OPERATING & MAINTENANCE

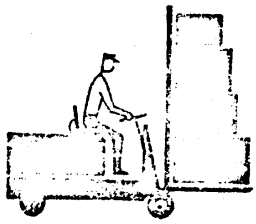
INSTRUCTIONS

GEK-40

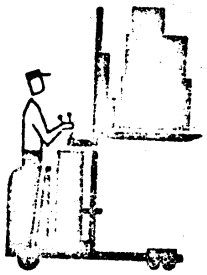
MODELS EV-1A, EV-1B, EV-1C, EV-1D
VOLTS 24-48, 48-84

General Electric Supply Co
300 NW 14th St
Portland, Or

EV-1* SCR CONTROL FOR ELECTRIC VEHICLES



CONTENTS



General Electric Co
Drive Systems Div.
Salem VA 24153
1501 Roanke Blvd
Industrial Sales Div.
221-5042-3
Pltd OR

*Trademark of General Electric Company

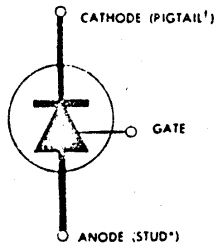
The information contained herein is intended to assist truck users and dealers in the servicing of SCR control furnished by the General Electric Company. It does not purport to cover all details or variations in equipment nor to provide for every possible contingency to be met in connection with installation, operation or maintenance.

Should further information be desired or should particular problems arise which are not covered sufficiently for the purchaser's purpose, the matter should be referred to the truck manufacturer through his normal service channels, not directly to General Electric Company.

GENERAL ELECTRIC

WHAT IS AN SCR?

Since the heart of the control is a silicon controlled rectifier (SCR), a general understanding of the characteristics of the device will be helpful. The SCR is a semi-conductor rectifier used as a latching switch; i.e., it may assume either a conducting or nonconducting state (On or Off).



The SCR can be turned On by a momentary application of control current to the gate. To turn it Off, it is necessary in addition to removing the turn-on signal from the gate, either to remove all power from the SCR or to apply momentary reverse voltage between cathode and anode.

¹Typical of SCR as used in GE control for electric vehicles.

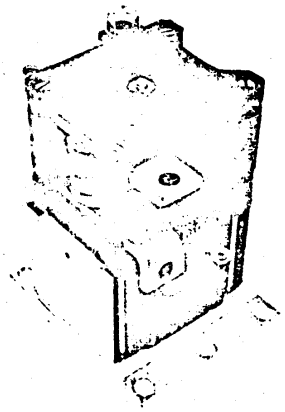


Fig. 2. Typical contactor

PHOTOS OF CONTROL

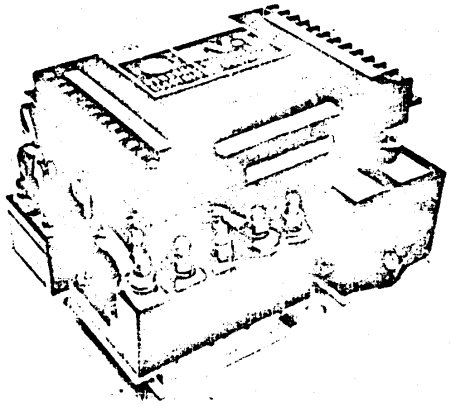


Fig. 1. Typical SCR static panel

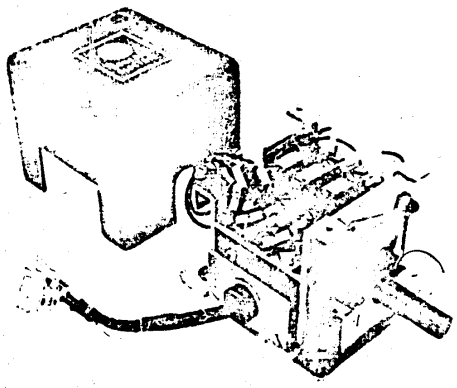


Fig. 3. Typical accelerator switch with cover removed

ELEMENTARY DIAGRAM

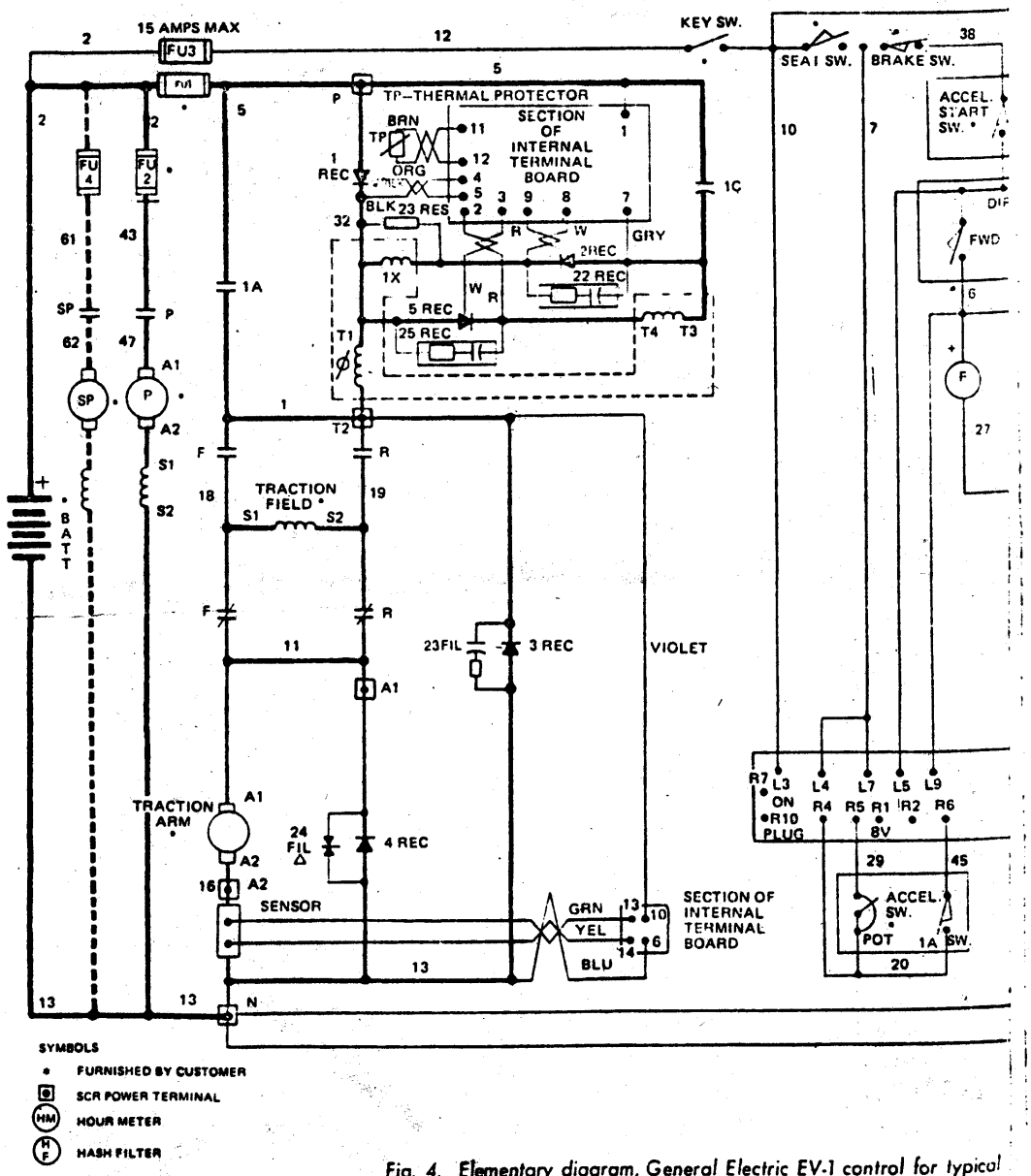
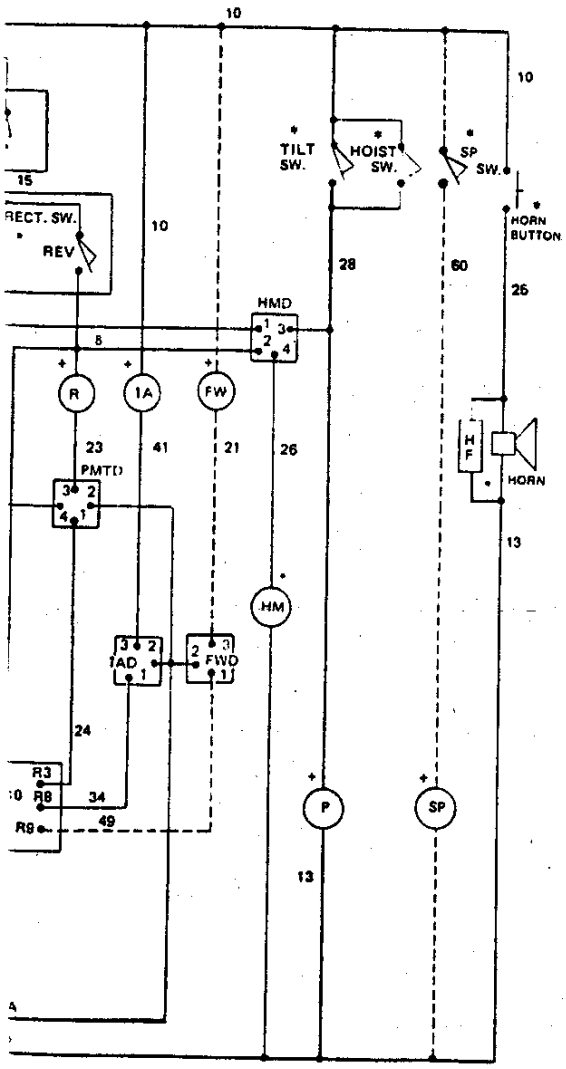


Fig. 4. Elementary diagram, General Electric EV-1 control for typical
Refer to the manufacturer's instruction book for diagram for



Note: A) BROKEN LINES DENOTE ACCESSORIES.
B) EV-1 CONTACTOR COILS HAVE INTERNAL SUPPRESSION
C) Δ 24 FIL ON MODELS C AND D ONLY
D) ◊ ON REACTOR MODELS OMIT PRIMARY T1-T2

down truck.
r specific truck.

CIRCUIT OPERATION (SEE FIG. 4)

The control circuit is energized by closing the Key switch, Seat switch, and moving the Forward or Reverse lever to either position and then depressing the accelerator, thus closing the Start switch. This applies power to the control card and, if the static return to OFF and pulse monitor trip requirements are satisfied, turns on the PMT driver, which will close the selected directional contactor, completing the circuit to the traction motor.

The control card supplies a gate pulse to 2 REC, turning it on to a conducting state, allowing current to flow from the battery through 1C, 2 REC, 1X, motor field, motor armature, current sensor, and back to the battery. After 1C charges, 2 REC shuts OFF due to lack of current. The control card checks that 1C is charged and unlocks the gates to 1 REC and 5 REC.

The control card then supplies a gate pulse to 1 REC, turning it ON to a conducting state, allowing current to flow from the battery through 1 REC, motor field, motor armature, sensor, and back to the battery. 5 REC turns ON and allows current to flow T4-T3, 1C, 1 REC, 5 REC back to T4-T3. This current charges 1C positive (card terminal 7 is now positive). This charge is now stored on the capacitor until it is time to turn OFF 1 REC. This charging cycle occurs in less than 1 millisecond (0.001 seconds) and 5 REC shuts OFF.

Current continues to flow in 1 REC until the control card turns ON 2 REC. When 2 REC conducts, capacitor 1C discharges around the circuit composed of 1C, 2 REC, 1X and 1 REC. This discharge current opposes the battery current through 1 REC until the resultant current is zero.

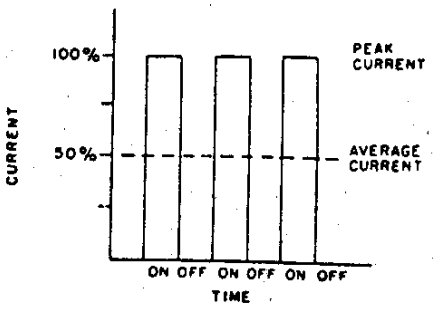


Fig. 5. Battery current

With reverse voltage across 1 REC, 1 REC is turned OFF. Current continues to flow in 1C, 2 REC, motor and the battery loop until the capacitor (card terminal 7) is fully charged negative. This charge exceeds battery voltage by an amount which is a function of motor current, and 2 REC turns OFF. Figure 5 illustrates the pulsing of current from the battery.

