SD40-2

LOCOMOTIVE SERVICE MANUAL

Electro-Motive Division
La Grange, Illinois

GM

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LOCOMOTIVE SERVICE MANUAL

2nd Edition
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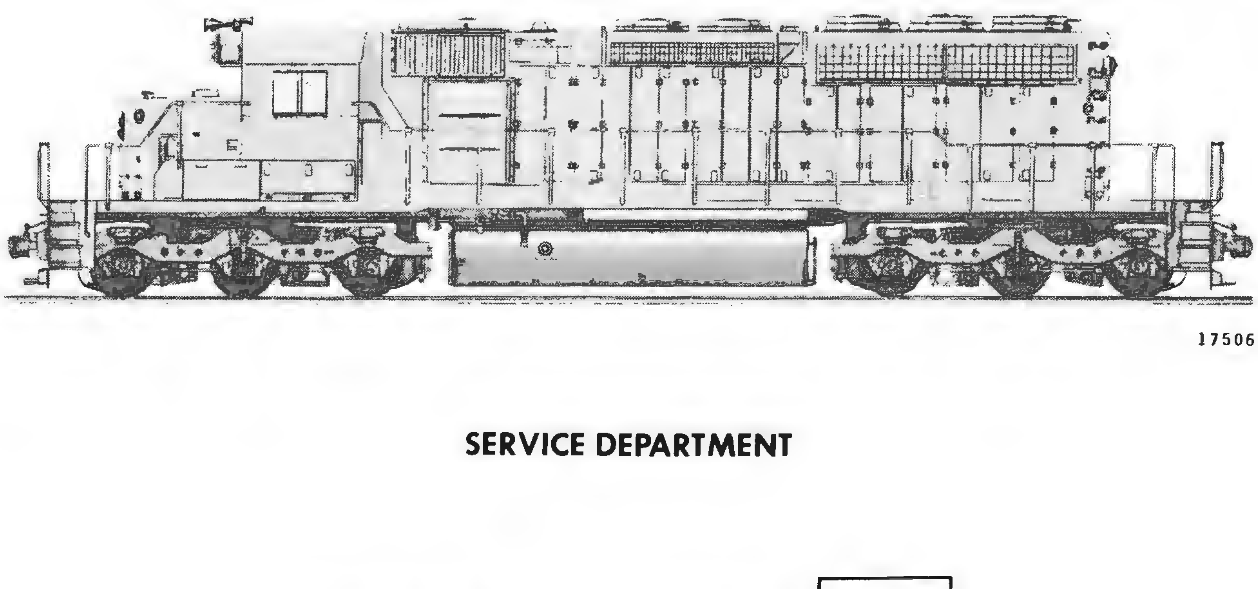

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SERVICE DEPARTMENT

Electro-Motive Division
La Grange, Illinois

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MARK OF EXCELLENCE

FOREWORD

This manual covers mechanical and electrical maintenance. Its purpose is to provide instructions for what may be called "on-the-locomotive" maintenance, and to provide under separate cover material for general familiarization with locomotive components and systems.

Instructions for maintenance that requires deep involvement with component repair, or instructions for rework that involves use of bench apparatus, will be presented in the standard EMD Maintenance Instruction form and in an electrical bench manual that covers repair and bench setting of control system modules and other selected components.

Instructions covering the diesel engine appear in the EMD Engine Maintenance Manual. Certain engine mounted equipment may receive brief mention in this locomotive service manual, but information in the engine maintenance manual covering such equipment takes precedence.

SERVICE DATA PAGES

A Service Data page is included at the back of each section of the Locomotive Service manual. This page provides the following:

1. Reference to applicable Maintenance Instructions and technical manuals.

2. Reference to applicable replacement part numbers.

3. Reference to component manufacturer's technical literature.

4. Reference to applicable tool and testing apparatus numbers.

5. Reference to instructions file numbers for customer manufacturing of testing apparatus.

6. Specific system values for operation or testing.

LOCOMOTIVE SERVICE MANUAL

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SD40-2 GENERAL INFORMATION

Model Designation	SD40-2
Locomotive Type	(C-C) 0660
Locomotive Horsepower	3000
Loaded Weight On Rails	
Minimum Basic	364,250
Maximum Basic	371,750
Diesel Engine	
Model	645E3
Operating Principle	Two Stroke Cycle
Number Of Cylinders	16
Cylinder Arrangement	45°-"V"
Compression Ratio	14.5:1
Rotation (Facing Flywheel End)	Counterclockwise
Bore And Stroke	9-1/16" x 10"
Idle Speed	315 RPM
Full Speed	900 RPM
Main Generator	
Model	AR10A7
Maximum Continuous Current	4000
Maximum Voltage	1250
Auxiliary Alternator	
Model	D14
Nominal Voltage AC	215
Number Of Poles	16
Frequency At 900 RPM	120 Hz
Auxiliary Generator	
Model - Basic	A-7159
Voltage DC	74
Rating	10 KW
Model - Extra	A-8102
Voltage DC	74
Rating	18 KW
Air Compressor	
Type	Water Cooled
Number Of Cylinders	
Basic - Model WBO	3
Special - Model WBG	6
Lube Oil Capacity - Nominal	
3-Cylinder Model	10 Gallons
6-Cylinder Model	18 Gallons

SD40-2 GENERAL INFORMATION (CONT'D)

Compressor Displacement At 900 RPM
- 3-Cylinder Model . . . . 254 Cu. Ft./Min.
- 6-Cylinder Model . . . . 400 Cu. Ft./Min.

Storage Battery
- Model MS420
- Number Of Cells 32
- Voltage 64
- Rating (8 Hour) . . . . 420 Ampere Hr.

Traction Motors
- Model D77
- Type . . . . Direct current, series wound axle hung with rubber nose suspension to damp torque shock.
- Current Rating
  - Maximum Continuous . . . . 1050 with 62:15 Gearing
1075 with 59:18 Gearing

Gear Ratio	Max. Speed	Minimum MPH For Full Horsepower	Minimum Continuous MPH	Tractive Effort At Minimum Continuous Speed
Basic Performance Control - PF17				
62:15	65	-	11.1	83,100
61:16	70	-	12.0	76,700
60:17	76	-	13.0	70,900
59:18	82	-	14.0	65,900
Low Speed Extra Performance Control - PF18				
62:15	65	12.4	7.2	87,400
61:16	70	13.4	7.8	80,700
60:17	76	14.5	8.5	74,650
59:18	82	15.6	9.1	69,300

Trucks -- The HT-C truck is not interchangeable with previous SD truck models.
- Model . . . . HT-C
- Wheel Diameter . . . . 40"
- Basic Bolster . . . . Solid
- Basic Brake Rigging . . . . Single Composition Shoe
- Basic Journal Boxes . . . . JEM
  - 6-1/2" x 12" roller bearing with lateral thrust taken up by cushioning directly by the box.
- Traction Motor Orientation . . . . All in one direction
- Rubber sandwich secondary suspension between truck and frame bolster.
- Hydraulic shock absorber at center axle.
- Dimensions
  - Between Bolster Centers . . . . 43' 6"
  - Truck Wheel Base . . . . 163-3/8"
  - Axle Spacing . . . . 79-5/8", 83-3/4"

SD40-2 GENERAL INFORMATION (CONT'D)

Characteristics
Static Wheel Load
(Basic locomotive weight of 368,000 Lbs.) - Nominally 30,760 Lbs.
Dynamic Wheel Loads
(Variation due to journal spring deflection) - 7000 to 9000 Lbs.
Lateral Wheel-Rail Loads
Steady state net force between leading outside wheel and rail (dry rail, no sanding) and without influence of lateral centerplate load due to coupler angle and buff load level.
5° Curve . . . . 8000 to 10,000 Lbs.
10° Curve . . . . 13,000 to 15,000 Lbs.
Dynamic loads at rail joints or transient rail irregularities on tangent track at 65 MPH . . Common - 10,000 to 12,000 Lbs.
Occasional - 15,000 to 20,000 Lbs.
Handbrake
Operator acts on one cylinder lever. Holds locomotive stationary on 4.2 percent grade when 125 Lbs. of force is applied to the operating handle.
Air Brakes 26L
Curve Negotiation Capability

193 Ft. Radius - 30° Curve -	Represents minimum single unit curve negotiation for an SD40-2 basic single shoe truck as limited by truck negotiation.
193 Ft. Radius - 30° Curve -	Represents minimum single unit curve negotation capability for an SD40-2 equipped with clasp brake truck as limited by truck negotiation.
262 Ft. Radius - 22° Curve -	Represents minimum curve capability for two SD40-2 locomotives in multiple as limited by units with 15-3/4" footboards.
359 Ft. Radius - 16° Curve -	Represents minimum curve capability of an SD40-2 coupled to standard 50' box car as limited by car coupler swing.

All figures are based upon worst conditions with no lateral.

Supplies
Lube Oil Capacity
Basic Oil Pan . . . . 243 Gal.
Increased Capacity Oil Pan . . . . 395 Gal.
Usable Oil
(Volumn between "Full" and "Low" on dipstick)
Basic Oil Pan . . . . 47 Gal.
Increased Capacity Oil Pan . . . . 195 Gal.
Fuel Capacity
Basic . . . . 3200 Gal.
Special Available . . . . 4000 Gal.
3600 Gal.
2600 Gal.
1700 Gal.
Cooling System Capacity . . . . 254 Gallons
Sand Capacity . . . . 56 Cu. Ft.
Major Dimensions
Distance, pulling face of coupler to centerline of bolster . . . . 12' 8"
Distance between bolster centers . . . . 43' 6"

GENERAL INFORMATION (CONT'D)

Distance, pulling face front coupler to rear coupler	68' 10"
Width over cab sheeting	10' 0"
Height, top of rail to top of cooling fan guards	15' 7-3/16"
Width over basic arm rests	10' 4"

WEIGHTS

The weights as listed below are approximate and are intended as an aid in determining the handling procedure to be used. Weights represent lbs. per unit as described.

16-645E3 Diesel Engine	32,500
Starter Motor	80
Starter Motor Bracket	60
Engine Governor	120
Turbocharger	1800
AR10 Main Generator Assembly	16,000
Auxiliary Generator And Blower Assembly	1000
Inertial Air Filter	600
Inertial Filter Screen	35
Inertial Filter Compartment And Hatch	4700
Inertial Filter Hatch (Less Filters)	500
Fuel Tank 3200 Gal.	6650
Fuel Tank 4000 Gal.	9940
Truck Assembly (Single Shoe; Solid Bolster)	57,200
Traction Motor	6000
Axle	1325
Wheel	1015
Gear 62 Tooth	409
Bearing - Inner Race	33
Air Compressor	2325
Air Compressor Shaft	136
Air Compressor Shaft Guard	68
Air Compressor Coupling	48
Lube Oil Cooler	845
Lube Oil Filter	675
Fuel Pump Assembly	81
Fuel Suction Strainer	8
AC Cabinet Assembly	250
Fuel Filter	60
Temperature Switch Manifold	20
Load Regulator Vane Motor	36
Dynamic Brake Fan Assembly	760
Dynamic Brake Resistor Grid	385
Dynamic Brake Grid Shorting Contactor	35
Fan Grill Assembly	190
Radiator Fan Assembly	700
Radiator Core	325
Cab Heater	71
Storage Battery	289
SCR (Generator Excitation)	29

GENERAL INFORMATION (CONT'D)

GENERAL DESCRIPTION

The diesel engine operates on a two-stroke cycle, with power applied on each downward stroke. At the bottom of each downward stoke cylinders are aspirated through cylinder wall ports opening to a chamber that is supplied with pressurized air from a rotary impeller. The pressurized air scavenges spent gases from the cylinder through multiple exhaust valves in the cylinder head. As the piston moves upward the ports are closed off and the exhaust valves close. Air is compressed in the cylinder. At the top of the stroke fuel is injected into the cylinder and ignited by heat of compression to provide power to drive the piston downward until the cylinder wall ports and the exhaust valves again open.

The exhaust gases from the cylinder pass through a manifold and drive a turbine before leaving through the locomotive stack. When starting and at lower power levels there is insufficient exhaust heat energy to drive the turbine and impeller assembly fast enough to supply all the air necessary for combustion. At this time the engine drives the turbocharger through a gear train, the available exhaust gas providing some assistance. At high power levels, the heat energy in the exhaust is sufficient to drive the turbocharger without any assistance, and an overrunning clutch in the gear train disengages the mechanical drive from the engine. The air discharged from the compressor assembly is routed through aftercoolers before it enters the air box.

Two engine mounted gear driven centrifugal pumps supply coolant to engine manifolds connected to cylinder head and liner jackets and to the turbocharger aftercoolers. A coolant return manifold encloses cylinder exhaust ducts. Heated coolant is piped from the engine through the radiators, and through an oil cooler before it returns to the centrifugal pumps. Part of the supply from the pumps is used for cab heating and part is used for air compressor cooling.

The entire system is pressurized, with pressure level maintained by a relief valve at the storage tank cap. A low water pressure detector is connected to the discharge side of the centrifugal pumps to bring about engine shutdown should pump pressure fail.

Automatic temperature control is accomplished by temperature sensing switches flange mounted on a manifold connected to the discharge side of the pumps. The switches control AC power from the D14 alternator to motor driven cooling fans at the radiators. The switches also control magnet valves that supply compressed air to radiator shutter operating pistons. A high temperature switch in the manifold operates to sound an alarm and reduce locomotive power, when engine temperature exceeds a predetermined maximum.

The coolant storage tank is provided with a "rattlesnake" type fill pipe equipped with a manually operated valve, the handle of which interlocks with the pressure cap handle to ensure release of system pressure through the fill pipe before pressure cap removal is possible.

A positive displacement gear type scavenging oil pump draws oil from the engine sump and through a strainer, then pumps it through filters and a cooler and to a second strainer chamber. A dual piston-cooling and lubricating oil pump receives oil from the second strainer and delivers it to engine manifolds for engine lubrication and piston cooling.

Additional filtration is provided in the circuit delivering oil to the turbocharger. A separate electrically driven pump and filter provide turbocharger lubrication and cooling at engine start and after shutdown.

Engine fuel is drawn from the underframe mounted tank through a wire mesh suction strainer to a gear type DC motor driven pump. The pump forces fuel through a primary filter assembly equipped with a dial indicator and pressure bypass that functions should the filter plug. Engine mounted fuel filters provide secondary filtration before the fuel reaches the fuel injectors located at each cylinder. Excess fuel not used by the injectors provides cooling before being returned to the tank.

Fuel injectors supply a precisely metered quantity of atomized fuel to the engine cylinder at a precise moment in the firing cycle. The engine governor operates injector gear racks to maintain the proper amount of fuel needed for the engine speed and power level called for.

GENERAL INFORMATION (CONT'D)

ELECTRICAL TRANSMISSION

Power from the diesel engine is applied to a main generator consisting of a high power alternator with integral rectifier assembly that changes the generated alternating current to direct current.

Main generator output is transmitted to traction motors by means of heavy duty power contactors and gang operated switchgear. The power contactors are rated at 1200 amperes and 1500 volts. They are equipped for flashover protection.

The gang operated switchgear uses a single motor to drive the multiple poles. The poles all operate together and will not drop out, since a positive feed is required to move the poles in either direction. Interlocks are provided for positive coordination of devices.

Direct current traction motors are directly geared to each axle mounted in the locomotive trucks. The motors turn the axles and wheels to provide locomotive pulling power.

LOCOMOTIVE CONTROL

A direct current auxiliary generator driven from the engine gear train provides nominally 74 volts DC for control circuits, battery charging, and lighting. Auxiliary generator voltage is automatically maintained at the desired level by a voltage regulator that uses solid state electronic devices to control the level of the auxiliary generator field excitation.

74 volt DC is delivered from the auxiliary generator to a reference voltage regulator that maintains very stable 68 volts DC at control circuits.

The control circuits are "packaged" in modular form and can be inserted and removed by means of a handle affixed to the face of the module. All modular circuits are bench set and require no readjustment on the locomotive, therefore any modules bearing identical identification numbers are completely interchangeable.

All circuit modules are provided with test points at the face of the module to permit troubleshooting and qualification of the module.

The circuit modules accomplish all control functions such as voltage regulation, throttle response, power control, performance control, generator excitation regulation, matching of generator voltage and current feedback signals with a reference signal, excitation control, wheel slip control, wheel overspeed protection, transition (if applicable), dynamic braking, sanding, and various protective and backup functions.

The load regulator, however, is still the main power controlling device. It modulates the voltage reference signal used by the control modules in order to maintain horsepower at a level related to injector rack position by the linkage and valves in the engine governor.

The horsepower demand of the main generator is maintained by varying the level of excitation current in the main generator field coils. This current, provided by the D14 auxiliary alternator, is rectified by a controlled rectifier that is triggered by the modular control circuits so that the needed value of excitation current is passed by the rectifier.

GENERAL INFORMATION (CONT'D)

GENERAL LEGEND OF ELECTRICAL REFERENCE

In the following general legend of reference designations, the long dash "--" means that a numeral or numerals will appear when the designation is used in a specific wiring diagram. The symbols appear in alpha/numeric order with letters of the alphabet taking first position followed by numerals (Represented by the long dash "--"). The list is general, and all of the reference designations do not necessarily appear on a given wiring diagram.

ALT	Auxiliary (D14) Alternator
AGR	Automatic Ground Reset Relay
AN	Annunciator Module
ASR	Alarm Silence Relay
B	Brake Power Contactor
BATT	Storage Battery (64 V DC)
BCT	Brake Current Transductor
BR--	Brake Relay
CA--	Capacitor
CCR	Compressor Control Relay
CCS	Compressor Control Switch
CDR	Contactor Delay Relay
COR	Motor Cutout Relay
CR--	Rectifier
CR-BC	Battery Charging Rectifier
CR-GR	Ground Relay Rectifier
CRL	Compressor Relay
CT--	Current Transformer
DC--	Braking Grid Shorting Contactor
DE--	Extended Range Dynamic Brake Control Module
DGT	Dynamic Brake Grid Transductor
DGX	Dynamic Grid Excitation Relay
DG--	Dynamic Brake Grid Protection Module
DP--	Dynamic Brake Protective Module
DP--	Dynamic Brake Pilot Relay
DR--	Dynamic Brake Regulator Module
EBT	Electric Blowdown Timer
EFL	Engine Filter Latching Relay
EFS	Engine Filter Switch
ELT	Excitation Limit Transductor
EL--	Excitation Limit Module
EQP	Equipment Protective Relay
ER	Engine Run Relay
ESR	Engine Stop Relay
ESS	Emergency Sanding Switch
ETS	Engine Temperature Switch
FCR	Fan Contactor Relay
FCT	Field Current Transductor
FC--	Fan Contactor
FFS	Fuel Filter Switch
FOR	Forward Directional Relay
FPC	Fuel Pump Contactor
FPCR	Fuel Pump Control Relay
FP-ES	Fuel Prime - Engine Start Switch
FPR	Fuel Pump Relay
FSR	Field Shunt Relay
FSRA	Field Shunt Auxiliary Relay
FS--	Field Shunt Contactor
FS--	Field Shunt Module

GENERAL INFORMATION (CONT'D)

FTX	Forward Transition Auxiliary Relay
FVS	Filter Vacuum Switch
GFA	Generator Field Auxiliary Contactor
GFC	Generator Field Contactor
GFD	Generator Field Decay Contactor
GFX	Generator Field Auxiliary Relay
GPT	Generator Potential Transformer
GR	Ground Relay
GV--	Generator Voltage Module
GX--	Generator Excitation Module
IPS	Independent Pressure Switch
LOT	Lube Oil Transfer Relay
LR	Load Regulator
LSC	Locomotive Spotting Contactor
LTT--	Load Test Transfer Switch
MB--	Motor-Brake Transfer Switch
MCOX	Motor Cutout Auxiliary Relay
MCO--	Motor Cutout Relay
MR	Motoring Relay
MRD	Motoring Relay Delay Relay
MSS	Manual Sanding Switch
MV-AH	Air Horn Magnet Valve
MV-CC	Compressor Control Magnet Valve
MV-DBI	Dynamic Brake Interlock Magnet Valve
MV-OS	Overspeed Magnet Valve
MV-SH	Shutter Control Magnet Valve
MV-818 -824 -880	Filter Blowdown Magnet Valves
MV-- -SF	Forward Sanding Magnet Valve
MV-- -SR	Reverse Sanding Magnet Valve
NLL	No Load Limit Relay
NLLD	No Load Limit Delay Relay
NVR	No (AC) Voltage Relay
OCP	Open Grid Circuit Protective Relay
ORS	Overriding Solenoid
PCR	Pneumatic Control Relay
PCS	Pneumatic Control Switch
PF--	Performance Control Module
PR	Parallel Relay
PRA	Parallel Relay Auxiliary
P--	Parallel Power Contactor
R	Radiator Spray Relay
RC--	Rate Control Module
RE--	Resistor
RE-BC	Battery Charging Resistor
RE-DB	Dynamic Brake Control Resistor
RE-GRD	Dynamic Braking Resistor
RER	Reverse Directional Relay
RHS	Reverser Handle Switch
RH--	Rheostat
RLR	Rated Load Relay
RLTD	Rated Load Time Delay Relay
RS	Radiator Spray Relay
RVF	Transfer Switch Forward Relay
RV--	Directional Transfer Switch
SA--	Sanding Module

GENERAL INFORMATION (CONT'D)

SB--	Sensor Bypass Module
SCR	Gen. Excitation Controlled Rectifier
SE--	Sensor Module
SHS	Selector Handle Switch
SLR	Signal Light Reset Relay
SM--	Starting Motor
SPX, SPY	Series-Parallel Auxiliary Relays
ST	Starting Contactor
STA	Starting Auxiliary Contactor
S--	Series Power Contactor
TA, TB, TC	Temperature Sensing Switches
TDLO	Time Delay Lube Oil Transfer Relay
TDR	Transition Delay Relay
THL	Throttle Limit Relay
THS	Throttle Handle Switch
TH--	Throttle Response Module
TLPA	Turbo Lube Pump Auxiliary Relay
TLPR	Turbo Lube Pump Relay
TLTD	Turbo Lube Time Delay Relay
TLP	Turbo Lube Pump Motor
TM--	Traction Motor
TR--	Transition Control Module
TSR	Transfer Switch Relay
T--	Transformer
VR--	Voltage Regulator Module
WL	Wheel Slip Light Relay
WO--	Wheel Overspeed Module
WS--	Wheel Slip Control Module
WST--	Wheel Slip Transductor

EMD SERVICE DEPARTMENT

LOCOMOTIVE SERVICE MANUAL

SECTION 1

FUEL SYSTEM AND ENGINE STARTING

DESCRIPTION

A pictorial diagram of the fuel oil system is shown in Fig. 1-1. Fuel is drawn from the storage tank through a suction fuel strainer by the motor driven gear type fuel pump.

From the pump the fuel is forced through a primary fuel filter to the engine mounted filter. After passing through the engine mounted double element filter, the fuel flows through manifolds that extend along both banks of the engine.

These manifolds supply fuel to the injectors. The excess fuel not used by the injectors returns to the fuel tank through the return fuel sight glass mounted on the filter housing. A restriction inside the return glass causes back pressure, thus maintaining a positive supply of fuel for the injectors.

The fuel pump delivers more fuel to the engine than is burned in the cylinders. The excess fuel circulated is used for cooling and lubricating the fine working parts of the injectors.

A 25 psi bypass valve is connected across the primary filter. If the primary filter becomes plugged, fuel will bypass and impose the total filtering load on the engine mounted filter.

FUEL SIGHT GLASSES

Two sight glasses, Fig. 1-2, are located on the engine mounted filter housing to give visual indication of fuel system condition.

