE REG. (MA SET)		
E6		17	1
E7	AUX. CONTROL (CAB SIGNAL)		

Fig. 1. Typical index section. (E-11223)

CONTROL GROUPS			
SYMBOL	LOCATION	PRINCIPAL FUNCTION	TYPE
AUX.GROUP	UNDER CAR	CONTAINS COMPONENTS TO CONTROL AUXILIARY EQUIPMENT	17KG208A1
MAIN GROUP	UNDER CAR	CONTAINS COMPONENTS TO CONTROL D-C POWER EQUIPMENT	17KG206A1
RECT.GROUP	UNDER CAR	CONTAINS COMPONENTS TO CONVERT A-C POWER TO D-C	17KG205A1

CONTACTORS - POWER SWITCHES								
	LOCATION				COIL			
SYMBOL	SECT.	ON CAR	FUNCTION	TYPE	CAT.NO.	AMPS TO OPERATE	25 C OHMS	INTERLOCK
A1, A2, A3	I6	Rect.Gr.	Accelerating Cntor.	17CP2W11	9960925	0.206	84.9	17AF21A20
AC1	I7	Aux.Gr.	Compr. Start Cntor.	CR106C003 XMA1				CR105X102A CR123C21.42(OL)
BMAC1, MAC1	I7	Aux.Gr.	Motor Start Cntor.	17CM57A9	4739477	I	180	NONE
BMASS, MASS	E1, E2 E4	Altr.Sets	Speed Limiting	17HM11C1				
GS	B	Roof	Panto. Gnd. Sw.	17GM1A2				
M1, M2, M3, M4	I4	Main Gr.	Motoring Cntor.	17CM55A5	4739065	0.748	27.5	17AF41C1
REV.	I5	Main Gr.	REVERSER	17DP25A3	9960925	0.206	84.9	
SHC	I6	Rect. Gr.	Strip Heater Cntor.	17CM57A6	4739318	0.4	46.3	NONE

SAM							
	LOCATION				COIL		
SYMBOL	SECT.	ON CAR	FUNCTION	TYPE	CAT.NO.	AMPS TO OPERATE	25 C OHMS
AC1P	I7	Aux.Gr.	Air Compressor Pilot	17LV66BD1	8827086	0.250	73
AHR	I6	Rect.Gr.	Anode Heater	17LV66BD1	8827086	0.250	73
ELR	I7	Aux.Gr.	Emergency Light	17LV2L10	2738601	130V.A-C	84
FC1P, FC2P	I7	Aux.Gr.	Freon.Comp.Pilot	17LV66BD1	8827086	0.250	73
GR	I5	Main Gr.	GROUND	17LV69E5	Reset manual oper. 9960960	0.27 A-C	135
NBR	I4	Main Gr.	NOTCH BACK	17LV66CB1	8827086	0.250	73
NVR1	I4	Main Gr.	No Voltage	17LV66V11D	8860477	0.138	295
NVR2	I7	Aux.Gr.	No Voltage	17LV66V23E	8860466	0.047	2780
OLR1, 2, 3	I6	Rect.Gr.	Line Overload	DB-1690-L4	8860440	0.51	35.2
OLRM1, OLRM2	I4	Main Gr.	Motor Overload	DB-1690-K4	8860440	0.51	35.2
OSPR	I4	Main Gr.	Overspeed pwr. removal	17LV66BD1	8827086	0.250	73
OSSB	I4	Main Gr.	Overspeed serv. brake	17LV66BD1	8827086	0.250	73
PLR	I5	Main Gr.	Pantograph Lowering	DB-1626-F5	Reset manual oper. 3122144	3.6A-C	0.404
PR	I4	Main Gr.	Pinion	17LV68F3	Reset manual oper. 9960942	0.044	460

Fig. 2. Typical apparatus tables. (E-11224)

Since many devices of the same type are used and each has a different function, a letter and/or a number is applied to each device. This helps to identify the device throughout the schematic diagram. The tables in Fig. 2 show the device symbol in the first column.

The general physical location of the device is given in a separate column. Also given in a separate column is the location of the device on the schematic.

When the device is mounted on any of the semiconductor cards, the apparatus table will also designate which particular card is involved.

DIAGRAM LEGEND (SECTION I)

The legend of electrical symbols shown in Fig. 3 should be understood before using the schematic diagram. This legend illustrates the various electrical symbols and describes the device that each represents throughout the circuits of the schematic diagram.

DEVICE SKETCHES (SECTIONS 1-4 THROUGH I-7)

The device sketches in Fig. 4 show (by number) the physical wire connections of the many devices. In addition, it shows where each connection is located on the schematic diagram (F1, F, etc.). These sketches are helpful in locating a circuit through a device which may control many circuits.

CIRCUIT DIAGRAM (SECTIONS B THROUGH F1)

The power and control circuits are shown schematically. Power or high voltage circuits are those using the secondary windings of the main transformer as a source of power. Control or low voltage circuits are those using the battery or the output of transformer T2 for battery charging and control power. The circuit description that follows describes the circuits as they would be used to operate the car from an assumed starting condition through the full operating range of the car.

Before the reader traces the circuits described, there are some basic rules that should be understood.

1. *All* &vices are shown in their normal (de-energized) position.

2. Reverser (REV) contacts are shown for motion toward "B" end of car.

3. When the operating handle of the master controller is moved for desired operation, acceleration is accomplished automatically by the signals received from the static cards to the ignitron tubes.

4. All contacts, interlocks, and coils of a device will have the same letter and/or number symbol where any part of the device is shown throughout the schematic diagram.

5. Wires are numbered and/or lettered for quick identification and should assist the personnel in trouble shooting the circuits. Some of the wires appear to end in an arrowhead; in this case, the nomenclature after the arrowhead indicates to what device or circuit the wire is connected. Lines representing wires on the schematic criss-cross each other at several places. If a heavy dot appears at the crossing point it means the wires are connected electrically. When a dot does not appear at a crossing point, the wires are not electrically connected.

AUXILIARY POWER

Auxiliary power is furnished by two motor alternator sets (MA & BMA). The MA set furnishes power to operate the air compressor, Freon compressors, blower fans, exhaust fans and condenser fans. The BMA set furnishes power to run the blower motor (BM) battery charging, auxiliary control power, fluorescent lighting, and traction control power.

MOTOR ALTERNATOR (MA)

The circuits to run the MA motor, voltage regulation of MA alternator, and voltage output circuits are described in the following text.

Starting Motor

The alternator motor is started and operated at a constant speed by the following circuits: (See Fig. 5)

1. When the pantograph is raised to engage the 11,000 volt overhead feed wire, the main transformer primary is energized and the 572 volt (C) secondary furnishes power to the MA motor.

2. A transformer (T5) is also furnished power from the secondary (C) of the main transformer (MT).

. .. secondary tap from [illegible] of 64 volts a-c picks up the motor alternator start contactor MAC1 shown at the top of Fig. 5.

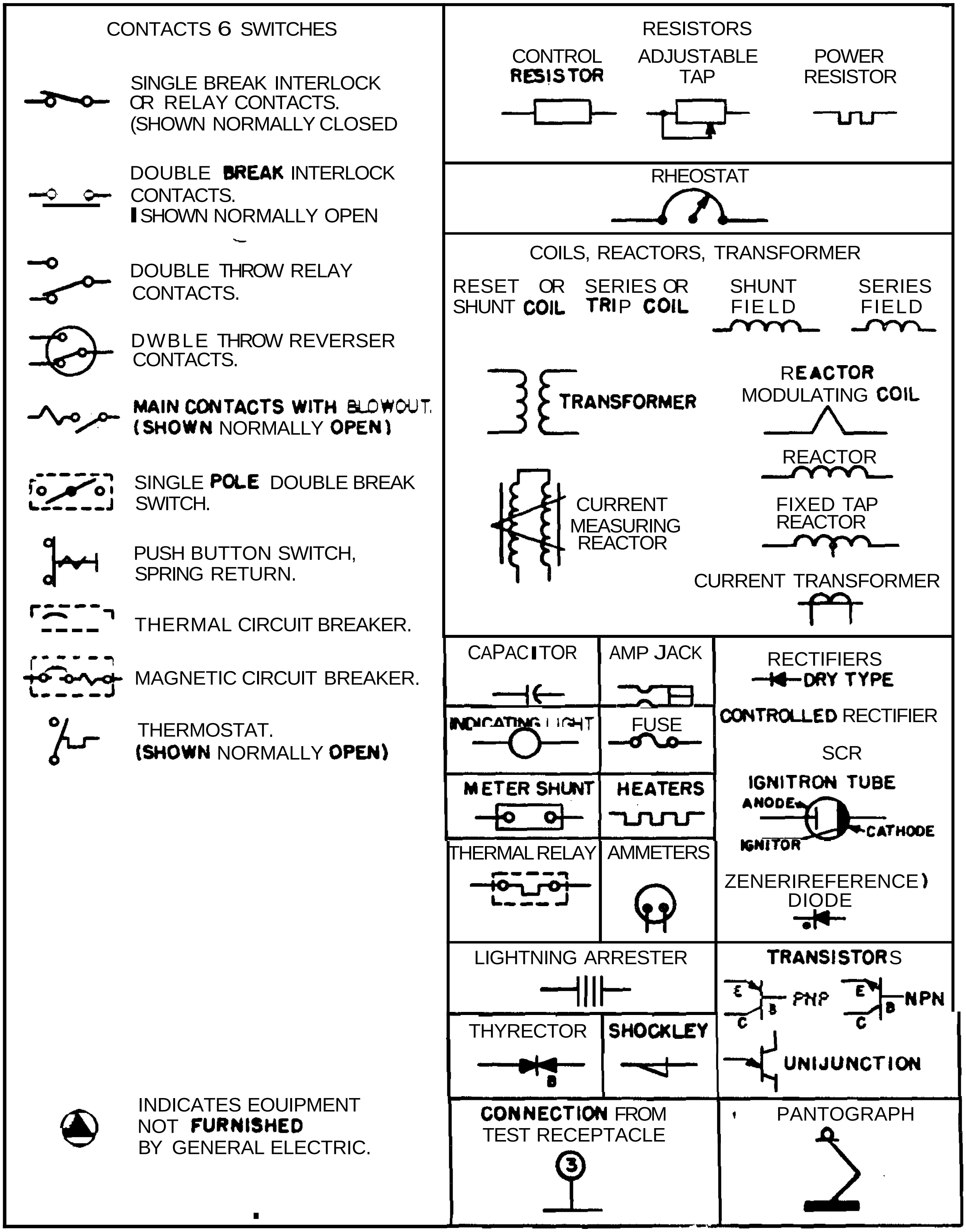


Fig. 3. *Electrical* symbols. *(E-11225)*

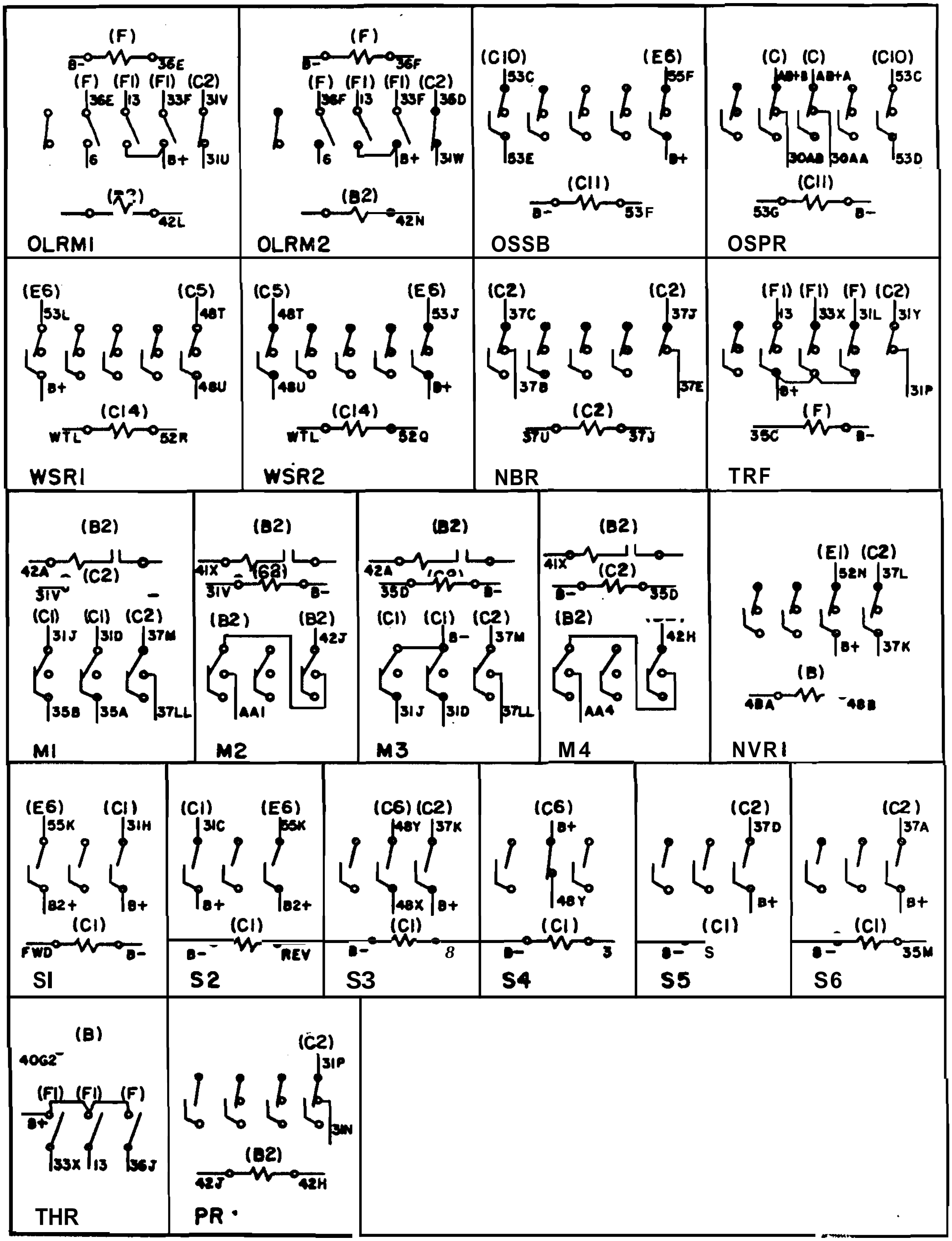


Fig. 4. Device sketches. **(E-11226)**

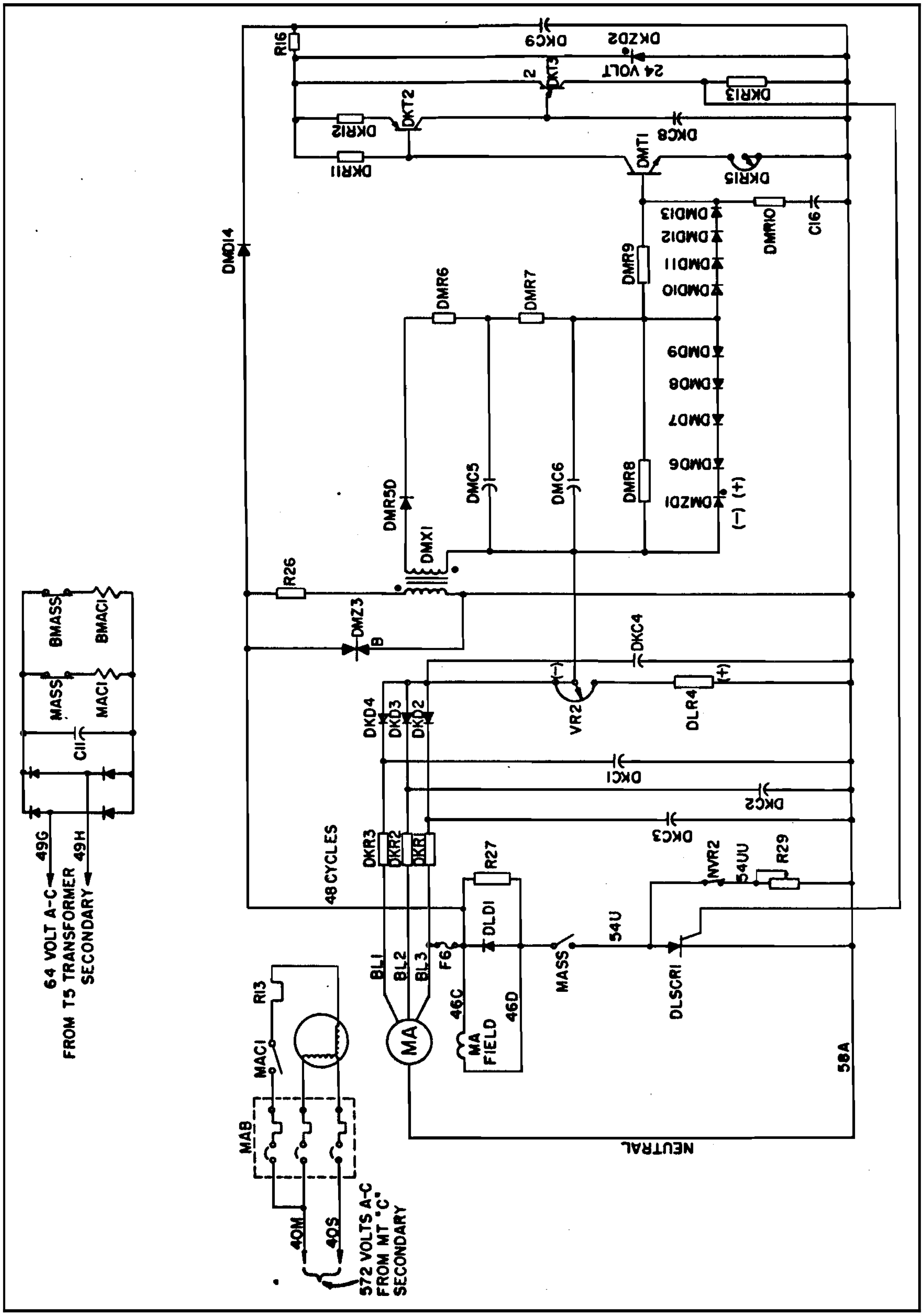


Fig. 5. Motor alternator voltage regulation 220 volt a-c, 3 phase, 48 cycle. (E-11227)

4. With MAC1 picked up, resistor R13 is inserted into the motor starting circuit until the 'motor reaches 1200 rpm.

5. When motor reaches 1200 rpm, the centrifugal contacwr (MASS) interlock opens and drops out MAC1 contactor, removing the R13 resistor from the circuit. Motor will now increase its speed to 1500 rpm.

