INSTRUCTIONS

GEK-38312 (2-2)

HEAVY MAINTENANCE INSTRUCTIONS
PROPULSION AND CONTROL EQUIPMENT
PRINCIPLES OF OPERATION

CONTENTS

GENERAL ELECTRIC

CONTENTS (Cont'd.)

INTRODUCTION

SCOPE

The propulsion and dynamic brake control systems for the SEPTA car contract are presented in detail in this section. A description of the equipment and operational theory is provided primarily to aid the reader in his understanding of the system operation. Understanding the system operation and familiarity with the schematic diagram and the equipment itself aids in fault finding.

This instruction covers the SEPTA (Reading and PCRR) "Singles" as well as the SEPTA (PCRR) "Married Pairs". The NJDOT "Married Pairs" are covered in another instruction.

Since this instruction covers equipment on what are essentially, from an equipment standpoint, four distinct and separate cars, the following coding is utilized throughout the text for clarification and simplification:

Reading Single	(1)
PCRR Single	(2)
PCRR Married Pair ("A" Car)	(3)
PCRR Married Pair ("B" Car)	(4)

In addition, page numbers (Sh. 5) after the identification of a component in the text indicates the page of the system schematic diagram 12B106899 on which the component can be found.

GENERAL EQUIPMENT DESCRIPTION

The propulsion and control equipment on the SEPTA "Singles" and "Married Pairs" consists of two sets of apparatus; Propulsion apparatus and Dynamic Brake apparatus. Because of some overlapping usage of these two systems, they cannot be completely divided.

Generally, the propulsion system is made up of:

1. Pantograph
2. Main Transformer
3. Ignitron Tubes
4. Rectifier Panels
5. Main Smoothing Reactor
6. Traction Motors, Gear Units and Couplings
7. Master Controller
8. Cab Signal Equipment (PCRR only)
9. Motoring Contactors and Control Circuitry
10. Trainline Relays
11. Propulsion Electronics

Also generally, the dynamic braking system is made up of:

1. The Motorman's Brake Valve
2. Trainline Relays
3. KM Controller
4. Braking Contactors and Control Circuitry

The function of the control circuits is to ensure that the traction motor circuit is connected in the proper configuration, that is, power or dynamic brake, and control that system for proper acceleration/deceleration of the car. A performance and fault indication panel (P&FI) is provided in electrical locker No. 1 for monitoring the performance of both propulsion and dynamic braking systems.

Pantograph
(1, 2, 4) (Sh. 1,2)

The AC propulsion circuit on the Reading cars is supplied with 11,000 volts, 25/60 Hz power, or 25,000 volts, 60 Hz power from an overhead catenary system, 11,000 volt 25/60 Hz power on the PCRR cars. A Faiveley style pantograph, located on the "A" end of each single and each B car of a car pair, collects power for that car or pair. The pantograph installation includes a lightning arrestor, LA, a pneumatically operated grounding switch, GS, and a current transformer, CT1. In addition, the Reading singles have a vacuum interrupter.

The lightning arrestor breaks down electrically under high surge voltages, preventing damage to the main transformer in the event of a catenary lightning strike.

The pneumatic grounding switch is operated automatically by protective devices and shortcircuits the pantograph (and catenary wire) to the roof of the car in the event an overload condition exists. This action will cause a loss of power to the train by tripping the track circuit breaker, and preventing damage to the main transformer of the car.

The current transformer supplies a representative sample of total current being drawn from the catenary wire into the car to operate the following devices and circuits:

1. Pantograph Lowering Relay, PLR. This relay will trip when a sudden, severe overload occurs within the traction circuit. When tripped, the ground switch is operated until the track breaker trips. The pantograph on the faulty car or pair is then lowered to the roof.

2. Thermal Relay, THR. This relay will trip when a continuous overload is present that is not severe enough to trip PLR. When a car draws 300 amperes for from 7 to 15 seconds, THR will trip, operating the grounding switch. The pantograph is lowered to the roof.

3. Transformer, TXPL. The secondary of this transformer supplies a scale voltage representing car intake current to the Performance and Fault Indication Panel (P&FI). A meter on this panel indicates the amount of power drawn by that car. In addition, a scaled voltage signal is sent to the pedestal level card FD483. This signal is used to limit the maximum current draw from the catenary to 150 amps.

In addition, the taps on the current transformer on the Reading Singles are reconnected in response to the main transformer tap changer by the TCR relay, located in the Main Control Group under the car. This recalibrates the voltage signal to THR, PLR, and TXPL when changing from 11,000 volts ac to 25,000 volts ac.

The vacuum interrupter opens the pantograph circuit during this transformer changeover operation. It also opens the pantograph circuit during a faulty changeover sequence.

Made of tubular steel, the pantograph is spring raised and air lowered, responding to signals from the motorman or the propulsion control system's protective devices. When extended, it makes contact with the catenary wire to supply the main transformer with electrical power. When retracted, it is completely de-energized and locked in place.

WARNING: *Do not enter the pantograph area or otherwise climb on the roof of the car with the pantograph extended to the catenary wire. High voltage is present in the catenary wire and touching the pantograph could prove fatal. Observe all pertinant railroad safety rules.*

Main Transformer
(1, 2, 3, 4) (Sh. 3)

The power arriving at the pantograph is supplied to the main transformer primary winding, H1-H2. This transformer has four secondary windings, three to supply propulsion power and one to supply auxiliary power. Each transformer secondary winding is equipped with a fused, surge protection circuit consisting of a capacitator and two 3.31 ohm resistors. The auxiliary winding is tapped at the 528-600 volt point for car heater operation (covered elsewhere in this manual).

Main transformer cooling is provided by two fans blowing air through a heat exchanger. A transformer coolant pump circulates a coolant fluid through the core of the transformer, then to the heat exchanger, and back to the transformer again. This fluid (Pyranol*) is also effective as an insulator between primary and secondary windings.

A movable tap is incorporated on each transformer to reconnect the primary winding when changing from 11,000 volt to 25,000 volt catenary power. This tap functions automatically in response to a track signalling system. Its operation consists of connecting the primary in a series configuration for 11,000 volt operation, and a parallel configuration for 25,000 volt operation.

Ignitron Tubes
(1, 2, 3, 4) (Sh. 3A)

Located in the rectifier control group under the car, mercury filled ignitron tubes, in response to regulating signals from propulsion electronics in the control system, control the output current of the "A" winding during all propulsion modes. Cooling is accomplished by a flow of air from the double ended blower (Sh. 91).

Rectifier Panels
(1, 2, 3, 4) (Sh. 3A)

The rectifier panels are located in the rectifier control group, along with the ignitron tubes. PRP1, PRP2, and PRP3 operate to provide full wave rectification of the three propulsion windings, A, B, and C respectively. Pulsating dc output current is fed through the main smoothing reactor (Sh. 3A) to the traction motor circuitry (Sh. 4).

In addition, PRP4 (Sh. 71) operates to provide full wave rectification of the auxiliary (D) winding. All power demand for the car other than propulsion is derived from this winding.

*Product of General Electric Co.

Each panel consists of an assembly of high current silicon rectifiers connected such that the ac signal impressed upon them causes output current to flow in one direction only (pulsating dc).

Each panel is cooled with a flow of air from the double ended blower (sh. 91).

Main Smoothing Reactor
(1, 2, 3, 4) (Sh. 4)

Located under the car, the main smoothing reactor receives the output of the propulsion (PRP1, PRP2, PRP3) rectifier panels, converts the pulsating dc to almost smooth straight-line dc for traction motor operation. Current flows from the rectifier panels through the main smoothing reactor to the traction motors, through the main smoothing reactors again back to the rectifier panels.

Auxiliary Smoothing Reactor
(1, 2, 3, 4) (Sh. 90)

This component, located under the car, receives the output current from the auxiliary winding rectifier panel PRP4 and converts this pulsating dc to almost smooth straight-line dc to run the air compressor (Sh. 90), the double and single ended blowers (Sh. 91), and the M/A set (Sh. 91). Return current from these components back to the PRP4 panel passes through the reactor again.

Traction Motor, Gear Units and Couplings
(1, 2, 3, 4) (Sh. 4)

These components provide the driving force to the wheels and axles. There are two of each component on each truck and thus four of each component on each car.

The traction motor is a dc machine, which receives a dc current from the main smoothing reactor. The traction motor armature turns, rotating gears in the gear unit. The torque of the motor is transmitted to the gear unit through a coupling.

As the gears rotate inside the gear unit, the axle, with the wheels pressed on the ends, also turns.

In the case of dynamic braking, propulsion current is removed from the traction motors and the traction motor circuit is reconnected in a closed loop so that the motors can become generators. Being driven by the inertia of the car turning the wheels and axles, torque on the gear unit gears is transmitted to the armature of the traction motor through the coupling. The motor armature continues to turn in the same direction, producing current and acting as a generator. The output loading circuit of these generators is regulated such that armature rotation is retarded by the generation of current. The higher the output current, the greater the retardation rate, etc.

Master Controller
(1, 2, 3, 4) (Sh. 170, 171)

The master controller is located in each motorman's cab. The motorman operates this controller to initiate, regulate and terminate the operation of the train.

Motoring and braking are accomplished with the operation of a master controller and a separate brake valve (Sh. 172). Operation of the brake valve is covered in Section 3 in this manual.

By selecting the various modes of operation on the master controller, certain trainline relays become energized throughout the train. These relays initiate the control logic necessary to cause the train to respond to the mode of operation selected. The selection of these relays by the associated trainlines is accomplished mechanically; that is, low voltage contacts are sequentially closed by the rotation of the master controller handle. The trainline circuits become sequentially energized with the operation of this handle.

The master controller supplies power commands to the traction control circuits. These power commands are supplied to the propulsion electronics to establish a motor current for the power call, and to the sequence relays to regulate the extent of the total control sequence, and thus the speed of the car. Braking commands are transmitted from the brake valve on the lead cab, to the air brake system and through a dynamic brake transducer to the dynamic brake control circuits.

Trainlines SW through P3 are energized respectively as the power call increases. The SW trainline is transmitted to the rest of the train through the interlocks of the PDR relay to ensure power is removed when (1) any door in the train is opened; (2) a brake application is made; (3) an overspeed condition occurs.

The power-presence-relay, PPR, will be picked up in all power positions. Interlocks of PPR will not allow the end-door-closed-relay, EDCR, to become energized with the MC in a power position when the doors close.

Cab Signal Equipment
(2, 4) (Sh. 156-159)

This equipment is comprised of track transmitters (wayside equipment), on-board car receivers, and the on-board electronics to decode the received intelligence.

The purpose of this equipment is to inform the motorman of maximum speed limits for various sections of track, and to bring the train to a stop if the motorman does not acknowledge those speed limitation signals. Signal aspects are displayed to the motorman via a series of indicating lights mounted on a panel in the cab. If a restrictive speed signal is received, the appropriate aspect is displayed on the indicating panel and a warning buzzer is sounded in the cab. In response to these warning devices, the motorman must depress the acknowledge button within six seconds. Failure to do this results in a penalty emergency brake application being made by the cab signal equipment.

If a less restricting speed signal is received, the appropriate aspect will be displayed on the indicating panel. There is, however, no warning buzzer and no response is required by the motorman.

KM Controller
(1, 2, 3, 4)

The KM54 cam controller is a motor driven (38 volts dc) cam shaft and switch assembly mounted in the cam control group, under the car. It is used to regulate the amount of dynamic braking current in the traction motors during a service brake application.

The cam controller motor (Sh. 16) is regulated (turned on and off) by the pilot motor drive electronics and the control logic relays. The direction of rotation of the motor is determined by the control logic relay PMR (Sh. 10).

The cam controller operates from a starting position (Position 17) then runs to Position 20 where it is held during propulsion modes of operation. When braking is desired by the motorman, he places the master controller to OFF and selects the service position with the brake valve and makes a service reduction. The controller then runs from Position 20 to 17 and then progressively notches to Position 1 under the control of the cam controller electronics. As the controller proceeds (notches) from Positions 17 to 1, resistance in the traction circuits (Sh. 4) is sequentially notched out by the opening and closing of the switches on the controller. By this method, the current in the traction circuit being generated by the traction motors is regulated to provide a smooth retarding force for the duration of the brake application.

After the stop is made or the brake application is terminated, the controller runs back to Position 17 where it remains until the next power or brake application is made.

NOTE: *Once a successful dynamic brake sequence has been completed, no subsequent dynamic brake function is possible without another successful motoring operation being performed.*

When an emergency brake application is made, the cam controller runs from Position 20 to Position 17 and holds. There is no dynamic braking effort developed and the stop is made with the pneumatic brakes alone.

Should a wheel slide occur during a service brake application, the KM controller, notching from Positions 17 to 1, reverses direction and notches back toward Position 17, re-inserting the resistance it had previously notched out. This reduces dynamic braking current in the traction circuit and reduces braking effort. In addition, the dump valves are activated to remove brake cylinder pressure.

When the slide is corrected or, if the slide lasts for more than 6 seconds, the dump valves are de-energized, re-applying pneumatic brakes.

Motoring Contactors
(1, 2, 3, 4)

There are seven major motoring contactors which establish basic traction motor circuitry during motoring. These contactors are energized through a combination of the relay, contactor and electronic logic of the control system.

Of the seven contactors used for establishing basic traction motor circuitry, four are used to connect the actual motor circuits (AM1, AM2, AM3, AM4) (Sh. 8A) and three are used to energize each of the three secondary main transformer windings used for propulsion (A1, A2, and A3) (Sh. 8A, 9).

The AM1, AM2, AM3, and AM4 contactors and the exhaust coils of A1, A2, and A3 contactors become energized immediately as soon as a forward or reverse position is selected and a brake application is not called for.

The A1, A2, and A3 contactors automatically pick up sequentially during motoring in response to motoring electronic regulation circuits. They also come up selectively, depending upon the selection of the various power positions by the motorman. That is, A1 comes up for Switch and P1, A2 comes up for P2 and A3 comes up for P3. The selection of the power positions must be slow enough, however, to allow car speed to develop before the propulsion system will respond. Otherwise, the electronics will regulate the energization of each contactor.

Braking Contactors (Sh. 9)

There are four braking contactors (P1, P2, B1 and B2) which, when they become energized, establish the dynamic braking traction motor circuitry. B1 and B2 contactors become energized through the relay and contactor logic of the control system. P1 and P2 become energized by the same logic but must be physically closed by the cam controller operation.

When the correct logic is established, P1 and P2 contactors come up at the same time. Then B1 and B2 come up together when the B relay is energized.

Trainline Relays
(Sh. 6)

There are eight trainline relays, one for each mode of operation. They are:

FWT	Forward
RVT	Reverse
SWTD	Switch, P1
S2TD	P2
S3T	P3
ER	Emergency
BRT	Dynamic Brake
APRT	Brake Apply

These trainline relays are energized as a result of the operation of the master controller and the brake controller in the motorman's cab. Additionally, as their name implies, they are trainlined. That is, these relays become energized in every car in the train. This is accomplished by the trainline circuits through the couplers.

Propulsion Electronics
(1, 2, 3, 4)

Precision control of the ignitron tube operation and motoring contactor logic is required in all modes of motoring. The propulsion electronics package is incorporated in the 17FL127 panel housed in electrical locker No. 1.

Briefly, this panel monitors propulsion system operation and car response, and regulates ignitron tube operation and contactor logic accordingly.

The panel is made up of 15 electronic plug-in type cards, with a specific function being performed by each card.

Wheelslip/Slide
(1, 2, 3, 4)

Another electronics package incorporates the circuitry required to provide wheelslip/slide protection. This is the 17FL133 panel. Incorporating six electronic plug-in cards, this panel monitors the speed of each axle on the car by sensing gear speed in the gear unit. These speed input signals are fed into the FL133 panel and compared to each other after compensating automatically for differences in wheel diameter due to wheel wear. If one or more input signals begin to differ beyond 5 mph, indicating a wheelslip or slide, the panel issues other signals to cause corrective action to be taken by the propulsion or braking system automatically.

Additionally, a synchronous slip or slide will be detected by monitoring the rate of change of input speed signals to the panel. If the rate of change exceeds 8 mph per second, the output of the panel results in the same corrective action being taken for a wheelslip or slide.

Performance & Fault Indication, P&FI
(1, 2, 3, 4)

Another electronics package consisting of both a card panel and a display unit is situated in the No. 1 electrical locker. This panel monitors many of the various aspects of the propulsion system and the auxiliary system, and provides a visual display of those aspects. The display is in the form of meters, and red, green and white lights.

Another feature of this panel is its latching ability. When a fault is monitored (a red light), an overload for example, the panel registers the fault and immediately latches. All of the lights on at that point will remain on, and no other lights will come on. (Wheelslip indications on both A and B truck do not latch the panel.) The panel remains latched until manually reset. However, it cannot be reset unless the fault is cleared.

PROPULSION MOTORING LOGIC

The GE1259A1 traction motors are series motors; that is, the armature and fields are connected in series. This type motor has long been used on suburban commuter vehicles, because it possesses the following general characteristics:

1. It can develop a high starting torque (or twist) which is needed for starting and moving the car or train.

2. Its direction of rotation can be reversed by reversing connections of the motor field. This is necessary because the car must operate equally well in either direction.

3. The motor can operate at high speeds to maintain maximum car speed.

ACCELERATING FUNCTION

The main transformer supplies the primary source of power, through the accumulative selection of secondary windings A, B, and C, to provide the driving power during accelerating and running modes. In all power positions on the master controller, the traction motors are connected across the output of the main smoothing reactor in series - parallel configuration.

Initially, when SW or P1 is selected, the A1 contactor picks up, energizing the ignitron tubes with power from the A winding. This current is fed to the PRP1 rectifier panel, main smoothing reactor MSX and on to the traction motors. Return current is through the MSX, PRP1 and back to the negative side of the A winding. The A winding is the only one controlled by ignitron tubes. The MSX takes the rectified power from the PRP1 and smoothes the output to a dc current with a 30% ripple.

In response to a P3 power selection at the master controller, the propulsion electronics (Sh. 25) causes the tubes to fire (turn on). Because 600 amps is required to effect a 2.2 mph/sec acceleration rate (P1, P2 and P3 only), the electronics, under the influence of current measuring devices in the traction motor circuit, causes the firing angle of the tubes to increase as train speed increases. This turns the tubes on gradually until they are fully on.

The tubes are connected back-to-back such that alternate firing takes place between them, each tube firing on its respective positive half cycle. This controlled ac power is supplied to the traction rectifier panel where it is rectified to pulsating dc. The main smoothing reactor MSX removes 70% of the pulse variation and supplies this dc power to the traction motors.

NOTE: *Ignitron firing angle is restricted to 90 degrees and the B and C windings of the main transformer are not used if the master controller is placed in the SW power position.*

When the tubes are fully on, output signals from transformers TXL and TXT (Sh. 3A) indicate to the notching electronics (Sh. 27, 29) that the tubes are fully on. TXL monitors the voltage on the A winding. TXT monitors the output voltage of the tubes. The stepped down scale voltage outputs of these transformers are compared in the notching electronics (Sh. 21), and when they are approximately equal, the A2 staging contactor is energized.

The ignitrons are shut down, or 'defired' at the same instant that A2 moves from the dropped out position. When in full operation, IG1 and IG2 supply approximately 600 volts to PRP1. Staging contactor A2 now connects the X3-X4 main transformer secondary to propulsion rectifier panel PRP2 making up the lost 600-volts which was available from PRP1. Staging contactor A1 remains picked up. The ignitrons now commence phasing up for the second time. Power supplied to PRP1 is now added to that supplied from PRP2. Both rectifier panels are in series so that total rectifier voltage now rises gradually from 600 volts to 1200 volts as the tubes phase on.