During the OFF time, the energy stored in the motor, by virtue of its inductance, will cause current to circulate through the motor around the loop formed by 3 REC, thus providing what is called "flyback current". Figure 6 shows the nature of the motor current, which is composed of both battery current and the inductive flyback current. It should be noted that the average motor current measured will be greater than the average battery current. The SCR control, in effect, converts battery current at battery volts into a higher motor current and a lower motor volts.

The time for the next On and Off cycle to start is determined by the time that the control card takes to oscillate. The oscillation times are controlled by the potentiometer in the accelerator. Slow speed is obtained by having maximum ohms in the potentiometer. As the resistance in the potentiometer decreases, the speed of the motor increases. With level operation, the SCR circuit is capable of delivering approximately 85 to 90 percent speed. For full-speed operation, the 1A contactor is closed to apply full battery voltage across the motor.

CONTROL FEATURES

- OSCILLATOR — The oscillator section of the card has two adjustable features, creep speed and controlled acceleration, and one fixed feature, top speed.

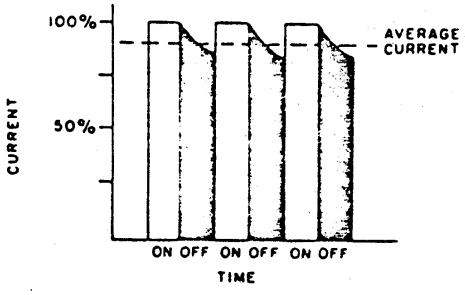


Fig. 6. Motor current

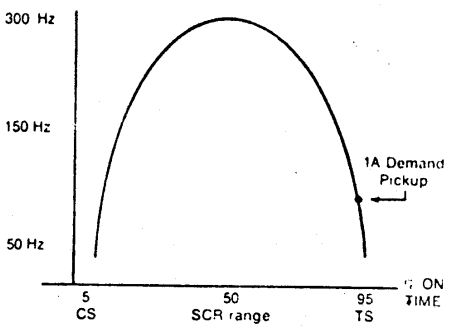


Fig. 7. Oscillator frequency curve

With the accelerator potentiometer at maximum ohms, the creep speed can be adjusted with a trimpot on the card. Top speed is fixed by card design, and is obtained with the accelerator potentiometer at minimum ohms.

The rate at which the oscillator may increase its % ON time is limited by "Controlled Acceleration". The minimum time required to go from creep speed to the 1A pickup point may be varied by an indexed trimpot (C/A) on the card, adjustable from approximately 0.5 seconds to 1.0 seconds.

The % ON time has a range of approximately 5 to 95 percent. The center operating condition of the oscillator is at 50 percent ON time with a nominal 1.7 milliseconds ON time and 1.7 millisecond OFF time. This corresponds to a maximum operating frequency of about 300 hertz. At creep the ON time will decrease to approximately 0.8 milliseconds while OFF time will become in the order of 20 milliseconds. At full SCR operation, this condition will be reversed (short OFF time, long ON time). This variation of ON and OFF time of the oscillator produces the optimum frequencies through the SCR range. See Fig. 7.

- CURRENT LIMIT — This circuit monitors motor current by utilizing a sensor in series with the armature. The information detected across the sensor is fed back to the card so current may be limited to a maximum safe value. If heavy load currents are detected, this circuit overrides the oscillator and limits the average current. An indexed trimpot for the current limit (C/L) adjustment is provided to maintain the peak voltage on the capacitor within its rating when

used on high source inductance and/or low motor resistance applications. Because of the flyback current through 3 REC, the motor current usually runs 2 to 3 times the battery current. The (C/L) trimpot adjustment will produce little or no variation of battery current when used with high resistance motors.

- PLUGGING — Slowdown is accomplished when reversing by providing a small amount of retarding torque for deceleration. If the vehicle is moving and the directional lever is moved from forward to reverse, the motor field is reversed, the motor armature is driven by the inertia of the vehicle and acts as generator. This generated current passes through 4 REC and the current sensor. When the plug signal is initiated, the oscillator circuit regulates at a plug current limit level as set by the Plug trimpot on the control card. This controls the pulse rate of 1 REC to regulate the generated motor current and bring the truck to a smooth stop and reversal.

- RAMP START — This feature provides SCR torque to restart a vehicle on an incline. The memory for this function is the directional logic in the card. When stopping on an incline, the Directional switch must be left in its original or OFF position to allow the control to assume full power when restarting in the same direction. The "C/L" trimpot affects this torque.

- FULL-POWER TRANSITION — This built-in feature provides smooth transition from SCR to 1A bypass. This is accomplished by the SCR continuing to pulse until the 1A contactor power tips close.

- 1A CONTROL — The 1A contactor has 6 modes of control:

  1. DEMAND PICKUP (fixed feature of the card) — If the oscillator has attained a % ON time equivalent to a motor voltage of 80 to 85 percent of the available battery volts, the 1A contactor will automatically pick up. The 1A switch in the accelerator is not necessary for this function. On "H3" cards, this feature may be eliminated by adding a jumper from R9 to R4.

  2. TIMED PICKUP — This feature works with the 1A switch in the accelerator. The time-delay pickup of 1A is provided by a circuit in the card. This feature allows 1A to be picked up after a time delay without reaching the demand point, and is normally used to apply full power at near stall conditions. This time delay is adjustable by means of a 1A time trimpot on the card.

  3. 1A THERMAL HOLDOFF — This feature prevents the 1A contactor from closing as a function of time when the truck is in severe thermal cutback to avoid torque jumps. When a truck starts to go into thermal cutback, the 1A time will rapidly increase to infinity as the control goes deeper into thermal cutback. On "E" and later cards, this feature may be eliminated by adding a jumper from R2 to R4.

  4. 1A CURRENT HOLDOFF — This feature is obtained by not wiring in the 1A switch in the accelerator. 1A will not pick up until the vehicle can accelerate to a point where the demand pickup will close the 1A contactor.

  5. 1A PLUGGING HOLDOFF — This built-in feature is designed to prevent 1A closure anytime during plugging.

  6. 1A DROPOUT (1A DO) — This adjustable feature can be set to open the 1A contactor if the traction motor is subjected to excessive currents. The dropout is adjustable with the (1A DO) trimpot. The directional or Accelerator switch must be returned to NEUTRAL to unlock the dropout circuit. Using this feature will reduce the 1A contactor tip life, thus it should be used only where needed to protect the motor.

- PULSE MONITOR TRIP — This function contains three features: The look ahead, the look again, and the automatic look again reset.

If 1 REC is shorted or 1A is welded, PMT will look ahead and prevent F or R from closing if either condition exists.

If 1 REC fails to commutate, or if 1A power tips remain closed when they should be open, the control will open F or R contactor. PMT will then look again by testing for a fault and, if none, reclose F or R. If the fault still exists, the F or R will reopen and remain open.

If 1A closes before a second commutation failure, the look again counter will automatically reset. This eliminates the inconvenience of resetting the PMT with the key switch if the tripping is due to random noise.

When the PMT circuit prevents F or R from closing, the PMT circuit can be reset only by opening the Key switch.

- STATIC RETURN TO OFF – This built-in feature of the control requires the operator to return the directional lever to NEUTRAL anytime he leaves the vehicle and returns. If the Seat switch or Key switch is opened, the control will shut off and cannot be restarted until the Directional switch is returned to NEUTRAL. A time delay (0.5 seconds) is built into the Seat switch input to allow momentary opening of the Seat switch. This same delay requires the Directional switch not be closed until both the Key switch and the Seat switch have been closed for 0.5 seconds.

- TIP BOUNCE TIMER – After F or R are closed or 1A opens, the oscillator card checks that the capacitor has been charged by 2 REC, the battery volts appear across 1 REC, and an interval of time has elapsed before 1 REC and 5 REC can be gated.

- COIL DRIVE MODULES – These modules are typically located on the contactor portion of the control. They are the power devices that operate F, R, 1A and FW contactor coils. These modules pick up or drop out these coils on command from the control card. All modules are equipped with reverse battery protection so that if the battery is connected incorrectly, none of the contactors controlled can be closed electrically.

- THERMAL PROTECTOR (TP) – This temperature-sensitive device is mounted in the 1 REC heat sink. If the 1 REC temperature exceeds design limits, the thermal protector will lower the maximum current limit and not allow 1 REC to exceed its temperature limits. Even at a reduced current limit, the vehicle will normally be able to reach sufficient speed for full 1A operation, thereby allowing the panel to cool. As the panel cools, the thermal protector will automatically return the control to full power.

- FIELD WEAKENING (optional) – If the vehicle is supplied with a field weakening circuit, the FW PU and FW DO trimpot adjustments will be on the SCR control card. Field weakening is a method of attaining higher running speed for the vehicle in level operation. The normal settings for this feature are: pickup of FW contactor from 125 to 150 percent of normal full-load running current (1A), and dropout of FW contactor from 275 to 300 percent current. The dropout puts the motor back to the 1A range to climb ramps and inclines.

- FW WITH 1A CURRENT HOLDOFF – The 1A switch in the accelerator has to close to allow the FW circuit to operate. To allow the two functions to operate, the 1A switch has to be rewired per Fig. 8.

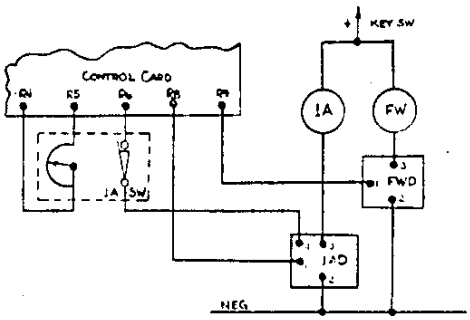


Fig. 8. FW with current 1A holdoff

- LOW VOLTAGE – Batteries under load, particularly if undersized or more than 80 percent discharged, will produce low voltages at the SCR control terminals. The EV-1* control is designed for use down to 50 percent of the nominal battery volts. Low battery volts may cause the control to not operate correctly but the PMT should open the F or R contactor in the event of a commutation failure.

- ACCESSORIES – Other functions and equipment available with SCR control for electric vehicles and their instruction references are:

IC3645	System Analyzer	GEK-40725
IC3645	Pump Time Delay	GEK-73400
IC4482	Contactors	GEH-4469
IC4484	Auxiliary Plugging Control	GEK-64881
IC4484	Battery Discharge Indicator	GEK-73401
IC4484	Dual Motor Control	GEK-64882
IC4485	Accelerator Switch	GEH-4470

- OSCILLATOR CARD CHANGES

Card IC3645	Volts	FW	Features (Described on page 8) 1	2	3	4	5	6	7
OSC1A3	24-48	Yes	X	X	X		X	X	
A4	48-84	Yes		X	X	X	X	X	
B3	24-48	No	X	X	X		X	X	
B4	48-84	No		X	X	X	X	X	
C3	24-48	Yes					X*	X	
D3	24-48	No					X*	X	
E3	24-48	Yes						X	
E4	48-84	Yes							
F4	48-84	No							
H3	24-48	No							X

*Only on cards up to Rev. B-2 (see card nameplate)

- OSCILLATOR CARD CHANGE FEATURES

1. Optional reduced current limit.
   Adding a connector from R1 to R2 will reduce motor current (by about 50 amperes when used with the EV-1B control.)

2. Low thermal cutback.
   Reduction in current limit is adequate only when the panel is mounted on a good heat sink. 1A thermal holdoff occurs at a low temperature. The low temperature thermal protector (group 1) must be used with this card.

3. No PMT look again reset.
   The PMT look again counter will not reset when 1A closes.

4. Motor current output signal location.
   IM Output is located at R2 instead of L6.

5. 1 REC synch circuit.
   1 REC synchronizing circuit shuts off 1 REC gate pulse causing failure to gate 1 REC with certain motors.

6. Non-optional 1A thermal holdoff.
   The provisions for disabling 1A thermal holdoff by adding a connector from R2 to R4 is not available.

7. Optional no 1A on demand and soft ramp start. Adding a connector from R9 to R4 softens the initial torque on ramp start on some applications, and also prevents 1A from picking up on demand.