Voltage Regulation

Voltage regulation is held to a constant 220 volts a-c by controlling the current flow through the MA armature field. The semiconductor components used to accomplish regulation are mounted on the DK, DL and DM cards which are pan of the 17FL2K1 panel.

Fig. 5 is a schematic diagram of the voltage regulation system. The system .can be considered as three basic circuits: power, reference, and pulse circuits.

Power Circuit

The power circuit runs from the half wave of the alternator through wire 44D to F6 fuse, wire 46C, MA field, wire 46D, MASS contact, DLSCR1 silicon-controlled rectifier, wire 58A and back to neutral.

Whenever DLSCR1 is turned on, current will flow in the alternator field. MASS closes when motor reaches 1200 rpm (explained under the section on starting the motor).

Reference Circuit

The reference circuit consists of a zener diode and several conventional diodes (DMZD1, DMRD5, 6, 7, 8, 9, and 10). At full operating speed, the reference voltage is approximately 12 volts and is relatively constant with temperature. The reference voltage is compared to a similar voltage measured from the alternator output (VR2) and an error voltage results which is the difference between the two voltages. If error volts are positive (reference volts higher than measured volts) transistor DMT1 will be turned on. If error volts are negative (reference volts less than measured volts) the transistor DMT1 will be turned off.

The reference circuit is as follows:

1. The 48 cycles per second half wave of the al rnator goes through wire 44D, to F6 fuse, R26 resistor, primary of DMX1 saturating transformer to 58A and back to neutral.

2. The DMX1 secondary is half-wave rectified. This entire circuit is designed so that the voltage across resistor DMR8 is at 12 volts and varies only as machine speed varies. As machine speed is very nearly constant, voltage across DMR8 is also very nearly constant.

3. The voltage drop across DMRD9, 8, 7, and 6 diodes and zener diode DMZD1 is also 12 volts, with polarity as marked: plus w minus.

4. Alternator voltage is measured with the circuit consisting of neutral, wire 58A, resistor DLR4, rheostat VR2, ,diodes KDK2, 3, and 4, resistors DKR1, 2, and 3 and to the MA set. This circuit sets a voltage proportional to MA voltage output with polarity as marked in Fig. 6.

5. If the voltage from the plus side of DLR4 to the brush arm of rheostat VR2 is greater than the 12 volt reference circuit, error voltage as described in the foregoing is negative.

6. If the voltage from the plus side of resistor DLR4 to the brush arm of rheostat VR2 is less than the 12 volt reference circuit, error voltage as described in the foregoing is positive.

7. When error volts are positive, transistor DMT1 will be turned on. This is caused by the base potential being more positive than its emitter when error volts are positive.

8. The base to emitter circuit of transistor DMT1 when turned on is from DMX1 secondary through DMRD5, DMR6, 7, and 9, base to emitter of DMT1, DKR15, DLR4, VR2 brush arm and back to DMX1 secondary.

Pulse Circuit

The pulse circuit is controlled by the error voltage. As described in the foregoing, error volts are positive and turn transistor DMT1 on when alternator volts are low. When transistor DMT1 is turned on, the following action takes place.

1. When transistor DMT1 turns on, it lowers the base potential of transistor DKT2 and it turns on.

2. When DKT2 transistor turns on, capacitor DKC8 will charge and raise the emitter voltage of unijunction transistor DKT3 to above its bane voltage; thus, DKT3 turns on.

3. When DKT3 turns on, capacitor DKC8 will discharge through DKT3 and supply the voltage and current to the gate circuit of the DLSCR1 silicon-controlled rectifier causing it to turn on.

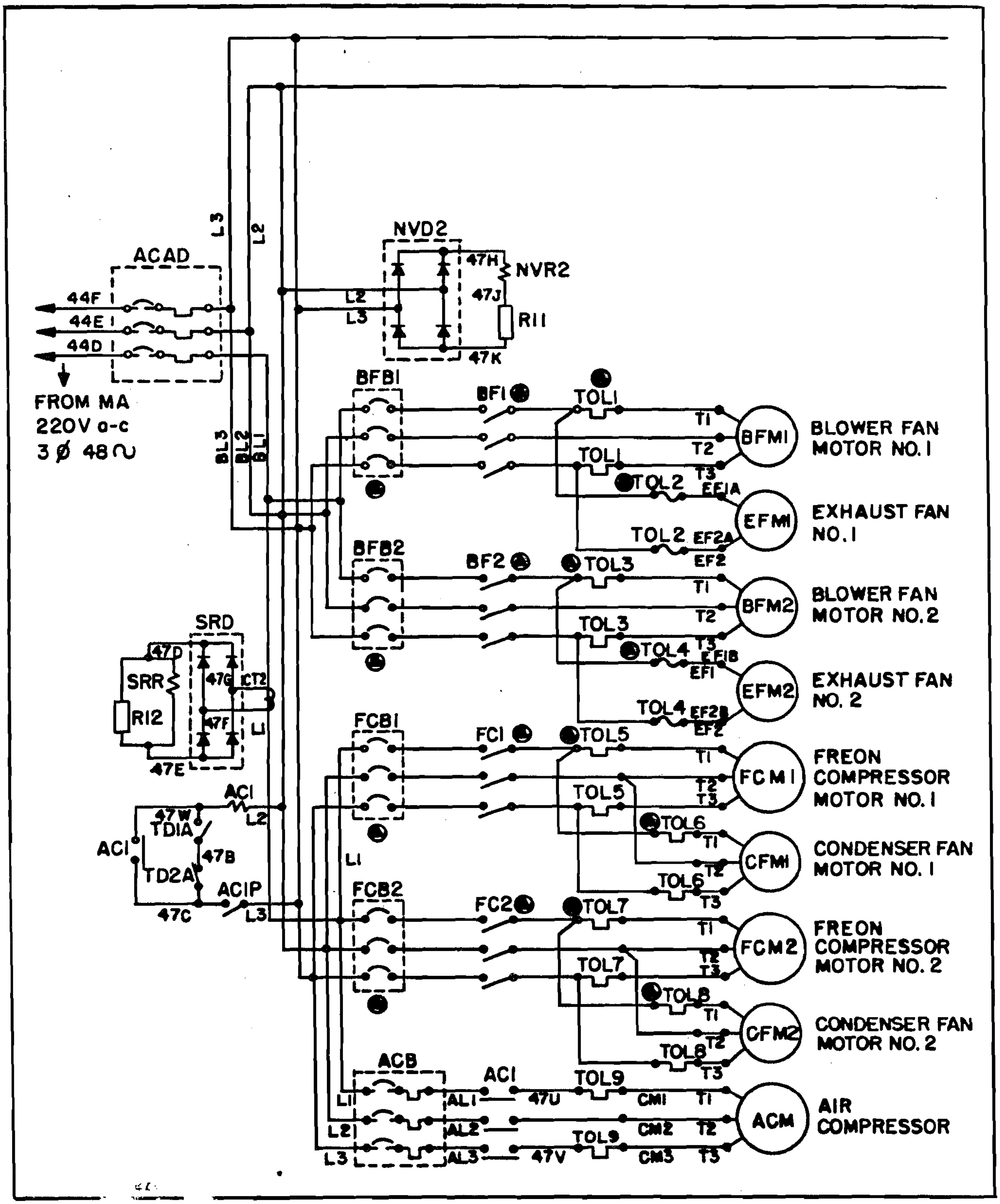


Fig. 6. Auxiliary power circuits (power supplied by MA). (E-11228)

4. The voltage supply for this circuit comes through half-wave rectifier DMRD14, filter capacitor DKC9, dropping resistor R16, and reference zener diode DKZD2.

Summary

When MA output voltage is less than 220 volts, error voltage to the pulsing circuit is positive. This allows capacitor DKC8 to charge at full rate and allows DLSCRl to be pulsed on at maximum rate. This tends to increase average exciter field current and raise alternator voltage. When alternator output tries to exceed 220 volts, error voltage to the triggering circuit becomes negative, capacitor DKC8 charges a slow rate delaying turn on pulses to DLSCRl and thereby decreases average exciter field current.

By maintaining a near-zero error voltage level, the regulator is able to hold alternator output voltage at 220 volts.

Motor Alternator Power Circuits

The 220 volt regulated voltage of the motor alternator furnishes power to the motors for air conditioning and furnishes power to the main air compressor motor.

The power circuits of the motors are shown in Fig. 6.

When the MA set is running and as voltage rises to 220 volts, NVR2 relay will pick up and its interlock contacts (shown in Fig. 7) will close to allow the control circuits of the air conditioning motors and air compressor to function. The function of the control circuits will be described after the power circuits have been described.

When ACAB circuit breaker is closed, NVR2 will pick up when voltage is up from MA. Closing BFB1 and BFB2 will allow the BFM1 and BFM2 blower fan motors to run if contactors BF1 and BF2 have picked up. Also, exhaust fans EFM1 and 2 will run because their power is supplied from the same source.

The Freon compressors and main air compressor will also run if their respective circuit breakers (FCB1, FCB2, and ACB1) are closed and their contactors (FC1, FC2, and AC1) are closed. However, the control sequence is such that the three compressors cannot all start at the same time.

Motor Alternator Control Circuits

The control power voltage LB(+) - LB(-) is supplied by the voltage output of the blower motor alternator.

When the control plug is inserted into its receptacle on the master controller, it will pick up TLR relay from the 14 wire to the B wire. The voltage LB (+) - LB(-) for the control circuits shown in Fig. 7 will be a nominal 37.5 volts d-c.

Assume that air conditioning is &sired and that the motor alternator and blower motor alternator are running. The sequence of events in the control circuits will be as follows in order to operate the motors discussed under the motor alternator power circuits:

1. Relay NVR2 contacts close as voltage output of MA rises to 220 volts.

2. Air conditioning and heat circuit breaker is closed.

3. Contactors BF1 and BF2 will pick up if thermal overload elements are closed (TOL1-TOL3). The blower and exhaust motors will now run.

4. Air conditioning switches are closed for automatic or manual control (TS1-TS2) and FC1P and FC2P relays will pick up providing temperature switches TOL 5, 6, 7 and 8, HP & LP, CMT1 and CMT2 are closed. The switches are normally closed and will open only to remove power from the motors if temperature causes the thermal elements to operate in their respective circuits. Some of these elements are shown schematically in Fig. 8.

5. The interlock contacts of BF1 and BF2 assure that the compressor motors will not start until the blower and exhaust fan motors have started.

6. The main air compressor relay (AC1P) will pick up from the LB(+) wire, GOV C.O. circuit breaker, compressor Governor switch, NVR2 interlock, TOL9 temperature switches to AC1P relay.

7. When FC1P and FC2P pick up, their interlock contacts open the HC1 and HC2 heater contactor circuits to prevent heat being called for when air conditioning is being used.

8. The relays FC1P, FC2P and AC1P set up the circuits to allow the compressor motors to start in the following sequence: ACM, FCM2, and FCM1.

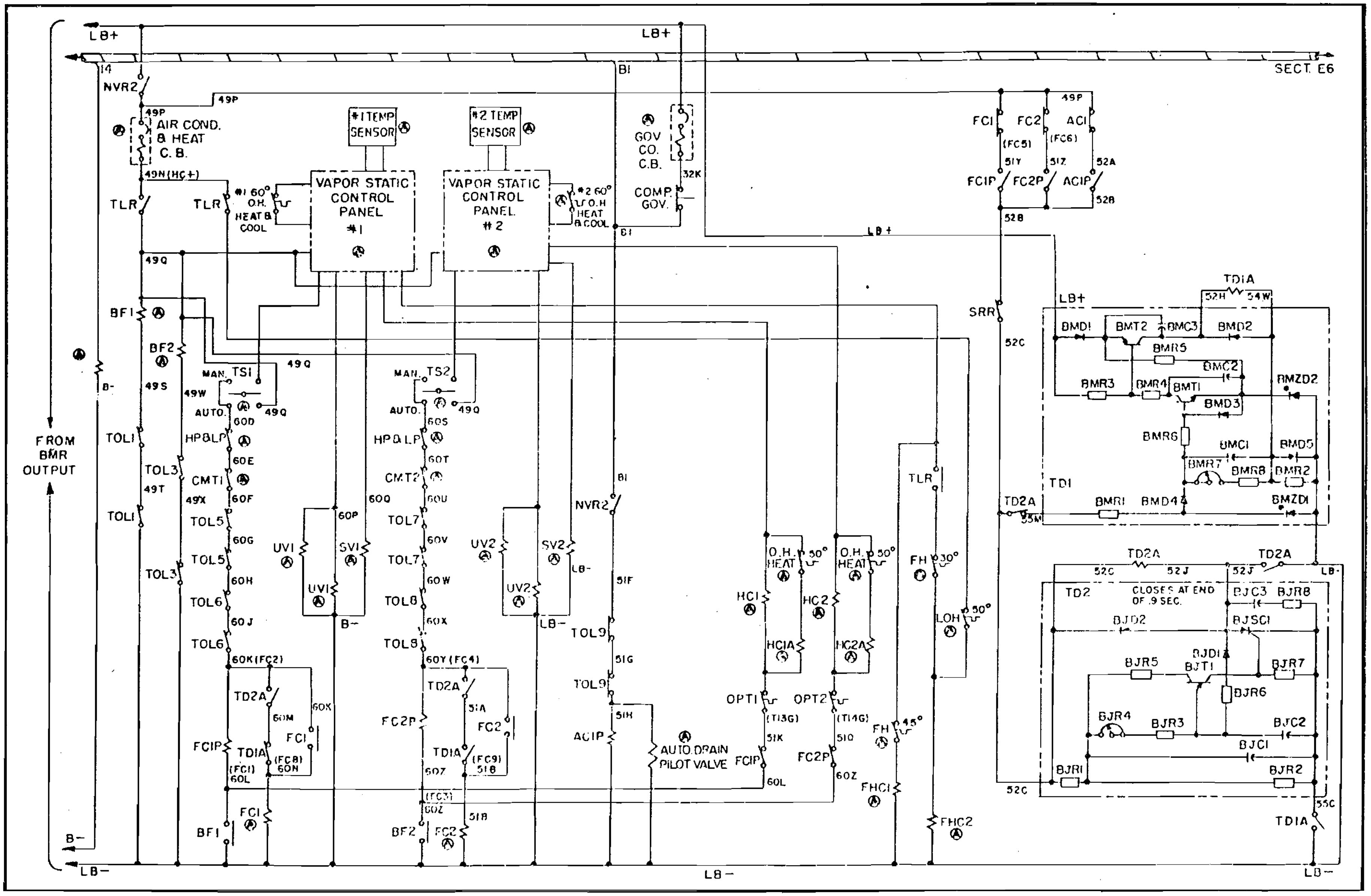


Fig. 7. Auxiliary power control circuits. (E-11229)