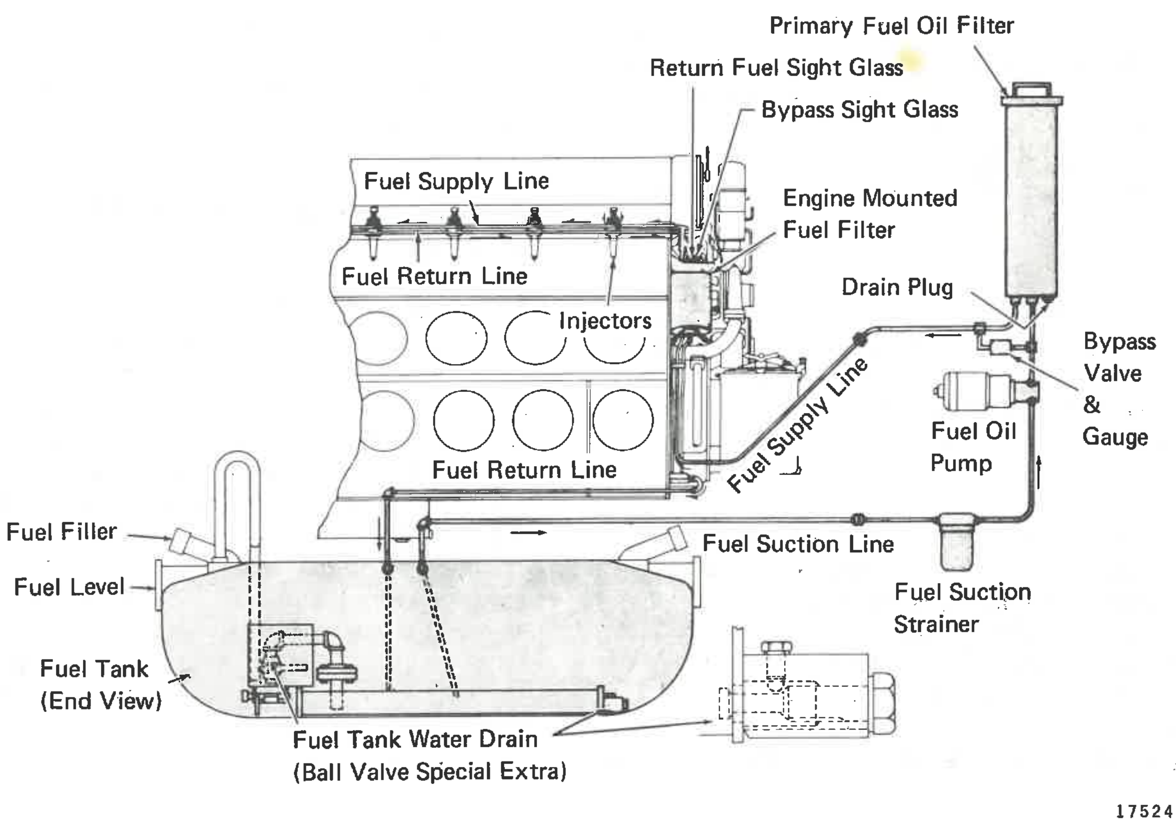

Fig. 1-1 – Fuel Oil System, Pictorial Diagram

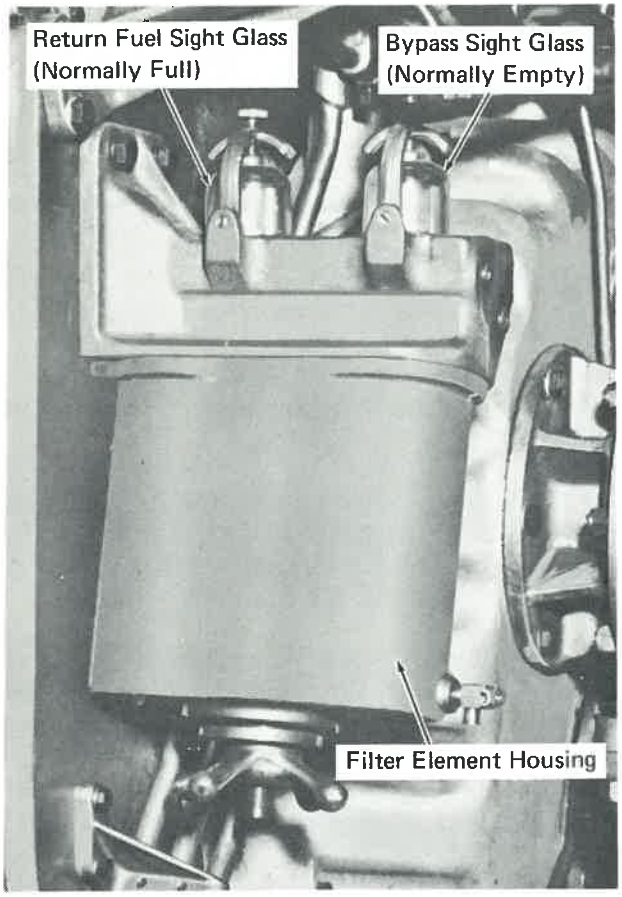

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Fig. 1-2 – Fuel Oil Sight Glasses

For proper engine operation the return fuel sight glass (the glass nearer the engine) should be full, clear, and free of bubbles. The fuel flowing through this glass is the excess not required by the engine. Upon leaving the glass it returns to the fuel tank for recirculation.

At the time of engine start the sight glass will be empty. When the fuel system is primed, turbulent flow will occur and when the fuel in the glass flows clear and free of bubbles the engine may be cranked.

The engine mounted filter is also equipped with a bypass relief valve and sight glass. This sight glass, farther from the engine, is normally empty. When more than a trickle of fuel is seen in the bypass sight glass, it indicates that the relief valve is open. Fuel will pass through the bypass sight glass and relief valve to bypass the engine and return to the fuel tank when the filter elements become clogged. This condition may become serious and cause the engine to shut down from lack of fuel.

EMERGENCY FUEL CUTOFF SWITCHES

In the event of an emergency, the fuel supply to the engine can be stopped by pressing on any one of the three emergency fuel cutoff switches. Two switches, one on either side of the locomotive, are located on the underframe in the vicinity of the fuel filler, and the third switch is located on the engine control panel. The switches are connected in series with the fuel pump control relay FPCR. Pressing in on any of the switch buttons, momentarily, will de-energize the FPCR, stop the fuel pump, and shut down the engine. The buttons are spring loaded and do not need to be reset. See the fuel pump circuit drawing at the end of this section.

MAINTENANCE

FUEL STORAGE FACILITIES

The presence of slime on fuel filters indicates that bacteria and fungi are present in troublesome quantities. Water in the fuel storage tanks should be kept at the lowest possible level. Contact the Electro-Motive Division of General Motors Corporation or the fuel oil supplier for recommendations regarding antiseptic treatment of fuel storage facilities.

DRAINING CONDENSATE FROM THE FUEL TANK

Condensate should be drained from the locomotive fuel tank at the intervals stipulated in the Scheduled Maintenance Program, or more frequently if conditions warrant. During draining, the locomotive should be placed on an incline with the drain end of the tank facing down hill to ensure condensate accumulation at the drain plug, Fig. 1-1, and adequate drainage without loss of fuel. The drain plug is secured to the drain block by a retaining screw. On special order a ball valve drain can be provided to facilitate rapid draining. This valve is enclosed in a protective box with a hinged lid for access to the valve handle. Effective use requires that the tank be at least one third full.

FILLING THE FUEL TANK

The fuel tank can be filled from either side of the locomotive. A short sight level gauge is located next to each fuel filler. This gauge indicates the fuel level from the top of the tank to about 4-1/2" below the top and should be observed while filling the tank to prevent overfilling. DO NOT HANDLE FUEL OIL NEAR AN OPEN FLAME.

The basic filler cap assembly, Fig. 1-3, is equipped with a strainer and pressure relief cap. Periodically inspect the fuel strainer and test the relief cap for operation against the spring. Also check the condition of the filler cap gasket.

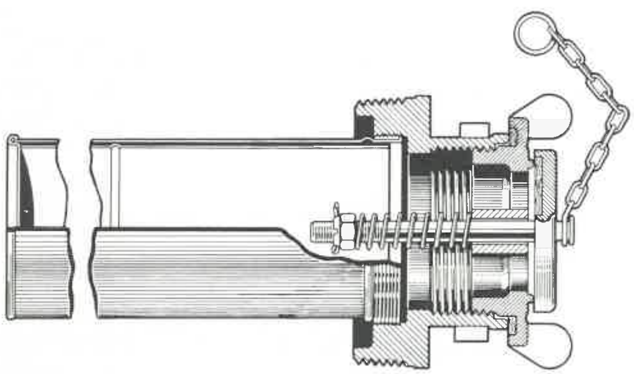

Fig. 1-3 – Fuel Filler Assembly

PRIMARY FUEL SUCTION STRAINER, Fig. 1-4

The fuel suction strainer should be cleaned and inspected at the intervals stated in the Scheduled Maintenance Program or at shorter intervals if operating conditions warrant.

CLEANING PROCEDURE

1. Stop the diesel engine, and place the fuel pump circuit breaker in the OFF position.

2. Remove the bolts holding the strainer shell to the strainer cover, and remove the shell and strainer from the cover. To prevent loss, thread the bolts with washers into the strainer shell threaded openings.

3. Withdraw the wire mesh strainer element, discard the oil and sediment held in the strainer shell.

Fig. 1-4 – Fuel Suction Strainer, Exploded View

4. Clean the wire mesh element in a container of clean fuel oil. A brush may be used and a round wooden dowel employed to spread the pleats and determine the degree of cleanliness, but no special tools are necessary.

CAUTION: Chlorinated hydrocarbon solvents and temperatures above 180° F. will damage the epoxy material bonding the strainer element to the end caps.

5. Clean the shell with fuel oil and wipe clean. Note that the spring in the bottom is spot welded to the shell.

6. Inspect the housing-to-cover "O" ring, and replace it with a new ring if necessary.

7. Place the cleaned strainer element in the shell and reapply the shell to the strainer cover. Tighten firmly into place after making certain the "O" ring is properly seated.

PRIMARY FUEL FILTER, Fig. 1-5

The primary fuel filter element should be changed at the intervals stated in the Scheduled Maintenance Program or at shorter intervals if operating conditions warrant.

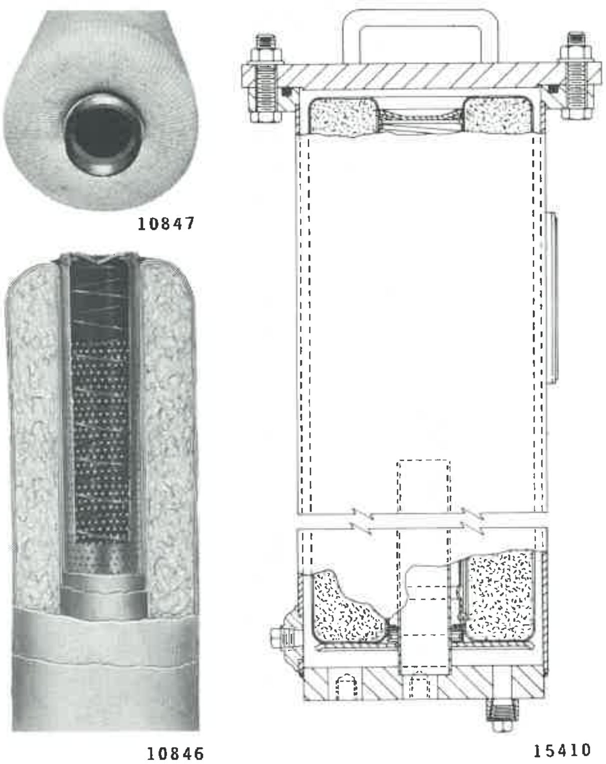

Fig. 1-5 – Primary Fuel Filter And Housing

CLEANING PROCEDURE

1. Stop the diesel engine; place isolation switch in ISOLATE position.

2. Place a container (about 5 gallon size) to catch fuel drainage, and open the 1/2 inch pipe plug drain located at the bottom plate of the filter housing.

NOTE: If the pipe plug or the filter cover are opened shortly after engine shutdown, pressure retained in the system will cause fuel to spurt out of the opening.

3. Loosen the filter cover plate retaining nuts, then twist the cover and remove it. Withdraw and discard the cageless waste-type filter element.

4. Place the fuel prime switch in FUEL PRIME position to introduce a flow of fuel and wash out any sediment that may be held at the base of the filter housing.

5. Insert a new filter element into the housing, being careful not to damage the lower seal on the filter element.

6. Inspect the filter housing cover gasket and replace with a new gasket if necessary. Replace the housing cover and firmly tighten the retaining bolts.

7. Retighten the 1/2 inch pipe plug at the base of the filter housing.

8. Operate the fuel prime switch until fuel runs free and clear of bubbles in the return fuel sight glass. Check for leakage at the drain plug and the housing cover.

PRIMARY FUEL FILTER BYPASS VALVE AND GAUGE, Fig. 1-6

This gauge, Fig. 1-6, only indicates the condition of the primary fuel filter. Increased pressure differential across the primary fuel filter will be indicated by a numerically greater pressure reading on the gauge. Normally, with a new primary filter, the gauge should read zero lbs. When the indicator on the gauge reaches 10 lbs,

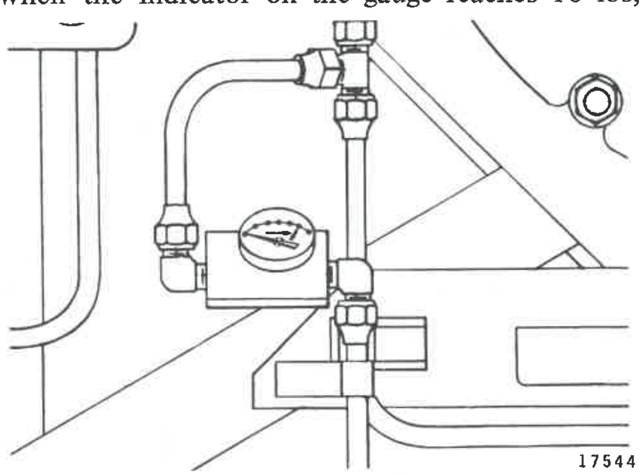

Fig. 1-6 – By-Pass Valve And Gauge

two-thirds of the primary filter has been used. At 25 lbs the fuel will start to bypass the primary fuel filter.

ENGINE MOUNTED FUEL FILTERS

The engine mounted fuel filters should be changed at the intervals stipulated in the Scheduled Maintenance Program and the filter assembly should be cleaned in accordance with the instructions in the Engine Maintenance Manual.

Check the ends of the filter elements for indications of rust. The presence of a combination of water and dirt can cause premature clogging of the filter elements and damage to the engine fuel injectors.

FUEL PUMP AND MOTOR

The motor driven fuel pump, Fig. 1-7, is mounted on the equipment rack. It is an "internal" gear pump driven by battery power during system priming and by power from the auxiliary generator during operation.

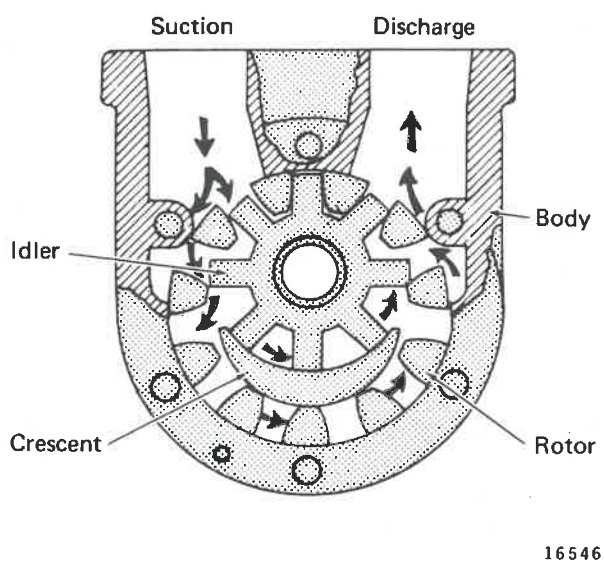

Fig. 1-7 – Fuel Pump Cross Section

Fuel is drawn into the inlet portion to fill a space created by the gear teeth coming out of mesh. The fuel is then trapped in the space between the gear teeth and carried to the outlet side of the pump. There the gears mesh, forcing the fuel from between the gear teeth and through the outlet.

The fuel pump and motor need no routine maintenance if operation is satisfactory. However, the motor and pump should be reconditioned in accordance with EMD Maintenance Instructions listed on the Service Data page. Maintenance should be performed at the intervals stipulated in the Scheduled Maintenance Program.

CAUTION: Use care during washing of the engineroom to protect the fuel pump motor from water. Water in the motor can cause an electrical ground.

FUEL PUMP CIRCUIT Fig. 1-8

When locomotive control circuits are established, and the control and fuel pump switch on the control stand is closed, the fuel pump relay FPR is energized. This establishes a circuit that provides the operator with the means of shutting off the fuel pump from a switch on the control stand. However, before the engine is running, the fuel pump relay performs no function.

FP/ES

SW	POSITION		
	Off	Prime	St
1-2			
3-4			
5-6			
7-8			
9-10			

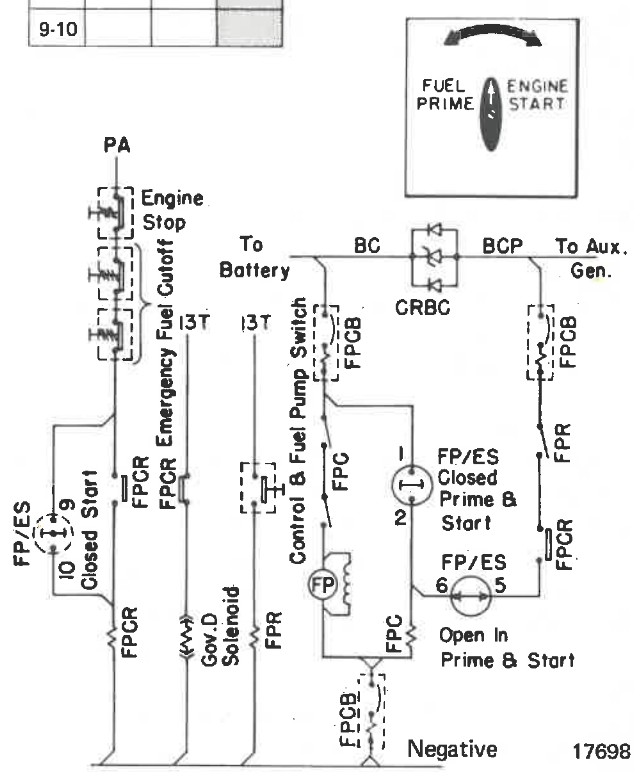

Fig. 1-8 – Fuel Pump Circuit

With the control circuits established, the No. 1 contact of the fuel prime/engine start switch is energized. Power is supplied to the fuel pump contactor coil when the switch is held in the FUEL PRIME position. The contacts of the fuel pump contactor close to supply power to the fuel pump motor.

After the system is primed and fuel flows free and clear in the return fuel sight glass, the fuel prime/engine start switch FP/ES is rotated to the START position. The fuel pump contactor is held picked up, and the 9-10 contacts of FP/ES switch close to pick up the fuel pump control relay FPCR. Other contacts of FP/ES cause cranking motors to turn the engine.

The battery continues to power the fuel pump motor until engine speed comes up sufficiently to cause auxiliary generator output voltage to exceed battery voltage. If the FP/ES switch is released after the engine fires, but before engine speed and auxiliary generator voltage are up, the fuel pump contactor may drop out. However, fuel in the system will allow the engine to come up to speed, and when auxiliary generator voltage is sufficient the fuel pump contactor will again pick up.

The fuel pump motor will stop if either the fuel pump relay FPR or the fuel pump control relay FPCR opens to drop out the fuel pump contactor FPC. However, dropout of FPR and FPC will not immediately stop the engine. Dropout of the fuel pump control relay FPCR is required for immediate withdrawal of injector racks and engine shutdown.

ENGINE STARTING CIRCUIT

The AR10 main generator cannot be motored by the locomotive battery, therefore the engine is provided with dual DC motors, Fig. 1-9, that engage the engine ring gear for cranking.

When the locomotive control circuits are properly set up for engine starting, the fuel pump relay is picked up, the turbo lube pump circuit breaker is closed, the turbo lube pump relay TLPR is picked up, the no (AC) voltage relay NVR is dropped out, and the isolation switch is turned to the START position. When the fuel prime/engine start rotary switch is placed in the PRIME position, the fuel pump contactor is energized by battery power. The fuel pump contactor contacts close to provide power to drive the fuel pump motor. Fuel is pumped to the engine injectors and returned to the fuel tank by way of the return fuel sight glass on the engine mounted fuel filters.

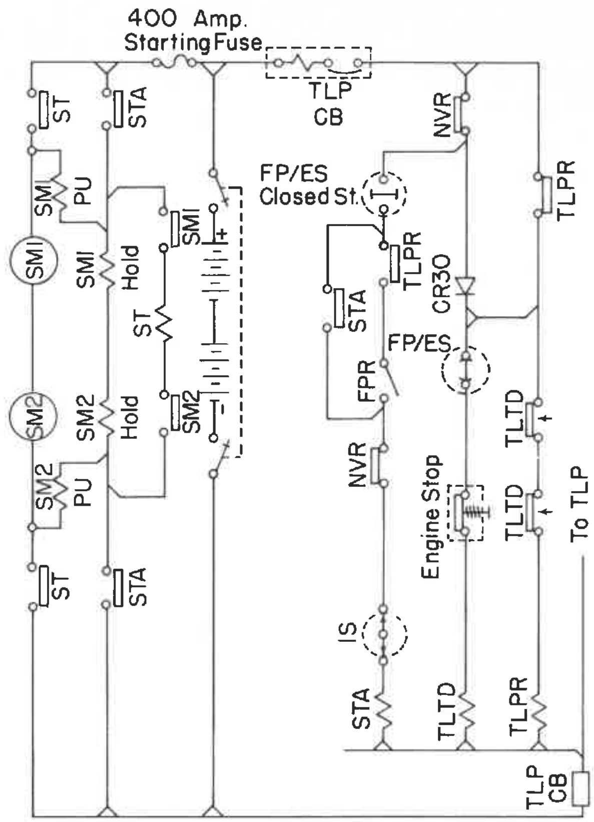

Fig. 1-9 – Engine Starting Circuit, Simplified Diagram

Engine starting contactor STA is energized when the fuel prime/engine start switch is placed in the START position. STA contacts close, and current flows in the pickup coils PU and the hold-in coils of the solenoid assemblies mounted on the starting motors. The PU coils are of low electrical resistance, while the hold-in coils consist of many turns of fine wire and are of high resistance. Current to drive the solenoid plungers flows through the PU coils and through the low resistance of the starting motors.

The solenoid plungers drive the pinion gears to engage with the engine ring gear. When engagement is complete, the SM contacts, operated by the solenoid plungers, close to complete a circuit to the operating coil of the main starting contactor ST. ST contacts close to directly connect the starting motors across the locomotive battery. The motors turn to rotate the engine.

When the ST contacts close, and with the STA contacts remaining closed, the pickup coils PU are effectively shorted out, and no more current flows in the PU coils. Current in the hold-in coils is sufficient to keep the starting motor pinions engaged with the engine ring gear.

After the engine has started and the fuel prime/ engine start switch is released, the STA contactor is the first to drop out, while ST contacts remain closed momentarily. When the STA contacts open, the short around the PU coils is removed, and current flows in the PU coils, but in a direction to obtain polarity opposite to that already established. The solenoid plunger is driven out and the ST contacts open.

As AC from the D14 alternator builds up, the NVR relay picks up. This opens the circuit to the STA operating coil and prevents starting attempts with the engine running.

ENGINE STARTING PROCEDURE

1. Check oil level of the engine governor and air compressor. Check engine coolant level.

2. Open cylinder test cocks and bar over the engine at least one revolution; check for leakage from test cocks. Close the test cocks.

3. Check that all fuses are installed and in good condition.

CAUTION: Make certain that the starting fuse is the correct rating, Fig. 1-10, for the type of starting motors used on the locomotive. Series connected motors (two cable supply) use a 400 ampere fuse. Parallel connected motors (four cable supply) use an 800 ampere fuse.