GENERAL MAINTENANCE INSTRUCTIONS

The SCR control, like all electrical apparatus, does have some thermal losses. The semiconductor junctions have finite temperature limits above which these devices may be damaged. For these reasons, normal maintenance should guard against any action which will expose the components to excessive heat, such as steam cleaning; or which will reduce the heat dissipating ability of the control, such as restricting air flow.

The following DO'S and DON'TS should be observed:

- Any controls that will be used in ambients of 100 F (40 C) or over should be brought to the attention of the truck manufacturer.

- All external components having inductive coils must be filtered. Refer to vehicle manufacturer for specifications.

- The control should not be steam cleaned. In dusty areas, use low-pressure air to blow off the control. In oily or greasy areas, a mild solution of detergent or denatured alcohol can be used to wash off the control and then blow completely dry with low-pressure air. The control can also be cleaned with Freon TF† degreaser.

- For the SCR panel to be most effective, it must be mounted against the frame of the truck. The truck frame, acting as an additional heat sink, will give improved truck performance by keeping the SCR control package cooler. The use of a heat-transfer grease (Dow Corning 340) is recommended.

- Terminal boards and other exposed SCR control parts should be kept free of dirt and paint that might change the effective resistance between points.

  CAUTION: The truck should not be plugged when the truck is jacked up and the drive wheels are in a free wheeling position. The higher motor speeds can create excessive voltages that can be harmful to the control.

- Do not hipot (or megger) the control. Unless the terminals of each semiconductor and card are connected together, the control may be damaged. Refer to control manufacturer before hipotting.

- Use a lead-acid battery with the voltage and ampere hour rating specified for the vehicle. Follow normal battery maintenance procedures, recharging before 80 percent discharged and with periodic equalizing charges.

†Registered trademark of the E.I. duPont de Nemours & Company

TROUBLE-SHOOTING INSTRUCTIONS

The pulsing of the main SCR is too fast for conventional instruments to measure. When the control is functioning properly, a low hum can be heard.

Malfunctions of the SCR will generally fall into one of two categories. They are either no power (Table 1) or full power (Table 2), when operating in the SCR control range.

These simple and easy-to-follow tables outline the various symptoms and the corrective action to be taken.

The same device designations have been maintained on different controls but the wire numbers may vary. Refer to the elementary and wiring diagrams for your specific control. The wire numbers shown on the elementary diagram will have identical numbers on the corresponding wiring diagrams for a specific truck, but these numbers may be different from the numbers referenced in this publication.

WARNING: Before trouble-shooting, jack up wheels, disconnect the battery and discharge capacitor 1C. Reconnect the battery as needed for the specific check.

If capacitor 1C terminals are not accessible, discharge capacitor by connecting from SCR POS terminal to 2 REC anode. Check resistance on RX1000 scale from frame to SCR power and control terminals. A resistance of less than 20,000 ohms can cause misleading symptoms. Resistance less than 1000 ohms should be corrected first.

Before proceeding, visually check for loose wiring, maladjusted linkage to accelerator switch, signs of overheating of components, etc.

Tools and test equipment required are: (a) 6-volt lamp, 6-volt battery, two A14 diodes (1 Amp 400V), clip leads, volt-ohm meter (20,000 ohms per volt) and general hand tools, or (b) EV-1 System Analyzer, volt-ohm meter (20,000 ohms per volt) and general hand tools. If the system analyzer is used, refer to the analyzer instruction book.

Note: To test an EV-1 Model D, 1 REC, use a 12-volt battery and test lamp.

FUNCTION OF EV-1 CARD TERMINALS FOR IC3645OSC1E3 AND E4 CARDS

TERMINAL	DESCRIPTION (Voltage measurements with respect to negative, SCR power terminal.)	CONDITION	VOLTS NOMINAL	VOLTS THRESHOLD† E3	VOLTS THRESHOLD† E4
L1	Not presently used				
L2	Not presently used				
L3	Card power supply input must be low to satisfy PMT reset.	Key open Key closed	0 BV	4.1	4.1
L4	SRO Input. When used ignores open switch between L4 and L5.	Key or seat open Key and seat closed	0 BV		
L5	Accelerator Start and Brake switch input. Must be high after L3 and L7 are at battery volts for over 0.5 seconds and while L9 and L10 are low to complete SRO logic.	Key, seat, brake, or start open. Key, seat, brake, and start closed. Key, seat, and direction closed. Key and seat closed, start and direction open.	0 BV 0.07 BV (E3) 0.17 BV (E4) 0.9 BV (E3) 0.5 BV (E4)	4.1 4.1	18 18

†Threshold is the voltage ± approx. 5% below which the logic is the same as for zero volts.

TERMINAL	DESCRIPTION	CONDITION	VOLTS NOMINAL	VOLTS THRESHOLD † E3	VOLTS THRESHOLD † E4
L6	Motor current sensor output	No current	1.8		
		500 Amps average motor current model "B"	3.3		
L7	Seat switch input	Key open	0	8.2	19
		Key and seat closed.	BV		
L8	Not presently used				
L9	Direction switch input from positive side of "F" coil.	Key open	0		
		Key, seat, start, brake and direction "F" closed.	BV	8.2	19
L10	Direction switch input from positive side of "R" coil.	Key open	0		
		Key, seat, start, brake and direction "R" closed.	BV	8.2	19
R1	Card power supply	Key off	0		
		Key on	8.2		
R2	1A thermal holdoff control jumper to R4 to disable 1A thermal holdoff.	Key on, cold T/P	0		
		Key on, thermal cutback	0.66 or more		
R3	Output to PMT Driver	Key off	0 Volts		
		Key, seat, start, brake and direction selected. See Note 1.	5-10 milliamps		
R4	Common return to card for accelerator pot and 1A switch	Key off, use VOM and read from TBR4 to "Neg."	Less than 1 ohm		
R5	Accelerator pot input	Key on and accelerator at "creep".	3-4		
		Key on and accelerator at top speed.	0-.2		
R6	1A switch input	Key on, 1A switch open	8		
		Key on, 1A switch closed	0	2.0	2.0
R7	% ON time output. See Note 2.	Creep speed	2.2		
		Top speed	6.2		
R8	1A driver output	1A contactor open	0 Volts		
		Top SCR Speed. See Note 1.	5-10 milliamps		
R9	FW driver output	FW contactor open	0 Volts		
		1A closed high speed. See Note 1.	5-10 milliamps		
R10	Plugging output logic	Not plugging mode.	0 Volts		
		Plugging mode.	8 Volts		

NOTE 1: Connect milliammeter from terminal to R4. If contactor picks up during this test replace driver. If zero milliamps open lead and recheck to eliminate possible driver short from terminal 1 to 2.

NOTE 2: If B card is used, remove wire to R7 when checking voltage.

†Threshold is the voltage ± approx. 5% below which the logic is the same as for zero volts.

ALL TESTING SHOULD BE DONE WITH TRUCK JACKED UP.

TABLE 1
FAILURES WHICH CAUSE REDUCED OR NO MOTOR TORQUE WITH SCR CONTROL

Trouble-shooting is based on using the voltmeter to determine if the proper voltages are available to permit the control to operate properly. Refer to table pages 9 and 10 for theshold voltages. Check for leakage in switches if voltage is close to the threshold.

SYMPTOM	PROBABLE CAUSE
1A. Contactors do not pickup. No control voltage from positive to negative.	• Check power and control fuses. • Check battery for low specific gravity and connections for looseness or broken fittings.
1B. Contactors do not pickup. Control volts present from positive to negative with proper polarity.	• Plug in battery with Key switch OFF. Volts on L3 should be less than 4 volts. • Close Key switch. Check volts at T2 (pin 10). Should be about 50% of battery volts. Above 70% locks out 1 REC. (Control card contains a 10 K bridge from pin 5 to L3 and pin 6). If near battery volts, check for shorted 1A tips or a shorted 1 REC. If near zero volts, check for shorted 3 REC. (4G). • Close Brake, Start switches (all switches needed to close F or R contactor except the Direction switch). Volts on L3, L5, L7 should be battery volts. Volts on L9 and L10 should be near zero. Wait for one second, then close FORWARD Direction switch. Volts at L10 should remain near zero. Volts at L9 and L9 side of F coil should be battery volts. If not, check wiring and switches. • Connect milliammeter (10 ma scale) from R3 to R4. Should read 5-10 milliamps. If not, open Key switch, open lead from R3 to PMT driver, reclose all switches except Direction switch, wait over one second and close FORWARD Direction switch. If reading is not 5-10 milliamps, replace control card. If reading is good, the coil or wiring to the PMT driver is open or the PMT driver is defective. Check driver. (4E)
1C. Contactors close. NO power and NO SCR hum with accelerator in SCR range.	• Check volts at SCR positive. Should be battery volts. If not, check power fuse. • Check volts at T2. Should be zero. If not, check volts at S1, S2, A1, and A2 to locate open circuit.

SYMPTOM	PROBABLE CAUSE
1C. Contactors close. NO power and NO SCR hum with accelerator in SCR range. (Cont'd.)	• Check volts at R5. Should be 3-4 at creep reducing to 0.2 or less at top speed. If R5 remains about 4 volts, check accelerator. If R5 is zero, check volts at R1. Should be 8-8.5 volts. If R1 is above 10 or near zero and L3 is battery volts, replace control card and check PMT driver for short. (4E) • Check volts at R7. Should be 2-2.5 when Key switch closed. When F or R contactor is closed and accelerator depressed, should increase to about 6.2 volts. If remains near 2 volts, check volts at 1C (grey wire or 2 REC anode). If more than 0.125 BV, check if 2 REC will gate on. (4G) If less than 0.125 BV, check if 1 REC will gate on. (4G) Check current sensor green lead to card input pin 13. • Check 23 FIL for shorted resistor. • Replace control card. (4A)
1D. Contactors close. Little or no power. Normal SCR hum.	• Check 3 REC for open circuit. (4H) • Check 4 REC for short. (4H) • Check for open thermal protector. (4J)
1E. Contactors close. Little or no power. Abnormal SCR hum.	• Check 2 REC for short. (4G) • Check 5 REC for short. (4G) • Check 22 REC and 25 REC. (4M) Note: A 25 REC which checks good with an ohmmeter can cause a misoperation of 5 REC under load, and can cause 1A to close on demand at lower than normal motor volts.
1F. Contactors close. Little power. No SCR hum.	• Check 1C for low resistance (4B).
1G. One contactor closes with normal operation but opposite contactor will not close.	• Close Key, Brake, Start switches (all switches needed to close F or R contactor except the direction switch.) Volts on L9 and L10 should be near zero. Wait for one second, then close Direction switch in the direction that contactor will not close. Volts at other direction input (L9 or L10) should remain near zero. Volts at non-closing direction (L9 or L10) and top of coil should be battery volts. If not, check wiring and switches. • Close switches as above. Check volts at negative side of coil or corresponding terminal of PMT driver. Zero volts indicates open coil, battery volts indicates open driver. (4E) • Replace control card. (4A)
1H. PMT trips after operating in 1A and acceleration is returned to SCR range.	• Check for cause of long 1A dropout time, i.e., defective 1A driver, low resistance in 1A filter, shorted turns in 1A coil, or low voltage coil.