When the ignitrons are again phased fully up, the notching electronics again receives equal scaled input voltage signals from TXT and TXL. Staging contactor A3 is picked up and the ignitrons are simultaneously defired. The X5-X6 main transformer secondary is connected to propulsion rectifier panel PRP3, again making up the lost 600 volts which was available from PRP1 when the tubes were ON. Staging contactors A1 and A2 remain picked up. The ignitrons now begin phasing up for the third time. Power supplied to PRP1 is now added to that supplied by PRP2 and PRP3 with total rectifier voltage at approximately 1800 volts.

Motoring contactors AM1, AM2, AM3, and AM4 are picked up whenever a power position is selected. These contactors connect the ac rectifier circuit to the traction motors. Rectified ac is supplied to motor fields 1 and 2, current measuring reactor CMRX1, motor overload relay OLM1, and motor armatures 2 and 1. Reactor CMRX1 (and CMRX2 in the other motor leg) is used to control ignitron firing through the operation of the propulsion electronics.

The second motor leg consists of power-check relay PC, motor overload relay OLM2, armatures 4 and 3, reactor CMRX2, anticipation transformer ATX, and motor fields 4 and 3. Power check PC indicates to the control circuits that motor current exceeds 90 amperes. Reactors CMRX1 and CMRX2 supply the propulsion and dynamic brake electronics with scaled motor current for propulsion/braking control. The higher output of the two reactors (both should be nearly equal in motoring) will control the propulsion and braking electronics.

The ground relay, GR, is tied to the center of the propulsion rectifier output. Normally, no current passes through the relay coil because no other ground connection exists in the rectifier circuit or traction circuit. A ground on either the 31MP and 31 MN wire will cause current to flow in the coil of GR, tripping this relay. Interlocks of GR remove the coil of GR from the tripping circuit, and a second set of interlocks removes traction power.

NOTE: *A third set of contacts closes to pick up RGR which is a manually reset relay (11A). This relay prevents any subsequent dynamic brake operation, and also limits all future motoring to SW. It also lights the local ground light (LGL).*

Relay GR is normally reset by placing the master controller plug into the reset receptacle. After resetting, the propulsion system can only provide SW power (ignitrons at 90 degree firing angle, A1 picked up), unless the ground remains, whereupon a second loss of power will result. (Restoration of full power can only be obtained by correcting the fault, resetting GR, then manually resetting summary-latching-ground-relay RGR.)

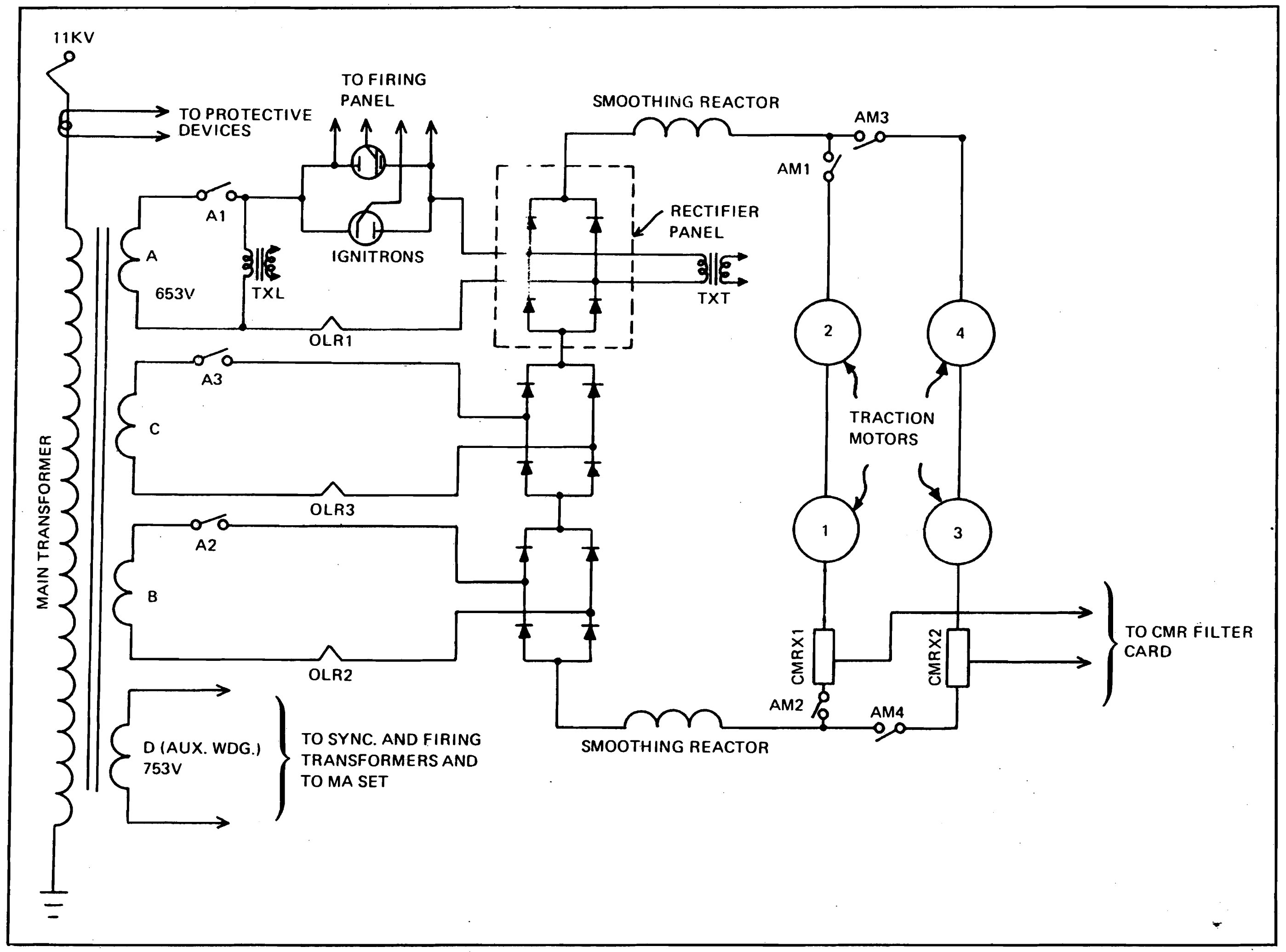


FIG. 2-1. BASIC POWER LOOP FOR PROPULSION SYSTEM. E-16483A

DYNAMIC BRAKING FUNCTION

The traction motors are connected as shown in Figure 2-3 to provide dynamic braking effort.

When the car is moving with no power call from the master controller, rotation of the motor armature causes the motor to generate electrical power. This power is dissipated in the form of heat through the grid resistors on the car roof. The torque needed to rotate the motor armature acts as braking force on the car and decelerates the car.

Observe in Figure 2-3 that the output of motor armatures 1 and 2 excites the fields of motors 3 and 4; and the output of motor armatures 3 and 4 excites the fields of motors 1 and 2. This is called "cross excitation" and promotes stabilizing and equalizing of braking effort.

As the train decelerates and the rpm of the motors, now acting as generators, begins to diminish, current through the grid resistors will diminish and the deceleration rate will decrease. To keep deceleration rate constant, current through the grid resistors must remain constant. To partially accomplish this, as current diminishes with motor rpm, grid resistors are sequentially notched out by the operation of the KM controller. The rate at which resistance is notched out determines motor current, thus deceleration rate. This notching current is regulated by the rate circuits, acting on command from the brake controller.

Dynamic Brake Circuit

The dynamic brake circuit requires that no external power enter the traction motors.

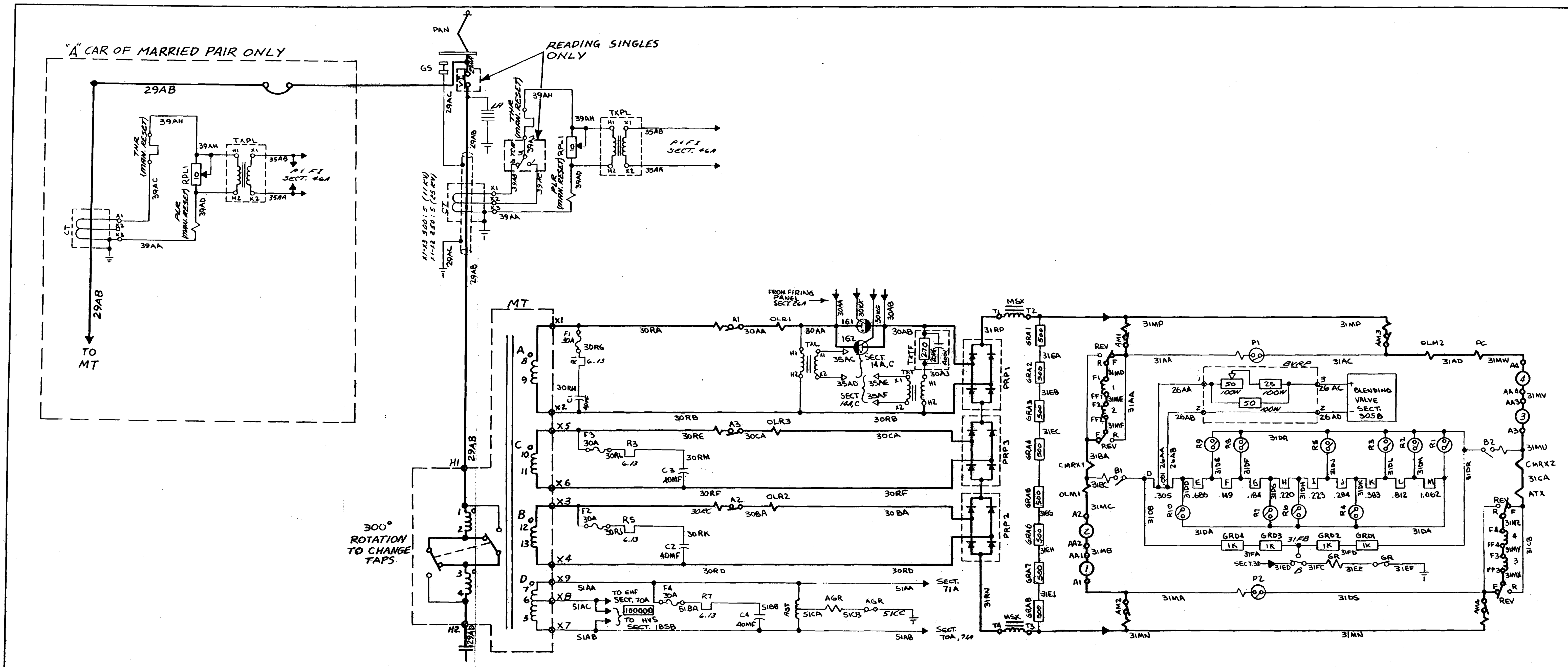


FIG. 2-2. TRACTION MOTOR CIRCUIT (MOTORING). E-19388

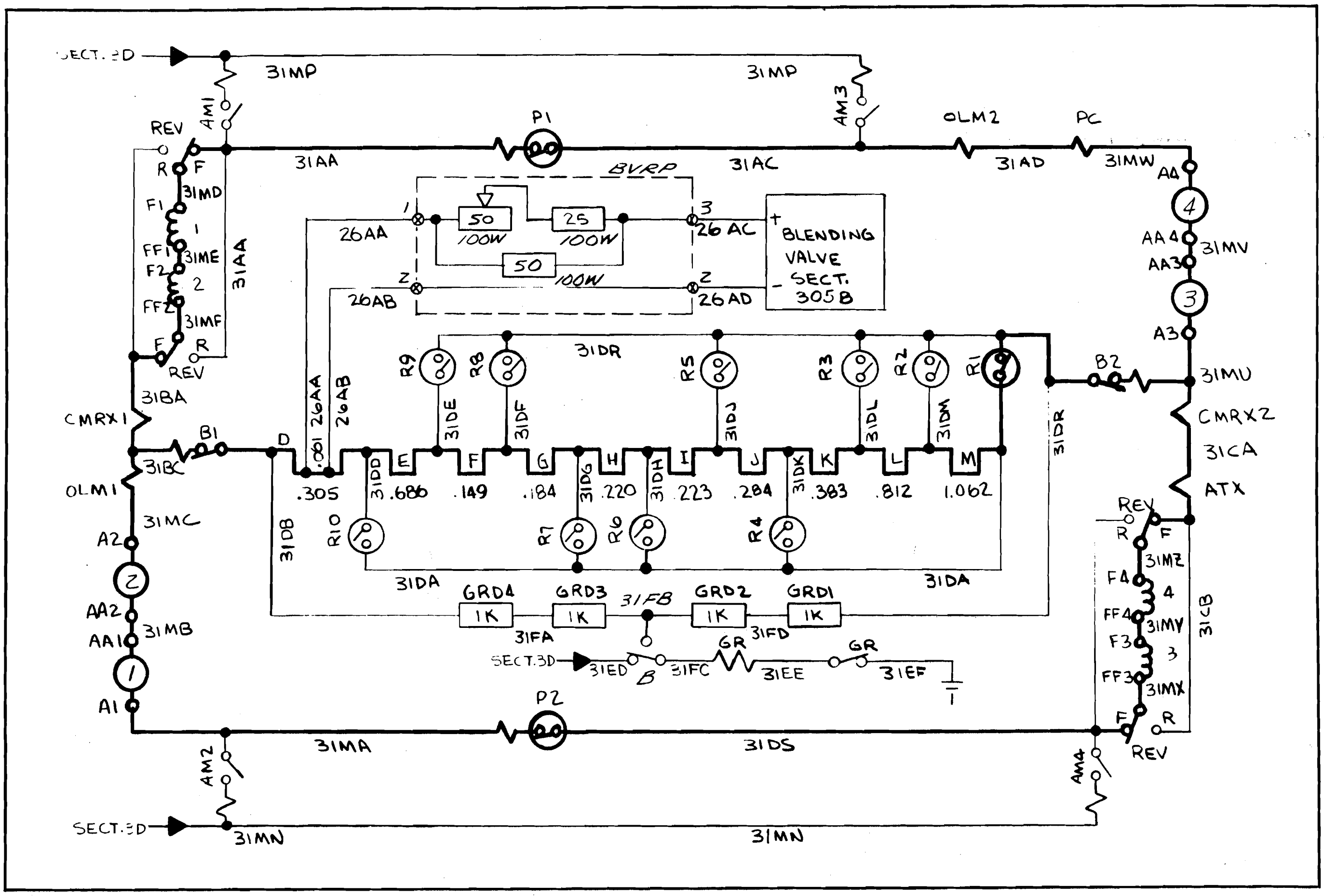


FIG. 2-3. DYNAMIC BRAKE CIRCUIT. E-19389

When OFF is selected, the power contactors are dropped out. The dynamic brake configuration is then established by picking up contactors P1, P2, on the KM controller, and B1 and B2. Motor current can now flow from contactor B1 through resistors D through M, R1 and B2. At this point, the current splits into two equal parts. Half of the generated current passes through armatures 3 and 4, P1, fields 1 and 2, back to B1. The other half flows through fields F4 and F3, P2, armatures 1 and 2, back to B1. This double loop circuit with motor armatures and fields cross-connected, ensures that one set of motors does not generate a higher voltage than the other set. The fewer resistors included in the circuit, the more load is placed on the motors (now operating as generators). The more electrical load, the higher the motor current. The more current that must be supplied by the motors, the harder it is to physically turn. It is this conversion of car inertia to electrical power generation and finally the conversion of electrical power to heat in the roof resistors, which slows the car in dynamic brake.

As the car slows down, the motors produce less current, providing less braking force. Braking effort is restored by shunting out resistance. The dynamic brake electronics controls the cam controller so that braking effort will be maintained as the car slows.

Motor current information is supplied to the dynamic braking electronics by the action of CMRX1 and CMRX2.

When the car slows to about 5 or 10 mph, the cam controller will arrive at Position No. 1. Motor current will fall below approximately 60 amperes at about 3 or 4 miles per hour, dropping power check relay PC. The result of this action will be that the cam controller runs back to Position No. 17 (COAST), and contactors B1, B2, and P1 and P2 (on the cam controller) drop out. A subsequent dynamic brake application is impossible without a successful power application. This is because the current check relay (CCR) is dropped out when the cam controller reaches Position No. 1, and will not pick up until 90 amps of motor current is established with a motoring mode. Final braking effort to stop the car is made by the air brake system alone.

Braking Grid Resistor D (Sh. 4) supplies a scaled sample of motor current to the blending valve of the air brake system to hold off the air brakes while dynamic brake supplies the required braking rate. Failure of the dynamic brake releases the air brake system so that it can provide the total required braking force. During a full service brake application, the air brakes will supplement the dynamic brakes as necessary to produce the required retardation rate, with the dynamic brakes dominating. The initial brake call is sent to both the air brake and dynamic brake systems. The dynamic brake system monitors the magnitude of this brake call from the air brake system through the pressure transducer which takes an air pressure and converts it into an electrical signal. This signal is sent to the dc suppression amp card FD698 (32A) through P3. The air brake, in turn, senses dynamic brake effort through the blending valve and reduces air brake pressure accordingly.

The air brake then supplies brake cylinder inshot pressure only as long as the dynamic brake system provides sufficient power to answer the brake call. The blending valve controls this feature. A combination of air and dynamic brake is used above 50 mph. The higher the car speed above 50 mph, the more air brake and the less dynamic brake is used.

PROPULSION SAFETY CIRCUIT

The propulsion safety circuits ensure that critical circuits are operating properly before traction power is applied.

Current measuring reactors are supplied control power from the same source as that supplying electronic cards. Failure of this common power supply will cause a complete loss of traction current. Ignitron firing is stopped, and all staging contactors are dropped out if the propulsion system is in use. The cam controller will stop notching if the brake system is in use.

Ground relay GR will trip if a ground develops in the traction motor circuit or braking resistors. The result will be a complete loss of power of dynamic brake on that car; however, the Pneumatic (air) brake will assume the brake function instantly. Relay GR can be reset in the cab. However, with manually reset RGR picked up as a function of GR, the offending car is restricted to P1, because an RGR interlock opens the feed to TLP2 (6). Acceleration of the offending car will also be limited to the minimum rate. In addition, the car fault light is lit throughout the train.

The low voltage and lockout circuitry on the FD503 card (Sh. 31) ensures that before traction power is taken:

1. Catenary voltage is above 8500 volts.

2. The rate selection card (FD679) (Sh. 31) is in place.

3. Propulsion electronics power supplies are operating correctly (HRP picked up on the FD698 card).

4. All ac propulsion cards are in place.

5. The dynamic brake and speed taper card (FD698) is in place.

6. All wheelslip cards are in place.

Propulsion Interconnections

When a power position is selected at the master controller, the motoring electronics are supplied with an input to indicate the motor current required.

The function of the rate selection card (FD679) (Sh. 13) is to receive trainlined motoring and brake commands and pass them on to the propulsion electronics and dynamic brake electronics. The rate selection card also receives a signal, at Pins 30, 32, indicating that the traction motors are in the dynamic brake configuration. This signal is used to switch the current feedback signal arriving from the current measuring reactor filter card at Pin 33 to the loadmeter to produce upward deflection of the indicator needle. This switching is required because the output of the CMR filter card is constantly positive.

When the signal indication for dynamic brake is lost, motor current will cause a downward deflection of the loadmeter needle.

The signal at Pins 30, 32 also causes the output of the DBRT (Sh. 13) to be connected to the dynamic brake suppression amplifier FD698 (32). The output of the dynamic brake suppression amplifier is supplied to the PC, ATX and current limit card FD471 (33). This signal will regulate the pilot motor, which in turn, drives the cam controller, notching out resistors from the motor circuit.

Traction motor current is measured by the two current measuring reactors CMRX1 and CMRX2 which are identical and work off the following principle:

A coil wrapped around the motor bus is provided with an iron core, and supplied with 900 Hz power from the oscillator card FD472 through the TOSC transformer (Sh. 12). The ac present in this reactor coil is absorbed by the iron core magnetically as long as no motor current flows. As motor current flows through the motor bus, the reactor core becomes proportionally saturated allowing the 900 Hz signal through the reactor to the CMR filter card. The amplitude of the 900 Hz leaving the CMRX is directly proportional to motor current amplitude.