4. Verify that the main battery switch is closed, and that the ground relay knife switch is closed.

5. Place the local control and the control circuit breakers in the ON (up) position. Verify that the turbo lube pump circuit breaker is in the ON position.

6. Place the control and fuel pump switch(es) in the ON (up) position.

7. Place generator field (and engine run if applicable) switches in the OFF (down) position.

8. Place the isolation switch in the START position.

9. At the equipment rack in the engine room, place the fuel prime/engine start switch in the PRIME position until fuel flows in the return fuel sight glass clear and free of bubbles.

10. Position the governor rack control lever (layshaft lever) at about one-third rack (about 1.6 on the scale), then move the fuel prime/ engine start switch to the START position. Hold the switch in the START position until the engine fires and speed increases.

11. Hold the rack control lever firm at 1.6 on the scale until the engine fires and comes up to idle speed.

CAUTION

1. Before attempting a start after engine has been shut down for any extended period, it must be barred over at least one revolution with the barring lever or equivalent and with the test cocks open.

2. Assist engine start with layshaft 1.6 on rack scale. Do not overfuel during starting.

3. Maximum cranking time 20 seconds.

4. After cranking allow minimum 2 minutes for starter cooling.

5. Do not inch engine with starter.

6. Preheat if engine temperature is less than 50° F.

7. If cylinders are overfueled during starting, pull layshaft full out and crank to purge, then position at 1.6.

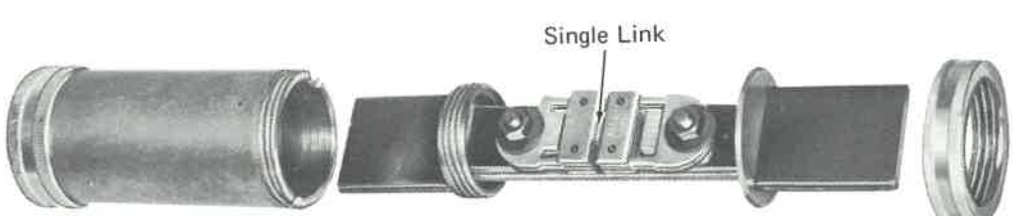

Fig. 1-10 – Starting Fuse - 400 Ampere

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FUEL SYSTEM AND ENGINE STARTING

REFERENCES

Fuel Oil Specifications	M.I. 1750
Fuel Pump Maintenance	M.I. 4110
Fuel Pump Motor Maintenance	M.I. 4101

ROUTINE MAINTENANCE PARTS AND EQUIPMENT

FILTERS

	Part No.
Primary Fuel Filter	8356717
Cageless Waste Type Element	8275432
Cover Gasket	8358905
Engine Mounted Filter	8427284
Honeycomb Element	8299457
Seal, Housing-To-Body	8177030
Suction Strainer	8341983
Wire Mesh Element	8344103
"O" Ring, Housing-To-Cover	8343161
Pressure Differential Gauge With Bypass Valve	8439798

FUEL TANK

Drain Plug Gasket	8010874
Filler Cap Gasket	8065493
Special Ball Valve (Water Drain)	8358203
Valve Repair Kit (Seats and "O" Rings)	8378372

SPECIFICATIONS

Fuel Tank Capacity	
Basic	3200 Gal.
Modifications	4000 Gal.
	3600 Gal.
	2600 Gal.
	1700 Gal.

LUBRICATING OIL SYSTEM

DESCRIPTION

A pictorial diagram of the lubricating oil system is shown in Fig. 2-1. Oil under pressure is forced through the engine for lubrication and piston cooling by the positive displacement combination piston cooling and lubricating oil pump. After circulating through the engine, the lubricating oil drains into the oil pan. The positive displacement scavenging oil pump draws oil from the sump and strainer housing, then forces it through the oil filter and cooler. From the cooler, the oil is delivered to another compartment in the oil strainer assembly where it is available for recirculation by the combination piston cooling and lubricating oil pump.

The lubricating oil pumps are mounted on the front end of the engine and are gear driven by the engine through the accessory drive gear train. The oil strainer housing is also mounted on the front of the engine. The oil cooler and filter assemblies are located in the equipment rack adjacent to the front of the engine at the long hood end of the locomotive.

TURBOCHARGER

The turbocharger lubricating oil is obtained from the engine lubrication system. A separate automatically started motor driven turbocharger auxiliary lube oil pump is used to supply oil to the turbocharger prior to starting the engine and whenever the engine is shut down. The motor is timed to operate approximately 35 minutes after each time it is started. Oil circulation through the turbocharger is necessary prior to starting the engine and during the period when the engine oil pressure is building up to provide proper lubrication. After the engine is shut down, continued oil circulation is necessary to remove residual heat from the turbo and return the hot oil to the oil pan sump. For this auxiliary pump to do the work for which it is intended, the main battery switch and the turbocharger auxiliary pump circuit breaker must be closed. See Fig. 2-2.

The turbocharger auxiliary lube oil pump draws oil from the oil pan sump. Discharge from the pump is then filtered and fed into the head assembly of the main turbocharger oil filter. This head assembly contains the check valves required for proper lube oil flow. Oil from the filter head assembly is then directed to the turbocharger.

TURBOCHARGER AUXILIARY LUBE PUMP CIRCUIT

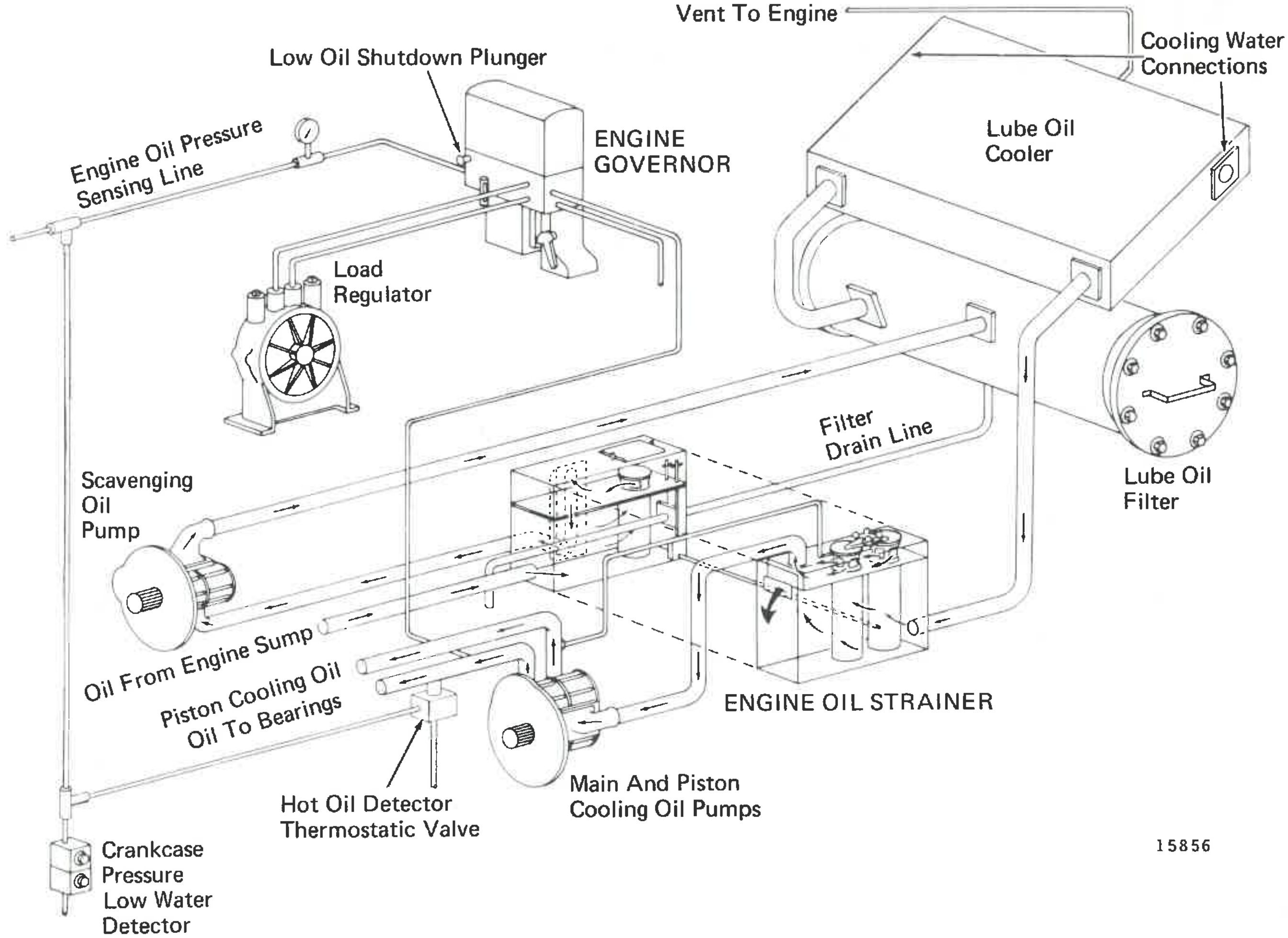
The following text in conjunction with Fig. 2-2 explains the function of the turbo lube pump circuit.

When the main battery switch is moved from an open to a closed position, battery power will flow through the turbo pump circuit breaker and through normally closed contacts of the no voltage relay NVR. (The NVR relay contacts remain closed until the engine is turning and the D14 alternator is delivering AC power.) NVR contacts close upon loss of AC power from the D14 alternator at engine shutdown.

Power through NVR contacts then flows through closed contacts of the fuel prime/engine start switch and through normally closed stop pushbutton contacts to energize the turbo lube time delay relay TLTD. The relay begins timing and normally closed time delay contacts of TLTD remain closed for the period set by the timing device (nominally 35 minutes).

Current flows through the closed time delay pickup contacts of TLTD to energize turbo lube pump contactor TLPR. Contacts of TLPR seal the relay in against NVR pickup, energize the turbo lube pump light, energize the turbo lube pump motor, and set up the circuit to the start contacts of the fuel prime/engine start switch.

The timing relay continues to time as long as current flows to the relay coil. When the relay times out, TLTD contacts identified on Fig. 2-2 with upward pointing arrows, pick up, and TLPR is de-energized. TLPR contacts drop open. The turbo lube pump motor stops, and the turbo aux. pump light goes out. If the engine is running at



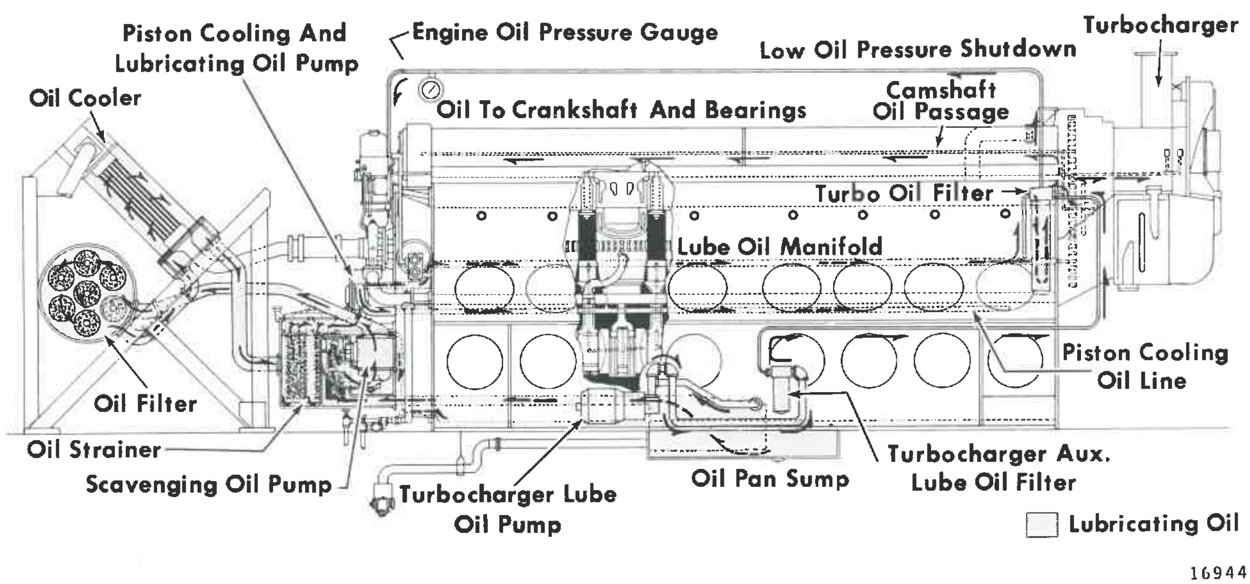


Fig. 2-1 – Lubricating Oil System Pictorial And Schematic Diagram

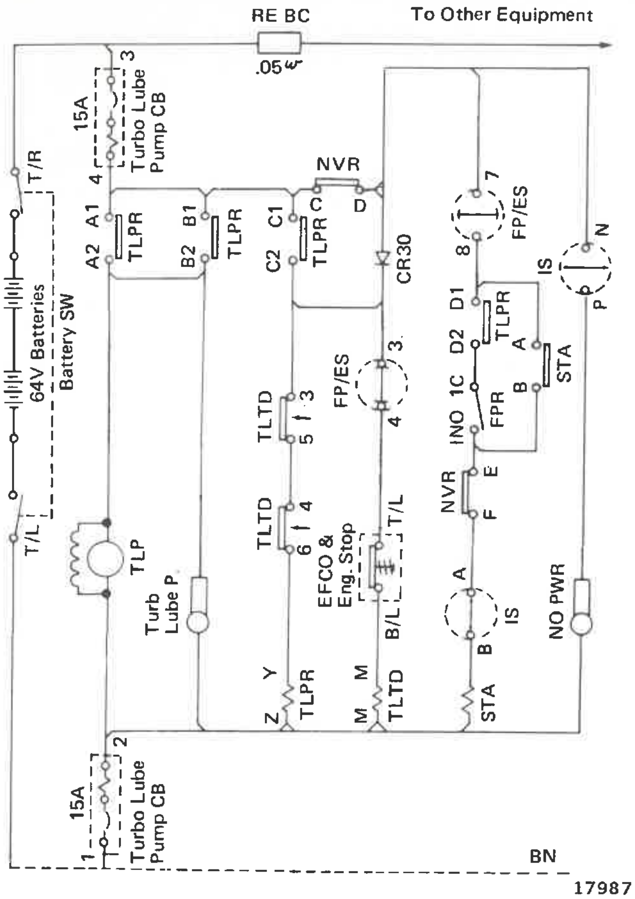


Fig. 2-2 – Turbocharger Auxiliary Lube Oil Pump Circuit

the time of relay timeout, NVR contacts are open and TLTD is de-energized. Dropout of NVR, pressure on the engine stop pushbutton, or movement of the fuel prime/engine start switch will re-establish the timing cycle and turbo lube pump operation.

If the engine is not running when TLTD times out, NVR contacts being closed will hold TLTD energized when TLPR drops out after TLTD pickup. The timing cycle and turbo lube pump operation can be re-established by operation of the fuel prime/engine start switch or by pressure on the engine stop pushbutton.

CHARGING THE LUBE OIL SYSTEM

When charging the system or when adding oil to the system, the oil should be poured through the square opening in the strainer housing, Fig. 2-6. Be sure that the strainer housing internal drain valves are closed.

CAUTION: If the system is charged by pouring oil at the top deck or through an oil pan hand hole, make certain that the last portion of the oil is added at the strainer, and make certain that the strainer housing is full before starting the engine. If the strainer housing is empty, serious engine damage can occur.

ENGINE PRELUBE

Always prelube a new engine, an engine that has been overhauled, or an engine that has been shut down for more than seven days.

Prelube Procedure

1. Remove the pipe plug at the main lube oil pump discharge elbow, and connect an external source of clean, warm oil at the discharge elbow. Pressure of 30 psi. is sufficient.
2. While oil pressure is being applied, open the cylinder compression relief valves and bar the engine over one complete revolution. Check all bearings for oil flow. Also check for restrictions and excessive oil flow. Check for fluid discharge at the cylinder compression relief valves.
3. Remove the pipe plug at the piston cooling oil pump discharge elbow and connect the external oil source at that opening. Check for unrestricted oil flow at each piston cooling tube.
4. Disconnect the external oil source and replace the pipe plugs at the pump discharge elbows. Close the compression relief valves.
5. Apply oil liberally at the engine top deck.
6. Momentarily place the Fuel Prime/Engine Start switch in FUEL PRIME position to activate the auxiliary turbo lube oil pump motor. (Main battery switch and turbo lube pump circuit breaker must be closed.) Look through a rear hand hole for oil flow at the turbocharger end of the engine.
7. Replace and securely close all hand hole covers and engine top deck covers.

LUBE OIL LEVEL GAUGE (DIPSTICK)

An oil level gauge, Fig. 2-3, extends from the side of the oil pan into the oil pan sump. The oil level should be maintained between the low and full marks on the gauge, with the reading taken when the engine is at idle speed and the oil is hot.

NOTE: Under some conditions the oil level may be above the bottom of the oil pan handholes, so care must be taken when the oil pan handhole covers are removed.

LUBRICATING OIL SAMPLING AND ANALYSIS

A lubricating oil sample should be taken for analysis at the intervals stipulated in the Scheduled Maintenance Program. The sample should be submitted to a competent laboratory to monitor the suitability of the oil for continued use. Obtain the sample in the following manner.

1. Run the engine long enough to ensure thorough circulation.
2. Shut the engine down and remove the starting fuse.

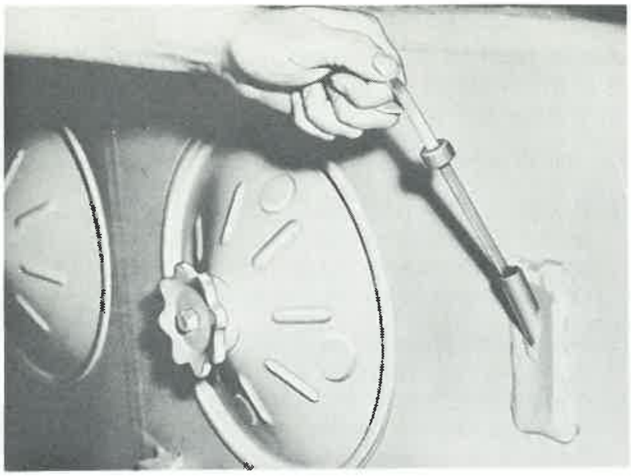


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Fig. 2-3 – Oil Level Gauge – Dipstick

3. Obtain the oil sample (normally 1 pint) at the center of the oil pan halfway between the surface and the bottom of the pan.

NOTE: Inconsistent sampling techniques will produce inconsistent results.

OIL COOLER INSPECTION AND MAINTENANCE

Major servicing of the oil cooler should not be undertaken until the need for such maintenance is definitely established by unsatisfactory operation, suspected oil cooler core leaks, or wide temperature differential between cooling water and engine oil.

DETECTION OF LEAKS

There are no simple methods of detecting water leaks to the oil side of the lubricating oil cooler assembly; however, evidence of water contamination will show up in the routine engine oil samples taken and analyzed as prescribed in the Scheduled Maintenance Program. Any such evidence calls for a close examination of the cooler. Maintenance instructions for cleaning and repair of lubricating oil cooler are listed on the Service Data page.

DETECTION OF DIRTY OIL COOLER CORE

Proper lubricating oil temperatures are dependent upon maximum lube oil cooler performance. Operation of the hot lubricating oil detector provides indication that the lube oil cooler may not be functioning efficiently. However, in order to obtain a valid indication of oil cooler performance, the locomotive must be operated at its full rated load and engine speed while the oil and water temperatures are allowed to stabilize.

PROCEDURE

1. At the water pump discharge elbow, Fig. 2-4, fill the thermometer well with oil. Water temperature into the engine will be taken at this point.

2. Set up engine loading apparatus capable of taking the full rated load of the locomotive. Refer to the Load Testing section of this manual for instructions covering the load testing setup.

CAUTION: Most standard load boxes are not of sufficient capacity to fully load the locomotive.

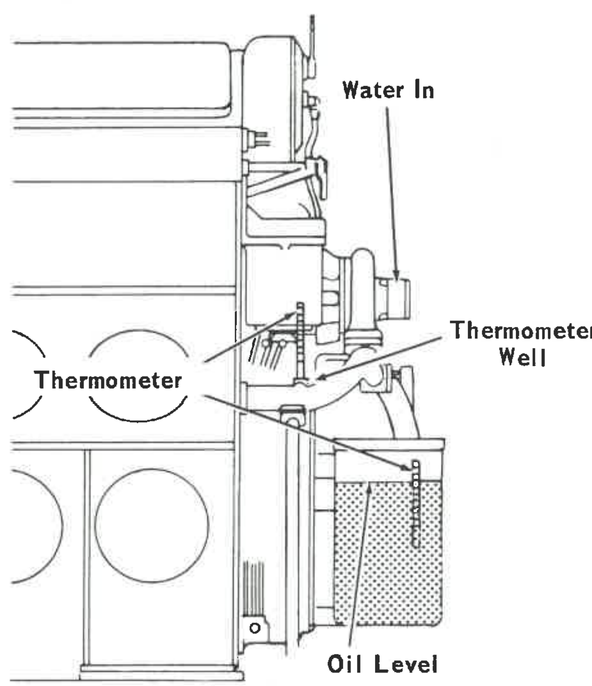

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Fig. 2-4 – Location Of Thermometers To Determine Oil And Water Temperature Differential

3. Remove the square cover from the engine mounted oil strainer and hang a caged thermometer in the overflow oil compartment of the strainer housing, Fig. 2-4. This is oil out of the cooler. Make certain that the thermometer bulb is well below the surface of the oil and is kept submerged when the reading is taken.

4. Insert a thermometer into the well located at the engine water inlet.

5. Operate the engine and apply load. Do not operate above throttle position No. 3 until water temperature is above 130° F. Operate at full load and full engine speed until engine water inlet temperature is stabilized. It may be necessary to operate engine cooling fans to maintain a constant water temperature in the range of 160° F. to 175° F. Refer to the cooling system schematic diagram in Section 3.

NOTE: Readings taken at 15 minute intervals will indicate when a stable operating condition is reached.

6. Record the temperature readings and compare them with the performance baseline given on the Service Data page. When oil temperature for a given water temperature reading is 15° F. higher than the limit indicated by the line, the oil cooler should be serviced in accordance with the Maintenance Instruction listed on the Service Data page.

OIL FILTER INSPECTION AND MAINTENANCE, Fig. 2-5

Oil filter elements should be replaced with new elements at the intervals stipulated in the Scheduled Maintenance program. Use only approved element combinations as indicated on the Service Data page.

PROCEDURE

1. Operate the diesel engine until oil is warm and circulating freely, then stop the engine and remove the starting fuse.

2. Remove the square cap from the engine mounted lube oil strainer housing, Fig. 2-6.

3. Raise and latch the gate valve handle in the engine strainer housing to drain oil from the filter housing into the engine sump. It is not necessary to move the valve handle that drains the oil strainer housing.