TABLE 2

FAILURES WHICH CAUSE FULL MOTOR TORQUE WITH SCR CONTROL

SYMPTOM	PROBABLE CAUSE
2A. Contactors close. Full SCR speed immediately with audible hum. NO PMT trip.	• Key switch on. Check volts at R5. Should be 3-4 volts at creep position. If near zero, check Accelerator potentiometer. (4D) • Replace control card. (4A)
2B. Contactors close once or twice and then remain open. PMT trips.	• Check 5 REC for open circuit or open gate. (4G) • Check 1C for open and connections. (4B) • Check 1C for dead short. (4B) • Check 5 REC for short. • Check 2 REC for short. • Check 1X choke and transformer T3-T4. (4N) • Replace control card. (4A)
2C. Contactors close. Stall currents, under SCR operation, higher than normal and uncontrollable with C/L trimpot. Contactors may open once or twice and then remain open.	• Check current sensor yellow lead from negative end of sensor to card input pin 14. • Replace control card. (4A)

TABLE 3
MISOPERATION OF OTHER FEATURES

SYMPTOM	PROBABLE CAUSE
3A. 1A or FW contactors close with Key switch.	• Check drivers for short from terminals 2 to 3 by disconnecting wires to terminal 1 on the driver. (4E) • Check resistance from R4 to SCR negative. If not zero, the control card has been damaged, probably by a high-current input to R4 burning open a run on the card. Check for possible shorts and improper leads being connected to this terminal. Normally only the accelerator pot, 1A switch from R6, and B card use R4 as a negative. • Replace control card. (4A)
3B. F or R will close without returning Direction switch to OFF.	• Check location of L5. Any open switch between L5 and Direction switch will satisfy SRO. • Open lead from R3 to driver. Close switches normally used to close F or R. If F or R close, replace driver. • Reconnect lead from R3. Close Key switch only. Volts at L3 should be BV, volts at L5, L7, L9, L10 should be near zero. Close Seat, Brake and Direction switches. Volts at L7 should be BV. Volts at L5 should be about 0.07 BV (0.17 BV on E4 card). If near 4.1 volts, (18 on E4 card) check Start switch leakage. Close Start switch. If contactor picks up, replace control card. (4A)
3C. PMT does not open F or R contactor.	• Operate traction drive. Jumper R3 to R4. If contactor does not drop out, replace PMTD driver. • Operate traction motor in low speed SCR range. Be sure wheels are turning freely. Push 1A tips closed manually. F or R should open. If not, replace control card. (4A)
3D. 1A will not close at run (percent pickup).	• Connect a milliammeter from R8 to R4. Should read 5-10 milliamps when 1A should be closed. If near zero, see later steps for improper inputs or control card. Check volts at terminal 3 of 1A driver. Should be battery volts decreasing to about 2 volts when 1A should be closed. If near zero, check coil and wiring to terminal 3. If remains battery volts, check wiring from R8 to terminal 1 and terminal 2 to negative, then replace 1AD driver.

SYMPTOM	PROBABLE CAUSE
3D. 1A will not close at run (percent pickup). (Cont'd.)	• If milliamps from R8 to R4 are near zero when 1A should be closed, open lead from R8 to 1A driver and recheck. If now good, there is a wiring short to negative in the lead from R8 or defective driver. (4E) • Check volts at R7. Should be greater than 6 at top speed. If less than 5.7 volts, 1A will not close on demand. Check volts at R5, should reduce to less than 0.2 volts at top speed. If over 0.2 volts, check accelerator. If less than 0.2 volts, check that creep trimpot is not turned too far CCW. • Check continuity of violet wire from T2 to pin 10. • Replace control card. (4A)
3E. 1A will not close at SCR stall (time pickup). (Check truck diagram to see if 1A switch closes card circuit R4 to R6.)	• Check 1A switch circuit. Key switch on. Volts at R6 should drop to less than 2 volts when 1A switch is closed. • Check volts at orange lead to TP. If volts are above 1.6 (0.06 on OSC1A and OSC1B cards), control is in thermal cutback. Allow to cool, and recheck 1A function. • Turn 1A trimpot fully CCW and recheck. • Check continuity of violet wire from T2 to pin 10. • Replace control card. (4A)
3F. 1A will not open until start switch is opened.	• Check volts at R6. Should be near 8 volts when 1A switch is open. If not, check wiring and 1A switch.
3G. FW contactor will not close after 1A pickup.	• Check volts at R6. After 1A contactor closes, this point must be less than 2 volts. If not, check 1A switch and wiring. • Open lead to R9 and connect milliammeter from R9 to R4. When control signals FW to pick up, should read 5-10 milliamps. If remains at zero, turn FW PU trimpot fully CW and recheck. If remains zero, replace control card. (4A) If reads 5-10 ma, reset FW PU trimpot. (6)

SYMPTOM	PROBABLE CAUSE
3G. FW contactor will not close after 1A pickup. (Cont'd.)	• Reconnect lead to R9 and check volts at R9 when FW should pick up. If near 8 volts, check lead from R9 to terminal 1 of FW driver and R2 to negative for open, then replace driver. If about 2 volts, check volts at terminal 3 of FW driver. Should be battery volts dropping to 2 volts or less when FW should pick up. If volts are near zero, check wiring from positive to FW coil, FW coil, and wiring to terminal 3 of FW driver. If volts remain greater than four volts, replace driver.
3H. FW contactor will not drop out with increasing load.	• Check dropout setting on card. (6) • Replace control card. (4A)
3J. Stiff plug. Severe reversal.	• Check plug adjustment setting on card. (6) • Check 4 REC for open circuit. (4H) • Replace control card. (4A)
3K. Very soft reversal.	• Check plug adjustment setting on card. (6) • Replace control card. (4A)
3L. Blown power fuse. Very hot power cables.	• Check 3 REC for short. (4H) (Possible damage also to 1 REC and transformer module.)
3M. Hourmeter feeder faults:	
(1) Pump contactor closes when either F or R direction is selected.	• Diode shorted 3 to 4. (4H) Replace hourmeter block.
(2) One direction okay; opposite direction picks up *both* F and R.	• Diode shorted 1 to 4 *or* 2 to 4. (4H) Replace hourmeter block.
(3) Either direction selected picks up *both* F and R.	• Diode shorted 1 to 4 *and* 2 to 4. (4H) Replace hourmeter block.

TABLE 4
CHECKING COMPONENTS

4A. Main SCR Control Card

All trouble-shooting is written to check all outside devices and eliminate them as the source of symptoms. The conclusion being then that the card is faulty.

1. Instructions for Removal of Card
   a. Remove the four (4) screws shown in Fig. 9.
   b. Jack out the right- and left-hand terminal board, using a screwdriver in the slots, (leaving the wires intact) as shown in Fig. 10.
   c. Pry open the latches carefully with a screwdriver as shown in Fig. 11.
   d. Jack out the bottom plug with a screwdriver as shown in Fig. 12.

The card can be removed by hinging 10 degrees and pulling out, or, if panel components (not related to card hinge mountings) are to be replaced, disregard all instructions above except "C" and the card will hinge up to 90 degrees.

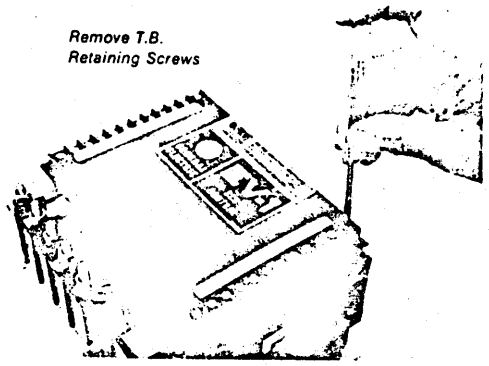


Fig. 9.

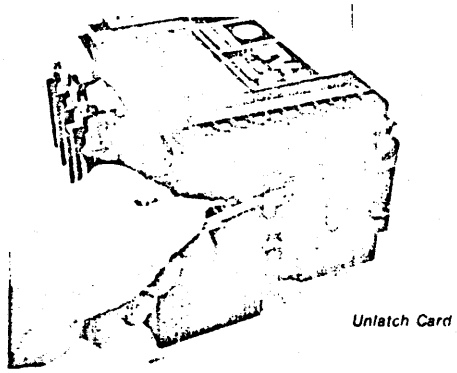


Fig. 11.

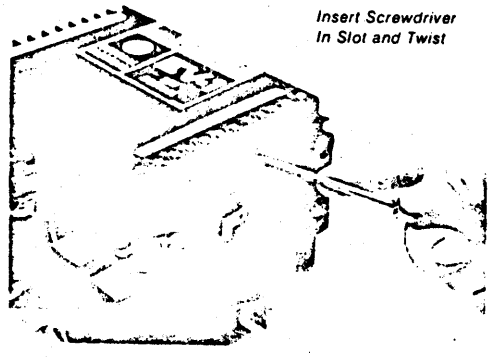


Fig. 10.

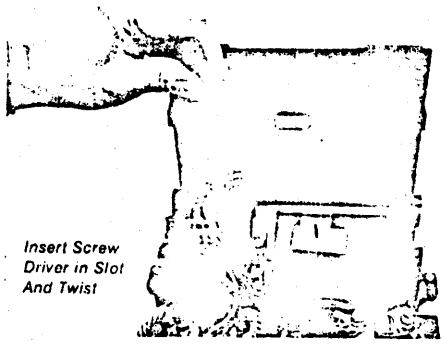


Fig. 12.

4B. Capacitor 1C

Disconnect battery and discharge capacitor. Measure ohms through the capacitor using the R x 10,000 scale. Meter should read zero and then swing slowly to above 100,000 ohms. Replace capacitor if above reading is not obtained.

4C. Contactors F, R, 1A, and P

75-ampere contactors (see GEH-3099)
150-ampere contactors (see GEH-4469)
300-ampere contactors (see GEH-4469)

NOTE 1. Control is arranged so that F and R do not break current. Check to see that 1A drops out ahead of F or R.
NOTE 2. Most contactor coils are polarity sensitive. The left-hand terminal must be connected to positive.

4D. Potentiometer in Accelerator

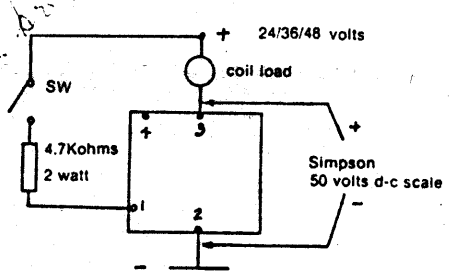
To check operation of the potentiometer, disconnect battery and disconnect wires at card terminal R4 and R5. Connect a VOM to wire removed with scale set to R x 100. With accelerator in creep speed position, the ohms reading should be 4800 to 6000 ohms. With accelerator in top speed position, reading should be 200 ohms or less. With wire disconnected as above, check for resistance of 1 megohm or higher from pot wires to truck frame.

4E. Driver Module

(IC3645CPM1RDA2 and IC3645CPMIRDB2)

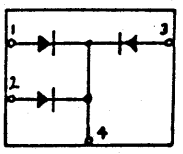
(a) Connect circuit as shown.
(b) Voltmeter should read battery volts with switch open.
(c) Close switch and meter reading should be 3 volts or less.
(d) Move load to terminal 4 and repeat steps (b) and (c).

NOTE: For 72 volt, use 8.2 Kohms 2-watt resistor.



4F. Hourmeter Module

Check individual diode circuits with trouble light or Simpson. (4H)



4G. SCRs (1 REC, 2 REC, 5 REC)

These are silicon control rectifiers. Before checking, disconnect battery and discharge capacitor 1C. Disconnect one power connection on the rectifier. Disconnect gate leads of SCRs at the card plug.

To check an SCR, it is necessary to have a 6-volt battery, a 6-volt lamp and 2 A-14 diodes.

NOTE: Models C and D require 12-volt battery and 12-volt lamp.

Connect the positive lead to the anode (1), connect negative lead to the cathode (3) as shown in Figure 13.

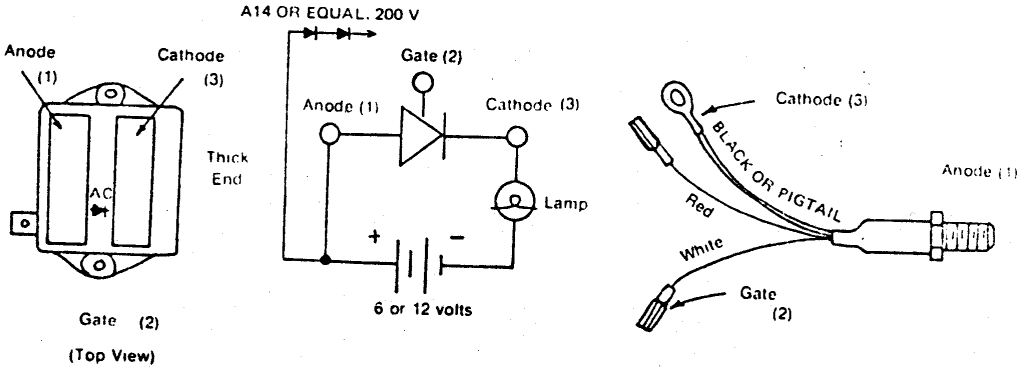


Fig. 13.