The resultant ac signal at the CMR filter card is rectified and filtered by the FD680 CMR filter card (Sh. 13). The dc output of the card is then directly proportional to the dc motor current; however, the direction of current flow in the traction motors will have no effect on the polarity of the CMR filter output. This filter output is always more negative with increasing motor current. The signals from both CMRX1 and CMRX2 are combined in the CMR filter in such a manner that the higher output of the two sets the filter output voltage.

The rate selection card supplies the ac propulsion electronics with two motoring rate signals; 220 amps, or 650 amps. The SW input is received at the 679 card to prevent the ignitrons from firing beyond the 90 degree angle. All other power settings of the master controller require the ignitrons to phase up completely, to full conduction.

PROPULSION CONTROL LOGIC

The sequence outlined in Table I occurs during motoring to (1) properly connect the traction circuits; (2) regulate the acceleration rate of the train and (3) cause the propulsion power to be removed and the application of a braking effort.

Assume that the following conditions are satisfied prior to the selection of a motoring selection on the master controller in the "B" end cab of a SEPTA "single" car:

1. Pantograph up and catenary voltage above 8450 vac. PTR4, PTR5 picked up.

2. Cab properly made up for operation: CMR1, 3, 4, 5, 6, ORR, WSKR, MVR, EMV p.u., EPCS closed. All doors in the train are closed - EDCR, EDCRA picked up.

3. All pneumatic brakes released - PKR, PDR, BR, picked up.

4. Brake system charged - EMPS, ER, DBPR picked up and DBR and BRT dropped out.

TRAINLINE AND SEQUENCE RELAYS

The trainline relays are picked up by the master controller in the operative cab. The power-sequence-trainline relays, SWTD, S2TD and S3T pick up in successively higher power settings of the master controller. All of these relays will be picked up when the master controller is in the P3 position.

The brake-release-trainline-relay, BRT, remains dropped out until a service reduction is made at the brake valve. The emergency-brake-relay ER, is picked up when the brake pipe remains charged up above 65 psi. The forward and reverse trainline relays, FWT and RVT are picked up during forward and reverse operation.

RATE SELECTION RELAYS

The function of the rate selection relays is to accept commands for motoring or braking. The relays on the Rate Selection Card FD679 (Sh. 13) are picked up as listed:

TLP2 - When P1, P2 or P3 is selected at the master controller.

TLP1 - Coil not used. Normally closed contacts remain closed.

M1-DB, M2-DB } These two relays will pick up whenever the cam controller is between Positions No. 1 and No. 17, and the brake controller has made a service reduction.

Interlocks of M1-DB switch the polarity of the current measuring reactor filter card output. This output is used by the loadmeter to indicate the relative power being consumed or generated by the traction motors. The loadmeter is a center-scale meter requiring deflection both up and down for brake and motoring current respectively. The output of the CMR filter card is always the same polarity, therefore, the switching is required.

Interlocks of the M2-DB feed the DBRT signal to the dynamic brake suppression card FD698 (Sh. 16) through potentiometer P3 (Sh. 16) when braking where it is used to regulate K4 controller notching which provides the dynamic brake effort.

TABLE I

STEP	SEQUENCE
1. MOVE MC FORWARD TO SW	1. 01FW trainline becomes energized (Sh. 170) and FWT picks up (Sh. 6A). A. FWR picks up (Sh. 7A) and seals in. 1). REV (FWD) coil becomes energized (Sh. 8). 2). A1, A2 and A3 contactor exhaust port coils become energized (Sh. 8). B. COAST signal removed from gated error amp card FD692 (Sh. 17).
	2. 03SW trainline becomes energized (Sh. 170) and SWTD picks up (Sh. 6). A. SW picks up (Sh. 7) 1). The current limit card FD471 (Sh. 10) receives a run signal. KM controller runs to Position 20 and stops. a. Contactors AM1, AM2, AM3, AM4 (Sh. 8) pick up. 2). A1 contactor (Sh. 9) picks up a. The defire pulse generator card FD456 (Sh. 9) provides an output pulse to defire the tubes when the positive feed at pin 16 is removed. b. AHR relay drops out, de-energizing AH1 and AH2 tube heaters. c. The ignitron tubes turn on and phase up to 90 degrees maximum. Acceleration rate is set at minimum. d. PC relay (Sh. 10) picks up when traction motor current reaches 95 amps. e. CLR (Sh. 10) picks up when PC picks up. f. CCR (Sh. 8) picks up and seals in when CLR picks up. 3). BRTD relay drops out (Sh. 10). 4). PMR relay drops out (Sh. 10). B. Pin 8 of the FD483 card (Sh. 14) becomes connected to 32– which permits firing pulse output.
2. MOVE MC FORWARD TO P1	1. 04PA trainline becomes energized (Sh. 170) and the TLP2 relay on the FD679 card (Sh. 6 and 13) picks up. The TLP2 removes the minimum acceleration rate signal from the ac suppression amp card FD683 (Sh. 14) and applies the maximum rate signal.
3. MOVE MC FORWARD TO P2	1. 05PB trainline becomes energized (Sh. 170) and the S2TD relay picks up (Sh. 6). A. The A2 contactor picks up (Sh. 9) 1). The defire pulse generator card FD456 (Sh. 9) provides an output pulse to defire the tubes when the positive feed at pin 14 is removed.
4. MOVE MC FORWARD TO P3	1. 06PC trainline becomes energized (Sh. 170) and the S3T relay picks up (Sh. 6). A. The S3 relay picks up (Sh. 7). 1). The A3 contactor picks up (Sh. 9) a. The defire pulse generator card FD456 (Sh. 9) provides an output pulse to defire the tubes when the positive feed at pin 12 is removed.

TABLE I (Cont'd.)

STEP	SEQUENCE
5. MOVE MC TO OFF FROM P3	1. 01FW, 03SW, 04PA, 05PB and 06PC trainlines become de-energized (Sh. 170). A. FWT relay drops out (Sh. 6) 1). A coast signal applied to the gated error amp card FD692 (Sh. 17). B. The TLP2 relay on the rate selection card (Sh. 6 and 13) drops out. The SPR relay contacts apply 90 degree phase limit to the pedestal level card FD482 (Sh. 14) limiting tube conducting to 90 degrees. The TLP2 removes the maximum rate signal from the ac suppression amp card FD683 (Sh. 14) and applies the minimum rate signal. C. S3T relay drops out (Sh. 6). 1). The S3 relay (Sh. 7) drops out after a 0.25 second time delay. a. The A3 contactor (Sh. 4) drops out. D. S2TD relay (Sh. 6) drops out after a 0.5 second time delay. 1). The A2 contactor (Sh. 9) drops out. E. SWTD drops out after a 1.1 second delay (Sh. 6). 1). SW drops out (Sh. 7) a. A1, A2 and A3 contactors drop out (Sh. 9). b. PMR relay picks up (Sh. 10) 1). The current limit card FD471 (Sh. 10) receives a run signal. The KM controller runs to position 17 and stops. a. AM1, AM2, AM3 and AM4 contactors drop out (Sh. 8) 1). P1, P2 and B contactors pick up (Sh. 8) 2). B1 and B2 contactors pick up (Sh. 9) -BCR picks up (Sh. 9) 3). A1, A2 and A3 contactor exhaust coils become de-energized. 2). AHR relay picks up (Sh. 9) energizing tube heaters AH1 and AH2. c. The firing pulses from the firing ramp card FD483 (Sh. 14) are prevented. 1). The ignitron tubes turn off. a. The PC relay drops out (Sh. 10) 1). The CLR relay drops out (Sh. 10)

Discussion

When the master controller is placed to a motoring position in the FWD direction (Step 1 in Table I), relay FWR will be picked up. Initially, all traction circuit contactors will be dropped out and power-off-relay POR, will be picked up. Relays FWR and POR complete the circuit to both sides of the forward-magnet-valve and the reverser switch throws to the forward position. Interlocks mounted on the reverser switch now bypass the POR interlocks, allowing power to be taken, with the magnet valve remaining energized.

The exhaust magnet valves of contactors A1, A2 and A3 (Sh. 8) will pick up if the following conditions exist.

1. The train is not in emergency brake (ER picked up).

2. No motor circuit ground exists (GR dropped out).

3. The dynamic brake circuit is not energized (B1 dropped out). This contactor is picked up if the master controller is in an OFF position.

4. No motor overloads are tripped (OLM1 and OLM2 dropped out).

5. Main transformer coolant temperature is below 100 C (212 F) (TRF dropped out).

Power is supplied to the current limit card FD471 through interlocks of SW relay and cam switch KM23 (Sh. 10) (the 16-T means that this cam switch is only closed when the cam controller is between positions 16 and 19, positions 18 and 19 termed the transfer (T) position). A HOLD signal is also present through cam switch KM16. The rate selection card FD679 is now supplying a rate command to the propulsion electronics, (ac suppression amp) FD683 (Sh. 14), however, no motor current yet exists. An error signal is generated by the FD683 card and fed to the pedestal level card FD482 (Sh. 14). With the RUN and HOLD signals present, the pilot motor electronics energizes the pilot motor. Pilot-motor-relay PMR (Sh. 10) is dropped out causing the pilot motor to drive toward position 20. When the cam controller leaves position 19, KM23 opens removing the RUN signal. The cam controller enters position 20 with a HOLD signal present, and therefore stops.

Cam switch KM26 (Sh. 8) is now closed, picking up motoring contactors AM1, AM2, AM3 and AM4. These contactors connect the traction motors in a series-parallel configuration across the output of the main smoothing reactor MSX (Sh. 4). Interlocks on AM2 and AM4 close to pick up the A1 staging-contactor through the following interlocks:

1. Sequence relay SW.

2. Ignitron-thermostat-switches IG1TH and IG2TH.

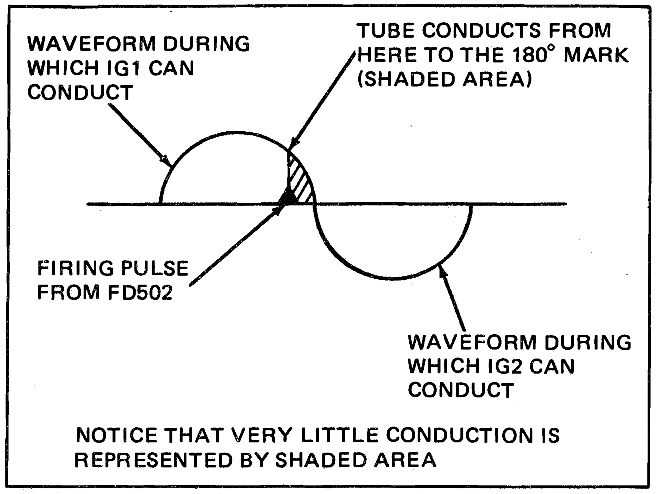
3. Failed-blower-relay FBR (picked up until 5 seconds after a loss of power to the clean air blowers which supply cooling air to the traction motors and the rectifier group).

4. Overload device OLR1 (this overload is located on the A1 contactor buswork and will trip if main transformer to rectifier current exceeds 1400 amps).

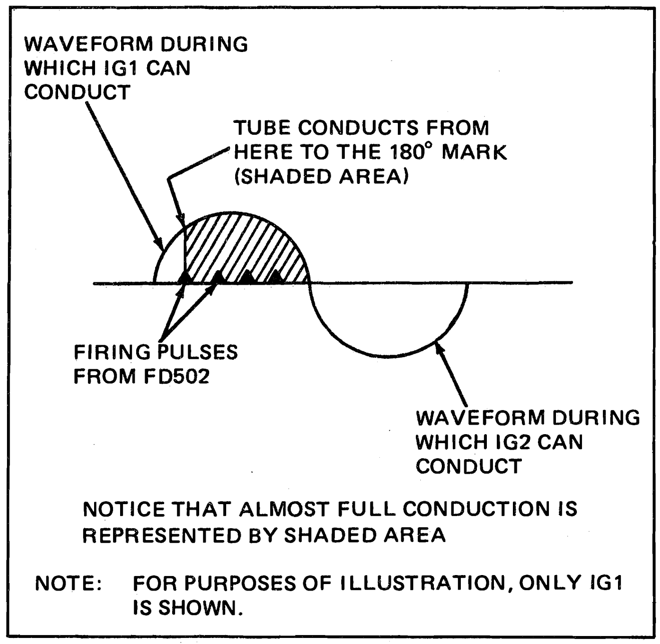
When the air-operated A1 contactor picks up, a defire pulse is generated by the 456 card (Sh. 13) in the propulsion electronics. This signal will prevent firing pulses until the A1 contactor picks up. Firing pulses will then commence initially at the end of the cycle. The propulsion electronics will advance the firing angle based on the power call and motor current. See Sketches A and B.

When the operator selects P2 power (Step 3 of Table I), the trainline relay S2TD picks up.

Interlocks of S2TD now complete the circuit to the pick-up-magnet-valve of staging-contactor A2. This contactor cannot pick up, however, until the ignitrons have



SKETCH A



SKETCH B

phased on to full conduction (Sketch B). When this occurs the A2 notch switch card 462-A1, turns on transistor Q8. When Q8 is turned on, the circuit from −38 volts is completed and the A2 pick-up magnet valve energizes. Defire occurs again through A2 interlocks recalibrating the firing pulses and the ignitrons must start firing at the end of the cycle once more (see Sketch A).

When P3 is selected at the master controller (Step 4 of Table I), the S3T trainline relay picks up. Interlocks of S3T pickup relay P3 which picks up staging contactor A3, regulated by the A3 notch switch card 462-A3 in the same manner as the A2. Defire occurs again (see Sketch A above).

NOTE: *If the motorman selects P3 directly from Coast, the sequence would be as described in Steps 1, 2, 3 and 4 above with the exception of the A2 and A3 contactors. The propulsion electronics senses the conduction of the ignitron tubes and based on this information, automatically energizes the A2 and A3 contactors at the correct time.*

When OFF is selected at the master controller, the following events occur.

1. The ac-staging-contactors drop out in accordance with the time delays associated with them (described in the preceding paragraph).

2. The cam controller runs back from position 20 to position 17.

The delays installed in the dropping of the sequence relays are necessary to allow the ignitrons time to cycle back before dropping a staging contactor. This prevents a sudden loss of power when dialing back, causing a sudden loss of acceleration and an uncomfortable jerk. S3 delays the dropout of A3 staging contactor for 0.25 seconds, S2TD delays the A2 drop out for 0.50 seconds, and SWTD delays the A1 drop out for 1.10 seconds. No delay is required for the P1 function since no staging contactor picks up or drops out when P1 is selected at the master controller.

The cam controller logic must be supplied with the proper signals to cause it to run in the reverse direction toward position 17. This is accomplished in the following manner.

Interlocks of SWTD will drop out SW 1.1 seconds after the master controller is moved to the OFF position. This drops out the A1 staging contactor, and picks up PMR. This completes a circuit which provides a RUN signal to the FD471 current limit card (Sh. 10) through the following interlocks.

1. A1 contactor interlocks

2. KM-17

3. PMR relay

At the same time, the pilot motor is also reversed picking up the pilot motor relay PMR (Sh. 10), which reverses the pilot motor field windings. Relay PMR is picked up through the following interlocks:

1. SW relay interlocks

2. KM9

The pilot motor is now connected in reverse, the KM controller electronics is supplied with both a RUN and HOLD signal, so the pilot motor drives the controller toward position No. 17. The RUN signal is lost when the cam controller leaves position No. 18 (T) through the opening of cam switch KM17. Relay PMR also drops out at this time through the opening of cam switch KM9. The pilot motor will remain in position 17 until a brake or power position is selected by the motorman.

Power check PC is a reed switch adjusted to pick up when motor current exceeds 95 amperes. When motoring up from a dead stop the following sequence occurs. Current limit relay CLR (Sh. 10) is picked up by PC. Interlocks of CLR complete a circuit from +38 volts to the coil of circuit check relay CCR (Sh. 8) picking it up. This circuit is completed through interlocks of overload relays OLM1, OLM2 (picked up when a motor overload occurs), the emergency relay ER (picked up except when in emergency brake), FBR and CLR. Once CCR is picked up it will hold itself up through cam switch KM27.

When the OFF position is selected at the master controller and the car is in motion (power has been taken previously to pick up CCR), power is supplied to the coils of the P1, P2 contactors and the B relay (Sh. 8) through the following interlocks.

1. Failed blower relay FBR (picked up until 5 seconds after a traction cooling blower failure).

2. Emergency brake relay ER (picked up when not in emergency brake).

3. Motor overloads OLM1 and OLM2 (trip out at 750 amps).

4. CCR

5. FWR relay

6. Cam switch KM15

7. Summary ground relay RGR (trips out on any traction circuit ground).

Interlocks of the B relay pick B1 and B2 contactors up (Sh. 9) through AM1, AM2, AM3, AM4 contactor interlocks. Interlocks of B1 and B2 pick up the brake circuit contactor BCR (Sh. 9), however, brake-release-time-delay-relay BRTD (Sh. 10) is dropped out until a brake position is selected at the brake valve. This prevents interlocks of BCR from providing a second circuit to the brake contactors through KM25 at this time.

When motor current drops below the level required to hold PC closed (approximately 60 amps), CLR will drop out. The circuit check relay CCR will remain closed, however, through its own interlocks and cam switch KM27. The car is in motion and a brake position has not been selected, the system is in COAST, therefore KM27 will not open up nor CCR drop out.

DYNAMIC BRAKING CONTROL

The operational sequence of the dynamic braking system is depicted in Table II. This control logic is required to:

1. Properly connect the traction circuits
2. Regulate the deceleration rate of the train
3. Blend the dynamic and pneumatic brake systems.

TABLE II

STEP	FUNCTION
1.	Perform the following: With the MC handle in the OFF position and the EPCS switch closed, move the brake valve handle momentarily through the holding and lap positions to the service position.

	The results are:
	A. 25RE trainline becomes energized when the brake valve reaches the holding position.
	    1. The holding magnet valve on the pneumatic brake control unit becomes energized.
	    2. DBCR picks up (Sh. 6).
	B. 25AP trainline becomes energized when the brake valve reaches the service position.
	    1. The release magnet valve on the pneumatic brake control unit becomes energized. This allows air to vent from the brake pipe at a service rate, propagating a pneumatic brake application.
	    2. DBR picks up (Sh. 172)
	        a. 07DB trainline becomes energized (Sh. 172)
	            1). BRT picks up (Sh. 6)
	                a). BR drops out (Sh. 7)
	                    1). BRTD picks up, causing a run signal to be sent to the KM controller current limit card FD471 (Sh. 10). The KM controller notches toward Position 1.
	                    2). M1-DB and M2-DB relays on the rate selection card FD679 pick up.

2.	Perform the following: Place the brake valve handle to the service position with the EPCS switch open and observe the reducing brake pipe (BP) pressure.
	The results are: A. When BP pressure reaches 103 psi, DBPS drops out (Sh. 7). DBPS will drop the BR relay out during an automatic air brake stop (with EPCS open). BRT, M1-DB and M2-DB relays operate as in step 1 above.
3.	Perform the following: After a service reduction is made with the brake valve and the EPCS switch closed, place the brake valve handle to Lap.
	The results are: A. The release magnet valve on the pneumatic brake control unit becomes de-energized cutting off any further escape of brake pipe air. B. The DBRT senses the brake call pneumatically from the brake control unit and provides a proportioned electrical signal through the rate selection card FD679 (Sh. 13) to the dynamic brake rate potentiometer P3 (Sh. 16). This potentiometer is adjusted to provide a proportional signal to pin 8 of the dc suppression amplifier card FD698 (Sh. 16). 1. The KM controller responds by notching at a speed which will develop the right amount of dynamic braking current in the traction motor circuit which will provide the requested retardation rate as called for by the motorman's brake valve. Dynamic braking current signals are fed back to the brake blending valve which acts to blend the dynamic braking effort with pneumatic brakes. Dynamic braking will be the primary braking force with the pneumatic brake supplementing as required to meet the total brake call.
4.	Perform the following: Observe that when the KM controller reaches position 1, dynamic braking current falls to zero and the stop is completed with the pneumatic air brakes.