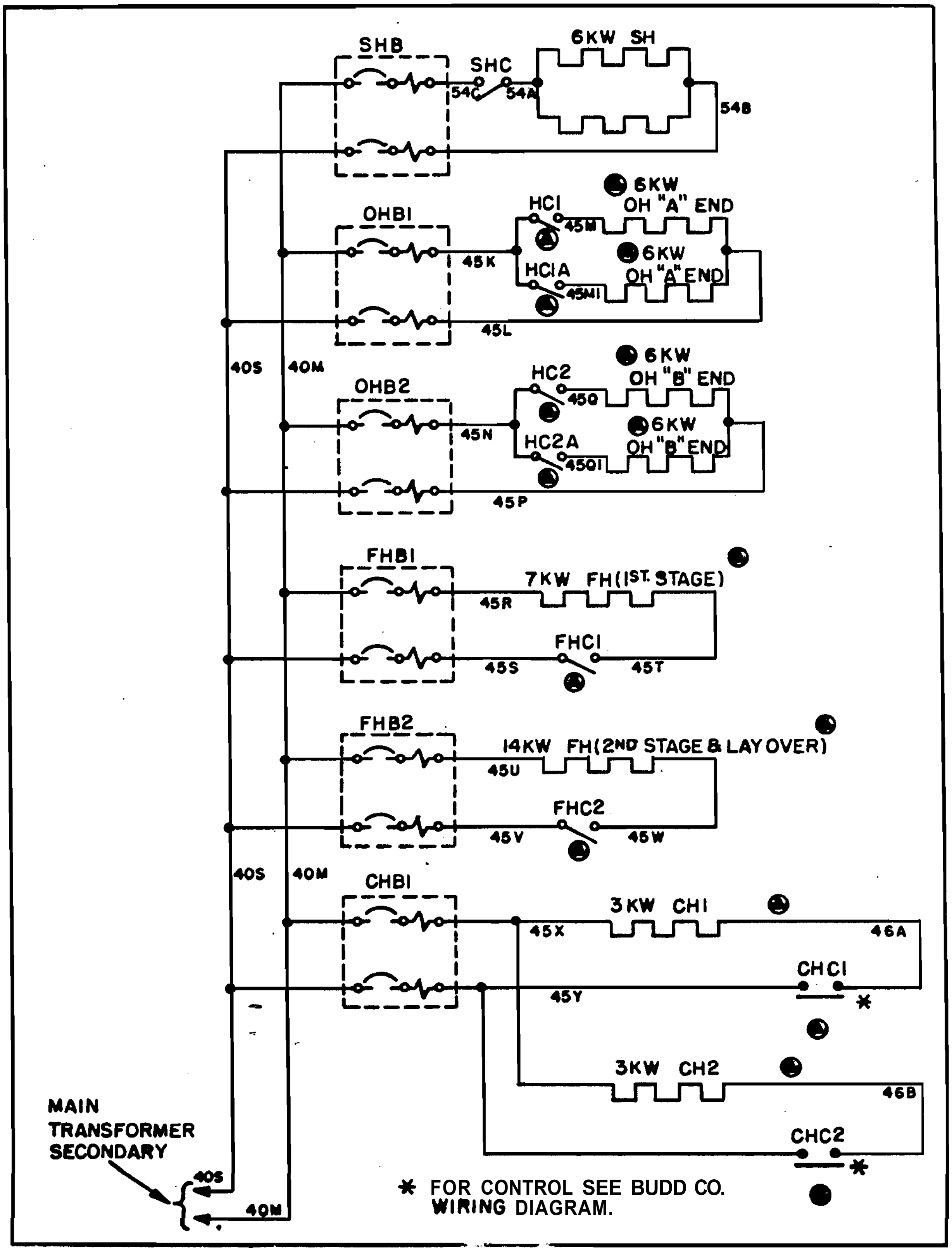


Fig. 8. Heater power circuits. (*E-11230*)

9. The control circuit sequence is as follows:

a. From wire 49P to FC1, FC2 and AC1 to FC1P, FC2P and AC1P contacts which are connected in parallel to the 52B wire.

b. From the 52B wire through SRR (compressor start, release relay) contact to TD2A relay interlock to TD1 (semiconductor card BM).

c. Relay TD1A picks up, connecting TD2 (semiconductor card BJ) into the circuit when TD1A interlock closes to LB(-) wire.

Note: Operation of the semiconductor circuits to pick up TD1A and TD2A relays will be discussed after the control circuits.

d. When TD1A relay picks up, its interlock contact (shown in Fig. 6) power circuits will close and AC1 contactor will close to start air compressor motor ACM. AC1 contactor locks itself in with its interlock contact AC1 in series with the AC1 coil.

e. Contactors FC1 and FC2 coils (shown in Fig. 7) will not pick up because TD2A relay is not picked up.

f. When ACM (air compressor motor) starts, the current will increase suddenly and induce a voltage in CT2 coil of SRD and pick up the SRR relay shown in Pig. 6.

g. When SRR picks up, it opens the circuit to relays TD1A and TD2A shown in Fig. 7 until current decreases in the SRR coil to drop out SRR relay.

h. After ACM has started and current has decreased, SRR will drop out.

i. When SRR drops out, TD1A and TD2A are re-connected into the circuit as before. (If SRR action is rapid, as with an unloaded compressor, TD1A may not drop out because of TD1 time delay.)

j. Relay TD1A again picks up and, after a 0.9 second time delay, TD2A picks up.

k. When TD2A picks up, then the FC2 coil is energized because with both relays picked up, the interlocks TD2A and TD1A in series with FC2 are closed.

l. Contactor FC2 is kept picked up by its interlock FC2 which is in series with the coil after it has been picked up.

m. Relay SRR again picks up as before and drops out when current decreases after the FCM2 motor is running.

n. When SRR drops out again, it also re-connects TD1A and TD2A relays as before.

o. Relays TD1A and TD2A again pick up as before, but FC1 cannot pick up until TD1A drops out.

p. Relay TD1A drops out after a short time delay. When TD2A picks up, it opens the TD2A interlack which is connected between SRR contact and TD1 circuit; thus TD1A drops out. Relay TD2A is held in until SRR relay picks up. Time delay of TD1A on dropout and time Belay of TD2A on pickup will be explained under TD1A and TD2A circuits.

q. When TD1A drops out, FC1 contactor will be energized because TD2A and TD1A interlocks are closed. in series with FC1 coil. FC1 will be held in by its interlock (FC1) which is in series with its coil.

r. Relay SRR now picks up for the third time when FCM1 starts to run. The SRR interlock again drops out TD2A as before.

s. After contactors AC1, FC2, and FC1 have picked up and motors are running, interlocks in parallel from the 49P wire will be open and the TD1A and TD2A time delay relays will be out of the circuit.

The semiconductor components that operate the TD1A relay are mounted on card BM and those for the TD2A relay are mounted on card BJ.

The action that takes place to operate TD1A relay is as follows:

1. When FC1P, FC2P, and AC1P pick up, a circuit is made from the 49P wire to TD1 as explained in the foregoing.

2. Transistor BMT1 will turn on because its base potential will be higher than its emitter.

3. When the BMT1 transistor turns on, it will lower the potential of transistor BMT2 base and cause BMT2 to turn on.

4. When BMTl and BMTZ transistors are turned on, TDlA relay will pick up.

5. The circuit of TDlA relay is from wire LB(+) through BMDl, BMTZ (emitter to collector), TDlA relay coil, BMD5 diode, and to wire LB(-).

6. When SRR relay contact opens, TD2A picks up and the circuit to BMTl and the transistor base is opened. Therefore, BMTl transistor will turn off. However, capacitor BMCl will keep BMTl turned on for a short period of time after the base circuit to BMTl is opened. This gives TDlA a time delay on dropout.

7. Zener diode BMZDl hits the base current of BMTl, and zener BMW 2 sets the reference voltage of BMTl (base to emitter) transistor to turn on. That is, the voltage from base to emitter must be great enough to cause BMZD2 to conduct before BMTl transistor can turn on.

The action that takes place to operate TD2A relay is as follows:

1. When FClP, FC2P, and AClP pick up, a circuit is made from the 49P wire to TD2 components as explained in the foregoing.

2. Capacitor BJCl charges and base 2 voltage of the BJTl unijunction transistor is raised to its value.

3. Capacitor BJC2 also charges but at a slower rate than BJCl. The rate of charge to BTC2 is set by rheostat BJR4.

4. When BJC2 has charged, the voltage at the emitter of BJTl will be high enough to turn on BJTl.

5. When BJTl turns on, capacitor BJC2 then discharges and turns on BJSCl .silicon-controlled rectifier.

6. Silicon-controlled rectifier BJSCl then connects the TD2A coil to LB(-) through TDlA interlock, and TD2A picks up.

7. Relay TD2A is locked in by its interlock (TD2A) which is in series with the coil. TD2A will then remain picked up until the circuit from the 49P wire is opened, either by SRR interlock or any of the relay or contactor interlocks from the 49P wire.

The components not discussed in the foregoing but shown as pan of the cards are for filtering and circuit protection from transient voltage spikes.

To summarize, TDlA has a electronic time delay on dropout and TD2A has a electronic time delay on pickup. This rime delay makes it possible to sequence the operation of the compressor motors as previously explained. Also, it is well to remember that once TD2A has picked up, it will not drop out until the circuit is de-energized.

Auxiliary Heat

Whenever heat is desired, the air conditioning and heat circuit breaker is closed, and blower and exhaust fan motor contactors pick up as explained under air conditioning. Switches TSl and TS2 are opened. This allows the contactors HCl, HClA, HC2, and HC2A to operate as determined by the vapor control panels. See Fig. 7 for control circuits. It can be noted that the interlocks of FClP and FC2P prevent heat contactors from picking up if air conditioning switches TSl and TS2 are not opened. The FClP and FC2P relays will be picked up when switches are closed.

The heater resistor elements shown schematically in Fig. 8 receive their power from the main transformer secondary. When their respective circuit breakers are closed and contactors pick up from the control circuit, the blower fane will circulate heat through the car.

BLOWER MOTOR ALTERNATOR (BMA) (See Fig. 9)

The circuits that operate and control the BMA set are as follows:

Starting Motor

The blower motor alternator voltage output is regulated to a constant 220 volts, a-c, 48 cycles, in the following manner: (See Fig. 6)

1. When pantograph is raised to engage the 11000 volt overhead feed wire, the main transformer primary is connected and the 472 volt secondary "C" furnishes power to the BMA motor.

2. Transformer T5 also receives power from the "C" secondary of the main transformer (MT).

3. A secondary tap from T5 of 64 volts (a-c) is also connected to the BMACl motor start contactor which picks up and inserts resistor R14 into the starting circuit of the motor.

4. Another secondary tap of 40 volts a-c from T5 is connected to the voltage regulator which will help boost the voltage output of RT2 until the BMA has built up in voltage.

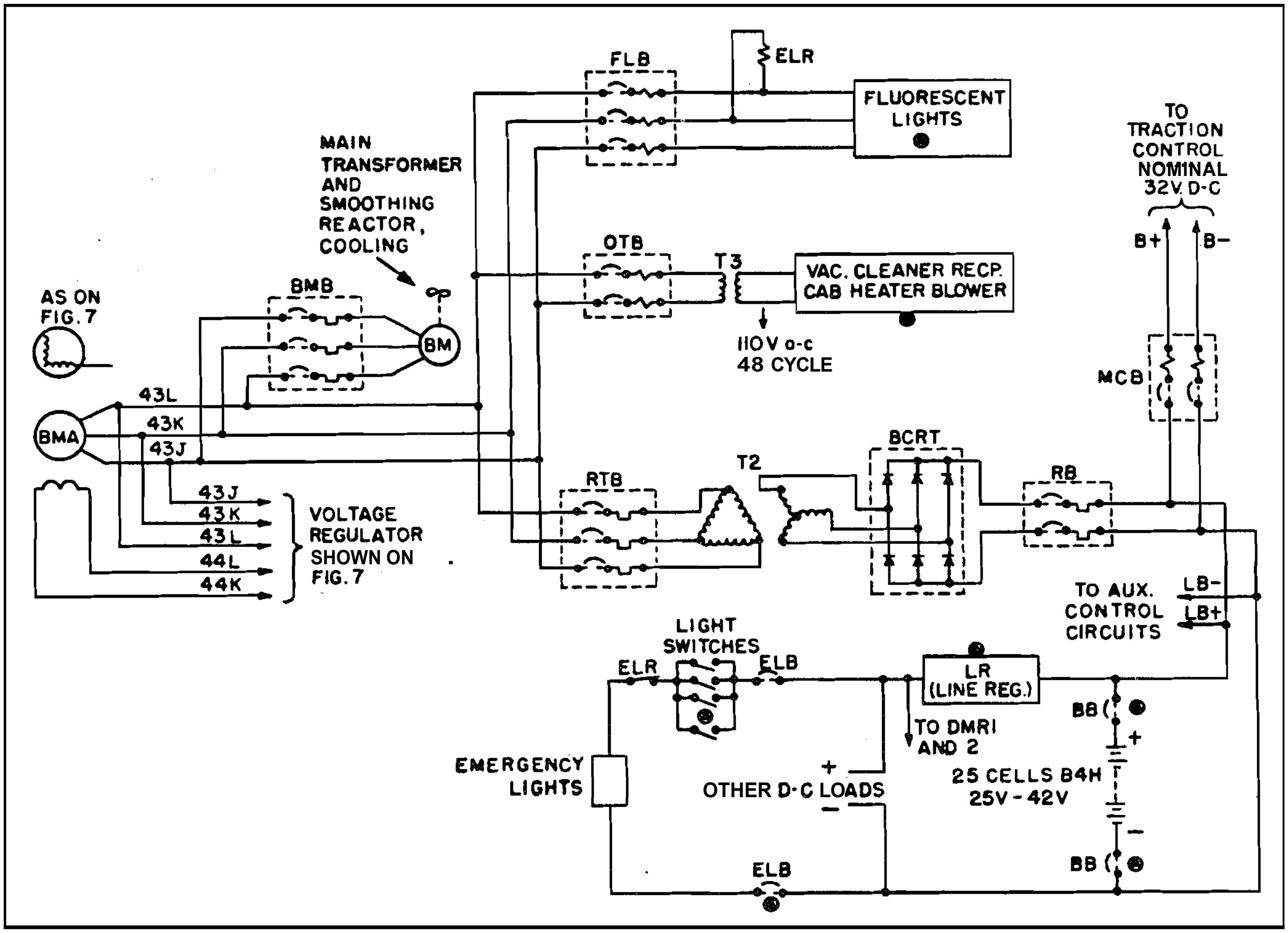


Fig. 9. *Blower motor alternator* circuits. (E-11232)

5. When the motor of BMA reaches approximately 1200 **rpm,** the centrifugal contactor **BMASS** interlock opens and **BMAC1** contactor drops out, removing the R14 resistor from the circuit. Motor can now increase its speed to approximately 1500 rpm.

6. The voltage output of BMA is then fed to **RT2** transformer primary.

Voltage Regulation

The secondary output of **RT2 is** rectified and its voltage **output** measured to control **the** BMA voltage output (**See** Fig. 10). **As** the output of RT2 is **proportional** to BMA output, it **can** be **used** to control the field current of BMA.

1. The power **transistor's** (AVT1) emitter and collector are connected in series with the BMA field. When the transistor is turned on, current flows through the BMA field to provide generator output.

2. Whenever **RT2** voltage is below 45 volts, transistor AVT1 is **turned** on. AVT1 turns on because the emitter is at a higher potential than its base. The base of AVT1 is at a lower potential **because AVT2** transistor is turned off.

3. The emitter to collector circuit is from the rectifiers of RT2 **secondary** to ALR10, **ALR1, resistors,** ALD3 diode, through the transistor emitter to collector. From collector to wire **44K** through BMA field, **to** wire **44L,** BMASS contact (which is closed when motor reached speed), **to** wire 54V and back to RT2.