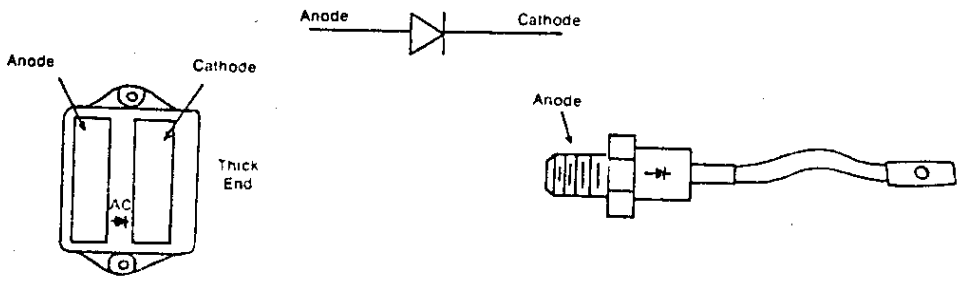
(a) The lamp should not light. If the lamp does light, the SCR is shorted and must be replaced.
(b) If check (a) was satisfactory, test the SCR for its ability to be turned on by the gate. Connect positive through two diodes to gate (point 2). If gate is operative, the lamp will come on and should remain on when the gate is removed. Some SCR's will operate correctly even if the lamp does not remain on, particularly with a weak battery.
(c) If lamp cannot be lit under step (b) the SCR is open and must be replaced.
(d) If the SCR is a stud-type device, check continuity between the red and black cathode leads.

NOTE: If you do not have a test light to check the SCRs as described above, they may be checked for shorts or opens by use of the VOM.
(1) Measure resistance from anode to cathode (R x 100 scale). If SCR is shorted (zero ohms), it must be replaced.
(2) Measure resistance from gate lead (white lead) to cathode and then from cathode to gate lead (R x 1 scale). If resistance reads either zero ohms (shorted) or infinity ohms (open), replace the SCR.
When reassembling SCRs, refer to TABLE 5.

4H. Rectifiers (3 REC, 4 REC, Diode Blocks)

When checking diodes, disconnect battery and discharge capacitor 1C to prevent burning out the ohmmeter. When replacing rectifiers, refer to TABLE 5. For 3 and 4 REC, disconnect one lead or

flexible connection. 3 and 4 REC are diodes with about 7 to 12 ohms in the conducting direction (+ ——▶|—— −) measured on the R x 1 scale, and 10,000 ohms or higher, in the non-conducting direction (− ——▶|—— +) measured on the R x 10,000 scale.



4J. Thermal Protector (TP)

Remove both connections from TP and with a VOM read less than 200 ohms terminal to terminal, if heat sink is at room temperature. Set VOM to highest ohm scale and check pins to heat sink, reading should be infinity.

4K. Filter Block (HF), 23 FIL, etc.

To check, disconnect all wires from filter block. With VOM on R x 10,000 scale, touch the lead to the filter terminals to charge the filter. After a few seconds, reverse the meter leads and touch the filter terminals. The VOM needle will deflect and return to infinity. If this capacitor action is not observed, replace the filter block.

4L. Filter Block — 23 RES, etc.

Should these filters fail, it will be evidenced visually by severe cracking.

4M. Filter Block — 22 REC, 25 REC.

The capacitor filter test, as in 4K, is valid for 22 REC and 25 REC only to detect an open or shorted filter. If control has symptoms as in 1E, interchange 22 REC and 25 REC and try again. If problem is corrected the old 25 REC is marginal. If problem is not corrected, replace both filters with known good filters.

4N. IX Choke — Transformer Secondary T3-T4

Refer to panel wiring diagrams, page 24 thru 27, to locate windings. With VOM on RX-1 scale, check choke winding or transformer secondary, reading should be zero ohms.

TABLE 5
REPLACEMENT OF EV-1 COMPONENTS

When replacing stud semiconductors such as 2, 3, 4, or 5 REC, it is not necessary to torque these devices to a specific value. However, the device should be screwed into the heat sink and tightened to a snug fit. SCR gates, not screw connected, terminate inside card plug. Remove card connector for access to stab terminals.

The use of a heat-transfer grease (such as GE Versilube G-350-M or equivalent) is recommended.

5A. When replacing module semiconductors such as 1 REC (Models A and B), 1 REC and 3 REC (Model C), and 1 REC, 2 REC and 3 REC (Model D):

(1) Remove all module connections.
(2) Remove module by backing out the two screws at the device sides.
(3) If a 1 REC, remove the thermal protector.
(4) Clean the insulator surface with a clean rag and isopropyl alcohol.
(5) Inspect insulator surface for tears or cracks. If defective, replace. Wipe a light layer of machine oil on base and smooth insulator into position.
(6) Coat insulator with a light coat of heat-transfer grease similar to GE-350.
(7) Install thermal protector in new module. Tighten until snug.
(8) Set new module on insulation and start screws back into the base. Be sure to use original screws and washers. Run screws in to "finger tight."
Check to see the bottom of the heat sink is flat against the insulator.
Alternately tighten the two screws by 1/4 turn until firm.
(9) Replace all connections removed in Step 1.

5B. Capacitor (EV-1A and B)

(1) Remove card completely.
(2) Remove card box right support.
(3) Remove nuts from capacitor connections and slide capacitor to the right.
(4) Reverse procedure to install new capacitor.

5C. 22 REC and 25 REC, 23 FIL (Models C and D)

When replacing these devices, use original hardware in the same holes, as the inserts are used for electrical connections to the transformer.

5D. Transformer/Choke

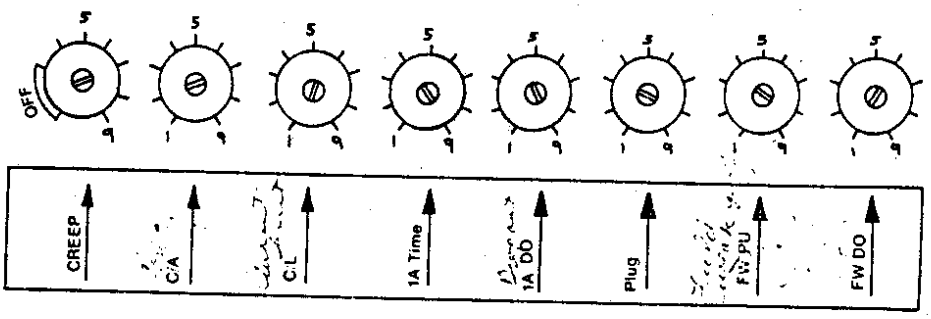
(1) Remove card box and card supports.
(2) Remove capacitor (Models A and B).
(3) Disconnect all transformer leads.
(4) Remove 2 REC, 5 REC, and snubbers as needed.
(5) Remove 4 mounting bolts and lift transformer free.
(6) Reverse procedure to reassemble.

TABLE 6
TUNEUP FOR NEW OR MISTUNED CARD 1

Panels are factory adjusted for a particular motor and truck and should not need adjustment. The card is supplied with single turn potentiometer with internal stops and the box is marked with "dial" setting.

The truck manufacturer should supply the "combination" setting for the particular model truck. The following is for explanation only and should not be used for setting your control:

Creep 7, C/A 7, C/L 5-1/2, 1A Time 4, 1A DO 9, Plug 8, FW PU 3-1/2, FW DO 6

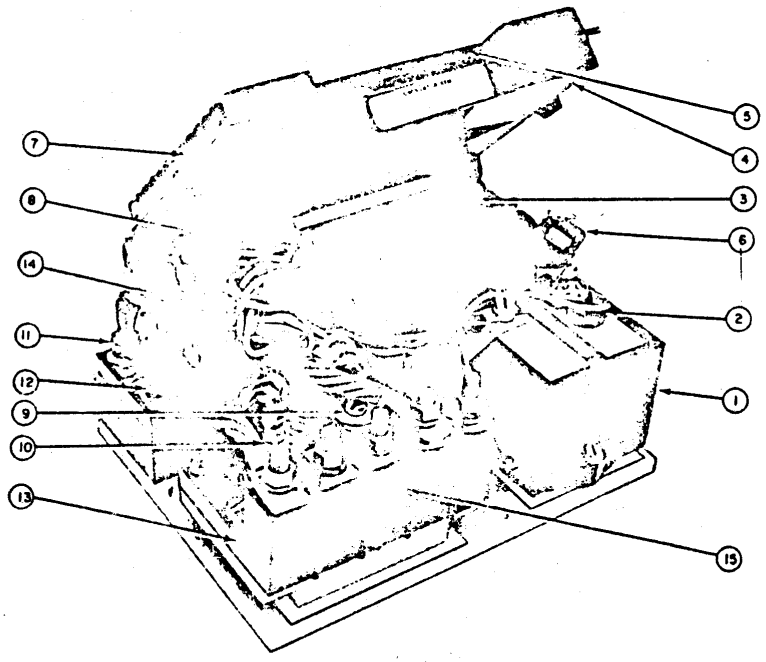


With a new card, turn all pots fully CCW to "1". Then set each pot to the setting for the particular truck.

Turning pots CW increases the particular function (i.e., CW adjustment increases creep speed, acceleration rate [C/A Pot], C/L, 1A Time, 1A DO, stiffness of plug, FW PU, FW DO).

TYPICAL PHYSICAL ARRANGEMENT AND IDENTIFICATION OF COMPONENTS

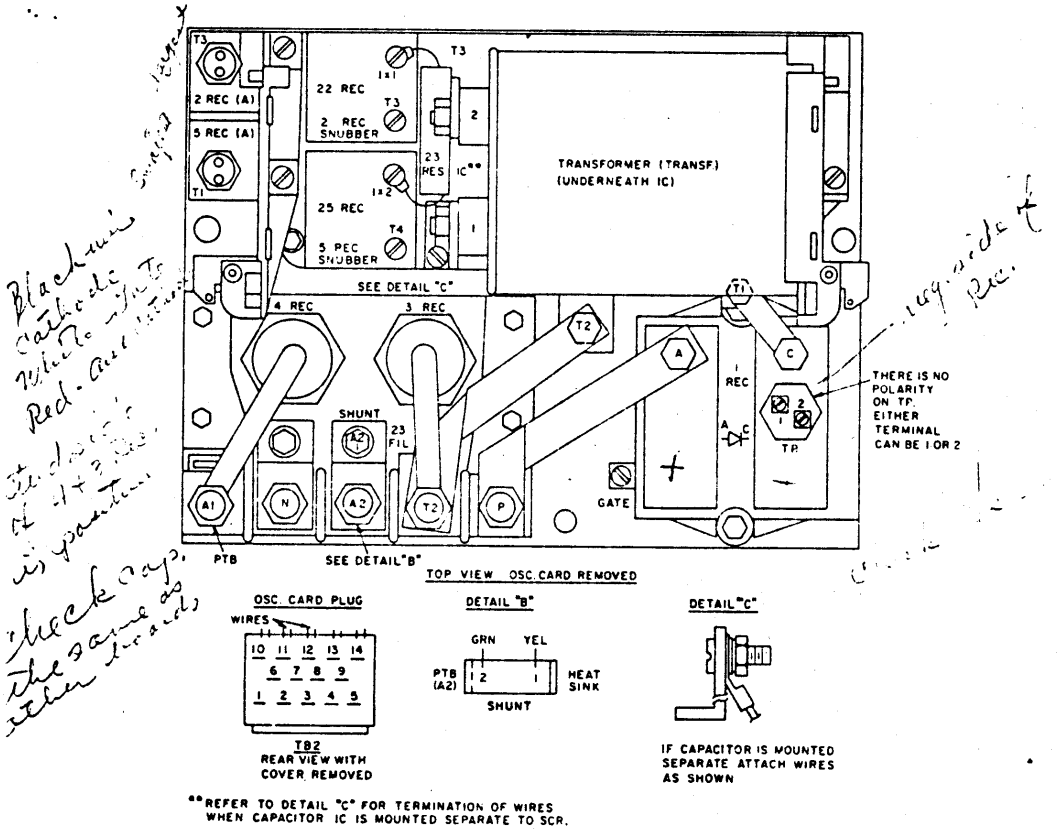
(Refer to wiring diagram furnished with truck for precise arrangement of components.)