TABLE II (Cont'd.)

STEP	FUNCTION
4. (Cont'd.)	The results are: A. PC drops out (10B) when dynamic brake current falls below approximately 60 amps. 1. CLR drops out (10B). a. CCR drops out (8B). 1). PMR drops out (10A). 2). The KM controller advance card FD471 (Sh. 10B) receives a run signal and runs toward position 17 where it stops to await a call for motoring. b. P1, P2 and B contactors drop out (Sh. 8). 1). B1 and B2 contactors drop out (Sh. 9). a). BCR relay drops out (Sh. 9). b). POR relay picks up (Sh. 9).
5.	Perform the following: Move the brake valve handle to "Holding" and with the EPCS switch closed, observe the the BP pressure charges to 110 psi while the BCP remains the same. Then move brake handle to "Release".
	The results are: A. When the BP pressure reaches 109 psi, DBPS (Sh. 7) picks up. 1. DBR drops out (Sh. 172) a. Trainline 07DB becomes de-energized (Sh. 172), dropping out BRT (Sh. 6). 1). BR picks up (Sh. 7) a). BRTD drops out (Sh. 10)
6.	Perform the following: While the MC handle is still in the P3 motoring position, move the brake valve handle to "Service".
	The results are: A. DBR picks up (172A) 1. PDR drops out, de-energizing 03SW trainline. a. SWTD drops out (6A) after 1.1 second time delay. 2. 07DB trainline (172) becomes energized, picking up BRT (6B). a. BR drops out. B. 1). SW drops out (7A). a) PMR picks up 2) A1, A2 and A3 contactors drop out. a) The KM controller electronics gets a run signal and runs toward position 17. (1) AM1, AM2, AM3 and AM4 contactors drop out. (2) P1, P2 contactors and B relay pick up. (a) B1 and B2 contactors pick up (4B) (1) BCR picks up (9B) (3) BRTD picks up (10A) (a) The KM controller gets a run signal and runs towards position 1. NOTE: The rest of the logic occurs the same as previously described in Step 1.

Discussion

When the brake valve is moved to provide a service reduction with the car in motion (Step 1, Table II), the cam controller will proceed into the dynamic brake zone, positions No. 16 through No. 1, notching out resistance from the traction motor circuit at each position. The order for the amount of motor current to be generated by the traction motors enters the dc suppression amplifier card FD698 (Sh. 16) from the rate selection card FD679 (Sh. 13). Both dynamic and pneumatic brake systems will answer the brake rate call from the brake valve. Initially, the air brake system will go into operation first, but is quickly checked by the dynamic brake system, as the cam controller moves down into the brake zone.

The error signal from the FD698 card is then supplied to the current limit card FD471 (Sh. 16). The same logic must be satisfied in the dc electronics with regard to RUN and

HOLD signals, and the error signal which is generated by the dc suppression card FD698 based on the relationship between the rate selected and the actual motor current regulates the speed at which the KM controller notches, thereby regulating dynamic braking current.

When the brake valve provides a service reduction, the 07DB trainline is energized and the 25AP trainline is energized. BRT relay (Sh. 6) picks up. This relay drops out brake-release-relay BR (Sh. 7). Interlocks of BR (Sh. 10), now supply power to pick up M1-DB, M2-DB (Sh. 13), and BRTD (Sh. 10). The motoring/braking relay M2-DB, provides the DBRT signal to the dc suppression amplifier card FD698 (Sh. 16). Brake-release-time-delay-relay BRTD interlocks complete a circuit through the following interlocks to hold up the dynamic brake contactors P1, P2 and B (Sh. 8):

1. FBR failed-blower-relay
2. ER emergency-relay
3. OLM1, OLM2 motor overloads
4. BCR brake control relay
5. BRTD
6. KM25 cam switch
7. RGR summary-ground-relay
8. FWR forward relay

The circuit which picked up the P1, P2 brake contactors and B relay will be broken by KM15 when the cam controller commences notching into the brake zone.

The pilot-motor-relay PMR must be picked up to reverse the pilot motor fields when in the brake mode. This is accomplished by interlocks of the following devices:

1. Cam switch KM24
2. Brake-release-relay BR
3. Circuit-check-relay CCR

The HOLD signal available from KM16 must now be overriden by a RUN signal, at least until the HOLD signal is withdrawn in position No. 16. The RUN signal becomes available through interlocks of:

1. KM17
2. A1
3. SWTD
4. PMR

The pilot motor now drives the cam controller toward position No. 1. When the cam controller leaves position No. 17 both the RUN and HOLD signals are removed, the controller operating in current limit down to position No. 1. At this time KM16 will again place a HOLD signal on the electronics. Train speed when the cam controller reaches position No. 1 depends on what the brake call is at the brake valve but will be somewhere between 20 and 5 mph.

The traction motors are unable to sustain the brake rate at these low speeds. To complete the stop at the required brake rate, the air brakes take over as the primary braking force. As motor current falls, more air is allowed into the brake cylinders. When motor current falls below approximately 60 amps PC drops out. Relay CLR (Sh. 8) drops out breaking the only circuit left to hold up CCR (KM27 is now open). Note that when CLR drops out the brake contactors also drop out because KM25 is now open. When B1 and B2 drop out so does BCR (Sh. 9).

Interlocks of CCR will now supply a RUN signal to the KM controller through the following interlocks (Sh. 10):

1. CCR circuit-check-relay (which just dropped out)
2. KM19

MOTORING ELECTRONICS

The ac motoring electronics system essentially provides two separate functions. One function controls the firing angle of the two ignitrons; the second controls staging contactor operation.

The ignitron firing circuit consists of the FD683, FD482, FD483, and FD502 (Sh. 14) cards and the firing panel 17FM214E1 (Sh. 26). The staging contactor control circuit consists of the FD681, FD462 and FD460 cards. The FD456 (Sh. 14) card is required for special firing control (defire) when staging occurs.

When the SW motoring rate is selected, +15 volts is applied to pin 26 of the FD482 pedestal card, and pin 22 of the FD683 ac suppression amp card. An error signal will be generated by the FD683 card until motor current (CMR feedback) reaches the selected motoring rate. This error signal is removed during receipt of a defire signal from the FD456 card, or a wheelslip signal from the FD691 card (Sh. 17).

The error signal from the FD683 card is fed to the FD482 pedestal card, which results in a pedestal output voltage being generated at pin 22. This error signal, which is again removed by wheelslip, defire signals or the safety circuit (low voltage lockout) is fed to the Firing Ramp FD483 card.

The firing ramp card is supplied with the modified pedestal voltage and a full wave rectified (but not filtered) sample of the incoming catenary power at low voltage. This sync voltage is supplied from the main transformer, through TXS, and the 502 card. The firing ramp card generates precisely timed firing pulses based on the amplitude of the dc pedestal voltage and the sync pulses. The frequency detector portion of the 503 card supplies an additional input governing the number of firing pulses generated per cycle based on line frequency.

When the car operates from 60 Hz power, this output will rise from zero to +10 volts. When the car operates from 25 Hz power, this output will be zero volts.

The firing pulse amplifier FD502 steps up the power of the firing pulses supplied by the firing ramp card. The additional power is supplied from transformer TXS. These power amplified pulses are supplied to silicon control rectifiers in the firing panel where sufficient power is added to cause ignitron firing. Transformer TXFC supplies this additional power.

The notch up comparator card FD681 (Sh. 14) receives inputs from transformer TXT and TXL which measure ignitron input and output voltages. A notch up pulse will be generated whenever these two inputs are approximately equal in amplitude. The notch up pulse will cause a transistor in the A2 notch switch card FD462 to energize the pickup magnet valve of the A2 staging contactor. The same action will take place at the A3 switch card if the A2 notch switch is already picked up. Picking up a notch switch causes the contactor to pick up and an interlock of the contactor removes a positive voltage signal from the defire generator. This causes a defire pulse to be sent to the pedestal card from the defire generator, temporarily eliminating the pedestal voltage. No firing pulses can be generated until the pedestal voltage is restored. Interlocks on the A2 and A3 contactors ensure that A2 picks up before A3.

A wheelslip or excessive motor current (CMR feedback) will operate the notch back comparator card FD460. The resultant notchback pulse is fed to the notching switch card FD462, at pin 2 which drops out the A3 staging contactor first. If a second notchback pulse is generated, then the A2 staging contactor drops out.

The defire prevent signal from the FD460 prevents defiring when notching back by sending a positive signal to the defire pulse generator card, FD456 at pin 10. This defire prevent signal prevents any output from pin 2 of FD456.

NOTE: *Numbers in parentheses refer to Fig. 2-4.*

1. Reference Inputs (1): A +15 volt reference voltage is either present or absent on each of these inputs depending on the motoring rate called for by the operator.

Rates are as follows:

Rate	Traction Motor Current
SW	180 amps (90 degrees firing limit)
P1	600 amps
P2	
P3	

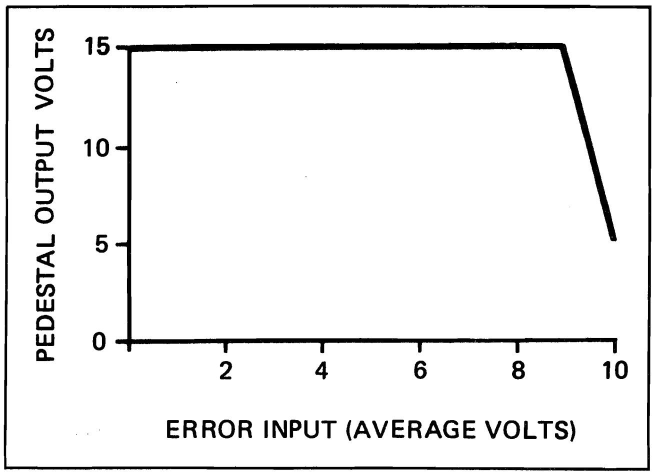
2. Error Voltage (2): This signal provides a control input voltage based on a comparison of actual acceleration with desired acceleration. It consists of the sum of suppression and current feedback during current limit (ignitron firing control) operation. This voltage will be nominal 10 volt dc average with a 30% 25 Hz or 60 Hz ripple superimposed on it. As motor current begins to fall, (when steady state speed is achieved) this voltage will fall in proportion to the CMR filter output of 1 volt per 60 amps of motor current.

3. Pedestal output (2A): If the average value of the dc input (error voltage) (2) is from 0 to 9.0 volts, this input voltage is approximately +15 volts dc. As the input increases beyond 9.0 volts the output falls rapidly. This block contains most of the system gain. The output is heavily filtered, and responds only to the average value of the input. See sketch A.

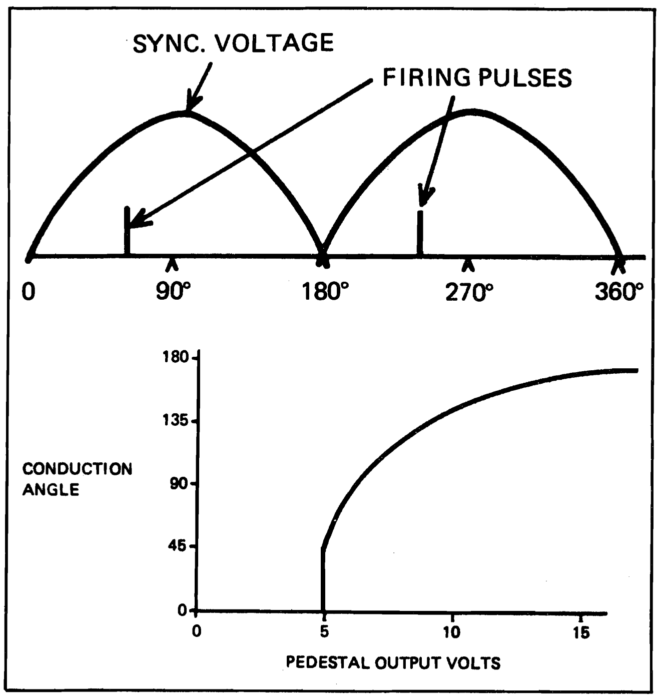
4. Stabilizing loop (2B): This is the unfiltered error voltage. It is used to advance or retard the firing angle of the ignitrons on a per-cycle basis depending on the rate of rise of motor current. This function is needed to prevent unequal conduction angles in the ingitrons on a per-cycle basis.

5. Firing pulses (3): These are phase controlled pulses which are synchronized to the main transformer voltage 14 and 15. The starting point of the pulses relative to the ac wave is proportional to the pedestal output. See sketch B.

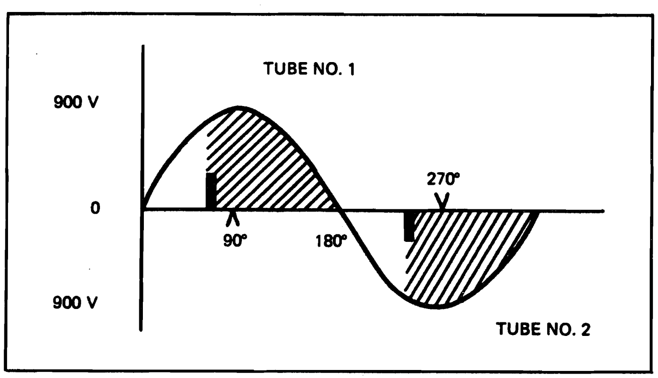
6. Amplified firing pulse (4): Same time relationship as firing pulse (3) except peak height is 20 volts.



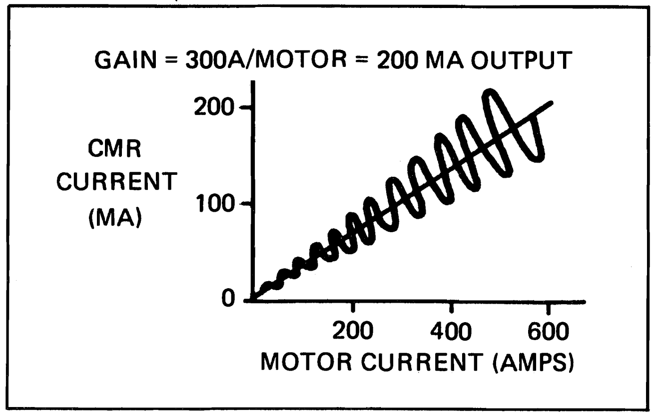
SKETCH A



SKETCH B



SKETCH C



SKETCH D

7. Ignitron firing pulse (5): Same time relationship as firing pulse 3 except that the peak voltage can be 1000 volts and the peak current as high as 80 amps. The minimum pulse width is 500 microseconds.

8. Ignitron tube output (6): This is an ac phase controlled output signal. The sketch shows the output wave form of the tubes. The darkened area reflects the amount of conduction occurring during this output wave form. The example shows a conduction angle of 120 degrees. See sketch C.

9. Rectifier Panel output (6A): This is a pulsating dc voltage obtained by rectifying the ac output from the ignitron tubes.

10. DC input voltage to traction motors (7): This is a dc voltage with a 30% ripple (50 to 120 Hz) superimposed on it. This voltage is the sum of the rectified voltages from the "A", "B" and "C" transformer winding. Only the output from the "A" winding is phase controlled. The notching system controls the closing of the A2 and A3 contactors, which cut in voltages from the "B" and "C" transformer windings, depending upon the power position selected on the master controller.

11. Motor current in leg 1 (8): This is a dc current with a 30% ripple superimposed on it, 0 to 600 amps.

12. Motor current in leg 2 (9): This is a dc current with a 30% ripple superimposed on it, 0 to 600 amps.

13. CMR feedback (10): This is a 1000 Hz square wave current which has a peak value directly proportional to motor current in leg 2. This has a 30% ripple superimposed on it. See sketch D.

14. CMR feedback (11): Same as statement 13, only in motor leg 1.

15. CMR filter output (see Fig. 2-4) (12): This is a dc voltage which is directly proportional to the higher of the two motor leg currents. 1 volt = 60 amps/motcr.

16. Frequency Detector output (13): If the catenary line frequency is less than 40 Hz this output is at 0 volts. It is +18 volts dc if line frequency is 40 Hz or higher.

17. Low Voltage lock-out output (14): If the transformer primary input voltage (catenary voltage) is 8500 volts ac or more, this output is +13 volts dc. If the primary voltage is less than 8500 volts ac, the output is 0 volts.

18. Synchronizing transformer output (15): This transformer has three secondaries which are used for synchronizing the phase control, sensing the main transformer input voltage and sensing the input frequency. The primary is connected to the auxiliary winding of the main transformer.

19. Firing transformer output (16): This transformer has two secondaries which are used to power the firing panel. The output voltage is a nominal 400 V rms and the primary is connected to the auxiliary winding of the main transformer.

20. "A" winding voltage (17): This is a nominal 653 V rms from the main transformer. The output of this winding is phase controlled by the ignitron tubes.

21. Primary Current (18): This is the main transformer primary current (catenary current) which can be 25 Hz or 60 Hz.

22. Primary Current Transformer output (19): This is an ac current proportional to the main transformer primary current (100 amps primary = 1 amp secondary).

23. Line Draw Transformer output (20): This is an ac voltage proportional to the primary current (150 amp primary = 10 volts).

24. Line draw suppression output (21): If the value of main transformer primary current exceeds a preset level (150 amps average) a dc suppression voltage proportional to the rise in current over this preset value is generated. The result is that less current feedback (12) is needed to balance the regulator and the motor current will decrease until the primary current is equal to the preset level.

NOTE: *Numbers in parentheses refer to Fig. 2-5.*

25. Wheelslip detection input (22): If a wheelslip is detected, this input goes to +22 vdc for the duration of the wheelslip. If this input persists longer than 1.0 seconds, a pulse is generated at (26) which causes A3 and A2 to notch back (de-energize) in sequence.

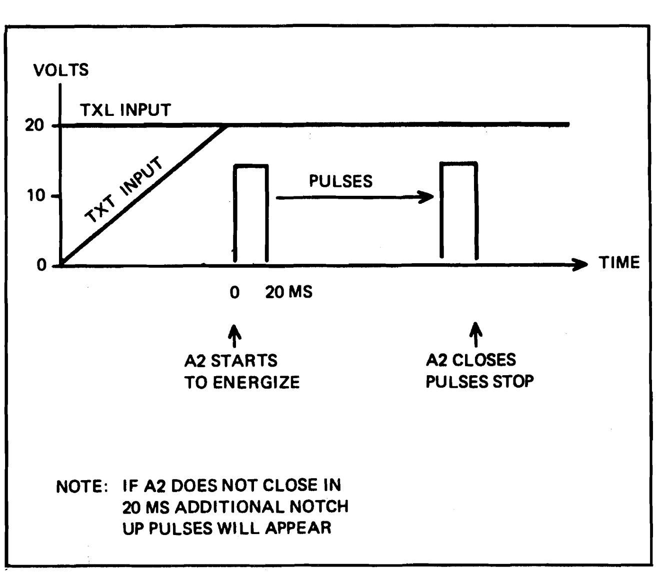
26. TXT comparator transformer input (23): This is an ac signal which has the same wave form as Step 8. The voltage can vary from 0.0 to approximately 20 V average, depending on how far the ignitrons are phase advanced. When this input is approximately equal to the TXL input (24), a notch up pulse is generated.

27. TXL comparator transformer input (24): This is an ac signal which has the same wave form "A" winding. The voltage is 20 V rms with 640 V rms on the "A" winding.

28. Notch up pulse (25): When the comparison of (23) and (24) indicate notch up should take place, a pulse is generated which causes A2 or A3 to be energized. See sketch E.