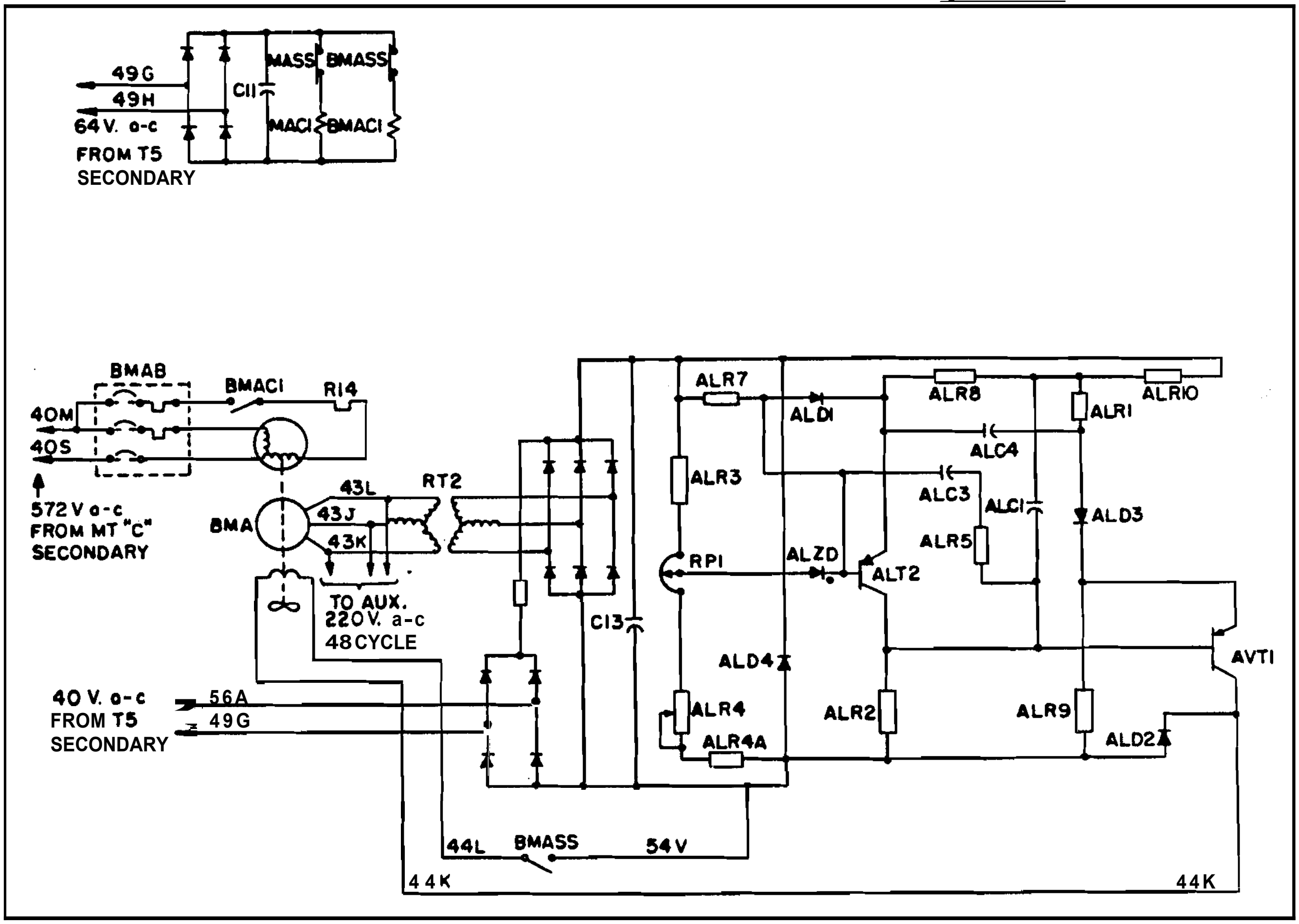


Fig. 10. blower motor alternator voltage regulation. (E-11231)

4. While the generator is building up voltage, the 40V a-c from T5 secondary wffl keep AVTl transistor turned on until RT2 output reaches 45 volts d-c.

5. When voltage output of RT2 reaches 45 volts, the zener diode ALZD will then conduct because the voltage across it will have exceeded 7.5 volts. This voltage reference is set by the voltage divider circuit of ALR3, RP1, ALR4, and ALR4A. The potentiometer (RP1) is used to adjust the voltage output at 45 volts.

6. When zener diode ALZD conducts, the emitter of ALT2 is at a higher potential than its base and it turns on.

7. When ALT2 turns on,'it causes the potential of AVTl transistor base to rise above its emitter potential; thus, transistor AVTl is now turned off.

8. When the base potential of a type PNP transistor is above its emitter, the transistor is said to be clamped off; therefore, no leakage current can flow from the emitter to the collector. This is more fully explained in the APPLICATION OF SEMICONDUCTORS publication, GET-2848.

9. With no current flow through the BMA field, its voltage will decrease. When it decreases, so will voltage decrease from RT2 secondary. When voltage of RT2 drops below 45 volts d-c, zener diode ALZD will become non-conducting and transistor ALT2 will be turned off. This causes AVTl transistor to again turn on, and current will flow in the generator field to increase voltage output.

10. . . -quence of switching between the two transistors keeps voltage output at a constant 220 volts a-c.

11. Components not discussed in the foregoing but shown on the schematic diagram and Fig. 6 are used to filter and protect the components from voltage spikes caused by the generator field inductance and associated circuits.

Voltage Output Circuits

The 220 regulated voltage of the BMA set is used to furnish power to the circuits shown in Fig. 7.

MAIN POWER CIRCUITS

Power is furnished to the car by a step-down transformer with three separate secondaries. The transformer is energized from an overhead feed wire of 11,000 volts a-c, 25 cycle, single phase. Each secondary supplies power to a bridge rectifier. The d-c output voltages of these rectifiers are additive.

The bridge rectifiers supply direct current to four traction motors through a smoothing reactor. The four traction motors are connected in series-parallel.

The voltage from each secondary is applied to the rectifier bridges when contactors A1, A2, and A3 are closed. A-C power to one rectifier bridge is applied through two ignitron tubes that are inverse parallel connected. By phase control of tube firing the average voltage at the motors can be varied to regulate traction motor current. The range of traction motor voltage (from a very low voltage to the sum of the three secondaries) is made variable by ignitron tube firing phase control and by operation of contactors A2 and A3.

To illustrate, closing contactor A1 only and modulating the ignitron tube firing gives a load voltage ranging from approximately 70 volts to 600 volts. By defiring (shutting off) the ignitron tubes and closing contactor A2, the second secondary stage may be substituted for the phase controlled first secondary stage. Then the ignitron tubes may be refired and phase controlled to raise the voltage to the traction motor load to a total of 1100 volts. In a similar manner secondary stage three can be added and the total traction motor load voltage raised to approximately 1685 volts. This procedure is reversible to allow reduction of traction motor voltage.

The power circuits are shown in Fig. 11. When A1, A2 and/or A3 are closed, power from the respective secondaries is furnished to the rectifier bridges, then to wire 42A, through the parallel paths of M1-M3 contacts; OLRM1, OLRM2 overload relay coils; Rev 1 - Rev 3 reverser contacts; 1, 2 - 3, 4 traction motor fields; Rev 2 - Rev 4 contacts; 1, 2, 3, and 4 traction motor armatures; CMRX1 and CMRX2 current-measuring reactor coils; M2 - M4 contacts; wire 41X to the MSX main smoothing reactor and back to the rectifier bridges and finally back to the secondaries.

CONTROL SYSTEM OPERATION

The system block diagram is shown in Fig. 12. Control of ignitron tube firing and of power contactors CA1, A2, A3 and the M contactor operation is by static type devices and circuits. Refer to Fig. 12 for the system block diagram. Functions are grouped as follows:

1. Notching cards - these units contain only static elements. They receive trainline, contactor position, supply voltage, ignitron voltage, and motor over current information. They coordinate contactor operation and initiation of ignitron tube firing and defiring.

2. Firing control cards - these units, containing only static elements, receive the firing command, motor current information, trainline, and a-c voltage synchronizing information. The cards supply phase control, signal level firing pulses to the firing panel and a notch back command to the notching cards.

3. Firing panel - this unit receives firing signal pulses and a-c power, and generates ignitor pulses to the ignitron tubes. It contains only static components such as silicon rectifiers, silicon-controlled rectifiers, resistors, and protective components. The a-c supply transformer, power pulse capacitors and reactors are external to the panel. The associated storage capacitors and pulse forming reactors are separately mounted.

4. Current measuring card - the two current measuring reactors of this card provide an isolated measurement of traction motor load current. Two reactors are used, one in each motor circuit (leg) so arranged that the motor leg having the higher current controls the output. Cut-out of one pair of motors leaves control with the remaining pair at correct per-motor current.

5. Power contactors - main contacts are shown in Fig. 12. Essentially this block of the diagram (Fig. 13) is concerned with contactor positions (opened or closed). Contact interlocks (on contactors) and interconnection between contactors plus connection to the notching cards provides signals to the eystem.

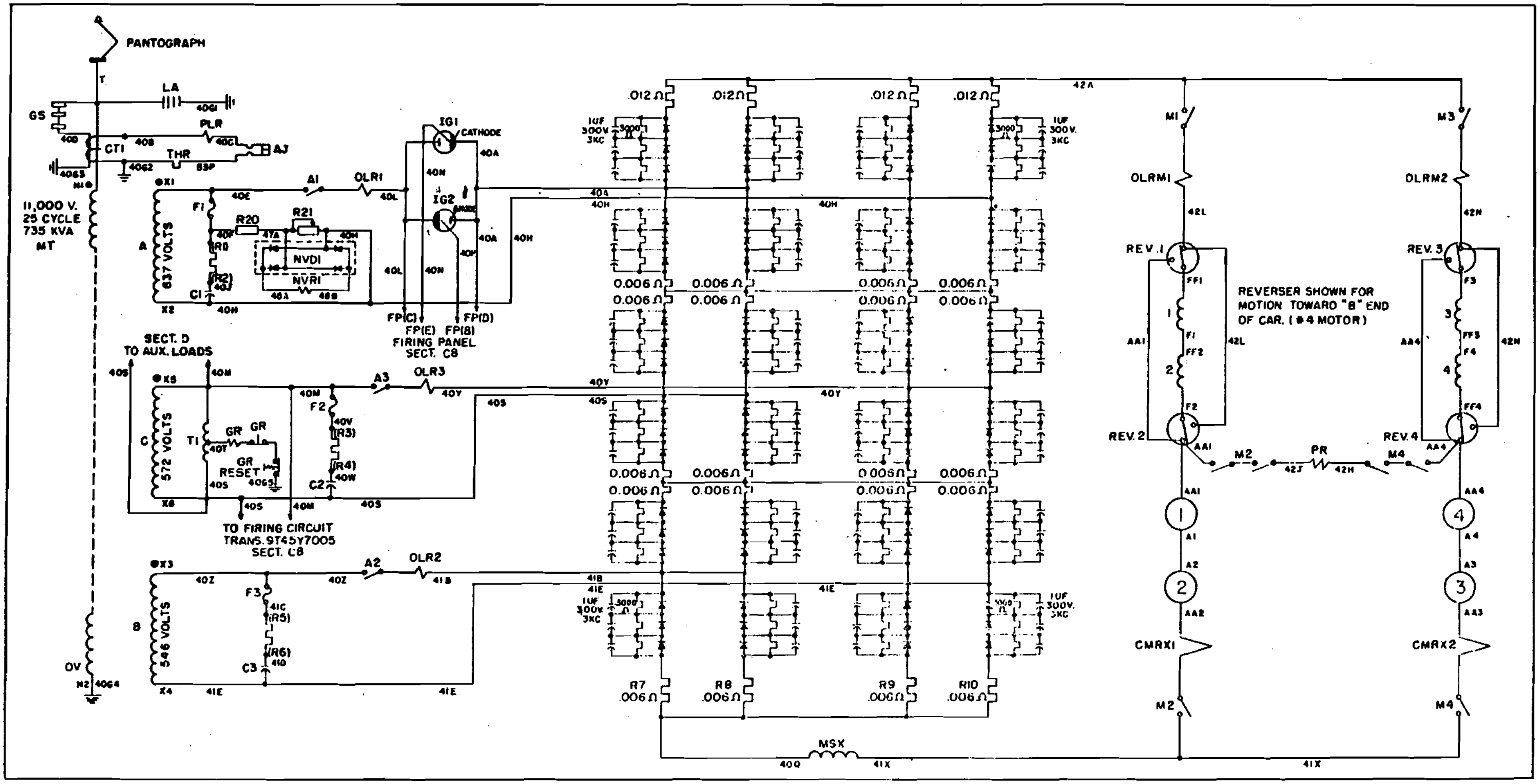


Fig. 11. Main power circuits. (E-11233)

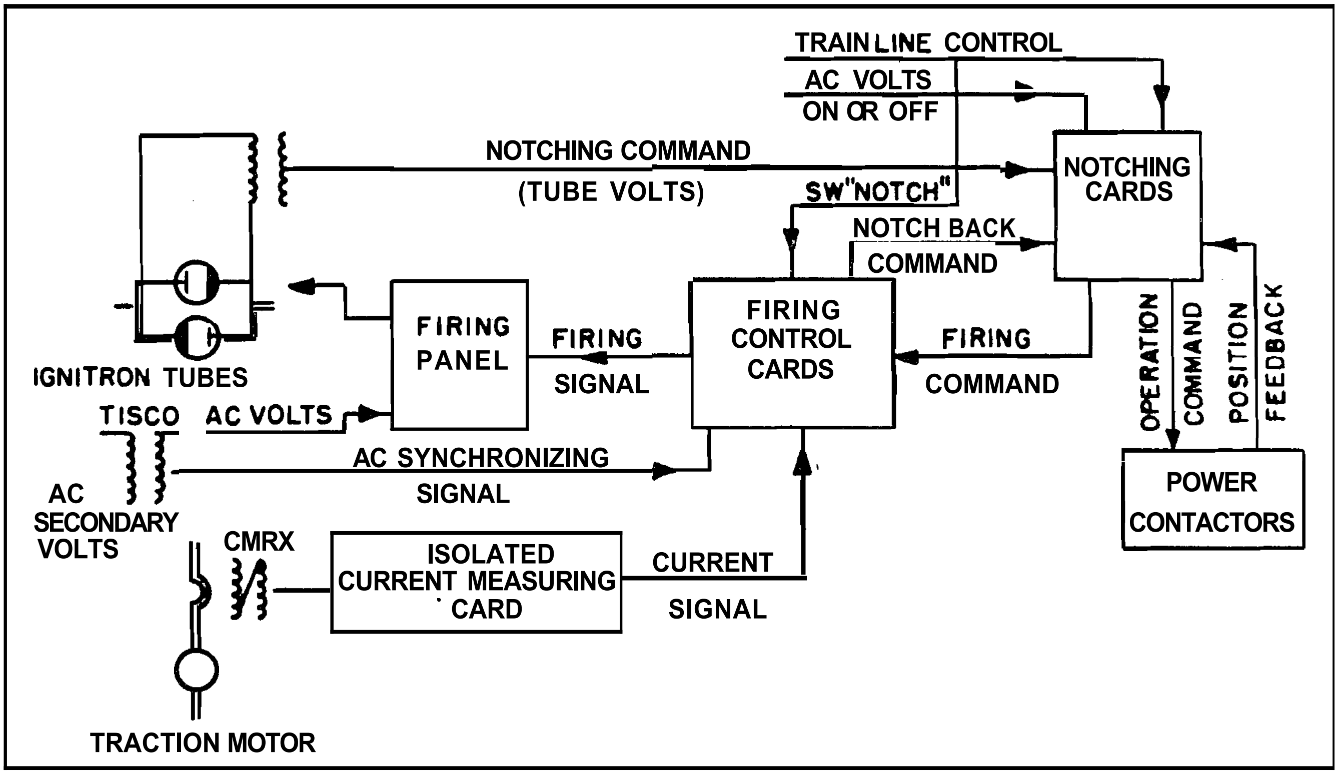


Fig. 12. Firing and notching system block diagram. (E-11234)

CAR ACCELERATION

Acceleration of the car is controlled by trainline control from the master controller. In the switching position (controller handle in SW position) only the "A" stage (transformer secondary) is allowed to energize the traction motor load. Accelerating current is limited to secure desired initial acceleration rate and the tube firing phase advance is limited to partially "on" to secure load voltage limit. Until the tube phase advance limit is reached, tube firing phase is controlled by the load current to regulate the motor current. As car speed increases, the firing advances in phase until the phase advance limit is reached. Further acceleration is at fixed load volts and decreasing load current.