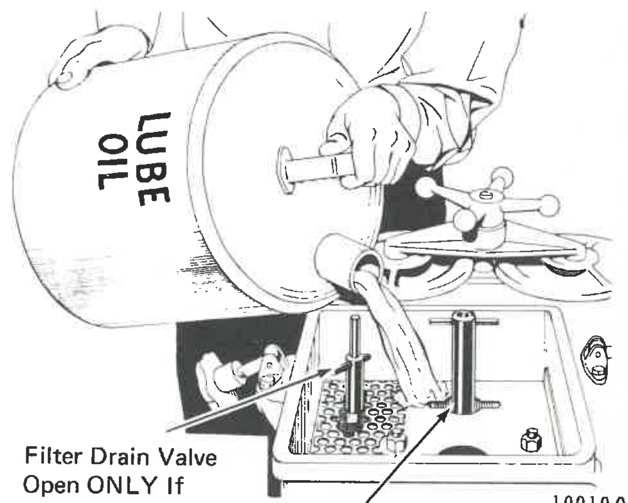
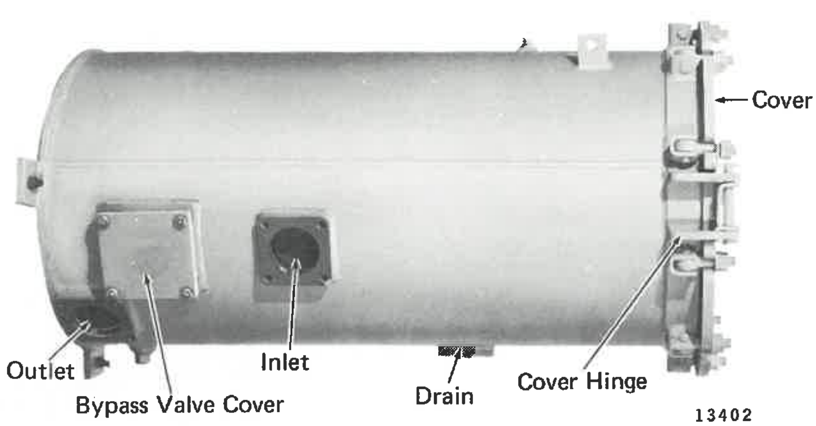


Fig. 2-6 – Adding Oil To Engine Through Strainer Housing



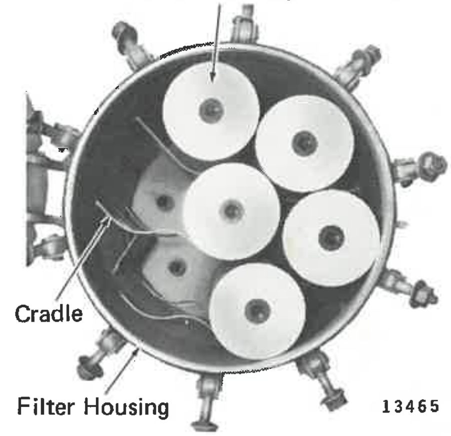


Fig. 2-5 – Seven Element Lubricating Oil Filter Assembly

NOTE: Depending upon the temperature of the oil and system at the time that the drain valve is opened, adequate drainage of the lube oil filters can take from 1/2 hour for hot oil and a hot system to several hours for a cool system.

If the system is fully charged at the time the system is to be drained, the oil level will rise above the bottom of the oil pan inspection covers.

4. After enough time has elapsed to allow adequate drainage and easy handling of the filters, slightly loosen the nuts on the filter housing cover. Oil remaining at the bottom of the housing will leak into the drain pan. From there it is piped to the engineroom drainage sump.

5. Provide adequate quantities of bound edge towels.

6. Place a container for used filter elements at a convenient location.

7. After oil has stopped draining from under the flat filter housing cover, loosen the retaining nuts and swing the hinge bolts clear of the cover. Swing the cover open. Remove and quickly dispose of used filter elements.

8. Using only clean bound edge towels, clean out the interior of the filter housing. Clean up the drain pan and surrounding area.

9. Insert a set of seven new filter elements consisting of part numbers shown on the Service Data page. Make certain that the elements are fully seated over the standpipes.

NOTE: Approved pleated paper elements have a red casing. When the compliment of seven paper elements is used, be certain to use approved elements.

10. When the filter elements are properly inserted, place a new gasket into the circular groove in the housing cover. Discard the used gasket.

11. Close the cover. A guide hole in the filter cover must mate with a dowel on the filter housing body before the cover can be closed.

12. Swing the hinge bolts into place and tighten the hold-down nuts.

13. At the intervals stipulated in the Scheduled Maintenance Program, remove and inspect the filter bypass relief valve assembly, Fig. 2-7. The procedure is detailed in the article entitled Inspection Of Bypass Valve Assembly.

14. Close the filter drain gate valve at the oil strainer.

15. Before starting the engine, check the oil level, using the dipstick. Oil level should be above the full mark on the dipstick with the engine shut down. Start the engine and allow it to run at idle speed. Check the oil level at the dipstick. Add oil if necessary. See Fig. 2-6.

16. Replace and tighten down the square cover on the oil strainer.

17. Inspect for oil leaks at the filter housing. Tighten the hold-down nuts as necessary to stop any leaks.

INSPECTION OF BYPASS VALVE ASSEMBLY

The filter bypass relief valve assembly, Fig. 2-7, should be removed and checked periodically at intervals stipulated in the Scheduled Maintenance Program or whenever improper oil filtration is suspected. However, operation of the valve assembly can not be effectively checked on the locomotive. For this reason it is recommended that qualified spare assemblies be available for exchange with the assembly in use. A bench test and inspection may then be performed in accordance with the appropriate Maintenance Instruction listed on the Service Data page.

PROCEDURE

1. After the oil has been drained from the filter housing, the filters removed, and the housing cleaned; remove the four hold-down nuts from the bypass valve port cover. Remove the valve assembly and discard the port cover gasket.

NOTE: Three light springs hold the valve assembly seated in position and against the valve port cover. Bypass valve spring pressure is not felt during removal of the assembly.

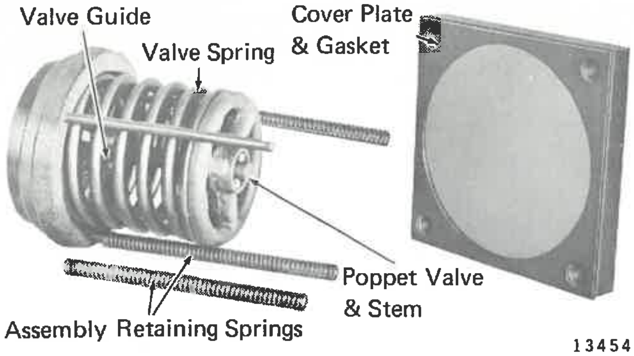


Fig. 2-7 – Filter Bypass Relief Assembly

2. Replace the filter bypass relief valve assembly with a qualified spare. Seat the assembly properly with the three light guide springs in place. Apply a new port cover gasket and the port cover. Tighten the cover hold-down nuts to between 55 to 60 ft-lbs torque, using standard tightening procedure.

   If a qualified spare is not available, the valve assembly should nevertheless be removed from the filter housing and cleaned of sludge and varnish by washing in solvent. The assembly should be carefully inspected after cleaning. If the poppet stem or valve body guide is worn, those pieces should be replaced with new pieces. Part numbers are listed on the Service Data page.

TEST OF VALVE SPRING

If a qualified spare is not available, the valve spring should be tested by compressing it to a specific height. If this requires more or less than the values shown on the Service Data page, the spring should be replaced with a new spring.

HOT LUBRICATING OIL DETECTOR, Figs. 2-1 And 2-8

A thermostatic valve located on the outlet elbow from the main lube oil pump is calibrated to open when lube oil temperature reaches nominally 260° F. At this temperature the probability exists that either the lube oil cooler is plugged on the water side, or steam pressure in the cooling system is preventing engine shutdown by the low water detector.

When oil temperature causes the valve to open, pressure to the oil pressure sensing device in the engine governor is dumped. The device sees low oil pressure and reacts to shut the engine down. The thermostatic valve is not latching, and it will reset automatically when oil temperature falls. Do not attempt to restart the engine until cause of shutdown is determined.

WARNING: After it has been determined that hot oil is the cause for engine shutdown, make no further engineroom inspections until the engine has cooled sufficiently to preclude the possibility that hot oil vapor may ignite. When a low oil shutdown occurs, always inspect for an adequate supply of water and oil. Also check engine water temperature. Do not add cold water to an overheated engine.

Start To Open Temp. °F.	Full Open Temp. °F.
252 - 257	275

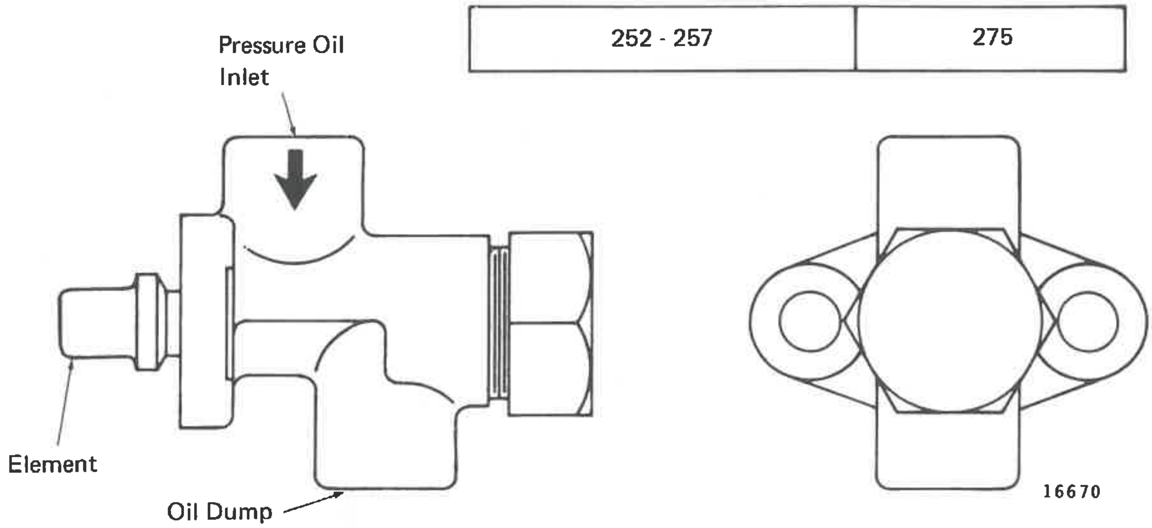


Fig. 2-8 – Hot Oil Detector Thermostatic Valve

CENTER BEARING LUBRICATION

Two quarts of all purpose lubricating oil per M.I. 1756 should be added to the truck center bearing at the interval indicated in the Scheduled Maintenance Program.

LUBRICATION AT THE TIME OF TRUCKING

Remove oiler pipe plugs, Fig. 2-9, before trucking or untrucking the locomotive.

If the bearing is dry, add 3-1/2 pints of oil before trucking, and add another 3-1/2 pints after the unit is trucked.

Reapply oiler pipe plugs after unit is trucked and oiled.

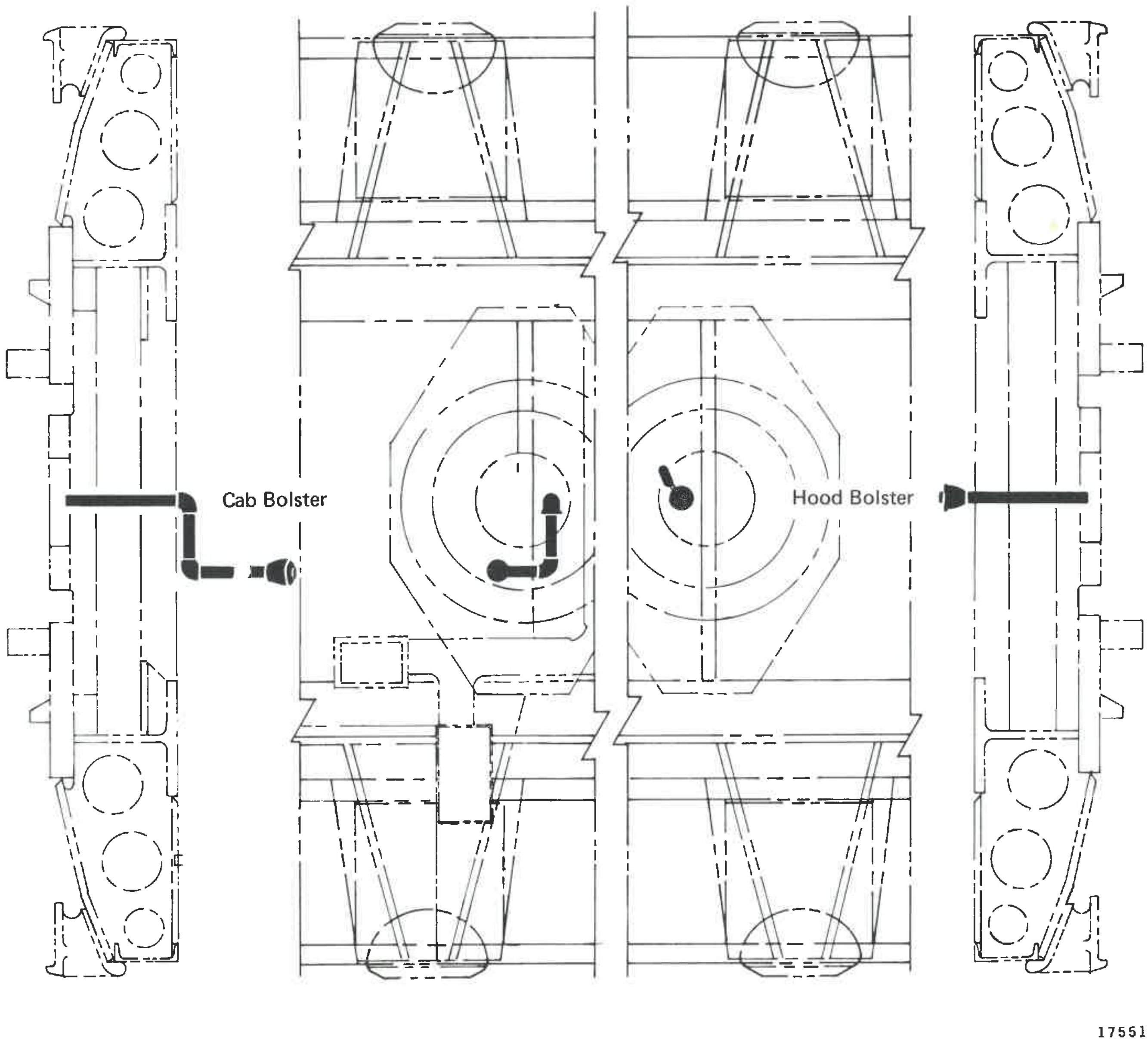


Fig. 2-9 – Center Bearing Oiler Pipe Locations

SERVICE DATA

LUBRICATING OIL SYSTEM

REFERENCES

Lubricating Oil Filter Maintenance	M.I. 926
Lubricating Oil Cooler Maintenance	M.I. 927
Lube Oil Qualified For Use In 645E3 Engine	M.I. 1752

ROUTINE MAINTENANCE PARTS AND EQUIPMENT

FILTERS

	Part No.
Lubricating Oil Filter Assembly	8411945
Pleated Cotton-Paper Elements (7 per housing)	8345482

NOTE: Filter changeout recommendation will be found in the applicable Scheduled Maintenance Program.

Filter Housing Cover Gasket	8268756
Bypass Valve Port Cover Gasket	8296030

BYPASS VALVE ASSEMBLY

NOTE: It is recommended that qualified spare bypass valve assemblies be kept available for scheduled maintenance replacement.

Weight required to compress valve spring 8317190 3-5/8" must be not less than 420 pounds or more than 500 pounds. (This is the 40 psi spring.)

Poppet Valve	8322839
Valve Guide	8322840
Valve Spring	8317190
Hot Oil Valve	8427032
Gasket	8430611

HOT OIL DETECTOR QUALIFICATION TEST

Remove detector from engine and test as follows:

1. Connect air lines to and from valve.
2. Fully immerse valve in heated, thoroughly agitated liquid bath. Temperature increase not to exceed 1° F. per minute over 240° F.
3. Apply 50 psi air pressure, and observe for leaks. No leaks between valve body and cap are acceptable.
4. At 250° F. and below, maximum air passage to be 10 standard cubic feet of air per hour (SCFH).
5. Turn off air to avoid chilling.
6. Raise temperature to 258° F.
7. Turn on air. Minimum air passage to be 10 SCFH.

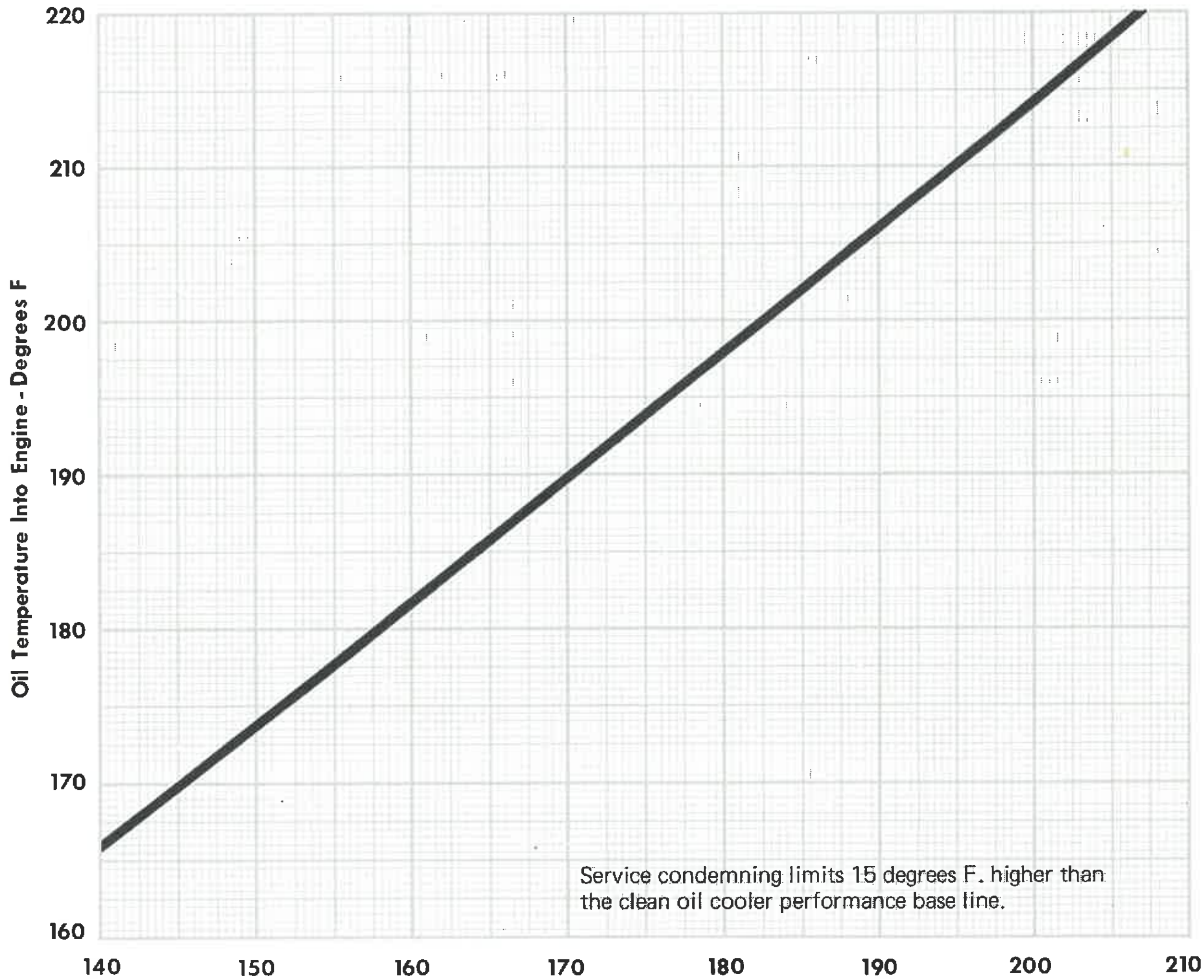
SPECIFICATIONS

Lube Oil Capacity Basic Oil Pan	243 Gal.
Increased Capacity Oil Pan	395 Gal.
*Usable Oil	
Basic Oil Pan	47 Gal.
Increased Capacity Oil Pan	184 Gal.

*Defined as volume of oil between "Full" and "Low" on dipstick.

Oil Level Gauge (Dipstick) for 16-645E3 Engine 8285976

OIL VERSUS WATER TEMPERATURE PERFORMANCE LINE



Clean Oil Cooler Core Baseline

17481

Cooler Assembly 8412061 With Soldered Copper Core 8318804 or 3146250

COOLING SYSTEM

DESCRIPTION

The cooling system is pressurized to provide uniform cooling throughout the operating range of the diesel engine. A schematic diagram of the system is shown in Fig. 3-1. Coolant is pumped by the engine mounted pumps from the cooling water expansion tank and lubricating oil cooler assembly and into the engine. The heated water leaves the engine and flows through the radiator assembly where it is cooled. The cooled water returns to the oil cooler to repeat the cycle.

Part of the water from the engine mounted water pumps is piped to the air compressor. There are no valves in the line, thus air compressor cooling will be provided whenever the engine is running. Water is also piped through a temperature switch manifold, then back to the water tank for recirculation. Temperature sensing elements located in the manifold, operate switches that control radiator fan and shutter operation and a hot engine alarm.

Part of the water from the engine mounted pumps is piped to the cab heaters. A shutoff valve is located in the supply line to the heaters and another shutoff valve is located in the return line from the cab heaters. These valves, along with an engine and compressor drain valve and heater drain valves are located at the sump between the engine and the engine accessory rack.

To drain the entire cooling system, open the engine and compressor drain valve, heater supply shutoff valve, heater return shutoff valve, and the two heater drain valves. If it is necessary to independently drain the heaters, the heater supply shutoff valve and the heater return shutoff valve must be closed and the heater drain valves opened.

CAUTION: Allow all valves to remain open until the system is completely drained. Do not close a valve independently when its discharge stops.

Whenever the heater supply and return valves are closed, it is good practice to open the heater drain valves and drain the cab heaters and associated piping. Always check to

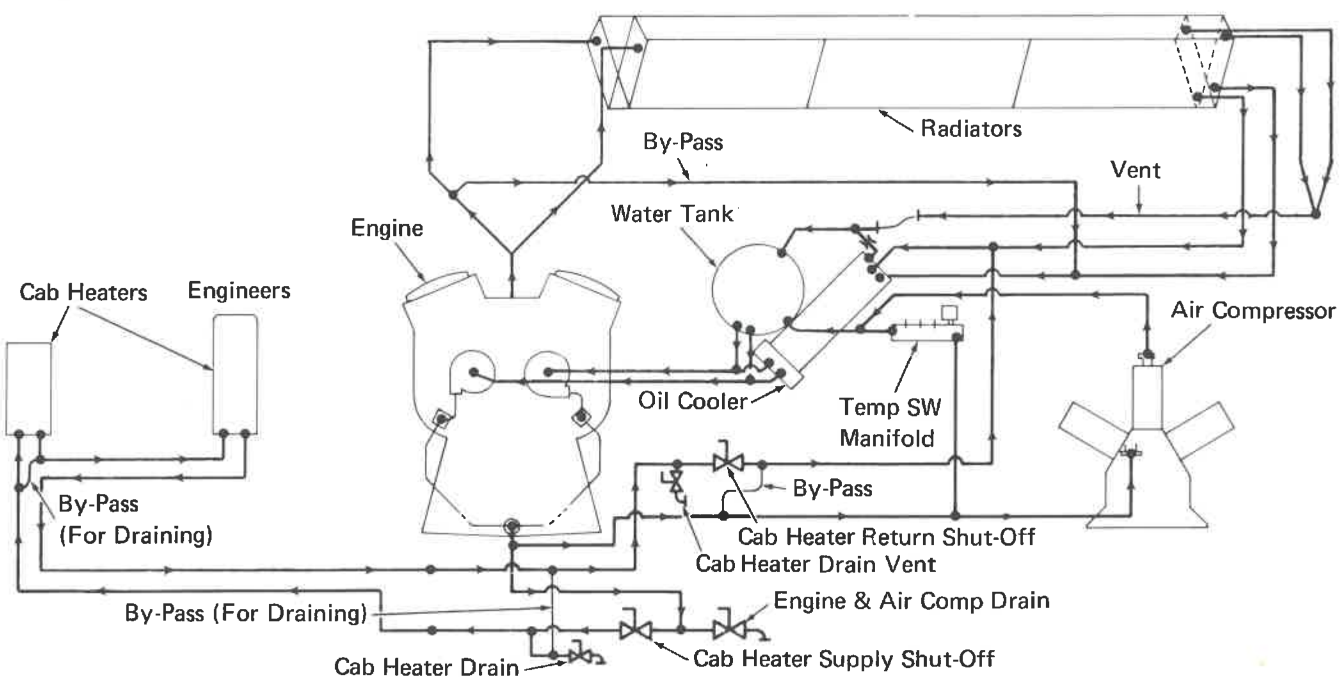


Fig. 3-1 – Cooling System Piping Schematic see that the heater drain valves are tightly closed before opening the cab heater supply and return valves.