29. Notch back pulse (26): The notch back pulse will occur if the current feedback exceeds a preset value (set for 720a) or if a wheelslip persists for longer than 1.0 second. A continuous pulse train will occur if either of these conditions exists.

30. Delayed notch back pulse (27): If A3 is energized when a notch back pulse is applied, this pulse will be delayed for approximately 0.4 sec. before it is applied to the A2 notching switch. If A3 is not energized, the pulse is sent to the A2 notching switch with no delay.



SKETCH E

31. Notch up delay (28): When A2 is energized, a dc level is applied to this input. This prevents the A3 notching switch from switching on for approximately 0.4 second. The arming signal must also be present on each notching switch to enable it to turn on.

32. A2 switch input (29): If the A2 notching switch is in the ON state, this input is connected to B– through a transistor.

33. A3 switch input (30): Same as above, only for A3 notching switch.

34. Defire inputs (31): If one of these inputs is high (has +37.5 vdc applied to it) and then switches to a low state, while the other two are in the low state, an output pulse will occur at Step 33. This happens when A1 closes, A2 closes and A3 closes during notch up.

35. Defire output pulse (32): This pulse is approximately 80 m-sec. seconds long and it causes all firing in the ignitrons to be cut off for this length of time.

36. Defire prevent input (33): When this input is energized with a dc level or pulse, the defire generation will not operate. During the notch back sequence, this input is used to prevent defire pulses.

DYNAMIC BRAKING ELECTRONICS fig 2-6

The dynamic braking system and its component interface is presented in the block diagrams (Fig. 2-6) and the associated numbers in the following statements. The system schematic (GE Dwg. 12B106899) should be referred to in conjunction with this explanation.

1. Dynamic brake reference signal (1): This is a positive signal from the DBRT, the value of which is directly proportional to a service reduction at the motorman's brake valve.

2. Regulator error (2): This signal provides control input voltage to the KM controller based on a comparison of actual deceleration with desired deceleration. This voltage is the sum of traction motor current feedback (16) plus a speed taper signal (17). Its normal value is 0 to 10 vdc. If this value exceeds 10 vdc, the pilot motor will stop. If it is below the value, the pilot motor will continue to run until the traction motor current is high enough to develop an excess of 10 vdc at this point.

3. Relay control logic inputs: There are three signals automatically applied to the KM controller electronics based on the selection of the master controller.

   a. Stop input (3): A +38 vdc signal applied here will cause the pilot motor to stop regardless of current feedback or other inputs.

   b. Run input (4): A +38 vdc signal applied here will cause the pilot motor to run whether the hold input (5) is energized or not. The regulator error must also be less than 10 vdc if the pilot motor is to run.

   c. Hold input (5): A +38 vdc signal applied here will cause the pilot motor to stop until the run input is energized.

4. Stop-Run signal (6): This is a low level signal (150 ma) resulting from the five inputs to the current limit and, which will cause the pilot motor to stop or run.

5. Stop-Run output (7): This is a drive current (3-8 amps) to the pilot motor. It is either off or on, depending on the state of the input to the pilot motor drive card.

6. The mechanical interface between the pilot motor and the cam controller contacts is a cam shaft (8) which is driven by the pilot motor.

7. Contact units (9): These are contactor tips which make or break an electrical circuit. They are opened and closed by the cams on the cam shaft. As these contactor tips close, portions of the current limiting resistors are shorted out. This causes the traction motor current to increase.

8. Total motor current (10): This is a dc current regulated by the cam controller up to 1080a, depending on the selection of braking effort.

9. Traction motor current in each motor leg (11) and (12): It can vary from 0.0 to 600a.

10. ATX output (13): This is a saturating transformer output which is a low dc voltage proportional to the rate of change of the traction motor current, and used to hold the KM controller if the rate of change is too great.

11. CMR outputs (14 and (15): These are scaled versions of the traction motor current. 600a = 200 ma. These are current feedback signals and are converted to low voltage signals in a resistor (not shown on block diagram).

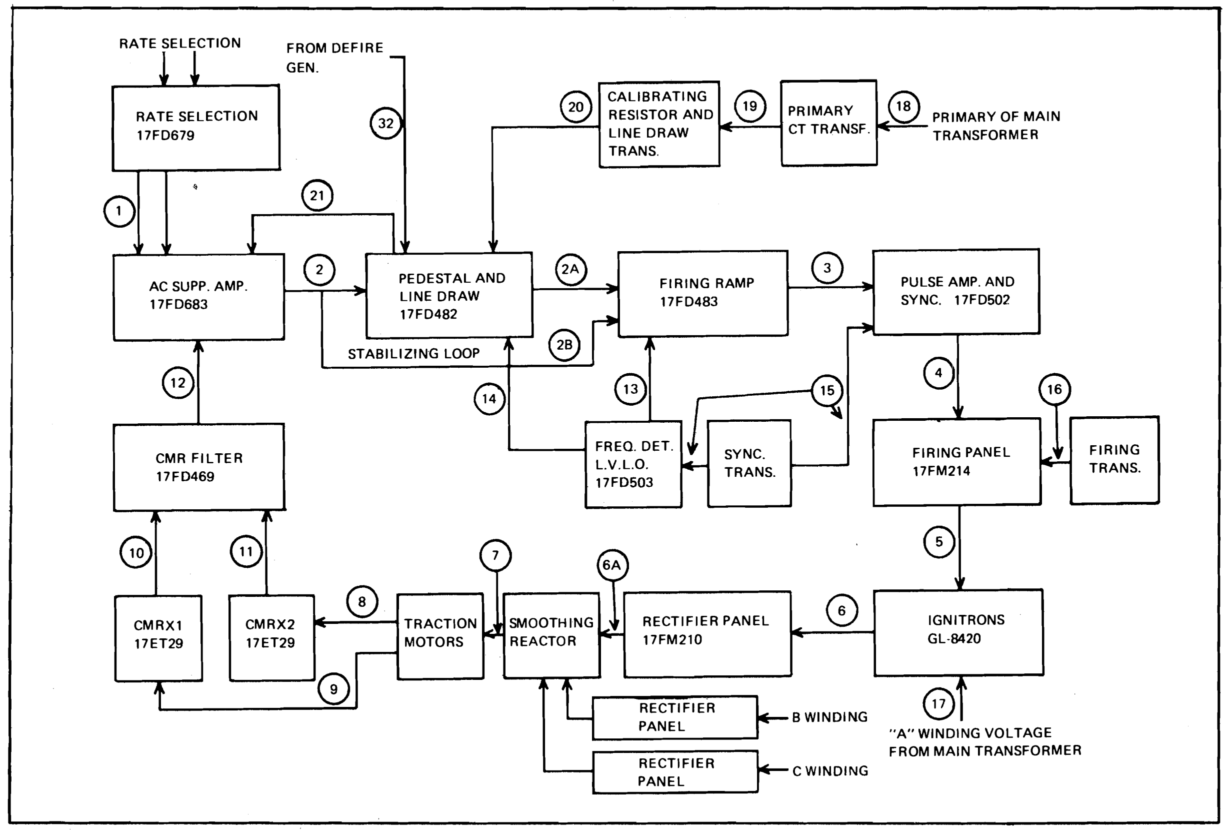


FIG. 2-4. PHASE CONTROL BLOCK DIAGRAM. E-16492A

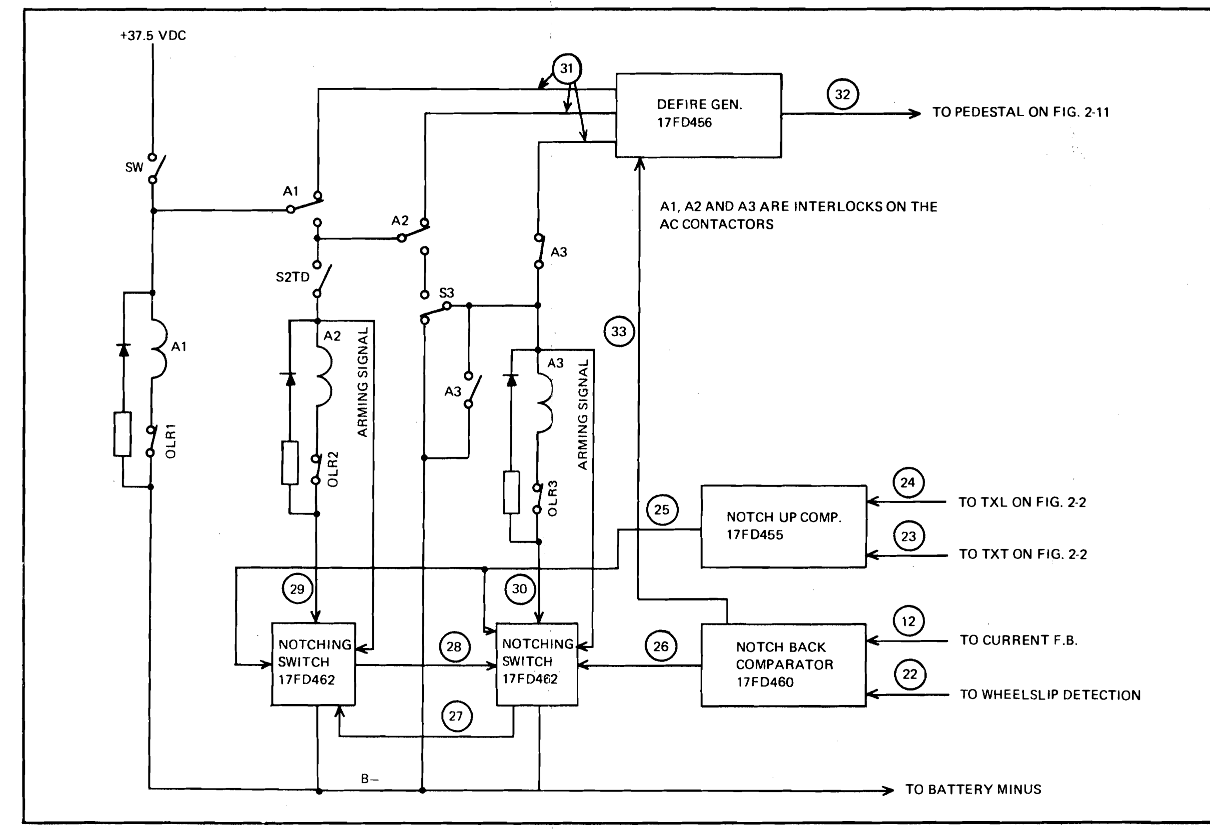


FIG. 2-5. NOTCHING SYSTEM BLOCK DIAGRAM. E-16493A

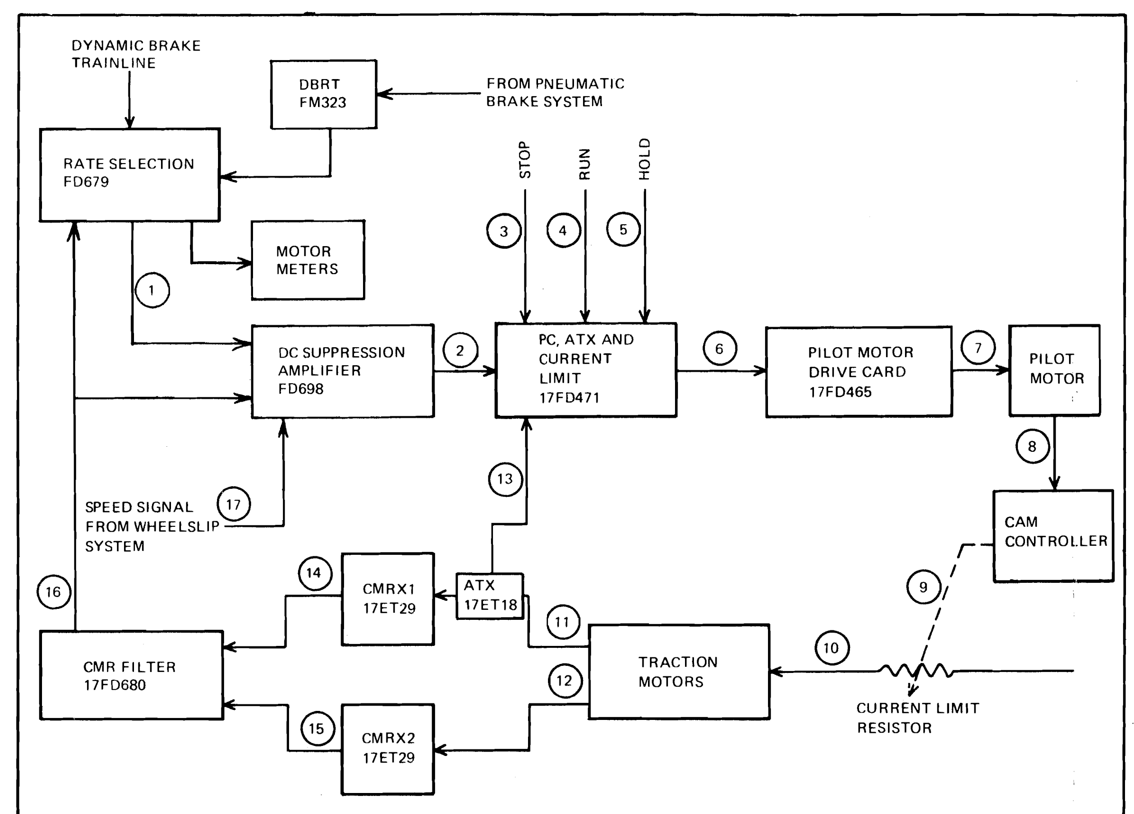


FIG. 2-6. DYNAMIC BRAKE CONTROL SYSTEM BLOCK DIAGRAM. E-16491A

12. Current feedback (16): This is a dc voltage signal which is proportional to the higher of the two CMR outputs. 10V = 600a.

13. Speed taper input (17): This is a negative dc voltage which is proportional to car speed. –5V = 100 mph. This is used in braking only and provides an input signal to the KM controller to reduce the maximum dynamic braking current if the car speed is in excess of 50 mph.

SUPPORT CIRCUIT LOGIC

AUTOMATIC TAPCHANGER AND VACUUM INTERRUPTER

NOTE : *Assume the car (train) to be operating in 11KV 25/60 Hz territory. This will cause the Vacuum Interrupter (VI), AU-2 and AU-3 to be closed, and AU-1 and AU-4 open. Also, SW1 and TCLR relays are picked up and SW2 is dropped out. The TCLL light is on. For logic, see Table III.*

TABLE III

STEP	FUNCTION
1.	First Sequence The car, as it approaches the change-over point in the track, receives an 11KV signal from wayside equipment. The Logic: A. K2 picks up on the FL120 panel (187) 1. LCR picks up (185A) a. LCIR picks up (185A) and locks in. 1). VITR drops out (185B) 2). VI trip solenoid becomes energized, tripping out the VI. AU-2 and AU-3 contacts open and AU-1 and AU-4 close. The trip selenoid becomes de-energized and power is removed from the car. VIOL (VI open light) comes on and TC25 (MV-2) magnet valve becomes energized, causing the tap changer to move from the 11KV position to the 25KV position. As it leaves the 11KV position, SW1 drops out causing TCLR to drop out, de-energizing TCLL. Upon reaching the 25KV position, SW2 picks up causing TCHR to pick up, energizing TCHL. (MV-2) de-energizes and TCR picks up.
2.	Second Sequence The car loses the 11KV signal. The Logic: A. K2 drops out (Sh. 187) 1. LCR drops out (Sh. 185)
3.	Third Sequence The car receives a 25KV signal from wayside equipment. The Logic: A. K1 picks up on the FL120 panel (Sh. 187) 1. HCR picks up (Sh. 185) a. HLR picks up and seals in (Sh. 185)
4.	Fourth Sequence The car loses the 25KV signal. The Logic: A. K1 drops out (Sh. 187) 1. HCR drops out (Sh. 185) a. CLMR picks up and locks in 1). "X" relay (on the VI) (Sh. 186A) picks up and seals in, energizing the VI motor (Sh. 186A). When the VI motor has completed closing the VI, AU-2 and AU-3 contacts open, de-energizing CLMR, the X relay, and the VI motor, and AU-1 and AU-4 close preparing the trip solenoid and the Y relay circuits for another operation. 2). HLR drops out 3). LCIR drops out a). VITR picks up

A manual changeover switch (Sh. 185) MCHS is located in the No. 2 electrical locker. The purpose of this switch is to manually operate the tap changer in the event the changeover receiver (Sh. 187) fails.

The operation of the switch establishes the circuitry to pick up HCR and LCR in sequence simulating the track signals which normally energize K1 and K2 (Sh. 187) which pick up HCR and LCR (Sh. 185) respectively.

Since the tap changer circuitry depends on the correct sequence of HCR and LCR, the following explains the correct operation of the switch.

1. When changing the tap changer from 11KV to 25KV, the switch is rotated in a clockwise direction, from OFF to 11K to 25K to OFF. This results in the following:

   a. It picks up LCR when the switch is at the 11K position, just as if an 11KV signal had been received picking up K2.

   b. It drops out LCR when the switch passes on to the 25K position, just as if the 11KV signal had been lost, dropping out K2.

   c. It picks up HCR when the switch is at the 25K position, just as if a 25KV signal had been received, picking up K1.

   d. It drops out HCR when the switch passes on to the OFF position, just as if a 25KV signal had been lost, dropping out K1.

2. When changing the tap changer from 25KV to 11KV, the switch is rotated in a counterclockwise direction, from OFF to 25K to 11K to OFF. This results in the following:

   a. If picks up HCR when the switch is at the 25K position, just as if a 25KV signal had been received, picking up K1.

   b. It drops out HCR when the switch passes on to the 11K position, just as if the 25KV signal had been lost, dropping out K1.

   c. It picks up LCR when the switch is at the 11K position, just as if an 11KV signal had been received, picking up K2.

   d. It drops out LCR when the switch passes on to the OFF position, just as if the 11kv signal had been lost, dropping out K.

NOTE: *When operating the MCHS, it is important to rotate the switch slowly, so that the control circuit logic can function properly. Also, the switch must be completely rotated from OFF to OFF after each operation.*

NO MOTION

The purpose of this circuitry is to prevent the opening of the doors when train speed is equal to or above 3 mph. To cause the panel to operate properly, it must first be "charged." This is accomplished automatically when the circuit breaker DCB is closed. The sequence is as follows:

1. DCB is closed, applying battery volts to the panel at pin A (Sh. 195).

2. C12 charges rapidly, sending a surge of current through the RS relay. This relay picks up momentarily, long enough to close its contacts at pins 4 and 5, then drops out.

3. When RS contacts 4 and 5 close, battery volts are fed to the CHK relay. This relay picks up and seals in with its own contacts 4 and 5.

The CHK relay remains picked up as long as the system functions normally, that is, as long as the speed sensor inputs are the same, and NMA and NMB relays operate together. Should a sensor fail or one of the relays fail to operate properly with the other one, CHK will drop out. BNMR cannot then be picked up.

A time delay of 30 seconds is built into the CHK relay to prevent nuisance dropouts of CHK.

If CHK does drop out for any reason, disabling BNMR, it can be reset with the no motion reset switch NMRS (Sh. 195), located in the No. 2 electrical locker, to open the doors.

After "charging" the panel (picking up CHK relay) the panel will function to pick up and drop out BNMR relay as it is designed to do. This operation is as follows:

The panel receives inputs from two speed sensors, SS5 on axle No. 2 of the "F" truck and SS6 on axle No. 3 of the "B" truck. These input signals are received simultaneously. Each signal is transformer coupled, filtered, and fed to an NPN transistor. The circuitry is designed such that at speeds equal to or less than 3 mph, the input signals from the speed sensors are not strong enough to keep Q1 and Q2 energized. Thus, with Q1 and Q2 turned off, Q3 and Q4 are turned on, energizing NMA and NMB respectively. Now, with RS dropped out and CHK picked up, BNMR can pick up. This causes B+ to be applied to the open and close trainline circuits which regulate the door operator controls.