When controller handle is placed in any of the three running positions (1, 2 or 3), acceleration is at maximum regulated motor current. Ignitron tube firing advance is not limited below full advance when in any of the running positions. Increase of car (traction motor) speed results in increasing firing advance, which holds regulated motor current until full advance firing of ignitron tubes is reached.

When sufficient advance is obtained, tubes are defired, contactor A2 is closed connecting transformer stage B and allowing refiring of the ignitron tubes at retarded phase. Further advance of ignitron tube firing results from further car acceleration under regulated traction motor current as before. The energization of transformer stage C occurs in a similar manner.

The operator (by selection of desired operation with operating handle on master controller) can stop notching sequence at the end of any stage. Four load voltage running steps are thus provided. The master controller operating handle may be notched up or down at any car speed.

When operating handle is moved from safety control position to OFF, the FWD or REV wires are energized depending on desired operation. As operating handle is moved to the desired accelerating positions the trainline wires are energized in the following requence: (See Fig. 13)

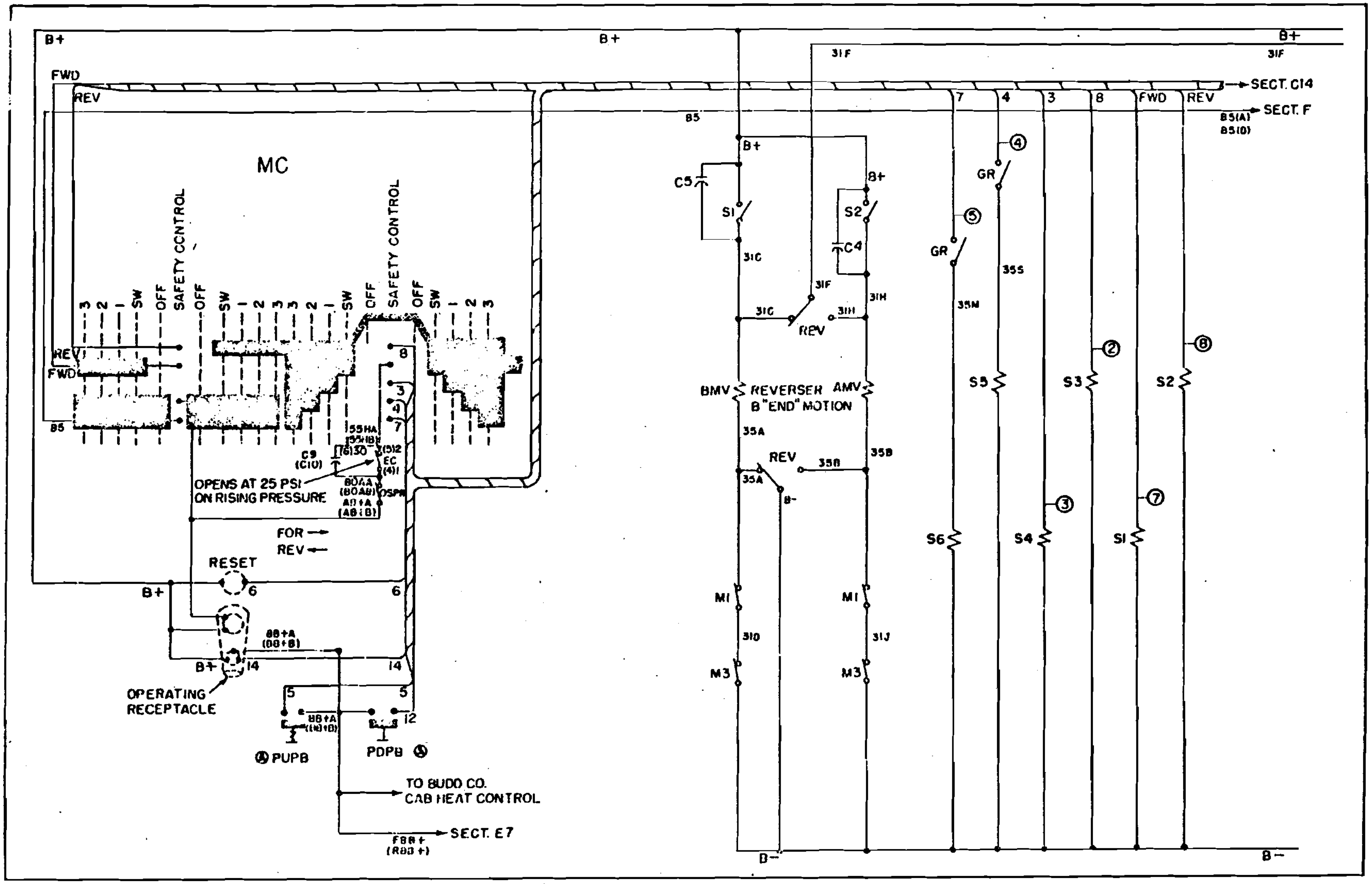


Fig. 13. Trainline control circuits. (E-11235)

CONTROLLER SEQUENCE

CONTROLLER NOTCH	TRANSFORMER SECONDARY	TRAINLINE WIRES ENERGIZED
Safety Control	-----	-----
OFF	-----	REV or FWD and 31F
SW	"A" Stage (With Tube Phase advance limited)	8
1	"A" etage (With No Tube Phase advance limit)	8 & 3
2	"A" and "B" stages	8 , 3 8 4
3	"A", "B" and "C" stages	8, 3, 4 and 7

Notching Control (See Fig. 14)

The main transformer must be energized and the no voltage relay (NVR1) picked up in the "A" stage secondary. Relay NVR1 assures that voltage exists in the "A" stage secondary. This circuit is shown in Fig. 11.

With operating receptacle plug in and operating handle moved to desired operating position as described in the foregoing, the following action will take place: (See Fig. 14 for notching circuits)

1. The 31F wire will energize the M1, 2, 3, and M4 contactors through control breaker CB, pyranol pump breaker PPB, pinion relay PH contact, transformer hot relay TRF contact, the two motor cut out switches MC01, 2, 3, and 4, and motor over load relays OLM1 and OLM2 to the coils of the contactors.

2. The dump valves of A1, A2 and A3 accelerating contactors will also be energized from the 31F wire, but contactors cannot pick up until their operating coils are energized from the B(+) wire.

Switch Position

Assume that the foregoing action has been completed and deeired operation is in switch poeition. The following action will take place:

1. Contactor A1 will pick up from the B(+) wire through contacts S3, NVR1, 1G2TH, 1G1TH, AR, 1G1TL, 1G2TL, M1, M3, A1 coil and contact OLR1 to B(-).

2. When A1 picks up, voltage appears across the ignitron tubes which energizes the T1SO primary.

3. The secondary of T1SO then supplies voltage to the 48W and 48V wires shown on the right of Fig. 14.

4. The voltage of T1SO secondary is rectified by rectifier bridge (CJD1, 2, 3, and 4).

5. The appearance of T1SO secondary volts allows turn on of the ignitron tubes. This will be explained under TURN ON TO INITIATE FIRING.

6. With controller in switch position, firing phase advance is limited to approximately 1/3 on. Action of this circuit will be explained under Fixing Phase Control.

7. As the car accelerates, firing phase is controlled by the traction motor load current. Firing phase advances as car speed increases until the firing phase limit is reached. When the phase limit is reached, it will remain at this point and limit the load voltage until operation is changed by movement of controller operating handle. Movement of the operating handle to OFF de-energizes trainline wires causing all contactors to drop out and etops the cube firing.

Notch 1

Action in notch 1 is identical to the switch notch except that when operating handle is moved to Notch 1, trainline wire 3 is energized in addition to wire 8. Wire 3 then picks up relay S4 thus removing the firing phase advance limit. Full transformer secondary "A" voltage may be applied to the traction motor load. Ignitron tube volts therefore may go to near zero as stage "A" volts are applied to the traction motor load.

Contactors A2 and A3 cannot close until operating handle is moved to notch 2 and 3 to energize the trainline wires 4 and 7 thus energizing relay S5 and 6.

Notch 2

When operating handle is moved to notch 2 position, trainline wire 4 is energized in addition to wires 8 and 3. This picks up relay S5 and closes its contact (See .Fig. 15) which allows contactor A2 to close when ignitron tubes have reached full on. Mis-operation of contactors A1 and A2 is prevented by the A1 contactor interlock which is in series with S5 contact. From the B(+) wire, operation of this circuit is obtained as follows:

1. Contactor A1 closes as described under notch 1.

2. With operating handle in notch 2 relay S5 is energized but A2 cannot pick up until after A1 has picked up because of the A1 interlock and its associated circuits.

3. Ignitron tube firing and load current control occur as described under switch position and notch 1.

4. In addition, anode voltage is furnished to SCR's CLSC2 and CJSCl so that when tube firing has reached full on, the A2 contactor coil will be energized.

5. The circuit to CLSC2 is as follows: From B(+) wire through S5 contact, A1 interlock, NBR contact, CLW diode, to the anode of CLSC2.

6. The circuit to CJSCl is as follows: From B(+) wire through S5 contact, A1 interlock, NBR contact, CLW diode, 37F wire, A2 interlock, 37G wire, A3 interlock 37H wire to the anode of CJSCl.

7. From the 37H wire another circuit is energized through R15 resistor and CKD1 diode, so that plus 20 volts appear on CKZD1 zener diode, and on CKR2 resistor, CKR4 resistor and CKC2 capacitor.

8. Momentarily, CKC2 capacitor applies plus 20 volts to base 2 of CKTl unijunction transistor. This voltage diminishes with time toward zero on the time constant of CKC2 and the approximate 7K ohms resistance of CKT1 base 2 to base 1.

9. As CKC2 changes, the voltage divider of CKR2 and CKR1 resistors (loading CKC1 capacitor) quickly establishes a fixed voltage on CKTl emitter.

10. As the voltage on base 2 of CKTl drops in voltage it would (in approximately 0.25 second) reach a level which would allow CKCl capacitor to fire into transformer CJX1 primary. Before this happens (normally) rectifier bridge (CJD1, 2, 3, and 4) is energized by appearance of ignitron tube volts and takes over control at the CKTl unijunction transistor holding base 2 volts at a level preventing CKTl from firing.

11. The voltage level on base 2 is limited to no more than plus 30 volts by CKZD1 and CKZD2 zener diodes connected in series.

12. Until the ignitron tube firing reaches full advance and the voltage across the ignitron tubes drops to a relatively low value, CKTl cannot fire.

13. When CKC2 and CKC3 allow the base 2 volts of CKTl to fall below the firing level, CKTl will discharge CKCl through CJX1 transformer primary.

14. The CJX1 transformer secondary will fire the gate of CJSCl and the anode voltage described in the foregoing will in sequence fire CLSC2, energize A2 contactor coil, raise capacitor CKC3 volts, cut off CKTl firing, and initiate de-firing of the tubes.

15. Closing of A2 contactor following energization of its coil applies power of stage "B" secondary to traction motor circuits with ignitron tubes fully retarded.

16. When A2 contactor closes, its interlock, moving from the 37F wire to 37R wire, momentarily interrupts voltage to the anode of CJSCl and allows it to return to its blocking state.

17. Capacitor CKC4 holds the base 2 voltage of CKTl up momentarily, preventing re-firing of CKTl (and CJSCl) if for any reason voltage on the tubes (and rectifier bridge) output arc momentarily non-existent.

In notch 2, relay S6 is not picked up; therefore, the operation of A2 interlock in series with S6 contact cannot supply anode voltage to CJSCl or CLSC1. Contactor A3 is thus not energized and the maximum voltage obtainable to the traction motor load is stage "B" plus stage "A" when ignitron tubes have reached full advance.

Notch 3

When conuoller operation handle is moved to notch 3, in addition to uainline wires energized in notch 2, wire 7 will be energized thus picking up S6 relay. Therefore, relays S3, S4, S5 and S6 will all be energized.

operation during acceleration will be as described for notch 1 and 2 until contactor A2 closes. Now with S6 relay closed, anode voltage will be applied to CJSCl and CLSCl after interruption of CJSCl anode voltage by A2 interlock moving from 37F wire to 37B wire. This prepares the circuits to close A3 contactor when the ignitron tube firing has again advanced to full on.

The second triggering of CKT1 (as &scribed in the foregoing) now turns on CLSCl, energizing A3 coil and closing A3 contactor. This, in turn, energizes stage "C" secondary. When A3 contactor closes, its interlock (37G-37H) opens to remove anode voltage from CJSCl which prevents further triggering at the notch card (CL) and defiring of the tubes is prevented (CC card).

After A3 contactor has picked up and tubes have completed their third advance in firing phase, further car acceleration and running is at maximum load volts. Load power may be reduced by moving operating handle in reverse order, de-energizing train line wires.

The conuoller operating handle may be notched up or down from or to any position at any stage of car acceleration or speed.

For example, from operation in notch 3 at full load voltage, if trainline wire 7 is de-energized the voltage supply to CLSCl is removed and A3 contactor is de-energized. Interlock A3 (37G-37H) closes but CJSCl cannot trigger or tubes defire because interlock A2 is still picked up (37G-37B). Load power continues at two-thirds maximum voltage.

Automatic Notch Back

If an adverse grade or a-c line voltage upsurge were to occur, causing an increase in load current, the load current regulating system would retard the ignitron tube firing phase to maintain current limit. Under some conditions of motor speed and stage "A", "B", and "C" secondary connections, full retard firing may not be sufficient to reduce load voltage by the required degree. It may be necessary to drop out contactors A3 or A2 in order to place the ignitron tubes back in control of load voltage.

A notch-back relay (NBR) with two normally closed contacts diode CLD7 and the A3 interlock (37E-37F) provide the notch-back action.

The diode CLD7 connected across the NBR coil serves to prevent inductive voltage surges on semiconductor elements and also to provide a dropout time delay of the NBR relay.

On the firing control card (CF), the CFSCl SCR is arranged to complete the NBR coil circuit when CFSCl is fired to its conducting stage by a gate pulse from CFTl unijunction uansistor. See Fig. 15 for triggering circuit.

1. The base 2 voltage of CFTl is supplied a fixed voltage from the B4 wire through R17 and CFR5 resistors. This establishes an emitter voltage trigger level.

2. Potentiometer CFP1 is supplied with a voltage signal proportional to load current by CG card current measuring system.

3. By adjustment of CFP1, a voltage exceeding the regulated level (by say 10%) may be applied, after filtering in CFR2 resistor and CFCl capacitor, to the emitter at a level to cause firing of CFCl capacitor into CFSCl gate circuit.

4. When CFSCl conducts, it completes the NBR relay circuit and NBR picks up.

5. When NBR relay picks up its interlock (37E-37J) opens and de-energizes NBR coil. This causes CFSCl to return to its blocking state.

6. NBR drops out after a time &lay, reclosing the NBR interlocks.

7. Unijunction uansistor CFTl is prevented from refiring for approximately 0.25 second by the slow recharge of capacitor CFCl through the time constant of CFR2 resistor and CFCl capacitor.

8. The CLD7 diode, A3 interlock (37E-37F), and NBR interlock (37B-37C) are so arranged that momentary interruption of NBR relay will return CLSC1 to its blocking state and drop out A3 contactor, if it is picked up.

9. Interlock NBR (37E-37J) will drop out A2 contactor in a similar manner if A3 was open.

10. If car operation was such that neither A2 or A3 contactors were closed, the retarding of ignitron tube firing can control the over voltage and maintain regulated load current.

IGNITRON TUBE FIRING

The firing panel, shown schematically in Fig. 16, supplies current pulses to the ignitron tube ignitors on signals received from the firing control cards. The pulse to the ignitors is supplied by stored energy in capacitors (**FC1** & FC2) released by SCR units (**FSCR1** thru 6) and formed into a pulse by series reactance. The circuit is of conventional design **but** uses **semi-conductor** devices to control the circuits.

The capacitors (**FC1-FC2**) are charged during the half cycle when the corresponding **tube** is reverse biased. During the forward biased half cycle the ignitor may be triggered by a signal pulse to its SCR gate transformer (**FT1** or **FT2**) primary. When the primary of either (**FT1** or **FT2**) is energized, it in turn energizes the secondary **sections** and supplies the SCR gate voltage to turn on the **SCR's.**

When the SCR's turn on, the capacitor (**FC1** or FC2) can then discharge to flre the ignitron tube ignitors through wires 40N or 40P. The signal pulse is generated at the appropriate time and on the appropriate SCR gate transformer by the firing control cards and associated devices.