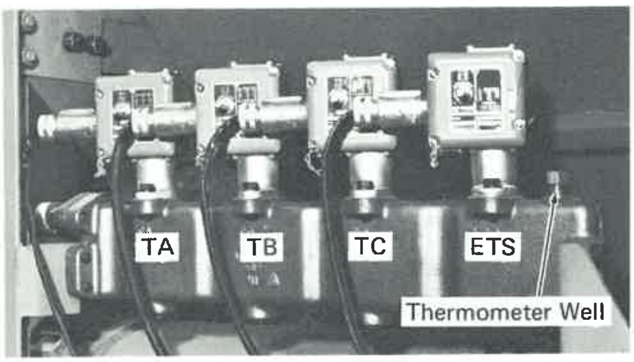
TEMPERATURE CONTROL

During circulation through the diesel engine and air compressor, the cooling system water picks up heat which must be dissipated. This heat is dissipated and the water temperature controlled by means of a radiator assembly and AC motor driven cooling fans.

The radiators are assembled in a hatch in the top of the long hood end of the locomotive. The hatch contains radiator sections which are grouped in two banks. Three AC motor driven cooling fans which operate independently are located in the roof above the radiators. They are numbered 1 to 3 from front to rear, with the No. 1 fan being closest to the cab. Shutters, located along the sides of the hood, adjacent to the radiators, are operated by air cylinders controlled by the shutter magnet valve MV-SH. Control of the fans and shutters, and thus of the water temperature, is entirely automatic.

Temperature control switches, Fig. 3-2, are designated TA, TB, and TC. These switches are located at the equipment rack and are flange mounted to a manifold located in the cooling system piping. Water piped from the area of the inlet to the engine passes through the manifold where it acts upon thermal elements that cause switches to respond and establish electrical circuits to cooling fan contactors. A fourth switch, ETS, responds to overheating. It sounds an alarm and reduces engine speed and load.

The cooling fan contactors are designated FC1, FC2, and FC3. These contactors are located in a cabinet mounted on the equipment rack, see Fig. 3-8. When energized, they electrically connect their respective AC cooling fans to the alternating current supply from the alternator to run the fans.



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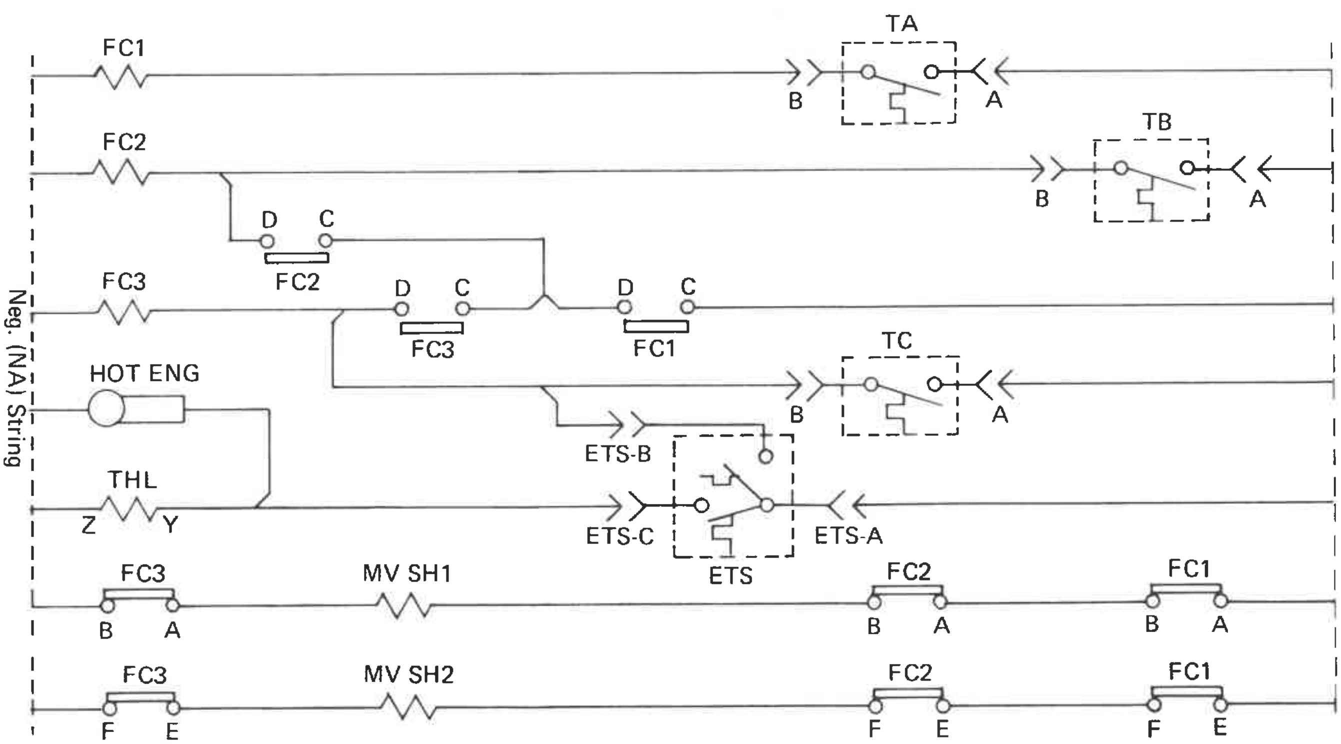

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Fig. 3-2 – Engine Temperature Switch Manifold And Circuit Diagram

FAN CONTROL

TA picks up first. This energizes FC1, which starts the No. 1 cooling fan, and simultaneously de-energizes the shutter magnet valve MV-SH, releasing air pressure from the shutter operating cylinders and allowing spring tension within the cylinder assembly to pull the shutters open.

When energized FC1 establishes the first part of a holding circuit to FC2 and FC3. TB picks up next. This energizes FC2, which starts the No. 2 cooling fan and completes the holding circuit to FC2.

TC picks up last. This energizes FC3, which starts fan No. 3 and completes the holding circuit to FC3. Once started, all three fans operate until TA drops out to break the holding circuit. Also, the shutters stay open until TA drops out.

The operating temperatures of TA, TB, and TC are given on the Service Data page, and on the switch nameplate. Part numbers of the switches are listed in the locomotive wiring running list.

The automatic temperature control functions as follows:

SHUTTER CONTROL

When the fan contactors are de-energized, normally closed interlocks energize the shutter magnet valve MV-SH, Figs. 3-2 and 3-3. Air under pressure is admitted to the shutter operating cylinders, where it drives the pistons and the shutter operating bars to close the shutters.

During operation, outside air is either drawn by a single operating fan through the shutters and radiators or, if greater cooling is required, an additional fan or all fans are energized and a greater volume of air is drawn through the shutters and radiators. The flow of air through the radiators picks up heat from the circulating water. The heat is then discharged through the roof of the locomotive.

MANUAL SHUTTER CONTROL VALVE

A valve, Fig. 3-3, is provided for control of the shutters. When the valve handle is in the operating position, the valve allows air from the shutter control magnet valve to drive the shutter operating piston and close the shutters. When the

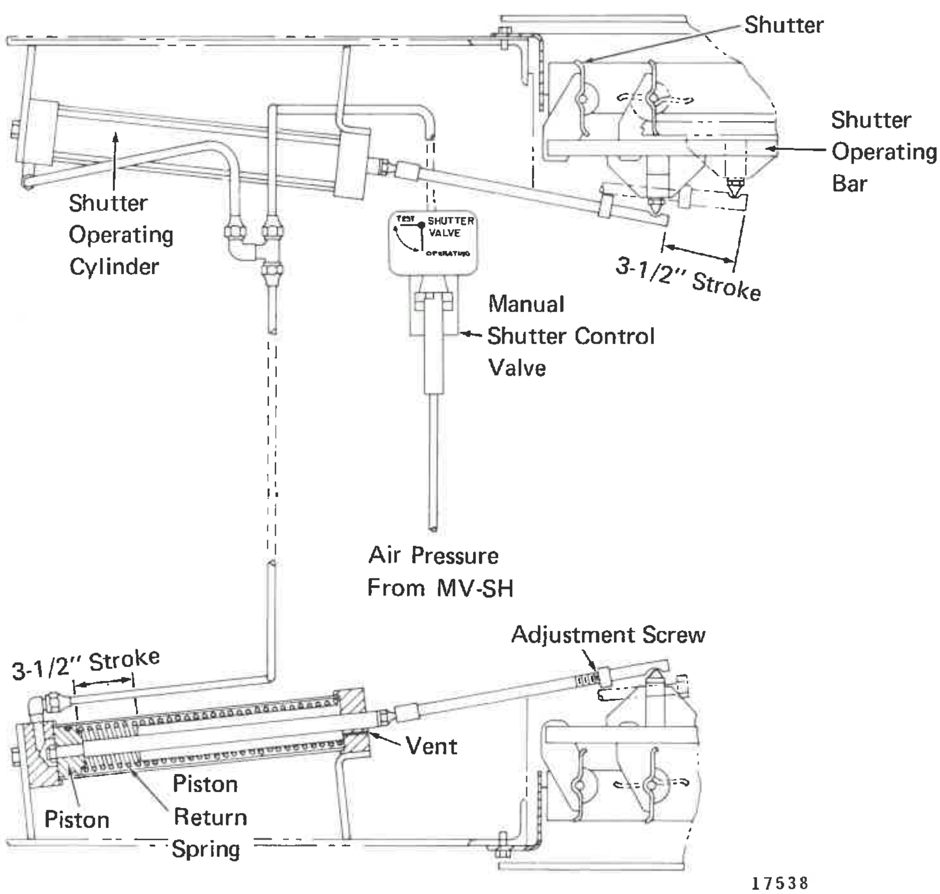

Fig. 3-3 -- Shutter Operating Piston Arrangement shutter magnet valve MV-SH is de-energized, air from the shutter operating cylinders passes through the manual valve and discharges at the magnet valve vent.

When the handle of the valve is placed in the piston-release position (90° clockwise from operating), air from the magnet valve is blocked, the operating cylinders are vented to atmosphere and the shutters open.

NOTE: On a unit shipped dead in a train, the dead engine feature limits main reservoir pressure. This pressure, applied through the shutter magnet valve, is not sufficient to operate the shutter piston against the built-in spring pressure.

SHUTTER POSITION ADJUSTMENT

1. Place the manual shutter control valve in the piston released position (90° clockwise). This will release operating air and allow spring pressure to draw the shutters open.
2. Release the locknut at the adjustment threads of the piston ball joint extension rod. Adjust the rod to obtain shutter blade angle of 90° ± 2° (fully open). Tighten the locknut.
3. Slowly operate the manual shutter control valve handle to the operating position to close the shutters.

NOTE: During usual maintenance conditions the No. 1 cooling fan will be required for engine cooling, therefore the shutter magnet valve MV-SH will be de-energized cutting off the supply of air to the shutter operating cylinders.

Since the locomotive is designed to have the shutters open when the No. 1 fan is energized, it may be necessary to jumper FC1 interlocks to keep MV-SH energized.

4. Verify shutter operation by alternately positioning the manual shutter control valve handle in the operation and test positions, then return the valve to the operating position. The shutters will close.

HOT ENGINE ALARM

A hot engine alarm switch ETS will close when water temperature at the outlet from the engine approaches the boiling point of water in the pressurized system. This is not the temperature at the switch sensing element. There is heat loss between the engine outlet and the temperature switch, therefore the switch is calibrated to pick up at a lower temperature. This temperature is close to the normal boiling point of water, but much lower than the boiling point of water in the pressurized system.

When the switch picks up, the alarm will ring in all units of a consist, and the hot engine light will come on in the unit affected. Pickup of ETS will also energize a throttle limit relay THL. This relay operates to light the hot engine indication on the annunciator and to reduce engine speed and power. The reduction of power facilitates engine cooling, and the reduction of engine speed reduces the possibility of cavitation at the water pumps. The return to full power and speed can be accomplished only by reducing cooling system temperature to a normal level.

Engine water temperature may be readily checked by means of a gauge located in the water inlet line leading to the left bank water pump. The gauge is color coded to indicate COLD (blue), NORMAL (green), and HOT (red), engine temperatures.

A more accurate check of engine water temperature may be obtained by placing a thermometer in the thermometer well located on the temperature switch manifold, Fig. 3-2. The proper operating temperature for the engine temperature switch is given on the temperature switch nameplate and is on the Service Data page. The switch part number can be verified on the locomotive wiring running list.

As a backup to ETS action, a hot oil detector is located on the outlet elbow of the main lube oil pump. Should ETS fail to reduce engine temperature and a boiling condition create pressure that prevents low water detector trip, oil temperature will increase. A thermostatic valve will dump pressure oil in the line to the governor low oil pressure detector and bring about engine shutdown.

The thermostatic valve will reset automatically after the hot oil cools, but it is recommended that no attempt be made to start the engine after a hot oil shutdown until a thorough engine inspection is made by qualified personnel.

WARNING: After it has been determined that hot oil is the cause for engine shutdown, make no further engineroom inspections until the engine has cooled sufficiently to preclude the possibility that hot oil vapor may ignite.

COOLING SYSTEM PRESSURIZATION

The cooling system is pressurized to increase the boiling point of the coolant and prevent cavitation at the water pumps during transient high temperature conditions, such as operation through long tunnels. A pressure cap, Fig. 3-4, on the water tank filler pipe opens at approximately 7 psi to relieve excessive pressure and prevent damage to cooling system components. The cap is also equipped with a vacuum breaker valve that operates as the system cools. Refer to the Service Data page for pressure cap operating limits and identifying number.

The pressure cap is equipped with a handle that facilitates application and removal, but more importantly it interlocks with the fill valve handle. This ensures that system pressure is released through the fill/release pipe before the cap can be loosened.

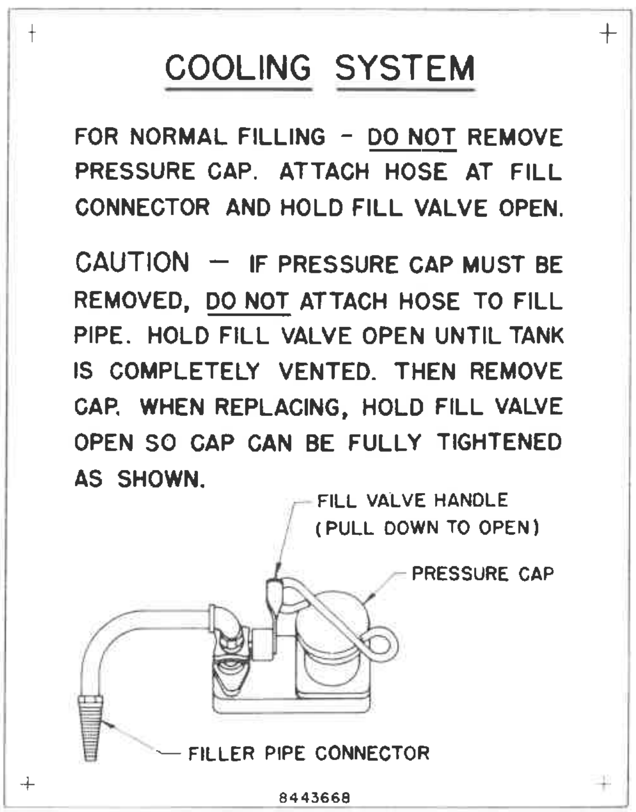

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Fig. 3-4 -- Cooling System Pressure Cap And Filler Pressure Relief Arrangement

WARNING: Always relieve system pressure before attempting to remove pressure cap or water tank plugs.

LOW WATER SHUTDOWN

A low water detecting device, Fig. 3-5, balances water pressure against airbox pressure. When water pressure falls, the device dumps oil from the governor supply line, causing an engine shutdown. When a low water shutdown occurs, the low water button pops out to display a red band, the low oil plunger on the governor protrudes, and the governor shutdown light on the engine control panel comes on.

While there is no air box pressure when an engine is shut down, there is spring pressure. This spring pressure must be acted against by water pressure in order to keep the device latched in. On certain devices the static water pressure working against spring pressure will not keep the device latched in when the engine is shut down. This is not necessarily an indication that the device is defective. It is merely necessary to reset the device immediately after engine start.

If the low water detector latches in with the engine shut down, it still may trip at engine start, particularly when the engine is cold or after the pressure in the system has been released. The reason for the trip being that the water pumps

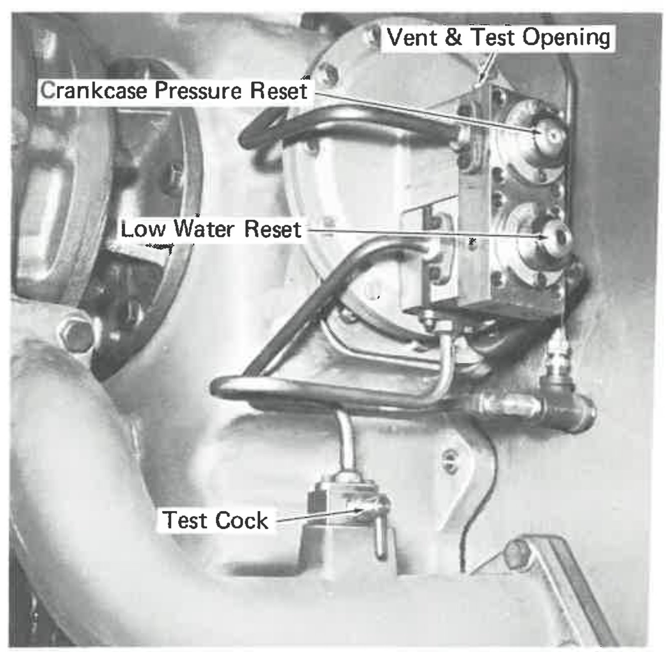

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Fig. 3-5 – Low Water And Crankcase (Oil Pan) Pressure Detector may cavitate until water is drawn from the makeup tank and distributed to the radiators for proper circulation. Tripping at engine start is not an indication that the device is defective. It is merely necessary to reset the device immediately after engine start.

TESTING FOR LOW WATER SHUTDOWN

Operation of the low water shutdown device, Fig. 3-5, should be checked at the intervals stated in the Scheduled Maintenance Program or whenever faulty operation is suspected.

To test operation of the low water detecting device, run the engine at idle speed and turn the test cock mounted on the water pump discharge elbow to the horizontal position. The low water button should pop out smoothly without hesitation after water trapped behind the operating diaphragm escapes through the drain hole provided (in not more than a few seconds of time). Return the test cock to the vertical position.

Observe the low oil plunger on the governor as it moves out. The plunger should extend fully and the engine begin to shut down in about 55 seconds. As the engine begins to shut down reset the low water button and the low oil plunger. Operate the rack positioning lever to bring the engine back up to idle speed before complete shutdown. Verify that the low water button stays set.

If the low water shutdown reset pushbutton does not pop out freely without assistance when the test cock is opened and the engine is at idle, the device should be removed and replaced with an operative device. Refer to the Service Data page for a listing of instructions covering maintenance and qualification of the low water protector. Special apparatus is required for proper testing.

The crankcase pressure detector may be tested in a similar manner by applying a rubber tube over the test opening on top of the detector and applying suction to trip the upper button.

OPERATING WATER LEVEL

An operating water level instruction plate, Fig. 3-6, is provided next to the water level sight glass. The instructions indicate minimum and maximum water level with the engine running or stopped. The water level mark should not be permitted to go below the applicable "low" water level mark.

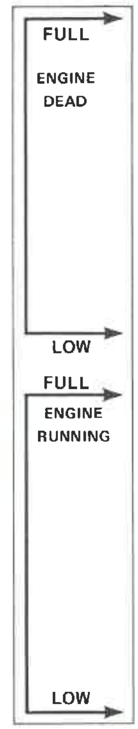


Fig. 3-6 – Typical Water Level Instruction Plate

Progressive lowering of the water in the gauge glass indicates a water leak in the cooling system, and should be reported. Normally, there should be no need to add water to the cooling system, except at extended intervals.

MAINTENANCE

FILLING THE COOLING SYSTEM

The coolant used in the engine cooling system should be made up and tested in accordance with the coolant Maintenance Instruction listed on the Service Data page.

When filling a dry system, remove the pressure cap and fill system through the water fill pipe. Before removing the water tank pressure cap first pull down and hold the pressure relief valve until the air stops blowing. The pressure cap cannot be removed without hitting the pressure relief valve. When adding water to the system through the "rattlesnake" connector, the pressure relief valve should be held down. This connection should be used only when adding small amounts of water.

WARNING: Do not overfill the tank. Overfilling can result in frozen radiators, and can constitute a hazard to personnel.

After filling a dry or nearly dry system, the engine should be run, with the filler cap removed, or the vent valve opened, to eliminate any air pockets in the system. After running the engine, check the water level and if necessary add water to the system.

NOTE: Draining the cooling system will trip the low water shutdown device; therefore, when filling the cooling system the low water reset button must be pressed before engine start.

After filling operations have been completed and before starting the engine, the pressure cap must be replaced.

DRAINING THE COOLING SYSTEM

The engine cooling system should be drained immediately in the event that the diesel engine is stopped and danger of freezing exists. The draining procedure is as follows:

Drain Engine Cooling And Cab Heater System

Make sure that the following valves are open.

1. Cab heater supply.
2. Cab heater return.
3. Cab heater drain valve and vent valve. Vent valve must remain open during entire draining period.
4. Engine water drain.

The above valves are located in engine drain sump, governor end of engine.

5. Preheater water supply (located at equipment rack, if so equipped).
6. Preheater water return (located at equipment rack, if so equipped).

All valves are tagged as noted and open when handles are in line with piping.

After system pressure is released, remove the water tank fill cap to allow drainage at an increased rate.

CAUTION: If a hot engine is drained, always allow the engine to cool before refilling with fresh coolant.

Drain Cab Heater System, Only

1. Close cab heater supply and return valves.
2. Open cab heater drain valve and vent valve. Vent valve must remain open during entire draining period.
3. Engine water drain valve is to remain closed.

Drain Flush Toilet (If So Equipped)

1. Flush toilet until all water has drained from tank.
2. Turn off electric toilet tank heater (if so equipped).
3. Remove pipe plug from bottom of toilet flush piping.

Drain Water Cooler (If So Equipped)

1. Remove and empty water bottle.
2. Drain remaining water in cooler by holding in the spigot button.
3. Turn off electric power to water cooler (if so equipped).

OBTAINING AN ENGINE WATER SAMPLE

When a sample of engine coolant is desired, it should be obtained with the engine warm and running. The coolant should be taken from a point where water flow is turbulent. Allow the water to run a few seconds to drain off any accumulated sediment.

TESTING ENGINE WATER TEMPERATURE SWITCHES

It is recommended that a routine check of temperature switch operation be made at the intervals specified in the Scheduled Maintenance Program. A thermometer well is provided in the temperature switch manifold to facilitate testing.

Temperature switches, Fig. 3-7, are easily removed from the temperature switch manifold and replaced with new switches. If a replacement switch with a new gasket attached is held at a ready position, the old switch and gasket can be removed and the new switch inserted with only a small loss of engine coolant.