(1) Main SCR (1 REC)
(2) Thermal Protector
(3) Commutating Capacitor
(4) Oscillator Card
(5) Card Adjustments
(6) Quick Card Release
(7) Card Connection Block
(8) Card Connector
(9) Flyback Diode (3 REC)
(10) Plugging Diode (4 REC)
(11) Turn-off SCR (2 REC)
(12) Charging SCR (5 REC)
(13) Power Connections
(14) Filters for 2 and 5 REC
(15) Motor Current Sensor
(Located behind middle power connector)

Transformer and choke (1X) located in encapsulated block under capacitor. 3 REC filter (23 FIL) located under pigtail of the diode.

Fig. 14. Typical EV-1 SCR panel (Model A or B)



WIRE TABLE					
WIRE NO OR SIZE	WIRE COLOR	FROM DEVICE	FROM TERM	TO DEVICE	TO TERM
BUS		TRANSF	T1	1 REC	C
BUS		PTB	P	1 REC	A
BUS		PTB	T2	1	T2
#10		1 REC	A	IC**	1
2 REC LEAD	BLK	2 REC	C	22 REC	1X1
5 REC LEAD	BLK	5 REC	C	25 REC	T4
SHUNT LEAD	YEL	SHUNT	2	TB2	14
SHUNT LEAD	GRN	SHUNT	1	TB2	13
TWIST #22	BLU	PTB	A2	TB2	6
TWIST #22	BRN	TP	1	TB2	11
TWIST #22	ORN	TP	2	TB2	12
TWIST #2 REC LEAD	RED	2 REC	C	TB2	9
TWIST #2 REC LEAD	WHT	2 REC	GATE	TB2	8
#22	GRY	IC**	2	TB2	7
#22	VIO	1	T2	TB2	10
TWIST #22	BLK	1 REC	C	TB2	5
TWIST #22	WHT-BLK	1 REC	GATE	TB2	4
5 REC LEAD	RED	5 REC	C	TB2	3
TWIST 5 REC LEAD	WHT	5 REC	G	TB2	2
#22	WHT-RED	IC**	1	TB2	1

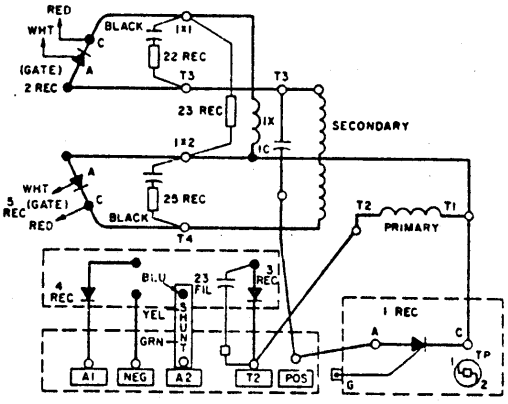
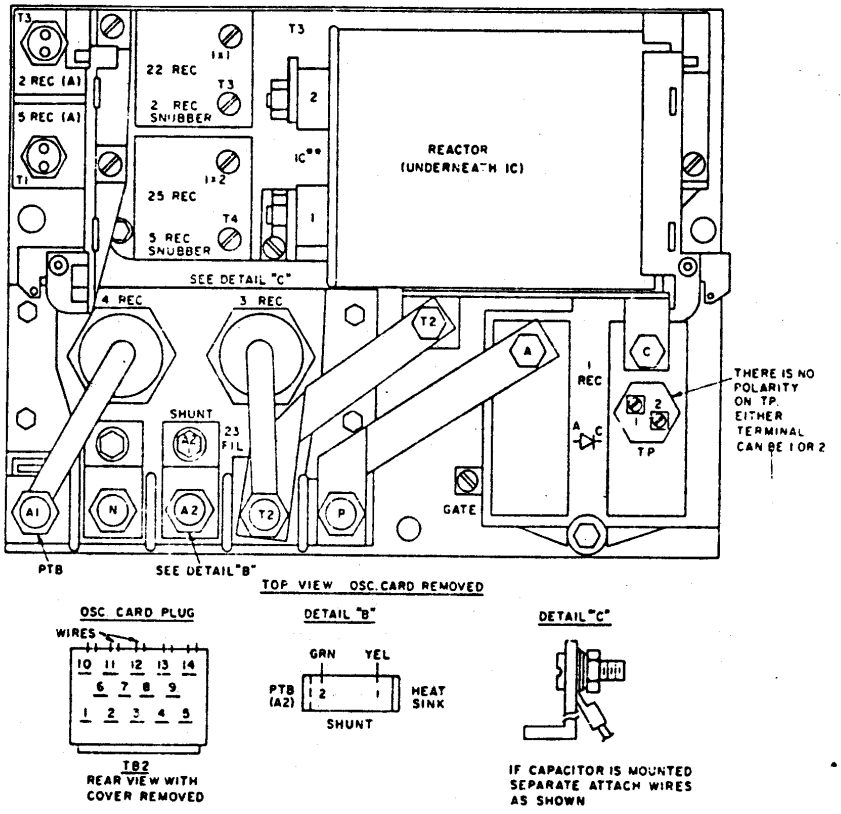


Fig. 15. Model A and B wiring diagram (transformer)



WIRE TABLE

	WIRE NO OR SIZE	WIRE COLOR	FROM DEVICE	FROM TERM	TO DEVICE	TO TERM
	BUS		REACTOR	T1	1 REC	C
	BUS		PTB	P	1 REC	A
	BUS		PTB	T2	1	T2
	#10		1 REC	A	IC**	1
	2 REC LEAD	BLK	1 REC	A	22 REC	1X1
	5 REC LEAD	BLK	2 REC	C	22 REC	T4
	SHUNT LEAD	BLK	5 REC	C	25 REC	T4
	SHUNT LEAD	YEL	SHUNT	2	TB2	14
TWIST	SHUNT LEAD	GRN	SHUNT	1	TB2	13
	#22	BLU	PTB	A2	TB2	8
	#22	BRN	TP	1	TB2	11
TWIST	#22	ORN	TP	2	TB2	12
	2 REC LEAD	RED	2 REC	C	TB2	9
TWIST	2 REC LEAD	WHT	2 REC	GATE	TB2	6
	#22	GRY	IC**	2	TB2	7
	#22	VIO	1	T2	TB2	10
	#22	BLK	1 REC	C	TB2	5
TWIST	#22	WHT/BLK	1 REC	GATE	TB2	4
	5 REC LEAD	RED	5 REC	C	TB2	3
TWIST	5 REC LEAD	WHT	5 REC	G	TB2	2
	#22	WHT/RED	IC**	1	TB2	1

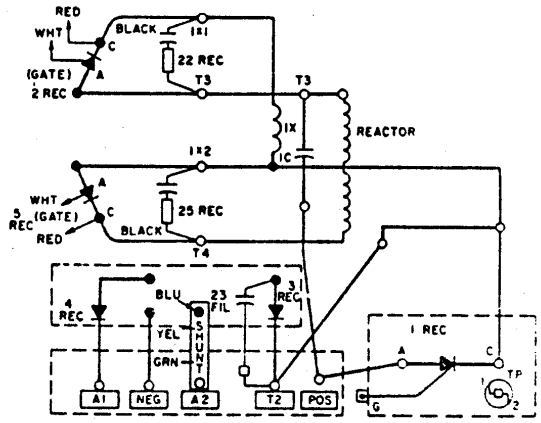
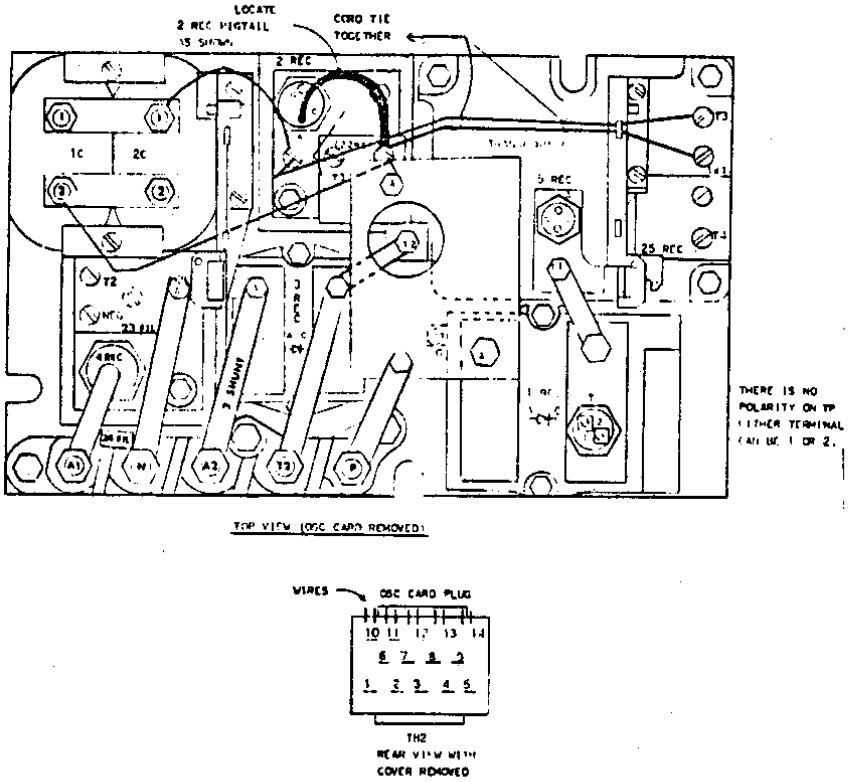


Fig. 16. Model A and B wiring diagram (reactor) not used on Yale Trucks



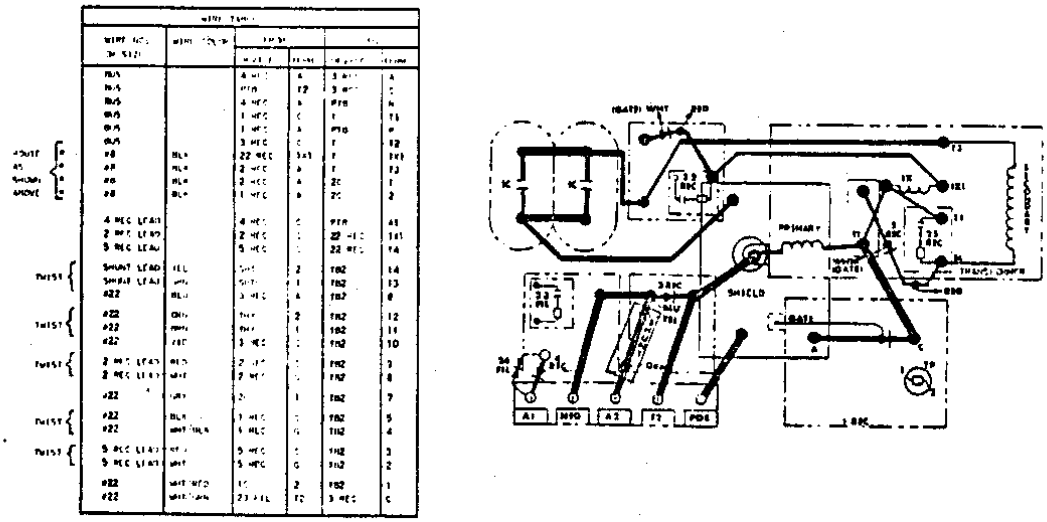
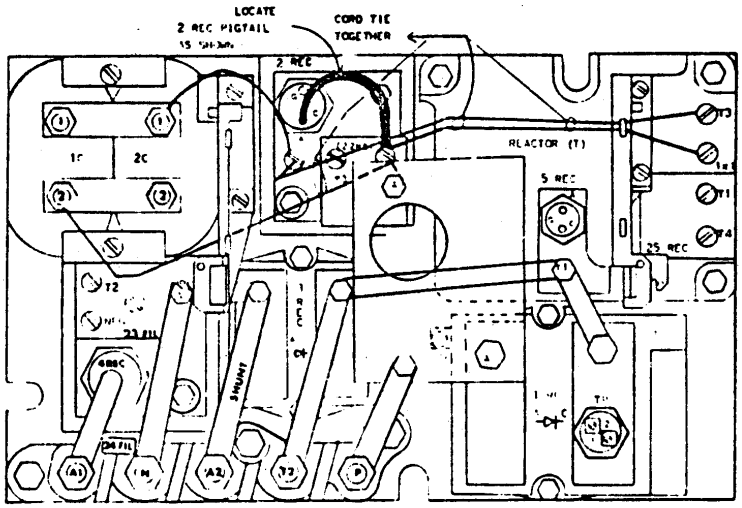
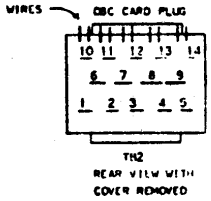
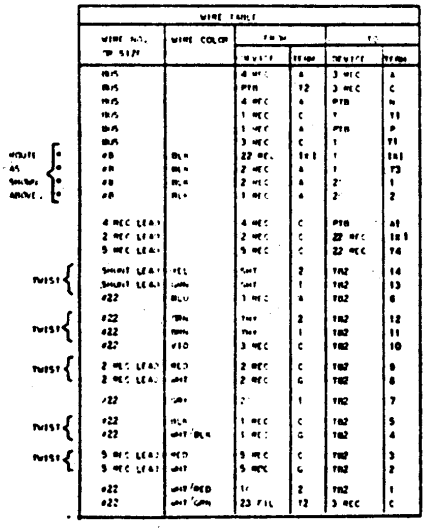