PULSE GENERATOR FIRING

The firing of the correct tube during an existing half cycle of a-c in the "A" stage transformer is done by the polarized connection of transformer T5 (See Fig. 16). The 64 volt secondary of T5 transformer supplies the anode voltage to **SCR's CASC1,** & **CASC2.** The **SCR** gate circuits are triggered simultaneously at the correct phase angle during both half cycles of the main transformer "A" stage. However, only the proper SCR (**CASC1 - CASC2**) will have forward polarity and therefore be capable of conducting and energizing its connected firing panel gate transformer primary (**FT1-FT2**). The diodes **CAD1,** 2, 3 and 4 are necessary to prevent spurious firing of **the** transformers **FT1** and **FT2.**

The firing pulse generator to fire the gate circuits of **SCR's (CASC1-CASC2)** is essentially a conventional unijunction **transistor** relaxation oscillator. That **is,** by varying the base 2 voltage and the emitter voltage of the unijunction transistor the firing of the unijunction transistor is **controlled.** When the unijunction transistor (**CVT2**) is turned on by capacitor (**CVC1**) it in turn energizes **transformer CVX1.** Transformer **CVX1** in turn supplies the gate voltage to turn on SCR's (**CASC1** and **CASC2**).

The unijunction transistor is additionally controlled **to:**

1. Synchronize the beginning of buildup with the descent to zero of capacitor (CVCl) inconjunction **with** each half wave of stage "A" main transformer volts.

2. **Lock** out ignitron tube firing below a minimum voltage level in each half wave of supply from stage "A" secondary.

3. **Turn** on, to initiate firing operation from a full retarded firing with a limited rate of advance of firing phase.

4. Establish traction motor current level from **signals** received which are proportional to traction motor current.

5. **Defire** (turn-off) at the conclusion of a defire signal pulse.

The conventional unijunction oscillator circuit with linerized capacitor loading current is shown in yellow in Fig. 17. The 20 volt (+) regulated to base 2 is divided by the interbase resistance (**APPR.** 7000 ohms) to cause the emitter to be back biased by approximately 12 volts. Attainment of a 12 volt level on capacitor (CVCl) causes firing and discharge of the capacitor. It also should be noted that lowering of the base 2 voltage lowers **the** emitter bias in proportion and the voltage on capacitor (CVCl) lowers at which firing occurs.

Synchronizing

The synchronizing circuit is **shown** in green in Fig. 17 with the rectified a-c supply shown in dashed green and red.

Resistors **CBR2,** 3, 4 and 5 supply a bias at the base of **transistor CBT2.** This establishes an upper limit to the charging voltage of capacitor **CVC1.** This is set to be above the **normal** firing voltage of capacitor **CVC1.** Thus, if transistor **CCT2** is off, transistor **CBT2** does not interfere with the charging of the capacitor or firing of unijunction transistor **CVT2.** If charging voltage of CVCl rises above set value it will cause transistor **CBT2** to turn on until capacitor voltage lowers in value and transistor **CBT2** turns off.

Synchronizing **action results** as follows: the existence of a **synchronous** wave voltage from the transformer **T5** (0-90V) **secondary** raises the voltage of transistor **CCT2 emitter** to the 10 volt level of **zener CCZD1,** holding the transistor **CCT2** off (non-conducting from collector to emitter) and loading of capacitor CCCl through diode CCD2. In this condition, the CBR2, 3, 4 and 5 resistors and transistor CBT2 establish the voltage limit of capacitor CVCl as explained in the foregoing paragraph.

As the synchronous wave descends below the zener diode 10 volt level the emitter of transistor CCT2 voltage is lowered, with the wave going to zero. Capacitor CCCl also descends in voltage, supplying base current to transistor CCT2 turning it on and holding it on. With transistor CCT2 turned on, it overcomes the bias of resistors CBR2, 3, 4 and 5 on transistor CBT2 and transistor CBT2 turns on discharging capacitor CVCl with the descending synchronous wave. Momentarily, after the synchronous wave reaches zero, capacitor CCCl is depleted and resistor CCRl establishes a higher potential to the emitter than the base of transistor CCT2, turning it off. The resistor divider CBR2, 3, 4 and 5 now resume control of transistor CBT2 and capacitor CVCl can begin to rise to its firing point.

Lockout of Ignitron Tube Firing

Ignitor firing can only occur when sufficient forward voltage appears across the ignitron tube from the "A" stage transformer to assure its conduction if the ignitor is fired. The components and circuits to assure this lockout of ignitor firing until sufficient voltage is present across the tubes is shown in red in Fig. 17.

These components in conjunction with the capacitor CVCl voltage limit from transistor CBT2 described in the foregoing, provide a lockout of unijunction transistor CVT2 as follows:

The rectified a-c wave. from transformer T5 co-exists with the a-c voltage across the ignitron tubes. The magnitude of the rectified a-c wave from transformer T5 is adjusted by resistor CCR8, so that when the voltage of stage "A" transformer is at the proper level the rectified a-c wave from T5 will unlock the CVT2 firing level.

As previously described, the unijunction transistor CVT2 emitter voltage to fire is a proportion of the voltage applied to base 2 (upper base). When transistor CVTl is turned on it raises the base 2 volts of CVT2 to a level that prevents capacitor CVCl from firing CVT2. Transistor CVTl is turned off by the appearance of the rectified a-c wave whenever it exceeds the 20 volt reference circuit.

Transistor CVTl is biased by resistors CBRl, CBR2 and diode CVDl to turn on, which causes the base 2 voltage of CVT2 to be above the charging voltage limit of CVCl capacitor, set by transistor CBT2 previously described. By adjustment of CCB8 resistor the rectified a-c wave from transformer T5 will back bias diode CVDl whenever the a-c wave voltage exceeds the 20 volt regulated voltage. This will cause transistor CVTl to turn off. Thus, the unijunction transistor CVT2 is permitted to fire if the other functions of the system will permit firing. Firing at the fully advanced point is possible if capacitor CVCl has reached its firing level or has reached its limit level and is waiting for the unlock to occur.

Rheostat CVR4 is an adjustment permitting use of various unijunction transistors having varying base 2 to base 1 resistance values.

Turn On of Ignitron Tuba Firing

The system is arranged to begin each period of operation of the tubes from the full retarded phase position. Also, it controls the rate at which the firing can advance in phase.

As previously 'explained, the time to fire the tubes is controlled by the current that is allowed to flow into capacitor (CVCl). The synchronizing portion sets a time limit for each half wave that capacitor CVCl can receive current before the capacitor charge is dumped and is forced to rebuild from substantially zero volts. If it is assumed that fully retarded firing requires a minimum current of 1/10 ma., less current flow will not accomplish firing of unijunction transistor CVT2 before the synchronizing action dumps capacitor (CVCl). To advance the firing phase, higher current must be supplied to capacitor CVC1.

For fully advanced firing, the current must be approximately 0.8 ma. This current is supplied and controlled by transistor CBTl. The action of the components traced in blue on Fig. 17 establishes a reference voltage at the base of transistor CBTl.

The reference voltage to the base of transistor CBTl is varied to control the charging current as desired. Capacitor DACl is used to control the base reference voltage in conjunction with transistor CBT3.

The action of this circuit is as follows: with transistor CBT3 turned off, transistor CBTl is turned off because transistor CBTl base is at a positive potential in respect to its emitter. Therefore, no current can flow from CBTl emitter to collector to charge capacitor CVCl. At turn on of transistor **CBT3,** the capacitor DACl starts to charge which causes transistor CBTl to partially turn on, allowing the minimum charging current of capacitor CVCl to flow (and fully retarded firing). As the capacitor (DACl) continues to charge to its steady state it causes transistor CBTl to turn on move fully and thus increase current flow to capacitor CVCl to its full regulated rate.

The turn-off to turn-on switching of transistor **CBT3** is done by the appearance of a-c voltage across the **ignitron** tubes. Whenever such voltage to any degree appears it will keep transistor **CBT2** turned on. The circuit is from rectifiers **CJD1,** 2, 3 and 4 (shown in Fig. **14),** filtered by resistor CBR9 and capacitor CBCl. This voltage is applied through limiting resistor **CBR10** to furnish a sufficient base bias to transistor **CBT3** to keep it turned on through the full range of **voltage** across the ignitron tubes. Resistor **CBR8** is a resistor to assure turn off of transistor **CBT3** at zero input current (zero tube volts).

Load Current Regulation

The prime objective of ignitron tube phase control is to maintain the load current at a selected level as traction motor speed and voltage requirement change. As in all closed loop regulating systems, phase lags occur requiring addition of stabilizing functions to achieve stable operation with sufficient loop gain to maintain the load current within a desirable range over the **wide** range of firing phase control required.

As described previously, the firing phase is **determined** by the current flow to capacitor CBCl. The current to capacitor CVCl is determined by action of transistor CBTl. Transistor CBTl action is to maintain a constant current in resistor **CBR1.** This current flows into capacitor **CVC1. If** current is extracted from this flow, as it is by the lead (bleed line) connected to the emitter side of transistor, the current to capacitor CVCl can be reduced. A complete range of firing phase control can be achieved by extracting more or all of the current from resistor **CBR1.** The extracted current must be large to hold a retarded firing phase and to drop with increase rapidity to effect uniform rate of firing **phase** advance.

Current regulation of the traction motors is achieved through current extraction **from** **.:sistor** CBRl by means of transistor **CET1.** Transistor CETl responds to a **load** current **signal·which** is proportional to traction motor load current. See the brown colored circuits in Fig. 17.

As traction motor load current rises it sends a signal to the base of transistor CETl which is great enough to exceed the breakover level of **zener** diode **CEZD1** in the transistor emitter lead. **This** action turns on transistor CETl which extracts current from resistor CBRl. Capacitor **CDC3** and resistor **CDR1** obtain a high degree of filtering of the extraction current. This high filtering of capacitor **CDC3** reduces current signal ripple effects sufficiently to avoid ignitron tube unbalance (one **tube** firing too far in phase advance of other). The resulting phase lag caused by the filtering of capacitor **CDC3** at high load signal rates make stabilization, through this channel, impractical.

Two stabilizing circuits are necessary. Both are based on the rate of change of the current signal, as fed back to control phase firing. They are described as the wide range stabilizer and the small range stabilizer.

<u>Wide Range Stabilizing</u>

The circuits to accomplish the wide range stabilization comprise a lead network with the amplified output of transistor **CET2** connected to operate in parallel with the current level transistor **CET1.** Transistor **CET2** also draws extraction current from resistor CBRl. It should be noted that transistor CETl can not effect phase control until the current signal level has exceeded the **zener** diode level of **CEZD1.** Therefore, **CET2** gives a controlled rate of current build up from zero to the regulated level of CETl, during initial load energization and to control current buildup during re-application of power after coasting. Transistor **CET2** is fully effective at current levels below which transistor CETl can respond. A rapidly rising current signal rate from the traction motor circuit increases the turn on of **CET2** and therefore, increases extraction from resistor **CBR1.** A falling current signal rate decreases the extraction current from resistor CBRl.

Because of filter lag (capacitor **CDC3)** introduced at **high** frequencies, the network cannot stabilize the system over the full traction motor speed range. The small range stabilizing is applied to secure this stability.

<u>Small Range Stabilizing</u>

In general, the small range **stabilizing** system controls **the** firing phase of the **synchronized** unijunction transistor (CVT2) firing-pulse generator by varying the firing voltage level at its emitter. This is achieved by variation of its base 2 to base 1 voltage.

The components colored in red and green in Fig. 17 form the conventional relaxation oscillator. The "synchronization and lockout" and "synchronization and end cycle dump" are auxiliary functions, previously described, causing each cycle of the unijunction oscillator to begin at the end of the previous half cycle of a-c voltage. The operation of such an oscillator is to discharge capacitor CVCl through the unijunction transistor (emitter to base 1) into the transformer CVX1 primary at the instant the emitter (capacitor CVC1) volts exceed the emitter back bias voltage (interior to the unijunction transistor).

Because the base 2 voltage of CVT2 can be raised or lowered, the voltage on capacitor CVC1 at which firing occurs can be raised or lowered in proportion.

The wide range stabilizing system controls the rate of charging current to capacitor CVC1. This can effect a full range of the firing point of unijunction transistor CVT2, from full retard (or off) to full advance. The second method of controlling firing point, by raising or lowering the base 2 voltage of unijunction transistor CVT2, can be used only over a limited range of advance and retard. The second method is completely independent of wide range stabilization and is called small range stabilization. The small range stabilization system may be considered a "wait and see" type circuit. Its function is to receive a signal proportional to rate of change of load current in the traction motor circuits. Thus, it controls point of firing of unijunction transistor CVT2 until the current measuring and wide range stabilizing systems take over.

To achieve the small range stabilization and to eliminate the "hunt" frequencies that would result from only the wide range stabilization the components colored with orange in Fig. 17 are used.

The resistors CDR6 and CDR2 form a steady state reference to the base of transistor CDTl. Transistor CDTl will immediately turn on partially to raise base 2 volts of unijunction transistor CVT2. These resistors then set a steady state level of base 2 voltage on CVT2.

If transistor CDTl were turned full off (no conduction) then resistor CVR7 will establish the base 2 volts of CVT2 at a minimum level. Again, if transistor CDTl were turned full on reeistor CDR3 and diode CDDl will act in parallel with resistor CVR7 to eet the maximum voltage level to base 2 of CVT2. Diode CDD1 is used to protect transistor CDTl emitter from excessive back bias during abnormal transient conditions.

The capacitors (CDC1 and CDC2) and resistor CER7 (See Fig. 15) form the stabilizing portion of the circuit. The zener diode CFZD1 shown in Fig. 15 is in conduction during operation and causes substantially zero impedance to transient current from capacitors CDC1 and CDC2, flowing through resistor CDR6 to the negative line B(-) in Fig. 16. Therefore, to consider the capacitor current flow, resistors CDR6 and CDR2 may be considered connected in parallel to the B(-) wire. Then capacitors CDC1-CDC2 and resistor CER7 and the parallel resistance of resistors CDR6-CDR2 form an RC (resistance capacitance) differentiating system to the load current signal input. The input signal is a "stiff" (i.e., constant voltage) source and substantially uneffected by the CDC1 and CDC2 capacitor currents. Thus, when a rising load current signal is received, current will flow in resistors CDR6-CDR2 proportional to the rate of rise of the load current signal. This causes the voltage at the base of transistor CDTl to rise and, in turn, causes the transistor to turn on (towards saturation) increasing the base 2 voltage of unijunction transistor CVT2. As previously described, this is the desired action to retard the firing phase and reduce rate of load current rise. Similarly, falling load current rate advances the firing phase.

Defire Timing System

The defiring system is incorporated to control the time of defiring and refiring of the ignitron tubes at retarded phase when the A2 or A3 contactors operate to connect their respective transformer stages. It is necessary to defire the ignitron tubes at the instant the main contacts of contactors A2 or A3 close. If the main contacts will close while the ignitron tubes were firing at full advance, a large voltage would appear across the traction motor load. Such a uansient would give a large over current sufficient to trip the overload relays. At the other extreme, if the ignitron tubes are defired too far in advance of the closing of main contacts of A2 or A3 contactors, a large decrease in load current would occur while transition is taking place. This would result in a car jerk at the time A2 or A3 main contacts re-establishedload current.

As previously described, under Notching Control, operation of contactors A2 or A3 is initiated by a pulse to their respective SCR's (CLSC1-CLSC2).

This pulse begins with triggering of SCR-CJSC1 by unijunction transistor CKT1, and terminates by the A2 or A3 interlocks in the 37H wire (shown in Fig. 14) opening the circuit.

The interlock contacts are so arranged that they break the circuit to CJSCl during the movement of the main contacts and before the main contacts close to connect their respective transformer stages. Because contactors vary considerably in speed of response as control air pressure or voltage vary with temperature, wear, etc., it is necessary to control the ignitron tube firing by actual motion of the contactor.

The defiring system is designed to defire the ignitron tubes at the instant of termination of the pulse from SCR-CJSC1. In Fig. 17 the components colored by the purple line accomplish the desired result.