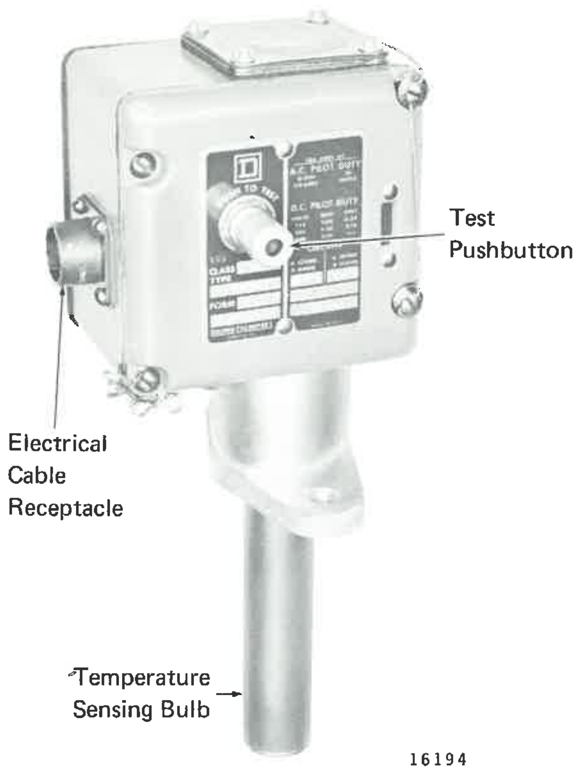


Fig. 3-7 – Engine Temperature Switch

On the locomotive, pickup and dropout of temperature switches can be checked by placing a thermometer along with some oil or water in the well located in the temperature switch manifold, Fig. 3-2, and loading the locomotive engine.

To facilitate the pickup check, disable fans by disconnecting the feed wires to the fan contactor coils. Use a test lamp at the disconnected leads to indicate temperature switch closure. The temperature switches will close in sequence TA, TB, TC, ETS. When ETS picks up the alarm will sound and engine speed and load will drop. Record temperature at pickup of each switch.

After the alarm sounds, reconnect the feed wires to the fan contactor coils in sequence FC3, FC2, FC1. The shutters will open when FC3 picks up. Allow time for each fan to come up to full speed before starting another fan.

When temperature comes down and ETS drops out, engine speed and load will increase. Record ETS dropout temperature, then reduce throttle to Run 5 and place the generator field switch in the OFF position to drop load. Record engine water temperature as each fan contactor drops out.

The correct part numbers for replacement switches are listed on the Service Data page and in the "Locomotive Wiring Running List," supplied with the locomotive wiring diagrams. The part number for the running list itself is referenced in the lower right corner of the wiring diagram.

After replacement switches are installed and the engine is running, press the switch test pushbuttons in sequence to verify fan operation.

CAUTION: Do not press switch test pushbuttons simultaneously. Allow time for a given fan to pick up speed before pressing the test buttons to bring in more than one fan.

Instructions for checking the temperature switches are referenced on the Service Data sheet, and plans for construction of bench testing apparatus can be obtained from the EMD Service Department upon request. Note that in any test of temperature switches, critical factors such as circulation of the test bath to prevent stratification, immersion of the temperature bulb to a proper depth, and ambient temperature approximating engineroom conditions must be observed.

INDICATIONS OF FAULTY SWITCH OPERATION

1. False hot engine indication due to incorrect ETS pickup.

2. Low oil shutdown due to hot engine oil. A fault exists in the cooling system and ETS did not operate properly.

NOTE: Hot lube oil can be caused by a plugged lube oil cooler. In such case a hot engine alarm will precede the hot oil shutdown.

3. Temperature switch cycling and picking up too soon after dropout. If the switch opens during a starting surge, fan contactor tips may be damaged. It is possible for the tips to weld closed. Damage to fan motors and the D14 alternator is also possible.

4. Two fan contactors must not pick up at the same time. If this occurs, switches may be operating improperly or an incorrect switch is installed. The strong starting surge resulting from such a condition can cause damage to the D14 alternator. The condition can be noted at the layshaft as the fans come in.

5. A cold engine may result from welded fan contactor tips or from sticking temperature switch pushbuttons.

INSPECTION AND CLEANING OF RADIATORS

The access covers between the engineroom and the radiator compartment must always be securely bolted in place during locomotive operation. If a cover is not in place, improper circulation of cooling air will result, and the slight pressurization of the engineroom provided by cooling air from the main generator will be lost.

Periodic inspection and cleaning of the radiators should be performed at the minimum intervals called for in the Scheduled Maintenance Program, at more frequent intervals as determined by operating conditions, or when trouble is suspected. Since the pressurized system will rarely require addition of water, any progressive lowering of the water level indicates that an inspection should be made for leaks. Inspect carefully for small leaks called "weep" at the junction of the radiator tubes and header.

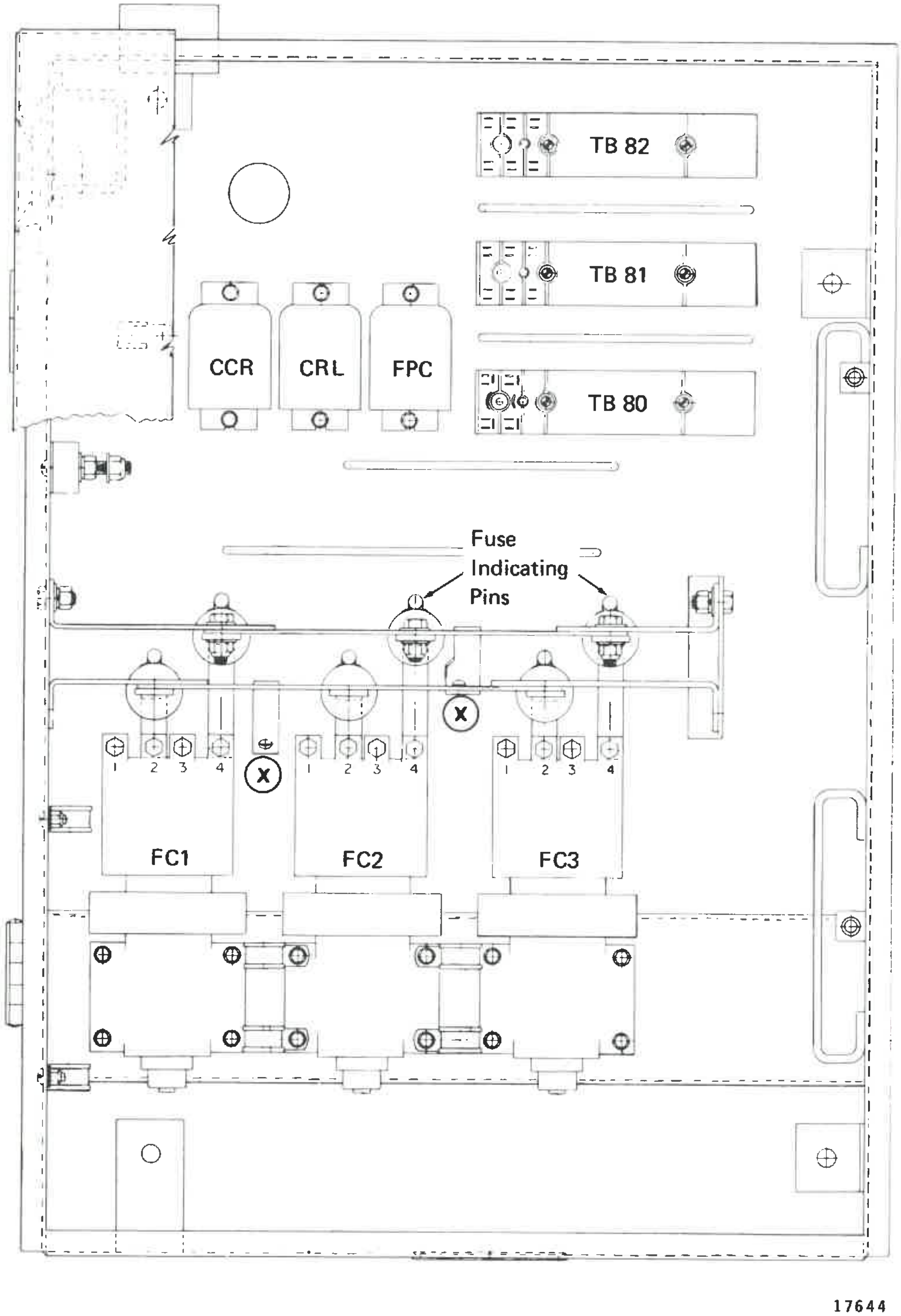
Normally, the application of clean dry compressed air to the top surface of the radiators, followed by reverse operation of the cooling fans will satisfactorily clean the radiator cores and radiator compartment.

Reverse operation of cooling fans can be easily accomplished by interchanging the position of two AC leads that are bolted to the buses connecting to the fan contactors in the AC cabinet. The leads are indicated on Fig. 3-8. Reversal of AC leads at the alternator terminal board is not recommended because the dirt evacuating blower in the central air compartment will also be reversed.

After the AC leads are reversed fan operation can be controlled by pressing the test pushbuttons on the manifold-mounted engine water temperature switches, Fig. 3-2. One fan must be working to ensure automatic opening of the radiator shutters, or the valve can be manipulated to hold the shutters open.

CAUTION: When using fan test pushbuttons, be careful not to accidentally release a button during the starting surge of current and be sure to allow a given fan time to speed up before pressing another button.

Make certain that the AC cables are returned to their proper connection points after radiator cleaning is completed.



CAUTION

Whenever a single blown fuse is indicated, always remove and discard both fuses in the fan motor circuit. Replace with two new fuses.

Fig. 3-8 – (AC) Cable Terminals To Be Reversed For Reverse Operation Of Fans. Cables To Be Reversed Marked By An (X)

COOLING SYSTEM PRESSURE CAP AND FILLER NECK

The pressure cap and filler neck should be inspected, tested, and rebuilt or replaced at intervals indicated in the Scheduled Maintenance Program. Refer to the service data page at the end of this section for replacement part numbers.

INSPECTION

Inspect for –

1. Hardened or damaged seals on both the primary sealing surface and the vacuum snifter sealing surface of the pressure cap.

2. Damage to filler neck sealing surface.

Perform pressure test to qualify pressure cap and filler neck.

COOLING SYSTEM PRESSURE TESTING

Quick disconnect fittings are provided on the water tank and in the air system piping at the equipment panel located below the water tank. A locally fabricated testing apparatus, Fig. 3-9, can be used to pressurize the cooling system with main reservoir air while the diesel engine is running and coolant is at normal level.

WARNING: Do not subject the water tank to pressure greater than 50 psi.

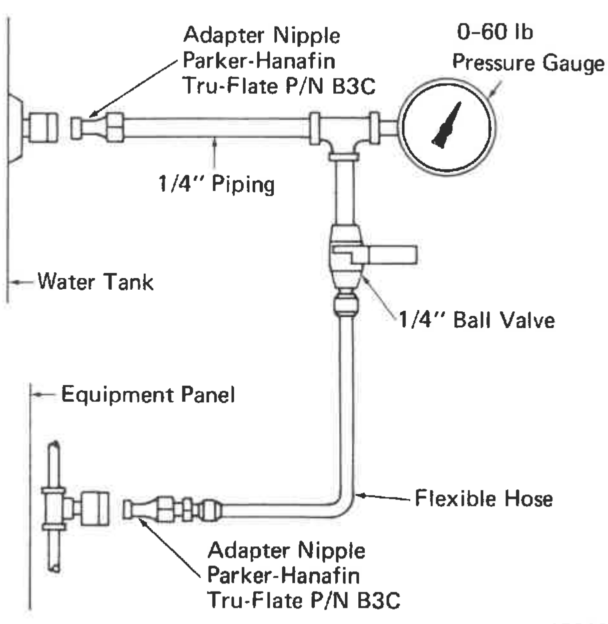


Fig. 3-9 – Cooling System Pressure Test Apparatus

1. Using the testing apparatus, operate the ball valve to gradually meter air into the cooling system until the pressure gauge shows a value near the relief rating of the pressure cap. Close the ball valve.

2. Place a container of water so that water level is above the discharge end of the overflow pipe from the filler neck.

3. Intermittently crack open and close the ball valve to admit additional air pressure to the system. Record pressure when bubbles occur at the end of the overflow pipe. This indicates pressure cap release.

NOTE: Due to the position of the gauge in the testing apparatus, the reading is influenced while air is flowing.

4. Close the ball valve. Record air pressure when bubbling stops. This reading will be close to the actual reseating value of the pressure cap.

NOTE: For a quick check, close observation of the pressure gauge, along with frequent lapping of the ball valve can substitute for the use of water at the end of the overflow pipe, provided there are no leaks in the cooling system.

5. When the pressure cap resets, observe gauge for further pressure drop. If leakage is apparent, inspect filler neck and gasket, and cooling system piping connections.

REPLACEMENT

1. If the pressure cap bell housing or other metal surfaces are bent, replace the entire cap with a new cap. The basic 7 pound cap is fitted with a shaped-rod handle. The special 12 pound cap is fitted with a flat metal strap handle. Provide seal and wire for use after cooling system filling if required by railroad rules.

2. If the filler neck sealing surface is damaged or distorted, replace the neck assembly with a new assembly. Use a new tank-to-neck gasket. Secure with four 3/8"-16 bolts and lockwashers.

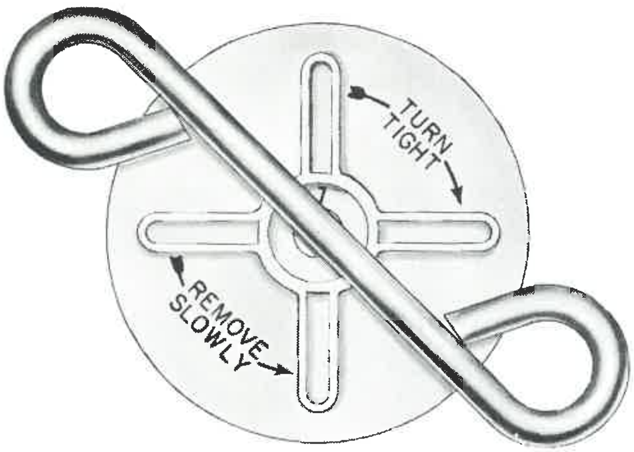
Perform pressure test to qualify pressure cap and filler neck.

REBUILD

If the primary and vacuum snifter gaskets are hardened, or if damage is limited to the gaskets, the pressure cap may be rebuilt. If the pressure cap bell housing or other metal surfaces are damaged, replace the complete cap.

Carefully pry the snifter valve assembly out of the pressure cap assembly, Fig. 3-10. Discard the snifter valve assembly and the primary gasket. Assemble a new primary gasket and a new snifter valve assembly to the pressure cap. Carefully tap the snifter valve assembly in place into the pressure cap bell housing until it is fully seated.

Perform pressure test of cap after rebuild.



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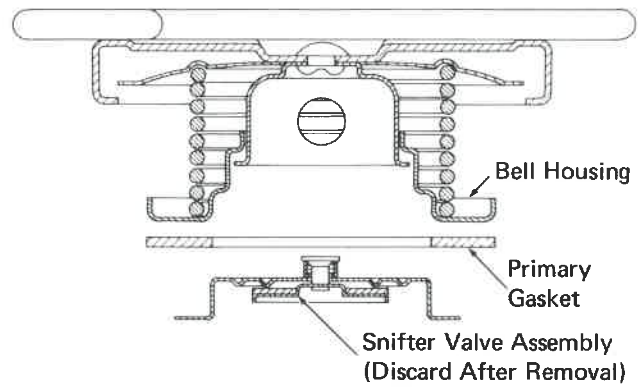

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Fig. 3-10 – Pressure Cap Assembly

COOLING SYSTEM

REFERENCES

Temperature Control And Hot Engine Alarm Switches	M.I. 5511
Engine Water Treatment	M.I. 1748
Maintenance And Qualification Of Low Water Detector	M.I. 259
Cooler, Lube Oil	M.I. 927

ROUTINE MAINTENANCE PARTS AND EQUIPMENT

	Part No.
Low Water Detector Qualification And Testing Apparatus	8349133
Temperature Switch-To-Manifold Gasket	8314926
Drain Cock 1/4" NPT	8386667
Thermometer Well 1/4" NPT	8268162
Water Tank Pressure Cap Assembly	8446821
Primary Gasket	8417470
Snifter Valve Assembly	8438234
Pressure Cap Identifying No.	7
Pressure Cap Operating Limits	(6-1/2 to 8) psi
Filler Neck Assembly	8458052
Tank-to-neck Gasket	8424925

SPECIFICATIONS

Temperature Switch Settings

Switch	Pickup	Dropout	Part No. or	Part No.
TA	174 ± 1-1/2° F.	159 ± 2° F.	8424293	8424290
TB	182 ± 1-1/2° F.	167 ± 2° F.	8424294	8424291
TC	190 ± 1-1/2° F.	175 ± 2° F.	8424295	8424292
ETS	215 ± 1-1/2° F.	205 ± 2° F.	8425023	8425575

NOTE: A temperature switch identified as TB on one model locomotive is not necessarily of the same temperature setting as a switch identified as TB on a different model locomotive.

ALTITUDE EFFECT ON ENGINE TEMPERATURE SWITCHES

Engine temperature switches are installed with an 8° F. nominal difference between set points to provide a time interval between fan motor starts. Two companies currently supply temperature switches to EMD. The set points of these switches vary with atmospheric pressure, but not to the same degree.

It is imperative on any locomotive operated at 6000 feet or above, that American Standard or Square D temperature switches be applied only in matched sets. We also recommend that whenever an alternator or fan malfunction occurs, the temperature switches should be checked for mixed application and/or proper calibration.

CENTRAL AIR SYSTEM

DESCRIPTION

Air is taken into the carbody (hood) of the locomotive to supply three separate systems.

1. Engine cooling.
2. Dynamic brake grid cooling.
3. Central system for motor and generator cooling, engine fuel combustion, and compartment pressurization.

This section of the locomotive maintenance manual covers the central system, the components of which are in or connected to an air-tight compartment, Fig. 4-1, located directly behind the locomotive cab.

The rear of the electrical cabinet makes up the front wall of the air compartment. The back wall is made up of the AR10 generator and a partition fitted around the generator. One opening is provided for air to the engine and another opening is provided for the auxiliary generator and blower drive.

The hood sides and roof and the generator pit complete the central air compartment. Ambient air enters the compartment through the carbody inertial filters that are located high on the sides of the hood. The filters are made up of wedge shaped cells, Fig. 4-2, which have shaped slots forming each wall of the wedge. The demands of devices that draw air from the central compartment create a depression within the compartment. Outside air is forced rapidly through the wedge shaped cells. Dirt particles, because they are heavier than air, tend to travel in a straight line and are carried into a bleed duct located at the narrow end of the wedge. The main portion of the air, separated by the action of inertia from the dirt it carries, changes direction abruptly, passes through the narrow side passages, and enters the compartment as clean air. The bleed air containing dirt is drawn through an electrically driven bleed blower and is expelled through the roof of the locomotive.

Approximately two-thirds of the filtered air goes to the generator and traction motor blowers to provide cooling air to the generator and motors. Supplementary use is also made of traction motor cooling air in the following manner.

1. Provides pressure to counteract the depression in the central compartment and enables an aspirator, Fig. 4-3, to drain water from the generator pit.
2. Provides filtered air under pressure to the electrical cabinet, and provides cooling air to the dynamic brake blower motor bearing.
3. Provides pressure to the oil bath engine air filter in order to alter its mode of operation and prevent filter oil from being drawn into the engine when operating at higher speeds.

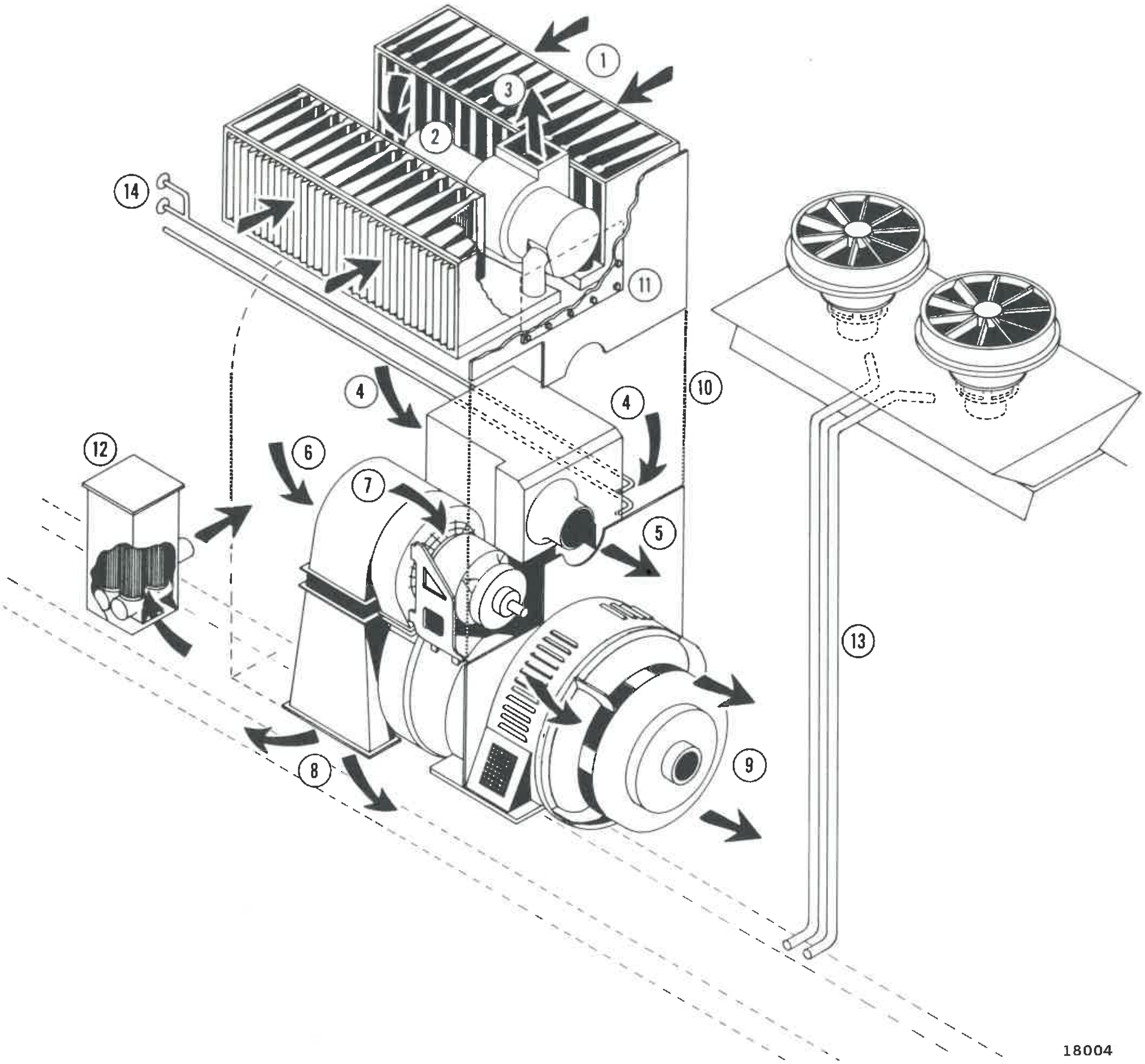
Air from the generator blower is applied first to cool the AR10 rectifier banks. From there it passes through the generator and into the engineroom. This creates a slight pressure which tends to keep dirt from entering the engineroom. This filtered air is used by the air compressor, reducing the load on its own air intake filter assembly.