As speed increases from zero, Q1 and Q2 become energized at 3 mph, turning Q3 and Q4 off, de-energizing NMA and NMB and dropping out BNMR. This removes B+ voltage to the door operator controls.

PANTOGRAPH CONTROL

The pantograph can be raised or lowered from the cab, by the motorman, by actuating the proper control. The MC plug must be inserted into the "Operate" receptacle (Sh. 168) to energize the "Rise" push button (PUPB).

1. Momentarily close the pan down switch PDS (Sh. 168) to initially charge the air lowering cylinder with air.

2. Depress the PUPB (Sh. 168) momentarily to raise the pantograph.

   a. The UMV (Up Magnet Valve) (Sh. 173) becomes energized, releasing the hold down hook on the pantograph. The pantograph is then allowed to raise by spring pressure. The rate of rise (7 seconds) is regulated by the pantograph lowering cylinder.

3. Close the PDS (Pan Down Switch) to lower the pantograph.

NOTE: *The MC plug need not be inserted to use the PDS.*

   a. The DMV (Down Magnet Valve) (Sh. 173) becomes energized. Air is allowed to pass to the pantograph lowering cylinder. This cylinder brings the pan down in opposition to the uplift of the main springs of the pan. Within 5 seconds the pan has fully descended, a latching hook engages and keeps the pan from raising after air is removed from the lowering cylinder.

CLEAN AIR BLOWER

The single-ended (SE) blower and the double-ended (DE) blower (Sh. 91) supply cooling air to the following components:

1. The SE blower supplies cooling air to two traction motors and itself (and the MA set on the "A" cars).

2. The DE blower supplies cooling air to two traction motors, the main smoothing reactor, the auxiliary smoothing reactor, and the rectifier panel.

The failed blower relay (FBR) (Sh. 92) monitors SE and DE blower operation by sensing air flow in the ducts. If either blower fails, FBR drops out, removing traction power.

The blowers are energized automatically as long as EFBA and EFBB circuit breakers (Sh. 91) in the auxiliary group are closed. As soon as PTR5 comes up, MAC1 picks up (Sh. 92). Then TDR1 comes up and MAC2 picks up 2 seconds later (Sh. 92), which picks up MACR (Sh. 92). Then, when the MA set reaches the correct output frequency, USR (Sh. 92) picks up as a function of AUSR and the MA speed regulating electronics (FD475 card) (Sh. 96). With both USR and MACR picked up, LAR picks up (Sh. 95), energizing the EFC contactor (Sh. 93), which energizes the blower motors with 650 volts dc (Sh. 91). As air is blown through the air ducts, air pressure sensitive contact (SE and DE) close which will energize the FBTD relay (Sh. 92) if the transformer cooling pump contactor TCPC is energized. FBTD in turn picks up to energize the FBR relay (Sh. 92).

Reading and PCRR Singles

If either the SE (MA set) or DE blower fails on the Reading or PCRR Singles, the following occurs:

1. FBTD (Sh. 92) drops out after a 5 second time delay and the FBL (Sh. 92) (Failed Blower Light) comes on.

2. FBR drop out (SH. 92).

3. ACOR relay (Sh. 93) drops out, resulting in de-energizing the air conditioning system, and energizing TDR2 (Sh. 93). TDR2 picks up, energizing TPF (Sh. 93) which de-energizes MAC1. MAC1 then de-energizes the MA set (Sh. 91), and PTR4. MAC1 also drops out TDR2, de-energizing TPF. Since TPF must be manually reset, it does not drop out. Located in the auxiliary group, this relay must be manually reset to operate the MA set (pick up the MAC1 contactor).

4. MAC1 drops out TDR1 and MAC2 (Sh. 92).

5. MAC2 drops out MACR (Sh. 92).

6. MA set electronics drop out AUSR (Sh. 92).

7. AUSR drops out USR, which drops out AFR (Sh. 92).

8. LAR drops out (Sh. 95).

9. EFC drops out (Sh. 93).

10. A1, A2 and A3 contactors (Sh. 9) drop out, removing traction power.

11. P1, P2, B (Sh. 8) drop out to cancel all dynamic braking effort.

SEPTA Married Pairs

If either the SE or DE blower fails on the SEPTA Married Pairs, the following occurs:

On the "B" Car

1. FBTD drops out after a 5 second time delay and the FBL (Failed Blower Light) (Sh. 93) comes on.

2. FBR drops out.

3. ACC drops out (Sh. 94). This de-energizes the air compressor.

4. P1, P2 and B contactors are dropped out, removing dynamic braking.

5. All "A" motoring contactors drop out removing all motoring power.

On the "A" Car

1. FBTD drops out after a 5 second time delay and the FBL (Failed Blower Light) (Sh. 92) comes on.

2. FBR drops out (Sh. 92).

3. ACOR relay (Sh. 93) drops out, resulting in de-energizing the air conditioning system, and energizing the TDR2 relay. TDR2 picks up, energizing TPF (Sh. 93) which de-energizes MAC1. MAC1 then de-energizes the MA set (Sh. 91), and PTR4. MAC1 also drops out TDR2 (Sh. 93), de-energizing TPF. Since TPF must be manually reset, TPF does not drop out. Located in the auxiliary group, this relay must be reset to operate the MA set (pick up the MAC1 contactor).

4. MAC1 drops out TDR1 and MAC2 (Sh. 92).

5. MAC2 drops out MACR (Sh. 92).

6. MA set electronics drops out AUSR (Sh. 92).

7. AUSR drops out USR, which drops out AFR (Sh. 92).

8. LAR drops out.

9. EFC drops out on both "A" and "B" cars (Sh. 93) de-energizing all of the DE and SE blowers.

   a. On the "B" car, the sequence occurs as described under "On the 'B' Car".

   b. On the "A" car, the A1, A2 and A3 motoring contactors drop out (Sh. 9), removing traction power. In addition, P1, P2 and B (Sh. 8) drop out to cancel all dynamic braking effort.

NO POWER AND FAULT LIGHT

The Reading and SEPTA cars are equipped with several fault indication lights both inside and outside of the car. They are:

1. No Power Lights (NPL1, NPL2) - on the outside (Sh. 176).

2. Fault Lights (FTL) - in each cab (Sh. 168).

3. Overload Lights (THL, LGL, LOL) - in the main group (Sh. 11) and the AGL in the auxiliary group.

4. Dynamic Brake Failure light (DBOL) - in each cab (Sh. 9).

The No Power Lights, NPL1 and NPL2, are located externally on the car on the left and right side respectively. They are white lights, and are lit as a result of NPLR relay (Sh. 176) becoming energized through the normally open contacts of NPTD relay (Sh. 11). NPLR seals in and cannot be released until the No Power Reset Switch NPRS (Sh. 176) located in the Trainline Relay Panel is manually actuated. NPTD is energized if a power call is made and the propulsion system does not develop 95 amps within 25 seconds (CLR on Sh. 11 does not pick up). There is one fault light in each cab. They are white lights and are lit (trainlined) as a result of the following:

1. No Power Light Relay (NPLR) - just explained.

2. Reset Ground Relay (RGR) - in the main group (Sh. 11).

3. Transformer Hot Relay (TRF) - in the main group (Sh. 11).

4. Thermal Relay (THR) - in the main group (Sh. 1).

5. Local Overload Relay (OVR) - in the main group (Sh. 11).

Of the above indicated operations, only the Local Overload Relay (LOVR) can be electrically reset either from the cab (reset receptacle on the master controller) or the Local Reset Switch (LRS) located in the main group.

The RGR operates when GR (Sh. 4) picks up as a result of a ground in the traction motor or dynamic braking circuits.

The TRF operates when the thermostat on the main transformer exceeds 95 C (203 F).

The THR operates when a constant excess in current is drawn from the catenary wire.

The LOVR operates when an OLR1, 2 or 3 closes, or when an OLM1 or 2 closes.

The Overload Lights THL, LGL or LOL (Sh. 11) are located in the main group, while the AGL (Sh. 93) is located in the auxiliary group. The THL is blue, the LGL and AGL are red and the LOL is white.

The THL operates when THR or TRF relays pick up (previously explained).

The LGL operates when RGR relay picks up (previously explained).

The LOL operates when LOVR relay picks up (previously explained).

The AGL operates when AGR (Sh. 3A) relay picks up. This relay operates when a ground occurs on the auxiliary winding circuit.

The Dynamic Brake Failure Lights (DBOL) are located one in each cab. The lights are lit during a dynamic brake operational failure only in the lead and offending cars.

The Dynamic Brake Failure Card FD835 (Sh. 63) contains the relay (DBOR) which establishes the circuit for the lights. This relay is operated as a function of the inputs to the electronics on the card. They are as follows:

1. A +22 voltage at pin 6.

2. A B+ voltage at pin 16 if dynamic braking current does not develop.

3. A speed event input voltage at pin 14 from the FD694 card (Sh. 40) which is 0-10V = 0-100 mph.

4. A B– return (common) at pin 44.

5. A B+ voltage when dynamic brake circuitry develops at least 95 amps of braking current (indicating normal operation.)

6. A B+ voltage at pin 38 to light the lights when DBOR interlocks close, the output being pins 30 and 24.

Under normal operating conditions, SCR1 is off and DBOR is dropped out (Sh. 63). If the car is stopped, Q2 is off because there is no speed event signal developed. Q1 is off therefore Q3 is on. With Q3 on, Q6 cannot fire. Q4 is off therefore Q5 is on. With these conditions, the DBOR relay has no current through it and it is dropped out.

As train speed increases to 15 mph, Q2 turns on, the turn-on point being set by P1. This input prevents operation of the panel relay DBOR below this point, which would be the case under normal brake operations.

When brake is called for B1 and B2 contactor interlocks (Sh. 9) close to pick up BCR. When CLR relay picks up as a function of PC (95 amps traction motor current), B+ is applied to pin 4 of the FD835 card. This voltage turns on Q4 and keeps Q3 on. When Q4 turns on, Q5 turns off.

If for some reason, traction motor current is lost (drops below approximately 60 amps) while in the brake mode above 15 mph, CLR drops out. When that happens, two things happen simultaneously.

1. The B+ input of pin 4 is removed, turning Q4 off and Q5 on.

2. B+ is applied to pin 16, turning Q3 off. When Q3 turns off, Q6 produces an output pulse, firing SCR1. Current flows from pin 32, R20, DBOR relay coil, SCR1, Q5 and pin 44. DBOR contacts at pins 4 and 7, also at pins 3 and 8 establish a circuit to light the DBOL indicating lights, one in the cab of the offending car and one in the made-up cab.

TRACTION CIRCUIT PROTECTION

Motor/Brake Cutout Switch (MBCS)

The MBCS is located in the No. 2 electrical locker. It functions to select any one of the following positions.

Normal – This position allows normal operation of both propulsion and braking systems on the car.

Dynamic Brake Cutout – This position cuts out the dynamic braking system on the car.

Motors 1-2 Cutout – This position cuts out traction motors 1 and 2 on the car, but maintains traction motors 3 and 4.

Motors 3-4 Cutout – This position cuts out traction motors 3 and 4 on the car, but maintains traction motors 1 and 2.

All Motors Cutout – This position cuts out all 4 traction motors on the car.

Description

When the propulsion and brake systems are operating correctly on a car, the switch handle is left in the normal position.

When the dynamic brake system is not operating properly, it can be cut out by placing the switch to the dynamic brake cutout position. This will produce a dynamic brake out light in the cab of the affected car and the motorman's cab when braking is selected by the motorman.

When the propulsion system is not operating properly, and if by observing the P&FI panel it can be determined that a fault has occurred with traction motors 1 and 2 or 3 and 4, or all four traction motors, the switch can be placed in the appropriate position to cut out the faulty motors. If any motor is out or all motors are cut out, the no power lights NPL1 and NPL2 come on outside the car and the fault light FTL comes on in the cab.

In addition, if any of the traction motors are cut out, the dynamic brake system is also cut out. This causes the DBOL to come on as previously described.

If any pair of traction motors are cut out (motors 1 and 2 or motors 3 and 4), the propulsion system on that car will be restricted to the minimum acceleration rate.

Operation

The position of the switch handle determines which of its 8 sets of contacts are opened or closed (Sh. 62). These 8 sets of contacts in turn operate the control circuitry required to provide the various functions of the switch.

The following describes the switch operation and its related circuit operation:

NOTE: *All of the contacts of the switch are shown in the system schematic diagram with the switch handle in the Normal position.*

1. In the Normal position, switch contacts 1, 2, 5, 6 and 7 are closed, and 3, 4 and 8 are open.

   a. Switch contact 1 (Sh. 8) is closed to establish AM1 and AM2 pick-up circuit.

   b. Switch contact 2 (Sh. 8) is closed to establish AM3 and AM4 pick-up circuit.

   c. Switch contact 3 (Sh. 9) is open, placing pick-up circuit of motoring contactors through interlocks of AM2.

   d. Switch contact 4 (Sh. 9) is open, placing pick-up circuit of motoring contactors through interlock of AM4.

   e. Switch contact 5 (Sh. 6) is closed, establishing TLP2 pick-up circuit.

   f. Switch contact 6 (Sh. 8) is closed, establishing P1, P2 and B pick-up circuit.

   g. Switch contact 7 (Sh. 10) is closed, establishing CLR pick-up circuit.

   h. Switch contact 8 (Sh. 6) is open, placing pick-up circuit of SPR through contacts of RGR.

2. In the Dynamic Brake Cutout position, switch contacts 1, 2, 5 and 7 are closed and 3, 4, 6 and 8 are open. This step is the same as step 1 except that switch contact 6 (Sh. 8) is open, preventing P1, P2 and B from energizing, thus preventing dynamic braking.

3. In the Motors 1 and 2 Cutout position, switch contacts 2, 3 and 8 are closed, and 1, 4, 5, 6 and 7 are open.

   a. Switch contact 1 (Sh. 8) is open preventing AM1 and AM2 from energizing.

   b. Switch contact 2 (Sh. 8) is closed to establish a pick-up circuit for AM3 and AM4.

   c. Switch contact 3 (Sh. 9) is closed to bypass the pick-up circuit of the motoring contactors around the open interlock of the de-energized AM2.

d. Switch contact (Sh. 9) is open, placing pick-up circuit of motoring contactors through interlocks of AM4.

e. Switch contact 5 (Sh. 6) is open, preventing the pick-up of TLP2, thus limiting the car to minimum acceleration.

f. Switch contact 6 (Sh. 8) is open, preventing the pick-up of P1, P2 and B, thus preventing dynamic braking.

g. Switch contact 7 (Sh. 10) is open, preventing the pick-up of CLR, which provides NPL1, NPL2 and FTL lights.

h. Switch contact 8 (Sh. 6) is closed to establish a pick-up circuit for SPR which when energized removes the 90 degree firing limit of the ignitron tubes.

4. In the Motors 3 and 4 Cutout position, switch contacts 1, 4 and 8 are closed and 2, 3, 5, 6 and 7 are open.

a. Switch contact 1 (Sh. 8) is closed to establish a pick-up circuit for AM1 and AM2.

b. Switch contact 2 (Sh. 8) is open, preventing the pick-up of AM3 and AM4.

c. Switch contact 3 (Sh. 9) is open, placing pick-up circuit for motoring contactors through the interlock of AM2.

d. Switch contact 4 (Sh. 9) is closed to bypass the pick–up circuit of the motoring contactors around the open interlock of the de-energized AM4.

e. Switch contacts 5, 6, 7 and 9 are the same as step 3 above.

5. In the All Motors Cutout position, switch contact 8 is closed and 1, 2, 3, 4, 5, 6 and 7 are open.

a. Switch contact 1 (Sh. 8) is open, preventing the pick-up of AM1 and AM2.

b. Switch contact 2 (Sh. 8) is open, preventing the pick-up of AM3 and AM4.

c. Switch contact 3 (Sh. 9) is open, removing bypass pick-up circuit for the motoring contactors from around the open interlock of the de-energized AM2.

d. Switch contact 4 (Sh. 9) is open, removing bypass pick-up circuit for the motoring contactor from around the open interlock of the de-energized AM4.

e. Switch contacts 5, 6, 7 and 8 are the same as step 3 above.

OLM1 and OLM2

The main coil of these relays sense traction-motor current. OLM1 is in one traction motor circuit, sensing current in motors 1 and 2, and OLM2 is in the other traction motor circuit, sensing current in motors 3 and 4 (Sh. 4).

If either of these overload relays senses excessive motor current in either motoring or dynamic braking, it picks up, causing the following to occur:

1. A1, A2 and A3 contactors (Sh. 8) drop out, removing traction power.

2. P1, P2 and B contactors (Sh. 8) drop out, removing dynamic braking.

3. LOVR (local overload relay) (Sh. 11) picks up which:

a. Drops out NPTD (Sh. 11) which drops out NPLR (Sh. 176) which causes the NPL lights (Sh. 176) to come on.

b. Energizes the 38FL trainline (Sh. 176) to light the fault light FTL (Sh. 168) on all cars.

NOTE: *After resettting from an overload, depress the LPRS (no power reset) to de-energize the NPLR relay and the NLP1, NLP2 lights.*

OLR1, OLR2 and OLR3

The main coil of these relays sense current in the secondary windings of the MT (Sh. 3A). OLR1 is in the "A" winding, OLR2 is in the "B" winding, and OLR3 is in the "C" winding.

If either of these overload relays senses excessive current in motoring, it picks up, causing the following to occur:

To reset after an overload

1. LOVR relay picks up (Sh. 11). See No. 3a and b above. (The NOTE still applies.)

2. The "A" contactor associated with the offending secondary winding drops out as follows:

   a. The exhaust winding becomes de-energized (Sh. 8).

   b. The main coil becomes de-energized (Sh. 9).

Resetting

To reset after an OLM1 or OLM2 overload has occurred, the motorman must place the MC handle to "OFF". This causes the motoring trainlines to become de-energized, and SW drops out (Sh. 7). When SW drops out, PMR picks up (Sh. 10), and a run signal is fed to the pilot motor electronics through the A1 contactor interlock, KM17 contacts and PMR contacts (Sh. 10). The KM controller runs to position 17 and stops. The motorman then places the MC plug from the "Operate" receptacle to the "Reset" receptacle. This energizes the 09RS reset trainline and the OLM1 and OLM2 reset coils are energized through the KM18 contacts and the LOVR relay contacts (Sh. 11).

To reset after an OLR1, OLR2 or OLR3 overload, the same procedure must be followed as just described with one exception. The operator does not have to select "OFF" on the MC. He can reset while remaining in a power position. He does have to observe a six second time element, however. That is, he must place the plug from "Operate" to "Reset" and back to "Operate" within six seconds or suffer an emergency brake application.

PTR Relays

PTR4 (Sh. 91) (1, 2, 3)

Monitors the output of the ASX (Sh. 90) when the MAC1 contactor comes up. Under normal operations, PTR4 is picked up. However, when catenary voltage drops below 8500 volts, PTR4 drops out. When that happens:

1. ACOR drops out (Sh. 93). The air conditioning (Sh. 136) thus becomes de-energized.

PTR5 (Sh. 90)

Monitors the voltage on the D winding of the MT. Under normal conditions, PTR5 is picked up. However, when catenary voltage drops below 6300 volts, PTR5 drops out. When that happens:

On Reading and PCRR Single
and SEPTA Married Pair "A" Cars

1. The MAC1 contactor drops out (Sh. 92), MA set stops.

2. MAC1 drops out TDRL and MAC2.

3. MAC2 drops out MACR.

4. EFC drops out.

5. LAR drops out.

6. ACC drops out, the air compressor stops.

7. FBTD drops out.

8. FBR drops out.

9. P1, P2 and B contactors drop out during dynamic braking.

10. All A motoring contactors drop out, removing propulsion power.

On SEPTA Married Pair B Cars

1. EFC drops out. SE and DE blowers stop.

2. FBTD drops out after a 5 second time delay, and the FBL (failed blower light) (Sh. 93) comes on.

3. FBR drops out (Sh. 93).

4. ACC drops out, de-energizing the air compressor.

5. P1, P2 and P3 contactors drop out, removing dynamic braking.

6. All A motoring contactors drop out, removing all motoring power.

HVS Operation

The High Voltage Sensor, HVS (Sh. 185), is a small panel mounted in the rectifier group. It contains a rectifier bridge, resistors and capacitors and two relays.