Fig. 17. Model C wiring diagram (transformer)



TOP VIEW (OBC CARD REMOVED)





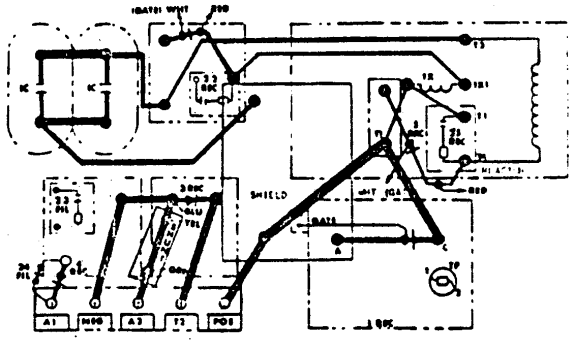
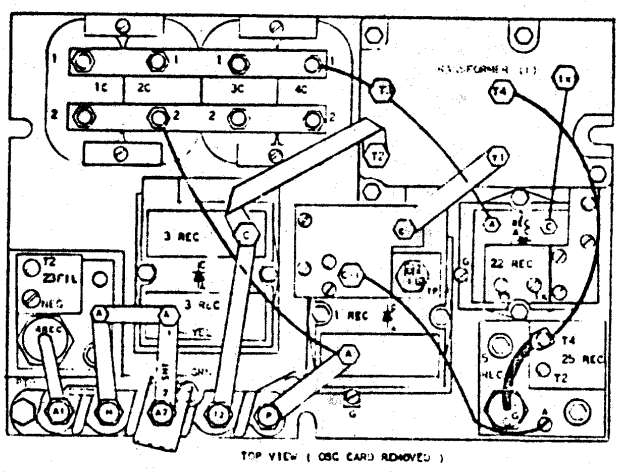
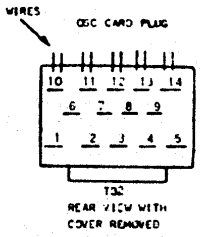
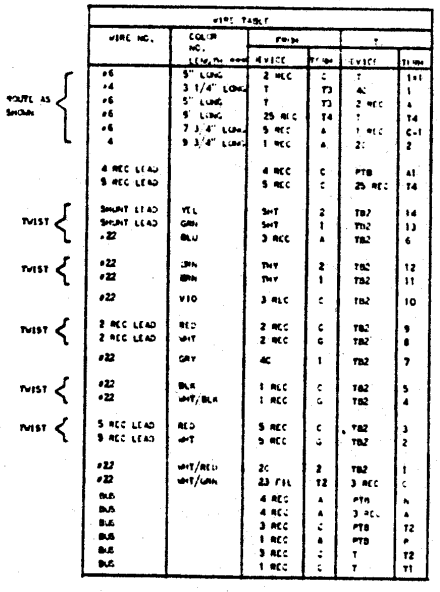


Fig. 18. Model C wiring diagram (reactor) returned on Jab sheets







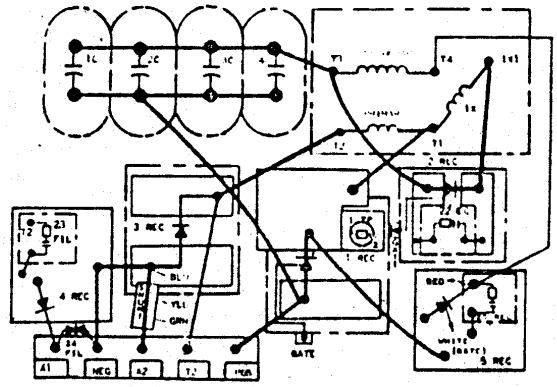
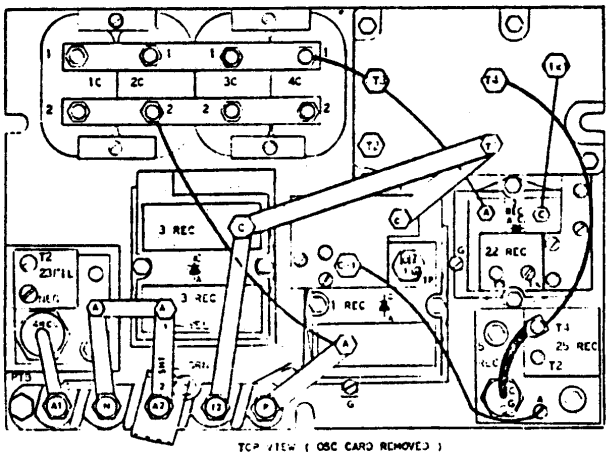
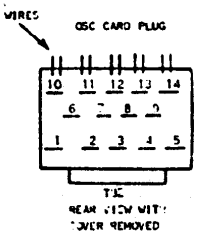


Fig. 19. Model D wiring diagram (transformer)



TOP VIEW (OSC CARD REMOVED)

NOTE:
THERE IS NO POLARITY ON THERMAL PROTECTOR (TP). EITHER TERMINAL CAN BE 1 OR 2.



REAR VIEW WITH COVER REMOVED

WIRE TABLE					
WIRE NO.	COLOR NO. LENGTH	FROM DEVICE	FROM TERM	TO DEVICE	TO TERM
#6	5" LUG	2 REC	C	T	T1
#6	3 1/4" LONG	T	T3	4C	1
#6	9" LONG	T	T3	2 REC	A
#6	9" LONG	25 REC	T4	T	T4
#6	7 3/4" LONG	5 REC	A	1 REC	C-1
#6	9 3/4" LONG	1 REC	A	2C	2
	4 REC LEAD	4 REC	C	PTB	A1
	5 REC LEAD	5 REC	C	25 REC	T4
TWIST	SHUNT LEAD YEL	SHT	2	T02	14
TWIST	SHUNT LEAD GRN	SHT	1	T52	13
	#22 BLU	3 REC	A	T02	6
TWIST	#22 GRN	TMT	2	T02	12
TWIST	#22 BRN	TMT	1	T52	11
	#22 VIO	3 REC	C	T02	10
TWIST	2 REC LEAD RED	2 REC	[illegible]	T02	9
TWIST	2 REC LEAD WHT	2 REC	G	T52	8
	#22 GRY	4C	1	T52	7
TWIST	#22 BLK	1 REC	C	T52	5
TWIST	#22 WHT/BLK	1 REC	G	T02	4
TWIST	5 REC LEAD RED	5 REC	[illegible]	T02	3
TWIST	5 REC LEAD WHT	5 REC	G	T52	2
	#22 WHT/RED	2C	2	T08	1
	#22 WHT/GRN	23 FIL	T2	3 REC	C
	BUS	4 REC	A	PTB	N
	BUS	4 REC	A	3 REC	A
	BUS	3 REC	C	T	T1
	BUS	1 REC	A	PTB	P
	BUS	3 REC	C	PTB	T2
	BUS	1 REC	C	T	T1

ROUTE AS SHOWN

TWIST

TWIST

TWIST

TWIST

TWIST

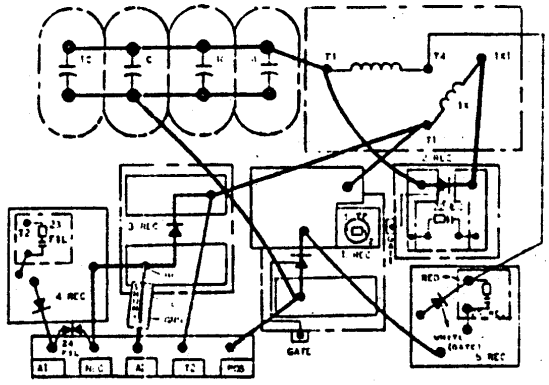
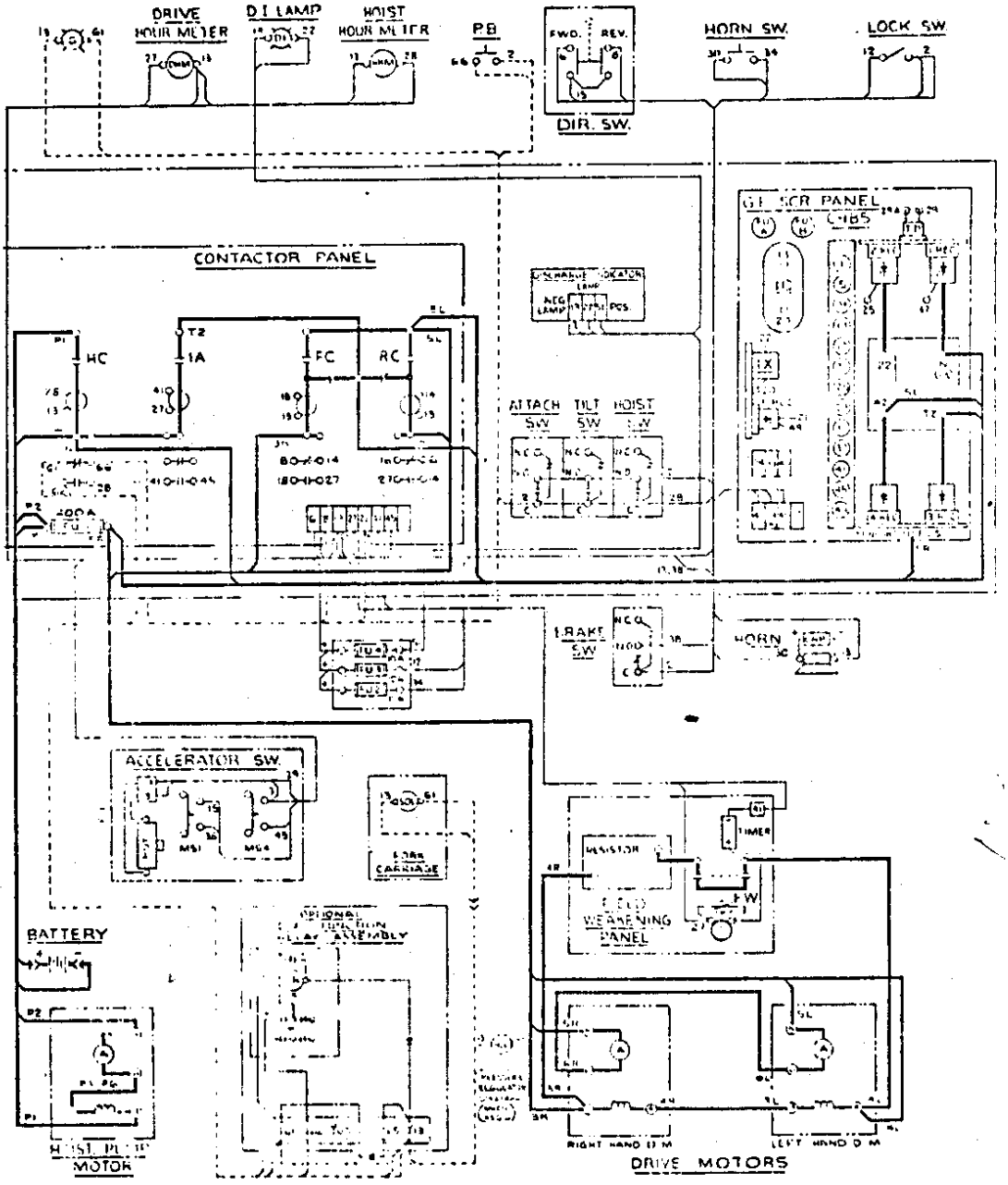
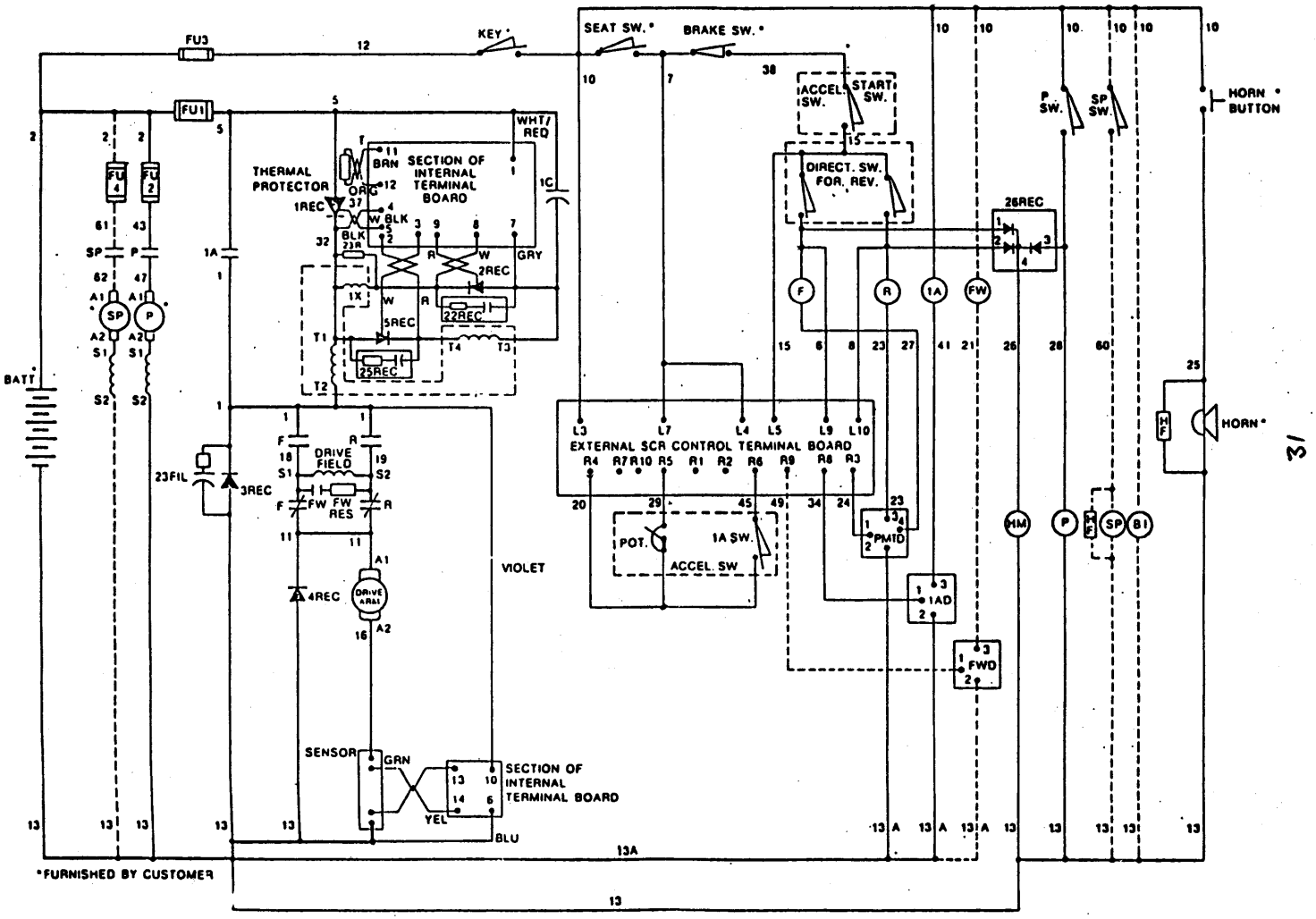