INSPECTION AND MAINTENANCE OF THE CENTRAL AIR SYSTEM

COMPARTMENT INSPECTION

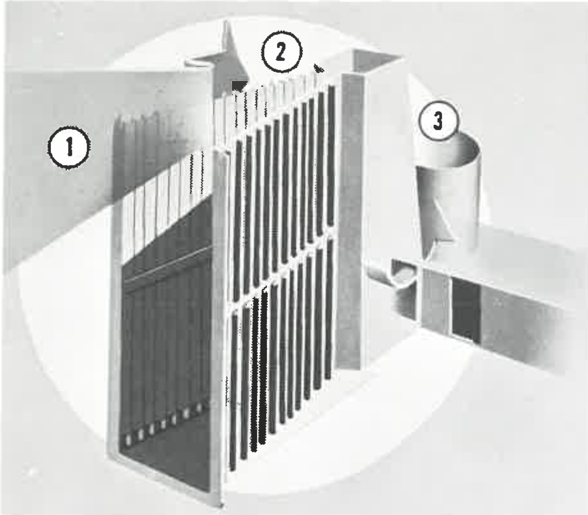
If any leaks exist in the central air compartment, unfiltered air will enter. This may be caused by any of the following defects.

1. Access panel bolts removed.
2. Access panel gaskets or seals not properly applied.
3. Compartment door not tightly closed.
4. Engineroom partition and attached cover plates not properly applied and sealed.



1. Outside Air Intake To Inertial Filters
2. Clean Air Into Sealed Compartment
3. Blower Driven Air Carrying Dirt
4. Intake For Engine Air Filter
5. Clean Air To Engine
6. Intake To Traction Motor Blower
7. Intake To Generator Blower
8. Cooling Air Ducted To Traction Motors
9. Generator Cooling Air Pressurizes Engine Compartment
10. Outline Of Sealed Central Air Compartment
11. Access Panel
12. Electrical Cabinet Air Filter
13. Cooling Air Piped To Dynamic Brake Blower Motor Bearing
14. Filter Vacuum Switch FVS, Engine Filter Switch EFS, And Manometer Hose Stem

Fig. 4-1 – Central Carbody Air System



1. Outside Air Intake
2. Clean Air Into Sealed Compartment
3. Blower Driven Air Carrying Dirt

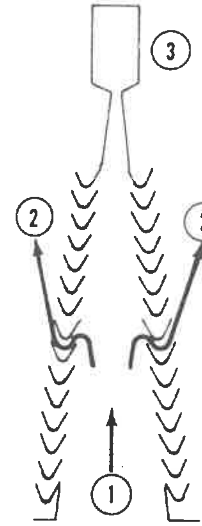


Fig. 4-2 – Inertial Air Filter Cell Diagram

5. Generator pit aspirator not properly connected.

ASPIRATOR INSPECTION

At the intervals stipulated in the Scheduled Maintenance Program, inspect the main generator pit aspirator, Fig. 4-3, as follows:

1. Check aspirator drain holes for obstructions.
2. Check that traction motor cooling air is exhausting from the aspirator tube causing venturi action at the aspirator drain holes.

FAULTY BLEED BLOWER OPERATION

The efficiency of the inertial carbody air filters will be significantly reduced if the bleed blower is faulty. If the blower is not operating, unfiltered air will be drawn in through the bleed blower exhaust stack, or if improper electrical connection is made, the blower may run backward with a resulting large drop in blower effectiveness. Either of the aforementioned conditions will cause an excessive amount of dirt to be blown into the generator and traction motor ducts. The engine filter will effectively clean the air taken in by the engine, but the added burden placed upon

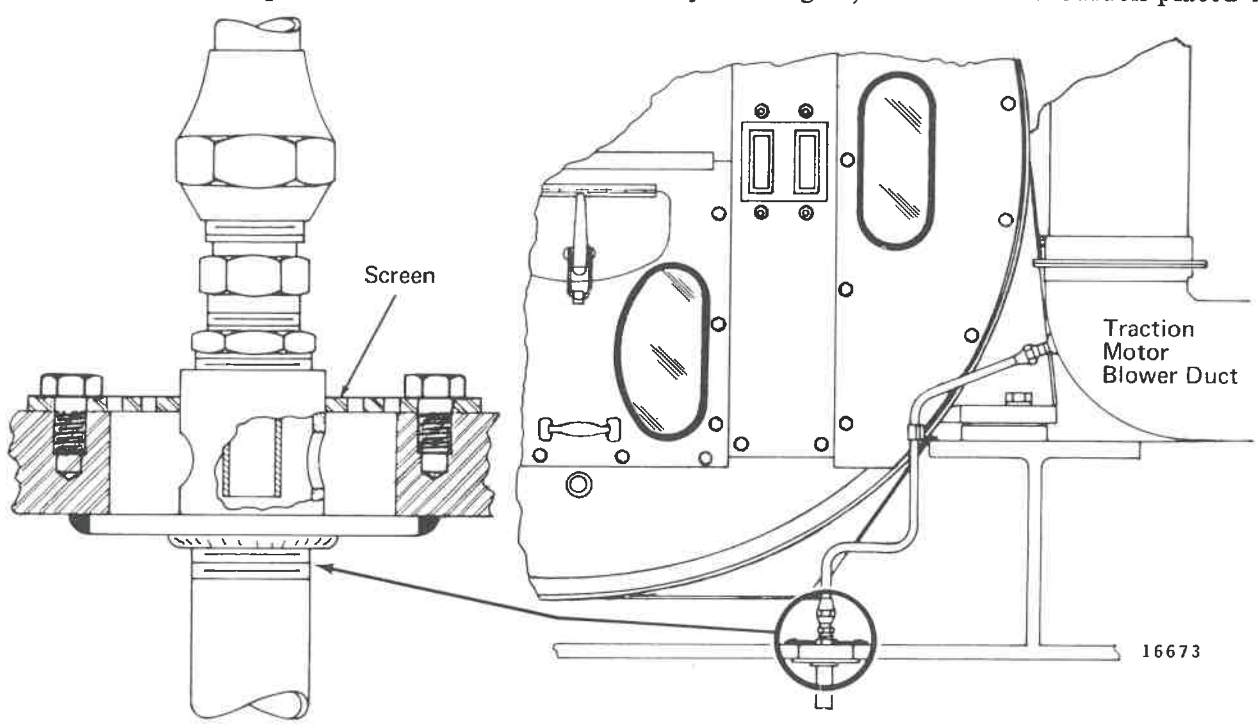


Fig. 4-3 – Typical Generator Pit Aspirator the engine filter may bring about the need for early filter maintenance.

Proper operation of the bleed blower can be most readily verified in the following manner. Climb to the top of the locomotive before the engine is started, and observe the squirrel cage blower through the exhaust filter compartment. When the engine is started, the blower will turn so that the vanes move up toward the observer.

NOTE: It is not sufficient merely to check that air is exhausting from the bleed blower hatch of an already running engine. The squirrel cage blower, if running backward, will still exhaust air from the hatch, but at a greatly reduced volume.

INSPECTION OF FILTERS

CARBODY INERTIAL FILTERS

When dirt accumulates on the inertial filter cell vanes, the pressure drop across the filter increases, thus increasing the depression inside the filter compartment. As depression increases, the carbody inertial filter becomes less efficient, but this in itself is not critical, since the efficiency of the engine filter may not be affected. However, as filter compartment depression increases, the traction motor and generator blowers, which take their air from the compartment, will put out less cooling air.

It is not possible to determine by a visual inspection whether the carbody filters are sufficiently clean or are plugged to the maximum allowable limit. It is possible for the filters to appear very dirty and still provide adequate filtration and adequate cooling air.

If dirt on the filters is evenly distributed, it has no adverse effect upon filtration, except for the resulting increased pressure drop that the cooling blowers must work against. However, if dirt is unevenly distributed, filtering effiency can be reduced without an increase in pressure drop.

It has been determined from experience that inertial filters should be removed from the locomotive and cleaned whenever compartment depression exceeds the value shown on the Service Data page.

ENGINE AIR FILTERS

Additional filtration is required for air used by the engine. It is provided by a filter assembly consisting of 12 pleated paper elements, Fig. 4-4.

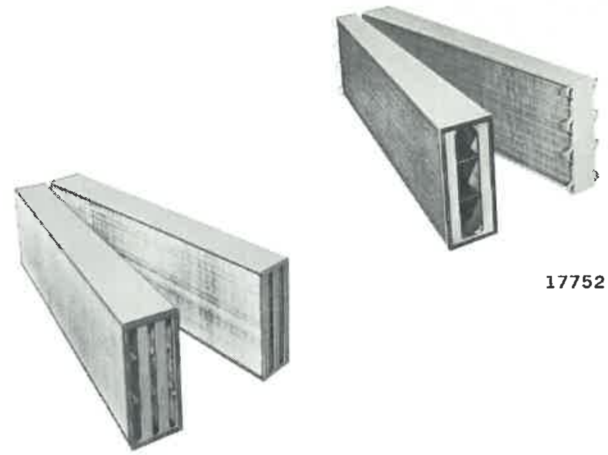


Fig. 4-4 – Pleated Paper Elements For Engine Air Filter

MEASURING DEPRESSION ACROSS INERTIAL PLUS ENGINE AIR FILTERS

Units equipped with pleated paper engine air filters are provided with pressure switches, Fig. 4-5, that sense the differential between ambient and pressure at the turbocharger inlet. The switches are located inside of the electrical cabinet, and connected by tubes to the turbo inlet side of the engine air filter, and to ambient.

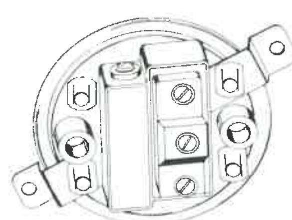


Fig. 4-5 – Filter Safety Device

When the primary switch FVS trips at 14" differential the ENG. AIR FILTER light comes on in the AN module, indicating excessive depression.

When the backup switch EFS trips at 24", differential a latching relay EFL in the electrical cabinet picks up. Relay contacts operate to limit engine speed and power and provide a backup signal to the AN module. The latching relay must be reset before the AN module can be reset.

Hose stems located at a corner of the electrical cabinet provide a convienient place to take a manometer reading of pressure drops across the inertial air filter or the engine plus inertial air filters. Monometer readings should be taken as indicated in the Scheduled Maintenance program or when operating conditions or the appearance of the filters seem to warrant such a check.

1. At the side of the electrical cabinet connect a rubber hose to the inertial filter hose stem, Fig. 4-6. Connect the other end of the hose to a U-tube manometer or other pressure measuring device.

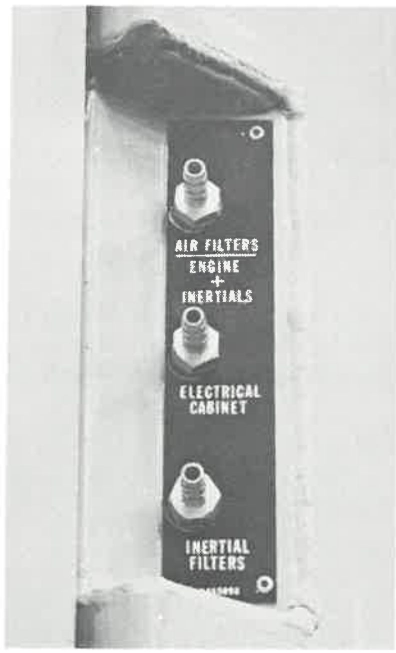


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Fig. 4-6 – Hose Stems For Manometer Connections

2. Operate the diesel engine until it is warm, then with reverser handle in neutral position, test switch in CIRCUIT CHECK position, and generator field CB off, place throttle in Run 8 position. Loading is not necessary.

3. If filter compartment depression is less than the minimum stipulated on the Service Data page, make certain that all central air compartment panels, partitions, and cover plates are properly applied and that no air is bypassing the carbody filters.

4. Filter compartment depression greater than the maximum stipulated on the Service Data page is cause for immediate cleaning of the inertial filters.

NOTE: A reading of more than 3" of water is indication that the inertial filters can be expected to plug within 12 months.

5. Connect the measuring device to the "Engine - Inertials" hose stem. If the reading is greater than the maximum stipulated on the Service Data page, and the inertial filter reading previously taken was satisfactory, the pleated paper filters must be renewed.

NOTE: If the inertial filter reading was near the maximum, cleaning of the inertial filters may extend the useful life of the paper filters somewhat.

6. Connect the measuring device to the "Electrical Cabinet" hose stem. Make certain that all cabinet doors are securely latched. Check the Service Data page for maximum permissible depression.

CLEANING THE CARBODY INERTIAL AIR FILTER

The only approved and recommended method of cleaning the carbody filters is immersion in a hot caustic or detergent bath followed by a cold wash. The filters should be removed from the locomotive and cleaned if filter compartment depression exceeds the maximum value shown on the Service Data pages.

REMOVAL AND CLEANING PROCEDURE

In order to facilitate inertial air filter cleaning and changeout, a spare set of filters should be available for rapid exchange with dirty filters. This practice will allow proper cleaning and maintenance of the filter assemblies without tying up a locomotive.

To remove the inertial air filter assemblies from the locomotive, perform the following:

1. In the engineroom, at a position adjacent to the turbocharger, remove 22 hex head 1/4"-20 screws and the filter compartment access panel, 11 Fig. 4-1, from the engineroom – air compartment partition. This provides access to clamps on dirt evacuating hoses.

2. Loosen the clamps on the hose that connects the inertial filter dust bin to the bleed blower assembly. Raise the rubber hose so that the hose is free of the filter assembly.

3. From the outside of the locomotive remove twelve 1/2"-13 hex head bolts and split lockwashers holding the inertial air filter inlet screen to the filter opening. Remove the screen. Fig. 4-7 shows a cross sectional view of the area where filter and screen are attached to the locomotive hood.

4. Thread several lifting eyes into the holes for the 1/2"-13 bolts, and attach a suitable lifting device to the filter assembly. Each filter assembly weighs approximately 600 pounds.

5. From inside the central air compartment loosen the flare nuts that connect drain piping to the underside of the filter assemblies. Bend the tubing slightly away from the fittings.

6. With a pipe wrench, remove the pipe nipples and attached elbows from the filter assemblies. This is done to allow easy removal of the filter assemblies and avoid damage to the pipe fittings. To avoid loss, the elbows and nipples may be temporarily fastened to the flare nuts.

7. Remove the 18 hex head 1/2"-13 bolts that hold the filter assembly in place, and remove the filter assembly from the carbody.

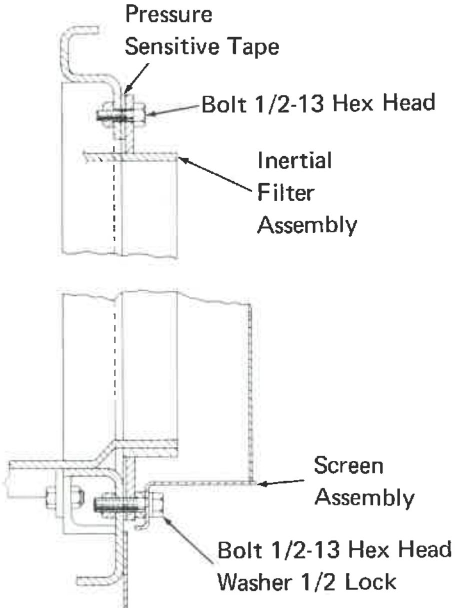


Fig. 4-7 – Inertial Filter And Filter Screen Attachment Cross Sectional View

8. Remove and discard the pressure sensitive backed tape-type gasket material from the filter flange.

9. Place the entire filter assembly in a hot caustic or detergent bath until clean. The time required for cleaning will depend upon the type of bath used, its temperature, and the condition of the filter.

10. When the filter is removed from the caustic bath it should be given a clear cold wash.

11. Dry the filter flange and apply a new pressure sensitive backed tape-type gasket.

12. Reinstall the filters and filter screens, reconnect water drain piping, and reconnect the hose between the dust bin and blower assembly.

13. Tighten the hose clamps, then after inspecting the gasket material on the access cover, replace the access plate and reapply the screws.

CAUTION: Make certain that the hoses are correctly mated to the dust bin openings before tightening the hose clamps.

14. Check all connections to see that no leaks exist. Check the filter compartment depression.

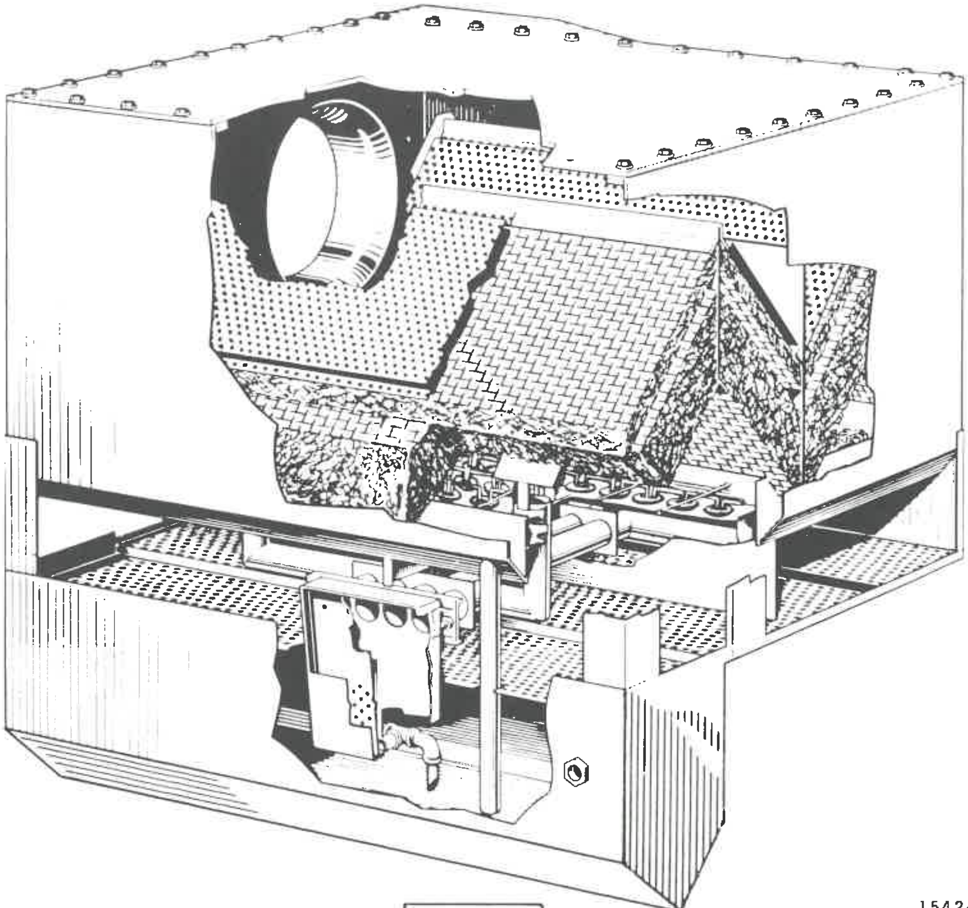
OIL BATH TYPE ENGINE AIR FILTER (SPECIAL ORDER ONLY)

GENERAL DESCRIPTION

The oil type engine air filter, Fig. 4-8, is provided when requested by the railroad. It is mounted within the central air compartment and on top of the main generator. It is an oil bath filter that relies upon oil-wetted media to remove dirt particles from the air that is drawn through it. The filtering media is both wetted and washed by filter oil that is drawn by the force of air from an oil sump and up to the filtering media.

FILTER OPERATION

Incoming air enters the front, side, and back of the filter housing through openings formed by structural iron legs that separate the drip pan and oil sump from the main body of the filter assembly. The air passes through a perforated plate, each perforation of which is covered by a disc that is elevated by the force of incoming air.



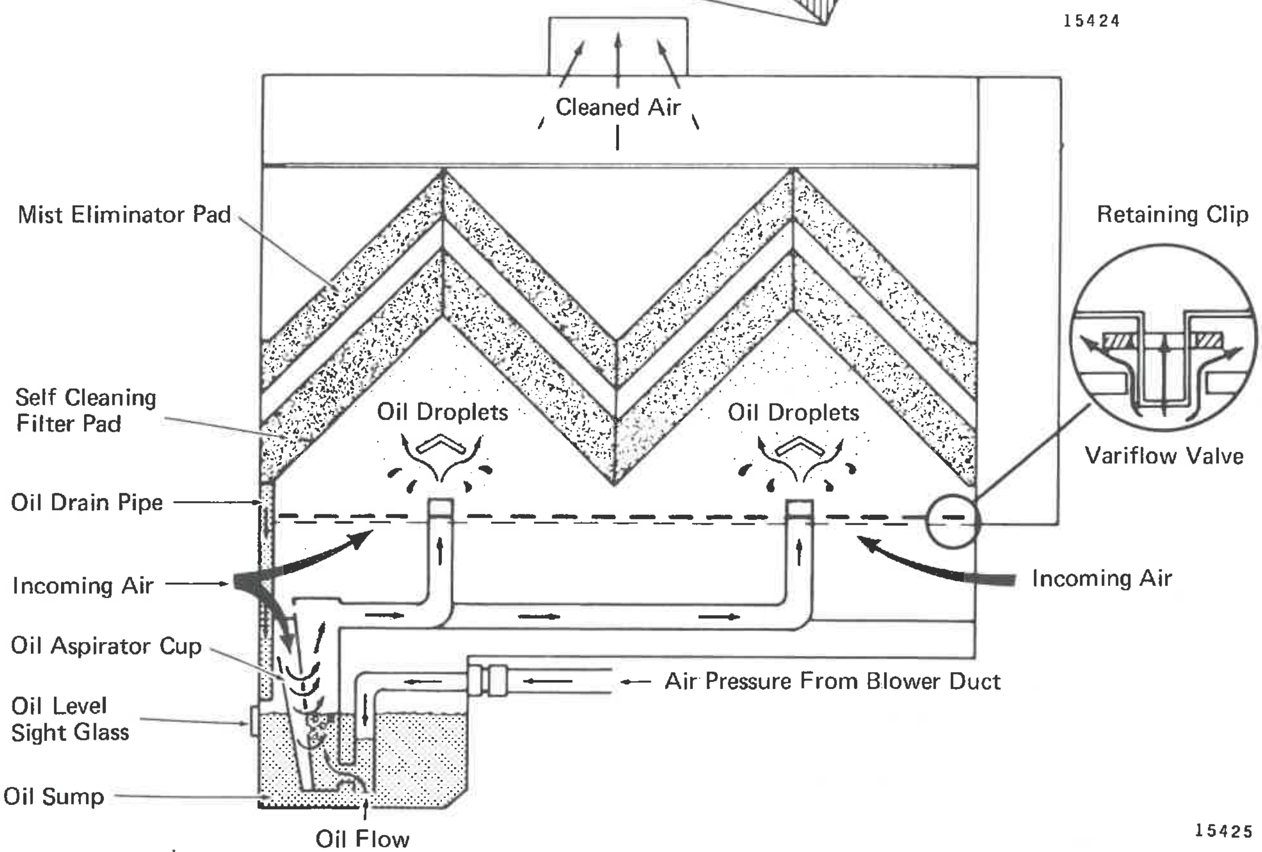


Fig. 4-8 – Engine Oil Type Air Filter Pictorial And Schematic Diagram

The openings in the perforated plate are calibrated to increase the velocity of air through them just the proper amount to pick up oil as it tends to spill over the edges of the holes. At the same time, the movable discs (vari-flow valves) act to distribute air flow uniformly over the filter pad area.

Oil and dirty air are carried upward from the perforated plate and into the primary filter pad. Dirt is collected by the pad, and clean air passes through the pad. The collected dirt is washed out by oil as it drains to the low edges of the pads and into channels and piping that returns the dirty oil to the sump. The accumulated sludge settles to the bottom of the sump.

A secondary pad catches oil that did not adhere to the primary pad. However, when the air velocity through the filter reaches a certain level, oil would pass through the secondary pad and into the engine. The manner in which this is prevented is detailed under ASPIRATOR CUTOFF.

OPERATION OF THE PNEUMATIC OIL LIFT

The restriction in air flow caused by the perforated plate and vari-flow valves develops a pressure drop across the perforated plate. Because of this pressure drop, oil is pulled in droplet form from the aspirator cup and into the lift tubes. A flow of oil is therefore supplied from the oil sump to the filtering media and top of the perforated plate. This occurs in the following manner.