The panel functions to remove power to the main transformer in the event that the automatic tap changing equipment becomes inoperative. To perform this function, it causes the following to occur in rapid succession:

1. The Grounding Switch Magnet Valve, GSMV (Sh. 173), becomes energized, grounding the catenary and tripping the wayside track breaker.

2. The Vacuum Interrupter, VI (Sh. 186) becomes energized, opening the primary winding of the main transformer.

3. The PLR relay (Sh. 2) picks up, energizing the Down Magnet Valve, DMV (Sh. 173), and the pantograph comes down.

The panel operates by monitoring the voltage on the D winding of the MT. During normal running operations, this voltage will not exceed 600 volts on either 11KV or 25KV catenary voltage.

If the automatic tap change equipment fails to change the taps of the primary winding of the main transformer when changing from 11KV to 25KV territory, a gross overvoltage will appear on all of the secondary windings of the MT. The HVS panel will sense this overvoltage with an ac voltage input at pins L1 and L2. This input is rectified, filtered and applied to R1. R1 picks up, picking up R2. Interlocks on R2 then close to apply battery voltage to the GSMV and the VI.

The panel automatically resets when the input voltage is removed.

Wheelslip Electronics

The wheelslip-slide system has the capabilities of providing protection against not only individual wheelslip-slides, but also synchronous slip-slides, correcting automatically for wheel diameter differences. It also provides several speed event functions, one used for the speedometer, one used for speed taper, one used for the train overspeed function and speed limitation when a train consist is not made up of entirely new cars, and one used for the dynamic brake failure indicator card. A wheelslip which exceeds 5 mph during motoring results in an output signal to the propulsion electronics which results in a reduction of power by (1) phasing back the ignitron tubes and (2) dropping and staging contactors in sequence.

A wheel slide in excess of 5 mph during braking results in an output signal to the dynamic braking system which (1) causes the KM controller to back up re-inserting traction motor circuit resistance and (2) energize the dump valves to remove air brakes.

The wheelslip electronics consists of:

FD689 card	Frequency to dc converter (Sh. 35, 35A)
FD690 card	Diameter Correction Amplifier (Sh. 36, 36A)
FD691 card	Differential Detector (Sh. 37)
FD692 card	Gated Error Amp and Oscillator (Sh. 38)
FD693 card	Rate of Change Detector (Sh. 39)
FD694 Card	Speed Output and Event (Sh. 40)

These cards are mounted in the FL133 panel located in the No. 1 electrical locker. Their purpose is to monitor axle speed, compare each axle speed signal in a comparator circuit, and respond to significant axle speed differentials (a slip or slide) by energizing WSR1 or WSR2 relays. These relays either reduce power or braking efforts as required to correct the axle speed differential.

The FD689 card (35, 36) receives the raw speed sensor signals at pins 12, 10, 26 and 24. Each input is fed into a Schmitt Trigger, which conducts on the negative half of the speed sensor signal.

NOTE: *Since all four speed sensor signals are treated alike on this card, for clarity, only speed sensor 1 (SS1) and its channel will be described.*

When the Schmitt Trigger receives its rectified signal from pin 12 through D1, it provides positive output pulses of 5-6 volts with a 20 micro-second duration to IC3 which is a "One Shot" multivibrator. This component produces a square wave output of sufficient magnitude to turn on Q1, Q9 and Q5. This creates a 22 volt square wave from the collector of Q9 which is fed through R27, R31 and R35 to IC5. C13 and C25 are filter capacitors which smooth out the square wave. The output of the A1 amplifier on IC5 is a positive voltage fed to pin 18 and directly proportional to the input frequency at pin 12. This voltage signal is fed to pin 6 of the FD690 card.

The 690 card is the diameter correction amplifier card which monitors the output voltage signals of all four speed sensors. Of the four input signals, the signal from SS4 at pin 34 is used to develop a reference signal at pin 32. It is fed through a voltage divider made up of R41, R42 and P1. The setting of P1 establishes a voltage which is fed into the positive pin of the A2 amplifier. The input voltage range at pin 34 is from 0 volts at 0 mph to 10 volts at 100 mph. The output range, which is fed to pins 32 and 30, is the same except that at 100 mph, the output is 9.132 volts. From pin 30, this reference voltage is fed to pin 4 of FD691 card, pin 20 of the FD692 card and pin 2 of FD694.

The other three speed sensor signals on this card are fed into identical circuits. Again using axle No. 1, the output of the 689 card (pin 18) is fed to pin 6, through R2 and on to the A1 amplifier on IC4. In parallel with this circuit are four transistor circuits, Q1, Q2, Q3 and Q4. They are regulated on and off by IC1, which is in effect a digital counter. The transistors and IC1 form a circuit which is called a variable gain amplifier. It works this way:

1. With a voltage at the + of A1 on IC5, a positive output is fed to pins 20 and 18.

2. Normal operation of the counter is such that it turns on Q1 through Q4. The counter operates with each pulse of Q13, which turns on and off by a 100 Hz signal through D2 and R1. Q1 through Q4 become energized in a sequence which draws gradually increasing current through R2, thereby lowering the voltage at the + input to A1 on IC5, thus lowering the output voltage at pin 14.

3. At a point dictated by the Gated Error Amp and Oscillator card FD692 an inhibit signal (explained later) is received at pins 22 and 38, through D1 or D2 as applicable, R1 and turns on Q13. This stops the operation of the counter immediately and it remains in this state with whichever transistors are on remaining on. A reset signal (explained later) is the only remaining influence on this circuit.

The voltage at pin 14 is fed to the FD691 card at pin 8, and to the FD692 card at pin 30. The latter is the feedback voltage required by the inhibit card (FD692) to produce the required inhibit signal at the correct voltage output at the FD690 card pin 16. The FD691 pin 8 input is used to supply the differential detector. This card monitors all four speed sensor voltages as well, and produces the signals to energize the correct wheelslip relays. The card works as follows:

1. Speed sensor inputs at pins 8, 22 and 20 are "corrected" inputs; that is, wheel diameter correction has already taken place in the FD690 card. The speed sensor input at pin 4 is the reference input which is not corrected, nor does it need to be. All inputs are of equal value.

2 Again using axle 1 input at pin 8 for the discussion, the signal is fed to R1 and the (–) of amplifier A1 (pin 1) on IC1. Note at this point that the inputs of axles 4, 1 and 2 are fed in parallel to the (+) of the amplifier (pin 2) through R2, R3 and R4 respectively. Note also that the value of R1 is three times those of R2, R3 and R4, which means that for a 6 volt signal (for example) at the (–) of IC1, there are three 2 volt signals, which combined equal 6 volts, present at the (+) of IC1. This results in a balanced circuit with 0 volts at pin 12 of IC1.

3. Assume that axle 1 slides during a brake application. The voltage at pin 1 of IC1 drops enough to unbalance A1. The A1 produces a positive output at pin 12, through D5, R29 to the base of Q5. If this positive voltage is large enough to overcome a preset bias voltage on the emitter of Q5, established by 22 volts supplying current through pin 6, R49, P1, R50 and Q9 (in the lower right hand portion of the card schematic) and the subsequent setting of P1, Q5 turns on. Note here that the bias voltage taken from P1 (measured at TP6) establishes the sensitivity of the circuit; that is, for a 5 mph speed sensor signal differential, a 5 volt bias voltage is present. For a 14 mph speed sensor signal differential, a 10 volt bias voltage is present. This bias voltage and a related recalibration signal is regulated by Q9 which, when turned on, supplies a 5 volt bias voltage at TP6. When Q9 is turned off, a 10 volt bias is present at TP6. This is regulated by the 10 volt zener ZD3 off the emitter of Q5.

When Q5 turns on, current is drawn from R36 and R35 which turns on Q3. Q3 supplies B+ to pin 16 to energize WSR2 (Sh. 17). When WSR2 picks up:

a. PMR drops out and the KM controller runs back toward the coast position 17, re-inserting resistance into the dynamic braking traction motor circuit.

b. The B Truck Dump Valves (BTDV) (Sh. 17) become energized, removing air brake cylinder pressure on that truck. (If either axle No. 3 or No. 4 would slide, Q6 would be energized, energizing Q1, picking up WSR1 and the A Truck Dump Valves, ATDV.)

Q3 also supplies B+ to D25, R42 to the base of Q4. Q4 now turns on, supplying B+ from D26, Q4 and out to pin 18 to energize WSTD2. This relay establishes the pickup circuit for WSR2 with a time delay of 6 seconds. After the 6 seconds time out, if the slide still exists, WSTD2 drops out, dropping out WSR2 and the BTDV, reapplying braking effort.

Q3 also supplies B+ to D22 and R46 to the base of Q8. Q8 turns on, lowering the bias voltage to TP6, providing a hysterisis effect on Q5. That is, to turn Q5 off, the voltage on the base of Q5 must drop to a significantly lower value than it took to energize it initially. This prevents the possibility of Q5 oscillating on and off.

NOTE: *A slide on axles 1 or 2 will cause the system to operate as just described. A slide on axle 3 or 4 will cause the system to provide the same basic results, using the WSR1 relay and the A Truck Dump Valves, through the circuit operation of D7 or D8, R30, Q6, R33, R34, Q1, pin 10, D24, R41, Q2, D27, pin 3 and D23 (D23 to operate Q8 as previously described).*

4. If a wheelslip occurs (again using axle 1) a rising positive voltage is felt at R1 (from pin 8), and pin 1 of IC1 (the (–) of A1). This produces a negative voltage at

pin 12 of IC1, drawing current through D1. This creates a negative signal which is fed to the negative (pin 4) of IC3 through R26. The output of IC3 switches positive at pin 10. This causes current to flow through R44 to the base of Q7. Q7 turns on, drawing current through D13, R52, D14 and F15, D33 and R36, R34, and R35, turning on both Q1 and Q3. The signals appear at pins 10, 3, 16 and 18 as previously described and Q8 is turned on to provide the hysterisis as previously described. WSR1, WSR2, WSTD1 and WSTD2 become energized (along with the ATDV and BTDV which are ineffective at this time). In addition to all of this,however, is a B+ signal at pin 14 which is supplied to:

a. The AC Suppression Amp (FD683) at pin 16. This removes the error voltage which calls for acceleration.

b. The Notch Back Comparator (FD460) at pin 14. This causes a notch back signal to drop a propulsion winding contactor.

c. The Pedestal card (FD682) at pin 14. This resets the firing pulses to the ignition tubes back to zero degrees.

Q5 and Q6 on the card are also turned on by signals from the rate of change card (FD693). This is explained later.

The Gated Error Amp and Oscillator, FD692, receives four input speed sensor signals at pins 30, 26, 24 and 20 from the FD690 card. These signals are corrected for wheel diameter differential and referenced to the axle No. 4 signal at pin 20. The basic objective of this card is to produce inhibit signals for the digital counters on the FD690 card. For example, they inhibit the counter for axle 1 by energizing pin 22, D1, R1 and turning on Q13 of the FD690 card. Q13 oscillations are halted, the counter ceases to operate, and the voltage at pin 2 of IC4 remains constant with respect to the incoming signal at pin 6.

As previously stated, the FD692 card monitors a feedback signal from the 690 card for each axle speed. IC1, IC2 and IC3 are amplifiers which produce a signal when the input differs by a preset amount. Again using axle 1 for explanation purposes, assume that a more positive voltage is felt at pin 30 and R1. A negative voltage is developed at pin 10 of IC1, and blocked by D1. The digital counter for axle 1 on the 690 card is allowed to lower the input voltage at the amplifier, thereby lowering the amplifiers output voltage. When this voltage, which is the voltage input to IC1, is equal to the reference voltage (or slightly lower), the output of IC1 switches positive. This positive voltage is fed to R17, D1, pin 38 of FD692, pin 22 of FD690, D1, R1, turning on Q13 and stopping the counter. The IC4 output at pin 12 is now constant, in relation to the input of pin 6, and equal in value to the reference signal, developed at pin 10 of IC5 on FD690.

IC4 on the FD692 card is the heart of a 100 Hz oscillator used to operate the 3 digital counters on the FD690 card.

IC5 on this card is a voltage regulator which takes 22 volts from pin 2 of the card and provides 5 volts at pin 8 when Q6 is pulsed off. This is a reset pulse, used by the FD690 card digital counters to reset back to zero. Q6 is pulsed on when the following occurs:

1. Train speed is above 35 mph which supplies a positive voltage at pin 14, ZD2, R32, turning on Q5.

2. Simultaneously with Step 1, a coast signal (positive voltage) is developed at pin 12, R31, R30 and turns on Q4.

3. With Q4 and Q5 on together, C10 discharges rapidly, which momentarily pulses Q6 off. This allows the 5 volts at the collector of Q6 to be felt at pin 8, resetting the digital counter on FD690.

Q4 and Q5 being turned on together also perform another function. That is, they remove an artificial inhibit signal on all three digital counters which is present during all motoring and braking modes. Therefore, in the final analysis, the digital counters only operate if the propulsion system is in a coast mode (master controller handle to OFF) with no braking in effect, and train speed above 35 mph. Otherwise, +22 volts is applied from pin 6, R29, through D5, D6 and D7 to the inhibit circuits and the digital counters on FD690.

Additionally, on FD692, there is a recalibrate circuit, made up of Q2, Q3 and SCR1 which operates to establish the low sensitivity of the FD691 card to 14 mph (10 volt bias on TP6 of FD691). The circuit operates as follows:

1. Using the 22 volt supply from pin 2 of FD692 (assume the car to be newly energized from a dead car status, and TCB circuit breaker just closed, energizing the 22 volt supply), Q2 turns on while Q3 and SCR1 are off. This supplies 17 volts at pin 16 of the FD692 card to pin 38 of the FD691 card. This turns Q9 off, creating a 10 volt bias at TP6. This bias develops the low sensitivity of 14 mph differential on initial startup.

2. As train speed increases to above 35 mph, Q5 turns on. Then when the motorman goes to a coast mode (OFF on the master controller), Q4 turns on. When Q4 turns on, the artificial inhibit signal is removed (as

previously described) and in addition, the base of Q3 drops to approximately 2 volts. Q3 then turns on, energizing the gate of SCR1. SCR1 fires, turning off Q2. The 17 volts at pin 16 is removed, turning on Q9 on the FD691 card, which establishes the 5 volt bias voltage at TP6 which is the high sensitivity mode of operation.

The rate of change card FD693 monitors the output of all four speed sensor signals, directly from the FD689 frequency to DC converter card. Again using axle 1 for explanation purposes, the following description applies:

1. Assume that a rate of change in the upward direction (acceleration) occurs to the car (indicating a synchronous slip). Pin 20 of the FD693 card senses the increase and charges C1. A positive voltage is felt at the negative of IC1 at pin 1, causing the amplifier to switch negative at pin 12. This negative voltage is felt at pin 1 of IC3 through R13 and D1, creating a positive voltage at pin 12 of IC3 which is fed through D9, P1, ZD1, R21, turning on Q1. When Q1 comes on, the voltage on the base of Q3 is drawn to zero, turning Q3 off. This allows C11 to charge up and fire Q4 which produces positive pulses through R30, D16 to turn on Q5. When Q5 turns on, Q6 turns off, Q7 turns on, turning Q8 on. This applies 22 volts to pin 8 and 4 through R40 and R39 respectively, energizing Q6 on the FD691 card through pin 32, D9 and R30, and also energizing Q5 through pin 28, D10 and R29. The resultant operation of Q6 and Q5 has been previously explained in the FD691 card description.

The explanation of axles 2, 3 and 4 result in the same sequence of events with axles 3 and 4 working through IC2, IC3 and Q2.

Q9 and Q10 are clamping transistors used to eliminate nuisance output signals at pins 8 and 4. 22 volts keeps Q9 and Q10 ready if Q8 turns on inadvertently.

The Speed Output and Event card FD694 takes the reference voltage of speed sensor number 4 to develop the speedometer indication and to operate the train overspeed relay TOSR. The input signals to the card are obtained from pins 28 and 2.

The speedometer circuitry is energized from the reference signal from the No. 4 speed sensor. This positive voltage is fed through R1 to the (+) input of IC1.

The output of IC1 is positive directly proportioned to the input signal voltage. For 1540 Hz speed sensor output, which represents a speed of 100 mph, an output voltage of 9.132 volts is created at pin 10 of IC1.

1. This output voltage (0 – 9.132 volts) is fed to R11 which turns on Q1. Q1 turns on Q2 which draws current from the 22 volt power supply at pin 6, through R23, R45, pin 12, the speedometer, pin 16, R19, through Q2 and R18, Q1, R20, P1 and R48. The adjustment for this circuit is P1.

2. The output voltage is also fed through R13, R15 to the positive pin 5 of IC2. Here it is compared with a bias voltage developed at the negative pin 4 of IC2, and adjusted by P2 (TOSR adjustment) off of pin 32 (see note). When the voltage at pin 4 exceeds that applied to pin 4, the output of IC2 switches positive. This does two things:

a. It turns on Q6 when the voltage feeds through D4 and R36. This draws current from B+ at pin 22 through R44, R38, R39 and Q6. This lowers the base of Q9, turning it on, causing current to flow from B+ at pin 22 through R44, Q9 and D5 and out pin 38. This picks up the train overspeed relay TOSR, which results in dropping out PDR and removing power to the car.

b. It sends current through R30 and R29 which turns on Q5. Q5 draws current through R28, lowering the bias voltage at pin 4 of IC2. This is the hysterisis effect to prevent oscillation of IC2.

NOTE: *The bias voltage developed at pin 4 of IC2 regulates the switching point of IC2, but it also has some help. Q3, when turned on by a signal from the new car presence relay at pin 28 which passes through R6 and R8, causes current to flow from IC1 through R13 and R14, lowering the input voltage to IC2. This says that whenever the train is made up entirely of new cars, the voltage of IC1 must be higher than if Q3 were turned off. The circuit is calibrated such that it requires a train speed of 100 mph to develop the required voltage to cause IC2 to switch positive with Q3 on. With Q3 off, a speed of 85 mph will trip IC2.*

3. The output voltage is also fed through R12 to the positive pin 5 of IC3. This amplifier compares this input with a bias voltage applied to pin 4, adjustable by P3 off of pin 18. When the input signal at pin 5 of IC3 exceeds this bias voltage at pin 4, IC3 output switches positive. This point will be adjusted to correspond to a train speed of approximately 35 mph. The positive output voltage is fed to D3 and R37 to turn on Q7. Q7 turns on Q8 which sends current through D6 and out pin 24 to the FD692 at pin 14. This is the 35 mph signal used to arm the circuitry which resets the digital counters on FD690 card.

PERFORMANCE AND FAULT INDICATION PANEL

The Performance and Fault Indication Panel is located in the No. 1 Electrical Locker in every car. The panel has five functions:

1. It will monitor the many propulsion and dynamic braking aspects of the propulsion system and provide a visual display of the correct functioning of these aspects.

2. It will monitor the protective circuits which operate when a fault occurs, and provide a visual display of the fault's identity.

3. The panel will latch on; that is, it will cause the visual indications to latch or "freeze" when a fault occurs, the display panel indicating, until manually reset, the point of successful operational sequence attained when the fault occurred. The panel will not indicate any further system operations or faults once it has been latched.

4. It will provide a visual display of transformer primary current, traction motor current, MA set voltage and MA set frequency.