The defire pulse is formed from trainline voltage to the SCR-CJSC1 and its amplitude may vary from plus 24 to plus 40 volts with normal control voltage variations. The resistor CCR5, diodes CCD8 and CCD7 conduct pulse current from CJSCl, through CCR5, CCD8, and CCD7 and back to the 20 volt plus regulated line. The 20 volt line, through zener diode CKZD1, can limit pulse voltage appearing at the interconnection point of CCD8, CCC2, CCD7 and CCR6 to approximately plus 20 volts. Pulse current is conducted to a degree sufficient to cause a difference between pulse volts and the 20 volt plus regulated line to appear across resistor CCR5. This assures defiring with varying trainline volts from CJSCl.

The defiring of the tubes is accomplished by discharging capacitor DAC1, thus turning off CBT1. Transistor CCTl will discharge capacitor DACl if turned on by passage of current from its emitter to base. Transistor CCTl is held off by the current flow through resistor CCR7 during normal tube firing, back biasing its base. Also, capacitor CCCZ is charged to substantially plus 20 volts. Plus (See Fig. 17) is connected from the 20 volt regulated line to B(-) through resistor CCR6.

If a pulse now appears through resistor CCR5, the capacitor CCCR negative side to resistor CCR6 interconnection is raised to plus 20 volts. This causes capacitor CCC2 to rapidly discharge through diode CCD6. The resistors CCRS and CCR6 substantially discharge capacitor CCCZ well before the conclusion of the defire pulse.

This action does not alter the off state of transistor CCTl. Therefore, ignitron tube firing continues during the time contactors A2 or A3 delays, accelerates, and moves to the point of opening its normally closed interlocks.

At the instant of interlock opening, the pulse terminates the defire pulse and capacitor CCC2 recharges drawing current through diode CCD5 and transistor CCTl base. Resistor CCR6 limits this initial current and determines the duration of CCTl transistor current. This time is sufficient to allow capacitor DACl to discharge completely through the emitter to collector of transistor CCT1.

As capacitor CCCZ approaches completion of charge, the transistor CCTl will be again turned off by the current flowing in resistor CCR7. This allows capacitor DACl to again begin recharging. As described in section Turn On To Initiate Firing, the recharging of capacitor DACl allows refiring of unijunction transistor CVT2 and thereby the ignitron tube 5, in a retarded firing phase condition.

The defire action is the same for either contactor A2 or A3 closing because both initiate defire pulses to resistor CCR5.

CURRENT MEASURING

Traction motor current is measured and controlled by signals sent to the system from the two current-measuring reactors CMRXl and CMRX2. Each reactor contains a bus bar through which the total current of two traction motors flows. This is shown schematically as a triangle across the coils of CMRX1 and 2 in Pig. 15. The coils shown are a-c coils which are fed from the secondary coils of CHX1 transformer at 800 cps.

The a-c to feed the current measuring reactor coils is furnished by a oscillator shown on the left side of Fig. 15.

OSCILLATOR OPERATION

The operation of the oscillator is as follows: When battery power is applied to the B(+) wire, current will flow from the B(+) wire to the B(-) wire as shown in red in Pig. 15. This is the start winding which will turn on transistors CHT2 and CHT3 shown in yellow. Current will flow through the main primary in direction as shown by the yellow arrow. The transistor CHT1 and CHT4 will be turned off because they are back biased by their particular winding having opposite polarity to CHT2 and CHT3.

Current will flow in the main primary only as long as it continues to rise in the inductive circuit.

When it reaches its maximum value, voltage in the windings to the CHT2 and CHT3 base circuits will collapse and reverse the action on transistors CHT2 and CHT3 turning them off.

This will cause all the windings to reverse polarity and transistors CHT1 and CHT4 will turn on and current will flow in the main primary in the opposite direction as indicated by the blue in Fig. 15.

The switching action continues in this manner at approximately 800 cps. The output of the primary then induces an a-c voltage of about 50 volts in each of the secondary windings to supply the a-c necessary to the current measuring reactors.

CURRENT SIGNAL CIRCUITS

The a-c from the oscillation is fed to the a-c windings of each current-measuring reactor. If no d-c is present in the d-c windings (bus-bar) from the traction motor circuits then no a-c will flow thru the rectifier bridges (CGD1 thru CGD8).

When d-c is flowing through the traction motor and thue through the bus bare of the CMRX1 and 2 it will allow a portion of a-c to flow through the rectifier bridges. This current flow then passes through smoothing reactor CGX1 and down through the rheostats CFPl and CEPl and back m their source. The reactor is such that the more d-c through the bus bar, the more a-c will flow through the circuit. The circuit is shown in green in Fig. 15.

The rheostats R18A and R18B are used to adjust the a-c volts across the rectifiers, with 480 amperes in the traction motor circuits. Rheostat CEPl is used to adjust the current signal to control the firing of the ignitron tubes, as previously described. Rheostat CFPl is used to adjust the notch back circuit to function if traction motor current increases to above 20% overcurrent.

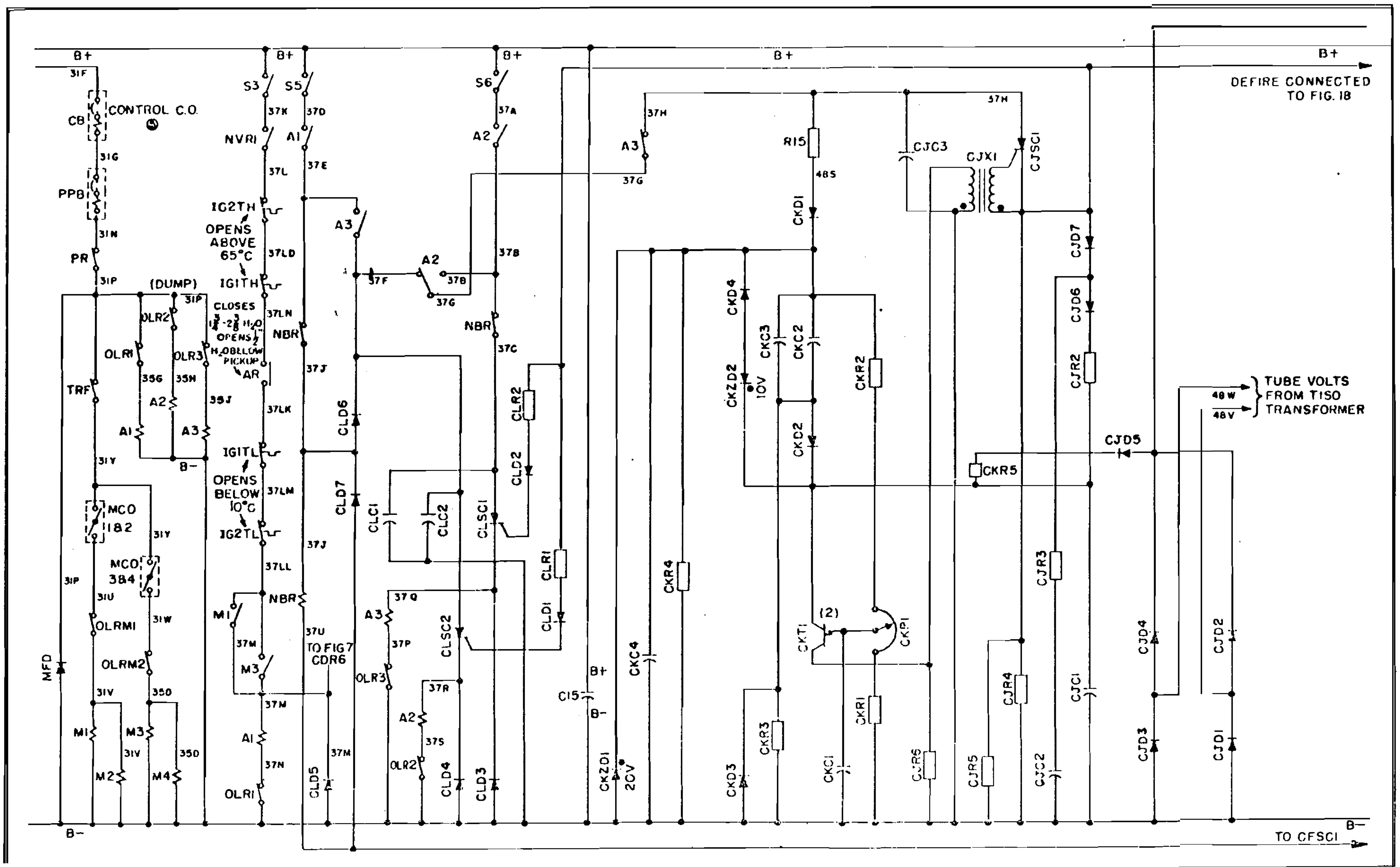


Fig. 14. Notching control circuits.

(E-11236)

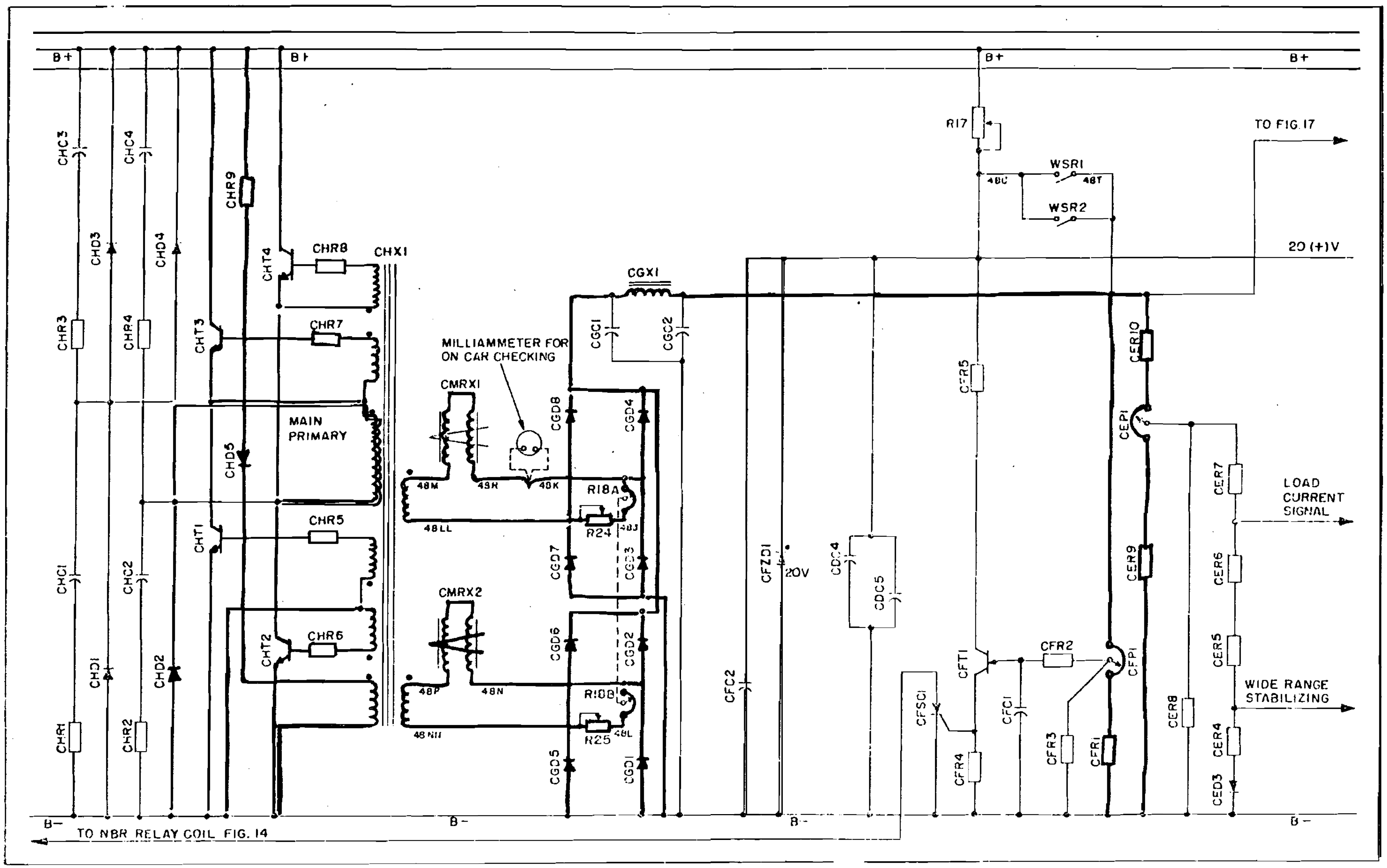


Fig. 15. Firing, notch back and current measuring circuits. (E-11237)

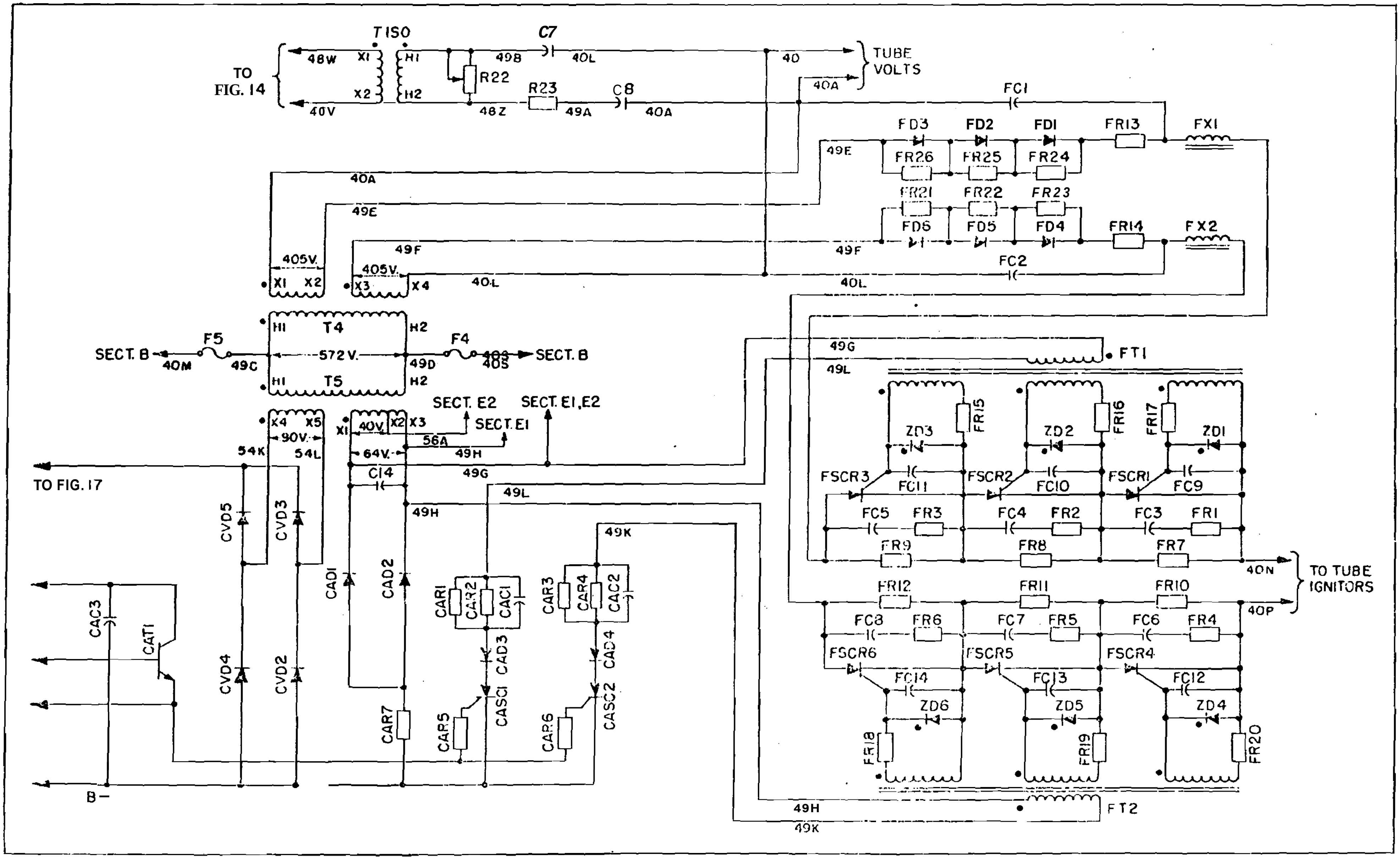
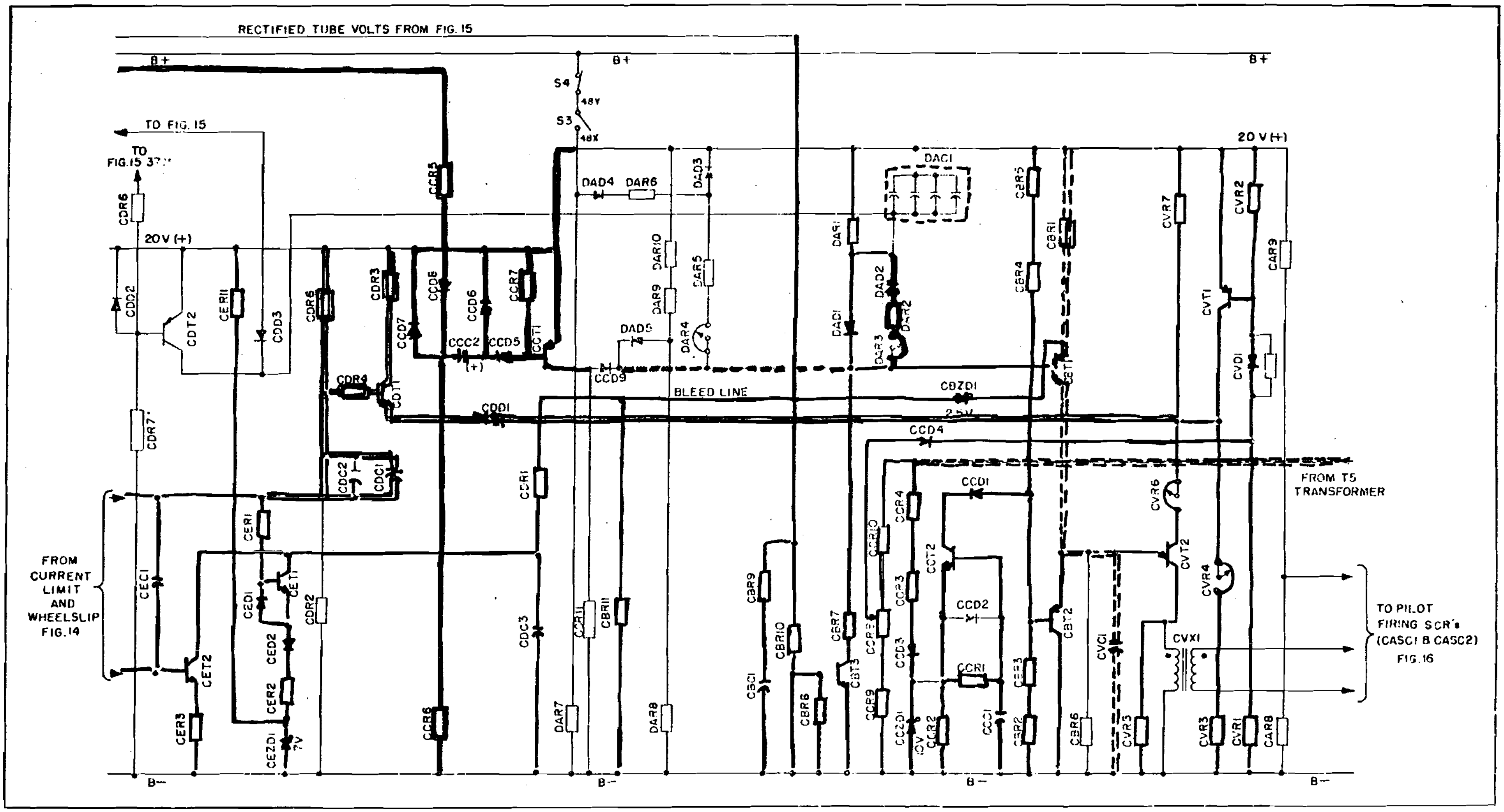