Fig. 20. Model D wiring diagram (reactor) not used on your truck

Yale

Industrial Trucks





Elementary diagram, General Electric EV-11 control for typical sit-down truck.
Refer to the manufacturer's instruction book for diagram for your specific truck.

NOTE: A) BROKEN LINES DENOTE ACCESSORIES.
B) * DENOTES CUSTOMER'S ITEMS.

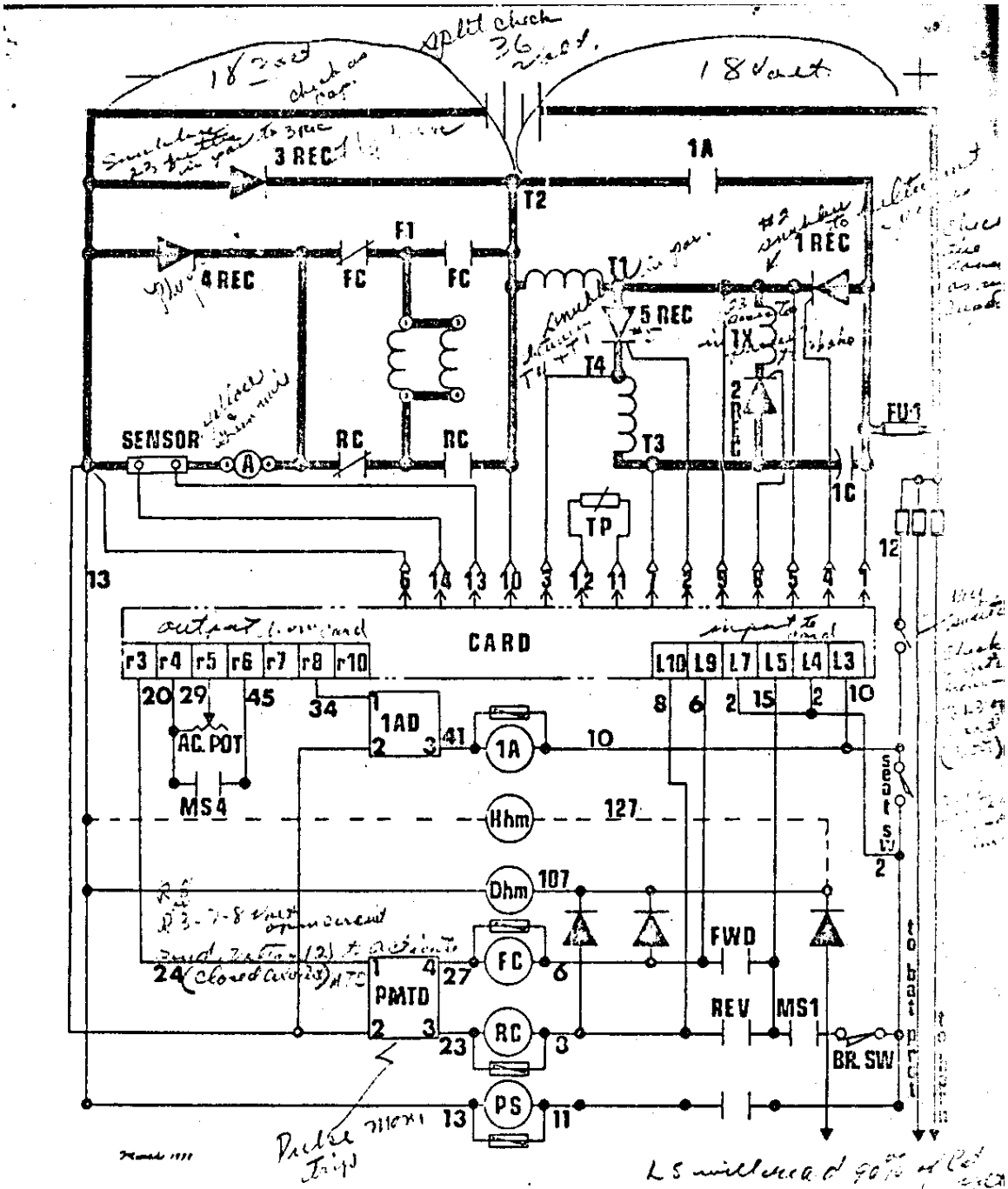
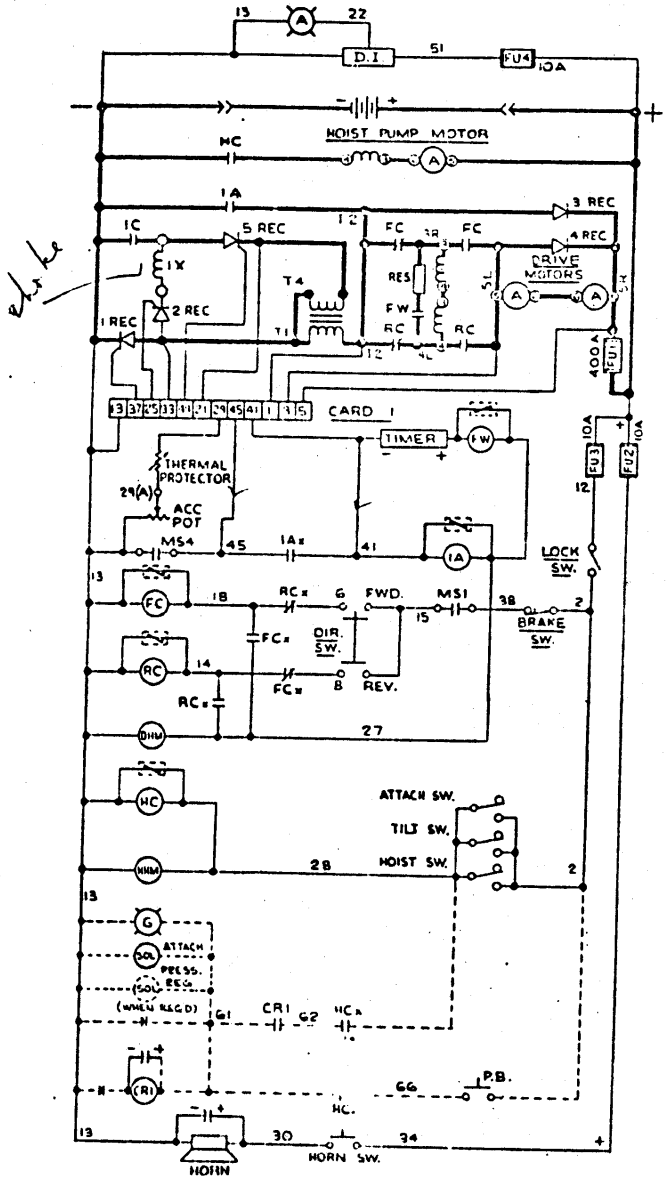
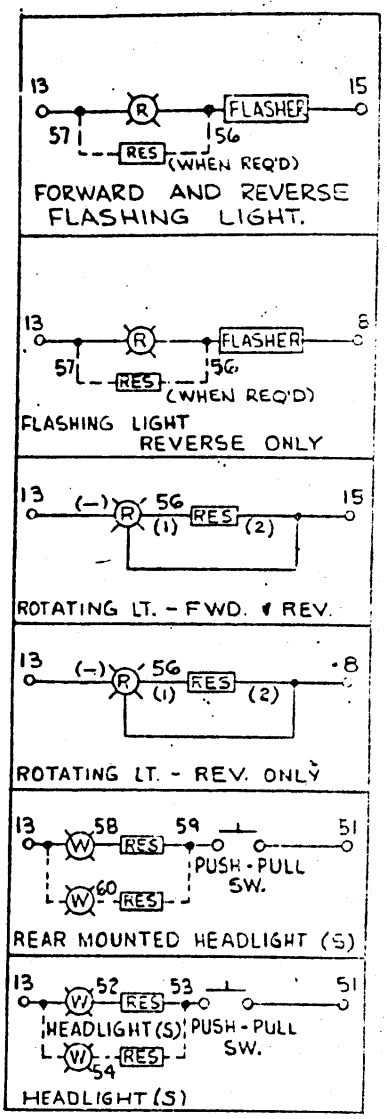


FIGURE 6b EV-1 WIRING DIAGRAM





Accessory Wiring