5. It will provide an indication of the total number of wheelslip or wheel slide occurrances on both the A and B trucks.

The following indications are provided by the P&FI display unit (Sh. 55) in the No. 1 electrical locker:

Meters

1. XFMR Primary Current – Shows the amount of current being drawn through the pantograph and the primary winding of the main transformer. This is a function of current transformer CT1.

2. Motor Current 1, 2 – Shows the amount of current through traction motors 1 and 2. This is a function of CMRX1.

3. Motor Current 3, 4 – Shows the amount of current through traction motors 3 and 4. This is a function of CMRX2.

4. MA Set Voltage – Shows the amount of output voltage from the MA set. This is the function of MA set.

5. MA Set Frequency – Shows the output frequency of the MA set. This is a function of the MA set.

6. Wheelslip Counter A Truck – Shows total wheelslip occurrances on the A truck since panel was last reset. This is a function of wheelslip relay WSR1.

7. Wheelslip Counter B Truck – Shows total wheelslip occurances on the B truck since panel was last reset. This is a function of wheelslip relay WSR2.

Red Lights

1. XFMR Overload – When THR or TFR relays pick up indicating an overload or hot main transformer, the light lights and the panel latches.

2. XFMR Cooling – When TCPC contacts open, indicating a transformer circulating pump failure, the light lights and remains on only if FBTD is dropped out. The panel does not latch.

3. IG Overheat – When one or both ignitron thermostats open indicating an overheated ignitron tube, the light lights and the panel latches.

4. GND – When the GR relay picks up, indicating a ground in the traction motor circuit, the light lights and the panel latches.

5. A1, A2, A3 Overload – When one of the ac overload relays OLR1, OLR2, OLR3, pick up, indicating an overloaded main transformer secondary winding, the light lights and the panel latches.

6. Blowers – When a Single Ended (SE) or Double Ended (DE) blower air sensing switch opens up, indicating a loss of air flow through the air ducts, the light lights and remains on only if FBTD is dropped out. The panel does not latch.

7. No Power – When the No Power Time Delay Relay NPTD picks up, indicating a failure to establish 95 amps or more of traction motor current, the light lights and the panel latches.

8. Motor Overload – When a motor overload relay OLM1 or OLM2 picks up, indicating a traction motor circuit overload, the light lights and the panel latches.

9. Wheelslip Light A Truck – When a wheelslip/slide occurs on the A truck the light lights. The panel does not latch.

10. Wheelslip Light B Truck – When a wheelslip/slide occurs on the B truck, the light lights. The panel does not latch.

NOTE: *The following green lights and white lights are designed to operate only if there is no fault signal applied resulting in the lighting of one of the preceding red lights (excluding the wheelslip lights). This is because the fault signal will also latch the panel. The green and white lights do not latch the panel.*

Green Lights

1. AC Volts – As long as the D winding on the main transformer remains above 6300 volts, PTR5 will remain picked up and the light will be lit.

2. A1 – After the A1 staging contactor picks up, the light lights.

3. A2 – After the A2 staging contactor picks up, the light lights.

4. A3 – After the A3 staging contactor picks up, the light lights.

5. AM1, 2 – When a power position is selected on the Master Controller, and there are no overloads or grounds, the KM controller reaches position 20, and the MBCS is not selecting a motor cutout position on motors 1 and 2, the light lights.

6. AM3, AM4 – The same as step 5, except that the motors are 3 and 4.

7. Motor Amps – When traction motor amps have reached 95 amps, picking up PC relay, and there are no traction motors cutout, the light lights.

8. B1, B2 – When a brake application is made and braking contactors B1 and B2 pick up, the light lights.

9. P1, P2 – When a brake application is made and the cam magnetic contactors P1 and P2 pick up, the light lights.

10. Motor Direction – When a brake application is made and the pilot motor relay PMR picks up to run the KM controller toward position 1, the light lights. When the PMR drops out to run the KM controller to position 20, the light goes out.

11. "20" (Cam position 20) – When a power application is made and the KM controller reaches position 20, the light lights.

12. "17" – When the OFF position on the Master Controller is selected, and the KM controller reaches position 17, the light lights.

13. "1-17" (Cam positions 1 through 17) – When a brake application is made, the brake relay BR drops out, and the KM controller operates in positions 1 through 17, the light lights.

14. "1" (cam position 1) – When a dynamic brake application has been successfully completed and the KM controller has reached position 1, the light lights.

15. Reverser – When a power application is made and the reverser has been successfully thrown to the correct mode, the light lights.

White Lights

1. FWD Trainline – When Forward is selected and the forward trainline 01FW is energized, the light lights.

2. REV Trainline – When Reverse is selected and the reverse trainline 02RV is energized, the light lights.

3. SW Trainline – When SW, P1, P2 or P3 is selected, the Power Dump Relay is picked up and the 03SW trainline is energized, the light lights.

4. P1 Trainline – When P1, P2 or P3 is selected and the 04PA trainline is energized, the light lights.

5. P2 Trainline – When P2 or P3 is selected and the 05PB trainline is energized, the light lights.

6. P3 Trainline – When P3 is selected and the 06PC trainline is energized, the light lights.

7. Emergency Brake – When an emergency brake application is made causing the ER relay to drop out, the light lights.

8. Dynamic Brake – When a service brake application is made and the 07DB trainline is de-energized, the light lights.

Card Functions

The equipment consists of the display unit plus an FL129 panel which houses the cards and interconnecting circuitry required to operate the display panel. The cards are as follows (see Fig. 2-7).

1. FD601 – Latching Lamp Driver (6 cards, identified FD601-1 through FD601-6 on the schematic)

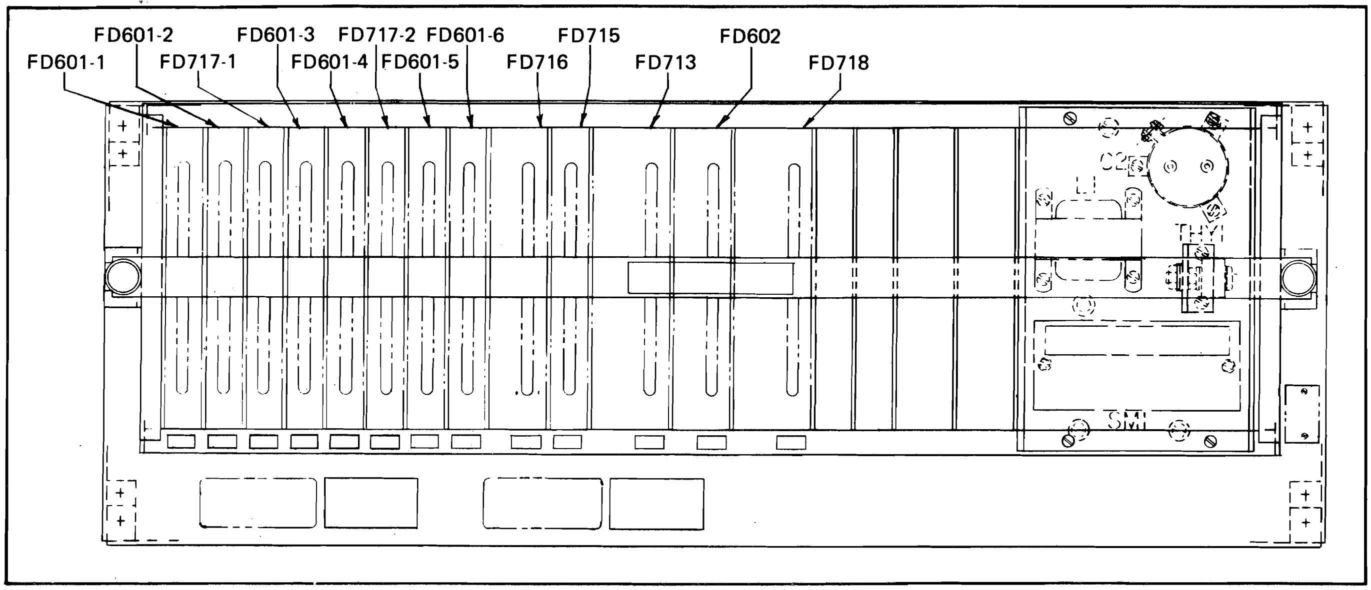


FIG. 2-7. P&FI CARD LOCATIONS. E-19390

2. FD602 – Power Oscillator

3. FD713 – Transformer and Blower Failure Detector

4. FD715 – Hot Ignitron Detector

5. FD716 – Wheelslip Driver and Inverter

6. FD717 – Diode and Resistor (2 cards, identified FD717-1 and FD717-2 on the schematic)

7. FD718 – Metering

An explanation of each card's function is as follows:

FD601 (Sh. 50)

This card receives B+ input signals from throughout the system and from the FD713, FD715, FD716 and FD602 cards within the P&FI panel. These signals are received at pins 8, 14, 20, 26 and 32. (A test switch input at pin 4 simulates all inputs for test purposes.)

When a signal is received at one of the above mentioned pins, the circuits operate as follows (since all of the circuits on the card are identical, this explanation will cover the circuits at pin 8):

The B+ signal is applied to pin 8, R1, D1, R2 to two points:

1. To D3 to pin 3 and out to FD602 to be shunted to common if a fault signal has been received by the panel and the panel is latched.

2. If there is no prior fault signal present and the panel is not latched, the signal will fire the SCR through D4 and the SCR gate circuit. When the SCR fires, current is drawn through the light, pin 12, the SCR, back to common at pin 7.

3. If the input B+ signal is a fault signal, then it is applied to the FD601 and the FD602 panel simultaneously. The result is the SCR will be fired, lighting the light, then the panel will be latched milli-seconds later by the FD602 card, preventing any further panel operation. The lights which are on remain on until the panel is manually reset.

Because there are 31 SCR circuits required to operate the lights of the panel, there are 6 of these cards in the panel, with 5 circuits on each card. The FD715 card (Sh. 53) contains one SCR circuit. The two wheelslip lights are not latched.

FD602 (Sh. 48)

This card contains a free running multivibrator in Q2 and Q3. Without a B+ input at pins 20, 22, 24 or 26, it produces an output signal which is B+ with negative going pulses. These pulses are generated by the operation of the multivibrator, and, as this signal is used through the FD717 cards to power the indicating lights through their respective SCR's, the negative pulses commutate the SCR's off when the gate signals to the SCR's are removed. To produce this output, Q4 is on approximately 90% of the time, providing the B+ at pin 34. The remaining 10% of the time it is pulsed off by Q3 turning on for that period of time.

When a fault signal is received, (this card receives fault signals exclusively) K1 relay picks up.

1. One set of interlocks close:

   a. To seal in the K1 relay through the reset switch and,

   b. To turn on Q1 through R1 and,

   c. To clamp on Q2 through R2 and D1 which causes the multivibrator to stop and clamps Q3 on. This causes Q4 to be clamped on providing a steady state B+ signal at pin 34, latching on all of the lights which at this time are on. All signals can be removed from the panel and the lights will remain on.

2. The other set of contacts close to establish a circuit from pin 3 through R12, Q1 to common. This circuit will bypass all future signals from the FD601 card to common once a fault has occurred, preventing any additional lights.

To reset the panel, de-energizing all of the lights and returning the FD602 card to its normal state, the reset switch is depressed, de-energizing the K1 relay. This releases Q2 which releases Q3, and they return to their normal oscillating state. Q4 again produces a positive signal with negative going pulses at pin 34. The negative pulses will commutate the existing energized SCR's to off, turning out the lights. Q5 on this card serves as a current limit device, becoming energized when output current at pin 34 exceeds .6 amps. As this current is drawn through R10, Q5 turns on, turning off Q4.

FD713 (Sh. 52)

This card monitors SE and DE blower operation and the transformer circulating pump (TCPC) operation.

1. SE and DE blower – A positive voltage is received at pin 12 from the SE and DE blower relay contacts when either the SE or DE blower fails. It is applied through R2, D5, R6 and out pin 26, to the FD601 card to light the Blower Failure light as long as FBTD is dropped out.

2. TCPC – A positive voltage is removed from pin 12 when the TCPC contacts are opened, turning off Q6. When Q6 turns off, B+ that supplied Q6 is diverted through D19, and out pin 24 to light the XFMR Cooling Failure light as long as FBTD is dropped out.

When the car is first being set up for service, and battery power is newly applied to the P&FI panel, the input at pins 42 and 32 are at 0 volts, SCR1 is off, Q3 is on, Q2 is therefore on and no fault signal will be provided at the output pins 24, 26 and 28.

When the MAC1 contactor comes up to start the MA set, pin 32 receives a B+ signal. This turns on Q4. There is still no signal output because SCR1 is off and Q3 and Q2 are still on. Then, when the blowers get up to speed, a B+ signal is applied to pin 42 when FBTD picks up. This turns on SCR1, which turns off Q3 which turns off Q2. The card is ready to provide fault signal outputs.

If the MAC1 input is removed (when MAC1 drops out) Q4 turns off, Q2 turns on, and the card is disabled until MAC1 comes up again.

FD715 (Sh. 53)

This card monitors ignitron thermostat operation and the arrival of the cam controller at position 1.

1. Hot Ignitron Fault Circuit – When both ignitron thermostats IGTH1 and IGTH2 close, indicating normal operating temperatures, pins 34 and 38 of the FD715 card receive B+, keeping Q1 on. Q2 therefore will be off, Q3 will be off, and there will be no output at pin 22 (light) and 24 (latch). If either IGTH1 or IGTH2 opens up, indicating an excessive tube temperature, the B+ at pin 38 is removed, and Q1 turns off. The B+ at pin 34 is now applied to the base of Q2 through D2, R2, D3 and ZD1. Q2 turns on, turning on Q3. Q3 applies B+ from pin 30 through Q3, D4, R8 and D5 to pin 22, and D7 to pin 24. The Ignitron Hot Light lights and the panel is latched.

2. Cam Control Position 1 – Pin 14 receives a B+ signal only when the cam controller reaches position 1 after a successful dynamic brake sequence. This fires SCR1, which establishes the circuit to light the light. At the same time, a B+ signal is applied to FD602 through D10 and pin 10. The signal to FD602 is shunted to common if a fault has occurred, and the SCR1 will not fire to turn on the light.

FD716 (Sh. 54)

This card monitors wheelslip and wheel slide occurrances, selectively lights the correct wheelslip light (truck A or B) and notches a digital counter which provides a running total of wheelslip panel operations.

This card also monitors dynamic braking and emergency braking applications and provides a B+ signal to FD601 to light those respective lights.

This card also receives hot ignitron, cooling system failure, transformer overload and no power fault signals at pins 2, 4, 6 and 8 respectively. These signals are passed directly to a summing point at pin 14 and on to pin 26 of the FD602 card.

1. Wheelslip – When a wheelslip or slide occurs on the A truck, a B+ signal is applied to pin 18, turning on Q1. Q1 turns on Q2, which establishes a complete circuit to:

a. Light the WS-A light at pin 22.

b. Cause the counter to add one more slip/slide occurrance to the total, at pin 24. Current for the counter flows from pin 16 through R7, R6, pin 26, the counter, pin 24, D2, Q2 and back to B– through pin 44.

When a wheelslip occurs on the B truck, a B+ signal is applied to pin 34, turning on Q4. Q4 turns on Q3 which establishes a complete circuit to:

a. Light the WS-B light at pin 32.

b. Cause the counter to add one more slip/slide occurrance to the total, at pin 30. Current for the counter flows from pin 16 through R8, R9, pin 28, the counter, pin 30, D5, Q3 and back to B– through pin 44.

When the wheelslip/slide is corrected and the B+ signal is removed from either pin 18 or 34, the light goes out. There is no latching operation here. Operation of the test switch at pin 20 causes a B+ signal through diodes D17 and D18 which operate both circuits just explained. Both lights (W.S.-A and W.S.-B) light and both counters notch up.

2. Emergency Brake – When an emergency brake application is made, (either electrically or pneumatically initiated), a normally present B+ signal is removed from pin 42. This turns off Q5. The B+ which supplied Q5 is now diverted through D9 to pin 40 to FD601. The emergency brake lights and the panel latches if a fault signal is present at FD602.

3. Dynamic Brake – When a service brake application is made, a normally present B+ signal is removed from pin 38, turning Q6 off. B+ is then diverted through D10 to pin 36 to FD601. The dynamic brake light is lit and the panel is latched if a fault signal is present at FD602.

FD717 (Sh. 49)

This card is the source of voltage for all of the panel's lights. Pin 44 on this card receives a B+ supply from the FD602 card. When there is no fault present, this input B+ signal is a positive voltage with negative going pulses. The negative going pulses are used to commutate the SCR's on the FD601 card off when there is no fault present. When a fault signal is present, the negative pulses are removed from the input voltage, and the SCR's remain on until the reset button is depressed.

Pin 42 supplies a B+ signal through the reset switch to supply the WS-A and WS-B lights.

Pin 2 supplies a B+ signal through the reset switch to supply the blower and transformer cool lights. This B+ signal is present only after the FBTD relay drops out (5 seconds after FBR or TCPC drops out).

FD718 (Sh. 51)

This card monitors traction motor current from CMRX1 and CMRX2, MA set output voltage, and primary transformer current from TXPL (Sh. 1, 2). The card's output is used to drive the traction motor current meters, the primary current meter, the MA voltage meter and the MA frequency meter.

1. Traction motor current – CMRX1 input voltage is applied to pins 10 and 8, rectified and filtered and sent to pins 4 and 12 to the motors 1 and 2 meter.

CMRX2 input voltage is applied to pins 18 and 16, rectified and filtered and sent to pins 14 and 20 to motors 3 and 4 meter.

2. MA Set – MA set output voltage is applied to pins 42 and 36 and fed to two places:

a. Directly to the MA set voltage meter through pins 34 and 38 through FU1.

b. To the MA set frequency meter through pins 30 and 32 after being transformer coupled, rectified and filtered.

3. Primary Current – TXPL, as a function of the output of CT1 applies a scaled voltage representing primary current from the catenary to pins 24 and 26. This voltage is rectified, filtered and fed to the primary current meter through pins 22 and 28. An explanation of the receipt of a typical signal and its path to energize a light is presented in the following. Assume that there have been no fault signals applied and that the panel is not latched.

When the A1 contactor picks up (Sh. 9) one of its interlocks closes at wires 32HJ and 32JA. A B+ signal is thus applied to 32JA and to the P&FI panel at TB252-F (Sh. 45). Pin 20 of the FD601-1 card is thus energized. Following the circuit from there, (on Sh. 50) from pin 20 through the 4.7k resistor, the diode, another 4.7k resistor to a junction point just above the 4.7mfd capacitor. Since the panel is not latched, the signal will proceed to the gate of the SCR, turning it on.

Current now flows from the power circuit breaker, (Sh. 44) through R1, D1, L1 to pin 8 of the FD602 card (Sh. 48), through R10, Q4 to pin 34 (a B+ signal with negative going pulses at this point) out to pin 44 of the FD717-1 card (Sh. 49), through R6 and D6 to pin 13, out to the green A1 indicating light on the display panel, to pin 24 of the FD601-1 card (Sh. 50) through the SCR to pin 7, and back to the power circuit breaker (Sh. 44).

When the A1 contactor drops out, the B+ signal as it was traced up to the gate of the SCR on the FD601 card is removed. The SCR is now turned off with the negative going pulses of its supply voltage from the FD602 card, and the light goes out.

If the just explained signal had been a fault signal, the signal path would be the same except that at the junction point mentioned on the FD601 card will be 2 paths. One will be to the SCR circuit. The other will be a bypass circuit to a diode and pin 3, out to pin 3 of theFD602 card (Sh. 48), through the K1 interlocks (K1 is now energized) R12, Q1, (K1 is now energized), pin 7 to the power circuit breaker (Sh. 44). Since all of the SCR circuits contain this bypass circuit any further signals to these SCR's will be shorted by the bypass circuit to common as just explained, preventing any additional lights.