Fig. 16. Firing panel circuits.
(E-11238)



— Conventional unijunction oscillator
Green — Synchronizing
Red — Lockout of ignitron tube firing
Blue — Turn-on to initiate tube firing
Brown — Current regulation and wide range stabilizing
Orange — Small range stabilizing
— De-fire timing system

Fig 17. Control circuits for pilot firing and main firing. (E-11239)

WHEEL-SLIP-SLIDE

The wheel-slip-slide **system (See** Fig. 18) initiates corrective action when adhesion is lost **between** the car wheels and rail. When in braking, if a wheel locks or slides, the correction is made on the truck the **sliding** wheel is on.

A frequency signal proportional to axle speed is fed to the wheel-slip **cards** (CM-CN) located in the **17FL2L1** panel. **This** frequency signal is supplied by an alternator driven by the intermediate shaft of each gear box. The signal is rectified and compared by the semiconductor components mounted on the cards. If the signal from any alternator is greater or less than the others (by a predetermined amount) corrective action is started automatically both in motoring and braking.

The circuit action occurs as follows:

The potentiometers **C1MP1, C2MP1, CNP1** and **CNP2** are adjusted so that when the alternators are **all** turning at the same speed, no current **will** flow to the rectifiers **CPD1** through **CPD8.** Each **alternator feeds** a saturating transformer **C1MX1, CRMX1, CNX1** and **CNX2** primary coil. The **secondary** voltage produced is proportional to speed and this is rectified by a pair of diodes off the center **tapped** secondary **C1MD1, C1MD2, C2MD1, C2MD2, CND1,** through **CND4.** The current produced is filtered to provide a good direct current output by means of capacitors and filter reactors **WSX2** through **WSX5.**

If the alternator speed increases or decreases with respect to the others, an unbalance will exist in the relationship of the voltages at the various brush arms and current will flow from the one with the highest voltage to those of lower voltage.

Assuming that **WSA2** alternator is slipping, the following action would take place. Voltage across **C2MP1** would increase, thus current would flow from its brush arm to the brush arms of the other three potentiometers. This would cause current to flow in the three circuits. Current would tend to split evenly between the three circuits; however, current flow in **WSA1** circuit would be much greater than **WSA2.** Therefore **transistor** CPT1 would turn on. **As** the current flow in **WSA3** and **WSA4** circuits would tend to balance, another transistor **CPT2** may not **turn** on; **although** if slip **was severe enough both transistors** would turn on.

When transistor CPT1 turns on it will connect sensitive relay DBR1 from the 37.5 volt **line** through CPT1 collector to emitter and to **B(-)** line. When **DBR1** picks up, it completes WSR1 relay circuit from the B(+) line to B(-) through WSLR relay interlocks.

When WSR1 picks up it sends a signal to the notch back **SCR-CFSC1 (shown** in Fig. 14) and also a signal to capacitor **DAC1** (See Fig. 17) to defire the **ignitron tubes.** In addition it **sends** a third signal to the load **control** potentiometer CEP1 (See Fig. 14). *All* of these signals result in reduced power to the traction motor load.

If a wheel **locks** or slides while air brakes are being applied the following circuit action takes place. The voltage in the sliding wheels circuit will decrease; the **voltage** from the other circuits will flow from their brush **arms** to the sliding wheel brush arm trying to balance the circuits. This will cause current to flow in the sliding wheel circuit and thus turn on the **transistor** base connected to it. This, in turn, will pick up the sensitive relay DBR1 or **DBR2** whichever transistor is turned on. When the **sensitive** relay picks up, the circuit to either WSR1 or **WSR2** is completed. Contacts on these relays then energize relay to reduce braking on whichever truck has the sliding wheel.

The secondary winding of FNX2, which is connected to rheostat **CPR1,** sets up a bucking voltage against the voltage across **CPD9** diode to de-sensitize the system at high speeds. That is, the system will detect wheel slips at about 5 mph differential at low speeds and will detect wheel slips at about 14 mph at high speeds. This is necessary to compensate for wheel size difference and wheel wear.

OVERSPEED (See Fig. 19)

The overspeed system is designed to remove power when a predetermined car speed is reached and, if the car continues to increase speed to make a service brake application.

The rectifier bridge **CDR1** through **CDR4** is fed from a secondary winding of the wheel slip alternator **WSA2.** The output is through the bridge, smoothing reactor **OSX1** down through the series resistances **CRR1** through **CRR8** and **CSR1** through **CSR8** and back to the bridge and thus back to the secondary winding of **C2MX1.**

When the output voltage is great enough it will turn on transistor CTT2. This voltage value is set by resistor **CCR7** slider. When transistor **CTT2** turns on, it **picks** up **sensitive** relay **BCR2.** Relay BCR2 in turn energizes the coil of OSPR relay from the

B(-) wire through BCR2 contact to the OSPR coil. Relay OSPR relay picks up and its contacts remove trainline power ale the master controller. The OSPR contact in Fig. 19 shorts out resistors CRR1-CRR6 which boost the turn on voltage of transistor CTT2 to hold it on until the car speed is reduced to a predetermined value.

If car speed should continue to increase after the foregoing action, then transistor CTT1 will turn on and BCR1 will pick up in a similar manner as BCR2. It will energize coil OSSB relay; OSSB relay contacts will energize the PAV valve and a service brake application will be made to slow car down to the predetermined value.

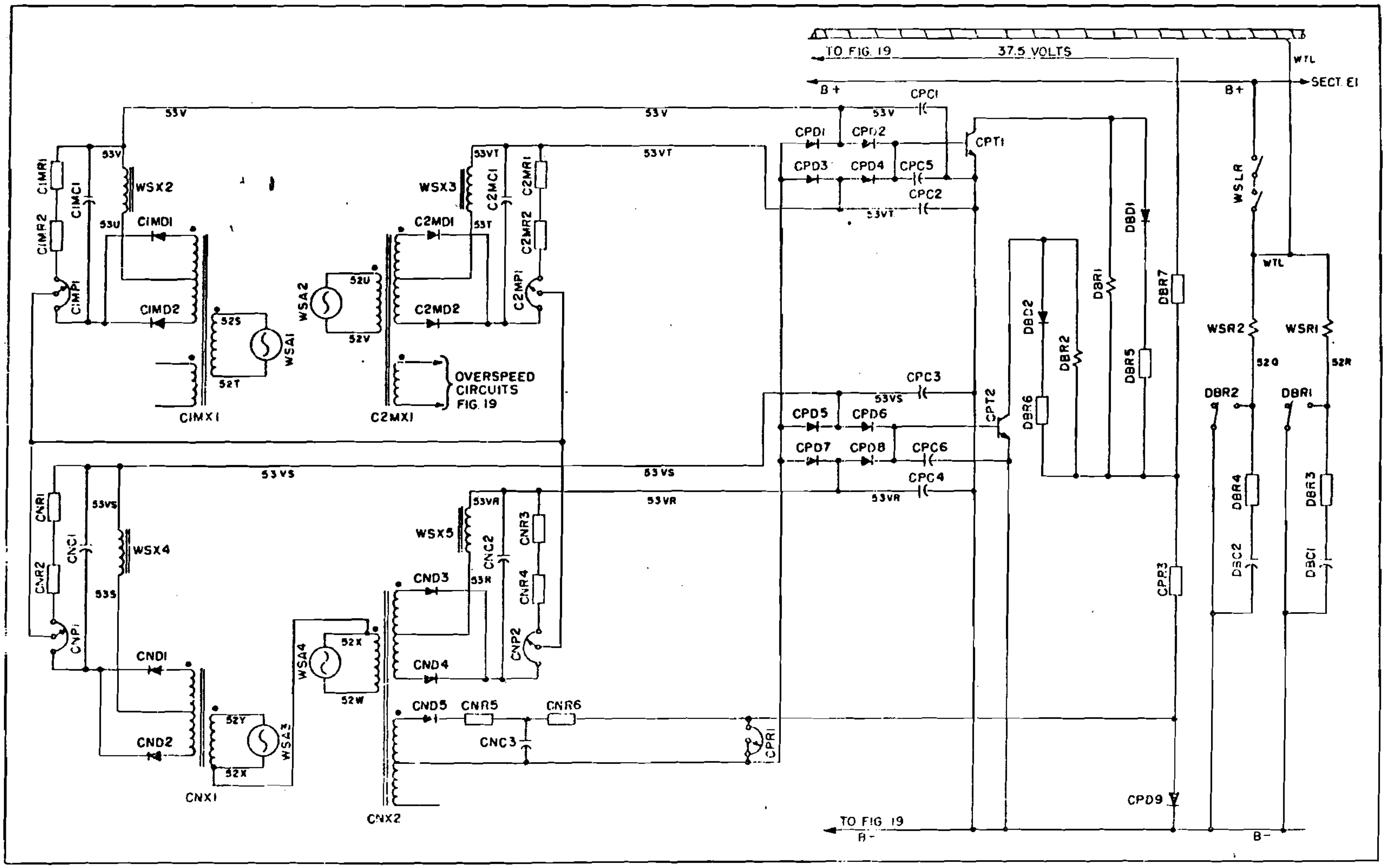


Fig. 18. Wheelslip circuits.
(E-11240)

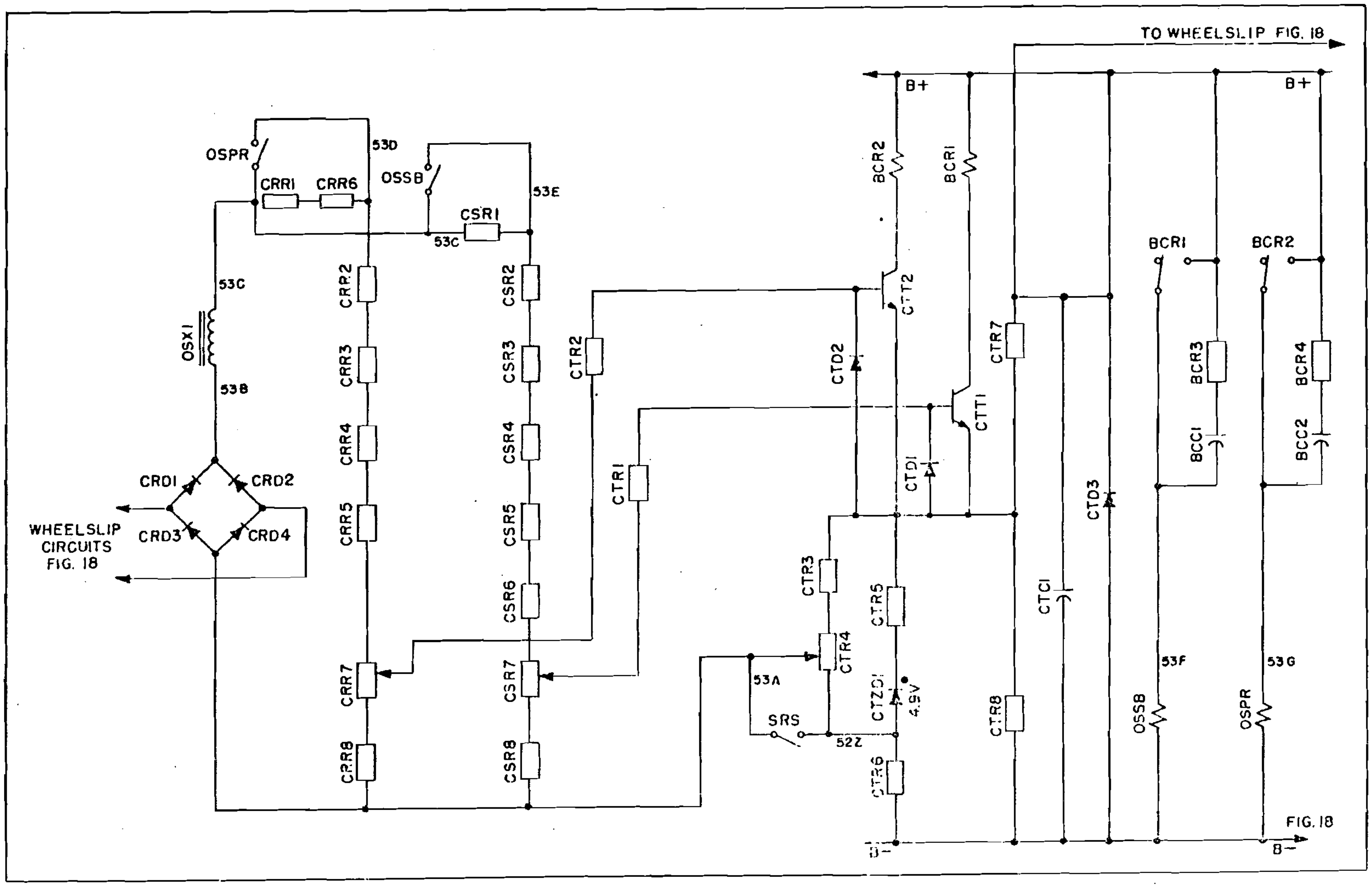


Fig. 19. Overspeed circuits.
(E-11241)