The pressure inside the lift tubes is less than the atmospheric pressure on the surface of the oil in the sump. Oil therefore starts to rise in the aspirator cup. See detail on Fig. 4-8. The pressure differential also causes air to enter aspirator holes in the cup, some of it below the level of the oil standing in the cup. The jets of air through the aspirator holes are of sufficient velocity to break oil surface tension and create oil droplets. The air-oil mixture combines with the air entering the aspirator holes above the oil level. This provides sufficient lift to deliver the oil to the area above the perforated plate. The small oil particles are carried to filtering pad; the larger drops fall to the perforated plate and form a film that is picked up and carried to the filtering pad by the force of incoming air through the vari-flow valves.

ASPIRATOR CUTOFF

The sump details on Fig. 4-8 show that traction motor blower pressure is used to influence the flow of oil to the aspirator cup. This is required because space restrictions limit the size of the oil bath filter, and the velocity of intake air at higher engine speeds would cause oil to be drawn through the mist eliminator pad and into the engine. The method used to prevent filter oil from being drawn into the engine is to cut off aspiration when engine speed reaches a specific throttle position. This is done by taking the pressure (proportional to engine speed) in the traction motor blower duct and directing it to the aspirator assembly. When this pressure becomes great enough, oil flow from the sump is blocked.

After aspirator cutoff, the filter acts as an oil wetted impingement filter of sufficient capacity to operate continuously at high throttle for over a day without plugging the filter. Since a locomotive does not operate continuously at high throttle for such long periods, filtering media plugging will not occur. The media will be cleaned adequately and re-oiled when the engine is operated at idle or low throttle position for at least 15 minutes every few hours.

MAINTENANCE

Operation of the engine oil bath filter should be checked at intervals stipulated in the Scheduled Maintenance Program. Filter oil should be changed and the filter cleaned at stated intervals, or at shorter intervals if operating conditions warrant. Filter oil must be of the type indicated on the Service Data page.

OIL LEVEL

A sight glass is located on the side of the oil sump. The oil level should be checked after the engine has been idling for at least 5 minutes to allow the system to balance. The oil level should be at the center of the sight glass. If oil level is checked immediately after engine shutdown it will also be at the center of the glass, but will rise to the top of the glass in about 20 minutes.

If frequent addition of oil is necessary, an investigation should be made to determine where the oil is being lost. If no external leak is found, the aspirator cutoff may be faulty and oil is being drawn into the engine.

Under normal conditions, there should be no need to add oil between scheduled oil changes.

CHECKING ASPIRATOR CUTOFF

Aspirator cutoff can be checked by looking with a flashlight up through the vari-flow valves toward the filtering pad while the locomotive is running in various throttle positions. When oil is being aspirated, tiny droplets can be seen being carried toward the filtering pad. Aspirator cutoff should occur at the throttle position listed on the Service Data page. Close the central air compartment door while making the check.

If the aspirator cutoff is not working, check the following:

1. The hose connecting the traction motor blower duct with the filter sump should be intact and secure.
2. Aspirator cutoff orifice plugged.
3. Air pressure line leaking inside the sump.
4. Additive type oil used instead of recommended oil.

CAUTION: Additive type oils tend to keep dirt particles in suspension, which increases its tendency to "mist."

5. While checking aspirator cutoff, check that all vari-flow valves operate properly and that the valve retaining clips are in good condition.

PROCEDURE FOR CHECKING ASPIRATOR CUTOFF

1. With engine at idle:
   a. Check oil level. The oil level should be at the center of the sight glass.
   b. Check oil level in the aspirator cup with a dipstick. Oil level should be at a minimum depth of 1".
2. Increase engine speed to 8th throttle. Within 3 minutes after reaching 8th throttle, the aspirator cup should be empty.
3. Reduce throttle to Run 6 and allow the engine to run at that speed for 3 minutes. If the aspirator cutoff is operating properly there will be no oil in the delivery cup.
4. Return engine to idle. Within 3 minutes the oil level in the delivery cup should be at a minimum depth of 1".

CHECKING FILTER OIL WASH

A periodic check should be made to verify that the aspirator is working properly and the filtering media is being washed with oil. If the filter air intake area is coated with dry dirt, proper aspiration is not taking place. The following items should be checked.

1. Check for proper filter oil level.
2. Check that the oil level in the aspirator cup is at least 1-1/2". A piece of metal can be used as a dip stick.
3. Verify that the proper type of oil is being used in the filter.

CLEANING THE FILTER

A drain plug is provided at the bottom of the oil sump. After the oil is drained, replace the plug temporarily and use a kerosene spray to clean the vari-flow valves and the oil drip pan surfaces. Drain out the kerosene, then with a scraping tool, clean the sludge from the sump. When the bulk of the sludge has been removed a further kerosene spray may be used to wash down the remaining sludge. With a brush or some pointed object, check that the holes in the aspirator cup are clear. Wipe out the sump with shop towels.

Add the type oil specified on the Service Data page. Oil level should be at the center of the sight glass.

The filtering and mist eliminator pads need no servicing and should not be disturbed unless there is definite indication of malfunction. Should some rare condition make it necessary to clean the filtering and mist eliminator pads, it is first necessary to remove the inertial filters and roof hatch from the locomotive, then unbolt and remove the filter top plate. Lift out the pads and clean them with kerosene or hot water.

EMD
SERVICE DEPARTMENT

SERVICE DATA
CENTRAL AIR SYSTEM

ROUTINE MAINTENANCE PARTS AND EQUIPMENT

	Part No.
Pressure Sensitive Backed Tape-Type Gasket	
1/16" x 3/4" Rubber Cork	8135382
100 ft. length	8133198
1/16" x 1-7/8" Rubber Cork	8135383
100 ft. length	8133199
Rubber Weather Seal	8324100

SPECIFICATIONS

Engine Air Filter -- Oil Type

No. 10 Weight, Non-Detergent, Low Additive Mineral Oil (Air Compressor Oil)	13-1/2 Gallons
Aspirator Cutoff Point Maximum Position	6th Throttle
Engine Air Filter – Pleated Paper Type (12 Required Per Assembly)	
Filter Element (Length 45" – Weight 19.5 Lbs.)	8377042 or 8468999
Electrical Cabinet Air Filter	
Pleated Cotton-Paper Elements (4 per housing)	8345482

FILTER SAFETY DEVICES

Filter Vacuum Switch FVS ($14\pm1/2$" H_2O Negative Pressure)	8465021
Engine Filter Switch EFS ($24\pm1/2$" H_2O Negative Pressure)	8466230

FILTER INTERCHANGEABILITY

SD40-2 engine filters are interchangeable with the SD45-2 and SD45T-2. But with no other models.

GP40-2 and SD40-2 engine filters are not interchangeable.

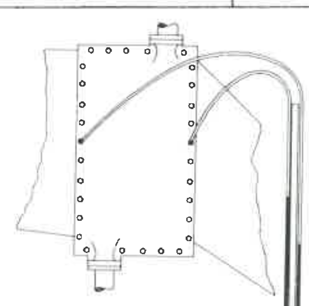
GP38-2 and SD38-2 engine filters are interchangeable with GP40-2 filters.

Minimum Allowable Central Air Compartment Depression . . . . 2 inches H_2O

Maximum Allowable Depressions:

		Maximum Depression Inches Of Water	Pressure Reading Location At Run 8, Load Or No Load
Units Equipped With Oil-Type Engine Air Filters	Carbody Inertial Filter	5	Measure at pressure tap on left side of electrical cabinet. See Fig. 4-6.
	Combined Oil-Type And Inertial Filters	16	Between oil-type filter top front (toward electrical cabinet) bolt hole and outside of filter compartment with door closed.
	Aftercooler Core	10	At bolts holes (5th from top) across after-cooler core. Apply and disconnect hoses with engine down or at idle speed. See sketch at bottom of page. CAUTION: Do not remove hoses with engine at high speed. Do not apply or remove hoses singly.

		Maximum Depression Inches Of Water	Pressure Reading Location At Run 8, Load Or No Load
Unit Equipped With Pleated Paper Engine Air Filters	Carbody Inertial Filter	5	Measure at pressure tap on left side of electrical cabinet. See Fig. 4-6.
	Combined Pleated Paper And Inertial Filters	14	Measure at pressure tap on left side of electrical cabinet. See Fig. 4-6.
	Aftercooler Core	10	See aftercooler core instruction above.



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Reading Differential Pressure On Aftercooler

RECOMMENDATION – INERTIAL FILTER CLEANING

It is recommended that filter compartment depression readings be taken periodically. However, if readings are taken only yearly, a reading of 3 inches of water indicates that the maximum allowable depression of 5 inches probably will be reached before the next yearly inspection.

RECOMMENDATION – OIL-TYPE FILTER CLEANING AND OIL CHANGE

Change oil, and clean the sump and valve distribution plate at intervals indicated in the scheduled maintenance program.
Monitor the combined inertial and oil-type filter depression at annual inspections. Also check the inertial filter depression independently. These readings will indicate whether the inertial filter alone, or both the inertial and the oil-type filters should be removed and cleaned.

The oil-type filter should be removed and cleaned when the pressure reading cannot be brought into tolerance by cleaning the inertial filter alone; or if with a clean inertial filter it is expected that the pressure limitation will be exceeded before the next annual inspection.

If the maximum depression is not reached, the oil-type filter should be removed and cleaned only at the filter rebuild interval.

RECOMMENDATION – AFTERCOOLER CORE CLEANING

On units equipped with oil-type engine air filters, the aftercooler cores should be cleaned at intervals indicated in the scheduled maintenance program.

RECOMMENDATION – PAPER ENGINE AIR FILTER CHANGEOUT

When a tripped engine air filter service indicator is noted, the indicator should be reset with the engine at idle speed. Speed should then be increased to Run 8 for 1 minute, then returned to idle. If the indicator is tripped, check the combined paper and inertial filter depression with a manometer, then check the inertial filter depression independently. These readings may indicate whether inertial filter cleaning will significantly increase the usable life of the paper filters.

Ideally, to obtain full use of the paper filters, the times of inertial filter cleaning and paper filter changeout should be staggered.

RECOMMENDATION – PAPER ELECTRICAL CABINET AIR FILTER CHANGEOUT

Electrical cabinet air filters should be renewed at intervals indicated in the scheduled maintenance program.

If unusually dirty operating conditions exist, the air filters may become plugged in a shorter period of time. Plugging can be detected by measuring static pressure inside the electrical cabinet with all doors tightly latched. Electrical cabinet air filters should be renewed when pressure is less than 1.5 inches of water with a properly sealed electrical cabinet.

Cabinet pressure can be sensed by means of static pressure tap on the left side of the electrical cabinet. Low cabinet pressure can indicate one or both of the following:

1. Dirt loaded filter element.

2. Poor cabinet seal. This condition will result in excessive air flow through the electrical cabinet air filters, causing them to become plugged at a faster than normal rate.

NOTE: To obtain accurate, representative electrical cabinet pressure, the central air compartment door must be tightly closed, and traction motor inspection covers must be secured in place.

COMPRESSED AIR SYSTEM

DESCRIPTION

Compressed air is used for operating the locomotive air brakes and auxiliary devices such as sanders, shutter operating cylinders, horn, bell and windshield wipers. Air is also required for atomizing the fuel oil supplied to the steam generator (if so equipped).

AIR COMPRESSOR

DESCRIPTION

Air is compressed by a deep crankcase water cooled, three cylinder (six cylinder optional), two stage air compressor, Fig. 5-1. The compressor is driven through flexible couplings from the front end of the engine crankshaft.

The compressor has its own oil pump and pressure lubricating system. With the engine running, the oil level in the compressor crankcase can be checked on the float type indicator. At idle speed with the lubricating oil at operating temperature (140° F.), the oil pressure should be 18 to 25 psi. A plugged opening in the relief valve block is provided for an oil pressure gauge.

The compressor has two low pressure and one high pressure cylinders. The pistons of all three cylinders are driven by a common crankshaft. Two low pressure cylinders are set at an angle to the one vertical high pressure cylinder. Air from the low pressure cylinders goes to a water cooled intercooler to be cooled before entering the high pressure cylinder. The intercooler is provided with a relief valve and a plugged opening for a pressure gauge.

The compressor is equipped with either of two dry type air inlet filters, Fig. 5-2, containing replaceable elements.

MAINTENANCE

The air compressor should be periodically checked to see that the lube oil level indicator needle is in the RUN zone on the sight gauge. If the gauge shows the oil level to be in the ADD zone, a sufficient amount of EMD approved lube oil should be added at the oil fill pipe. The oil should be changed at intervals stated in the applicable Scheduled Maintenance Program. The addition of oil between changes is normally not necessary due to the high capacity of the deep crankcase.

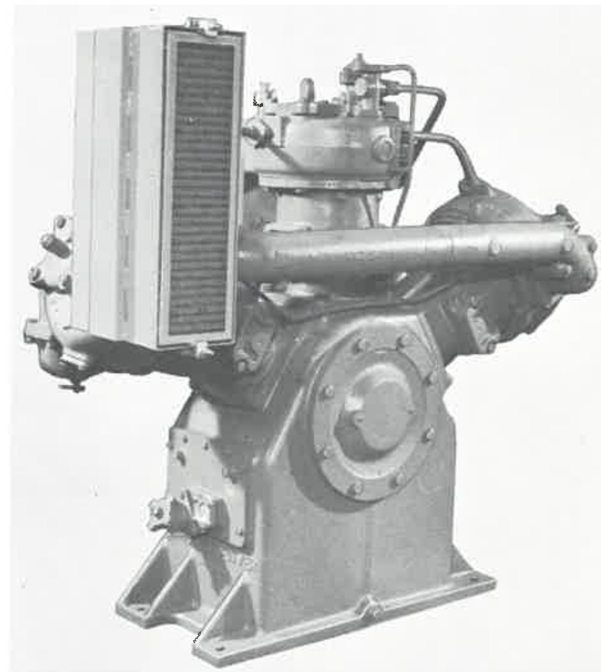

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Fig. 5-1 – Air Compressor

When it is necessary to install a pressure gauge to check intercooler or lube oil pressures, be sure the gauge is removed and replaced with a plug and the plug tightened sufficiently to prevent loosening from vibration.

The air inlet filter element should be changed at intervals specified in the applicable Scheduled Maintenance Program. Consult the Service Data page at the end of this section for the correct replacement filter element.

13552

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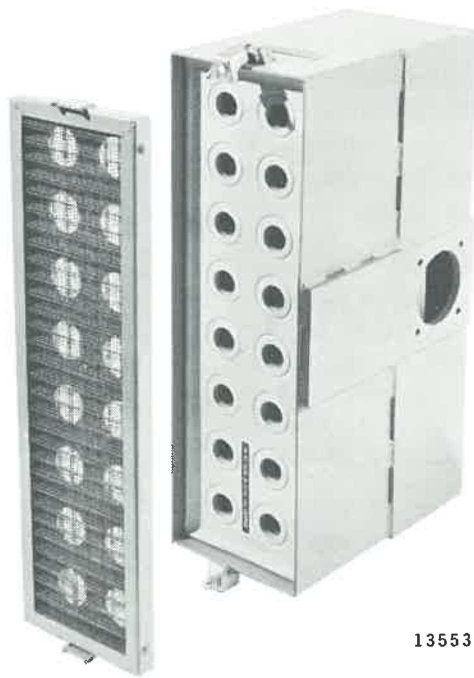
Fig. 5-2 – Compressor Air Filter

13552



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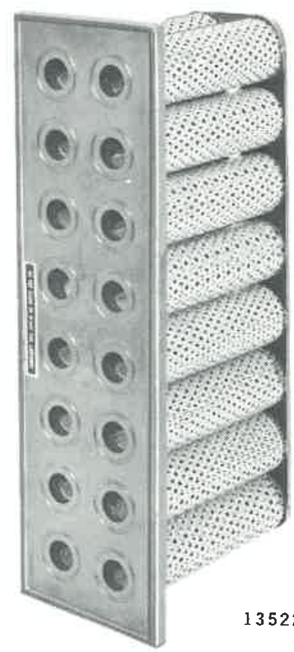
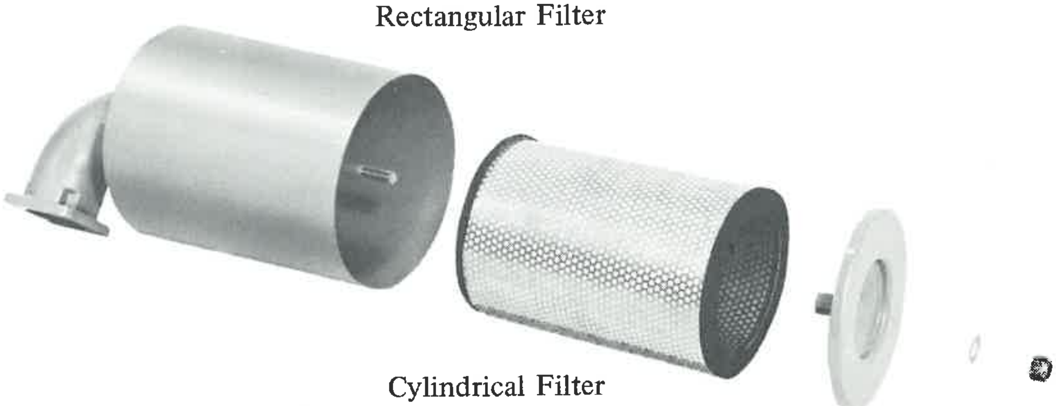


13522

Rectangular Filter



Cylindrical Filter

Fig. 5-3 -- Replacing Compressor Filter Element

15462

To remove the element from the rectangular shaped filter, remove the nut, lockwasher, and retainer hook at the top and bottom of the filter, Fig. 5-3. The impingement screen can then be removed and the element pulled out of the housing.

To remove the element from the cylindrical shaped filter, remove the elastic stop nut and the retainer at the bottom of the filter. The element is then free to drop out of the filter body.

COMPRESSOR CONTROL SWITCH – CCS

DESCRIPTION

Since the air compressor is directly connected to the engine, the compressor is in operation (although not always pumping air) whenever the engine is running. An unloader piston that cuts out the compressing action when actuated by air pressure from the compressor control switch, Fig. 5-4, is provided in the head of each high and low pressure cylinder. The unloader accomplishes this by blocking open the intake valves in the high and low pressure cylinders. When the air operating the unloader is cut off, the unloader releases the intake valves and the compressor resumes pumping. Main reservoir air pressure is used to actuate the unloader valves.

When the locomotive is furnished with the optional extra compressor synchronization, each locomotive unit is equipped with an electro-pneumatic system for compressor governor control. The electrical arrangement is such that the compressor in each unit of a consist pumps air to its own main reservoirs whenever the main reservoir pressure in any single unit drops to 130 psi, Fig. 5-5. All units will continue to pump until main reservoir pressure in each and every unit reaches 140 psi.

Another available option is a dual compressor control switch which acts to unload the compressor on an individual unit when the main reservoir pressure for that unit reaches 145 psi. This prevents individual compressors from working against the main reservoir safety valve when other units in the consist have not yet accumulated sufficient main reservoir pressure to signal unloading of the compressors.

MAINTENANCE

The compressor control switch, Fig. 5-6, is manufactured to close tolerances and therefore inspections should be limited to intervals specified in the applicable Scheduled Maintenance Program. If air compressor difficulties arise, all other sources of possible trouble should be investigated before any attempt is made to disturb the settings of the compressor control switch.

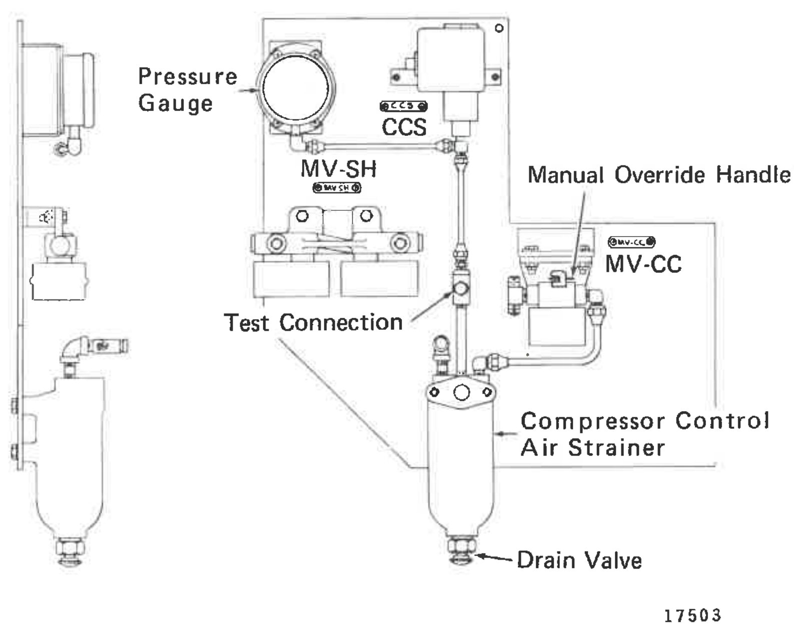
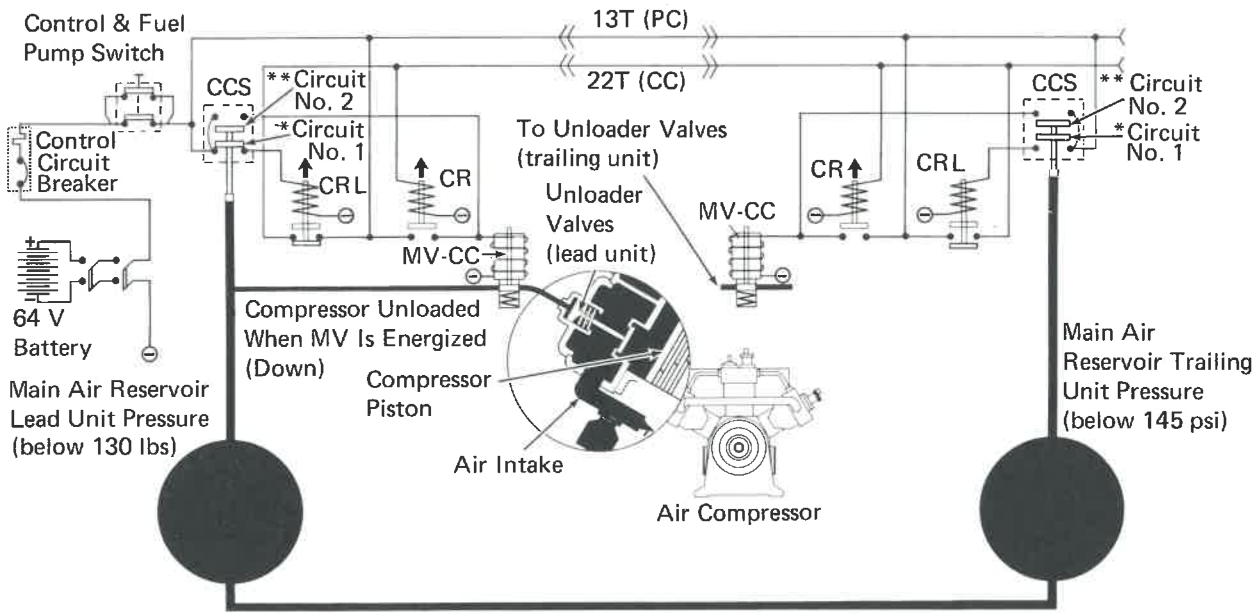


Fig. 5-4 – Compressor Control Panel



* Makes At 130 $^{+0}_{-3}$ psi Decreasing Pressure
Breaks At 140 $^{+0}_{-1}$ psi Increasing Pressure

** Makes At 145 $^{+3}_{-0}$ psi Increasing Pressure
Breaks At 135 $^{+3}_{-0}$ psi Decreasing Pressure

Fig. 5-5 – Electro-Pneumatic Compressor Control 13569

During periodic inspections of the compressor control switch or when faulty operation is suspected, the switch should be removed from the locomotive and replaced with a qualified switch. The faulty switch should be taken to a bench for any further testing or setting.

COMPRESSOR CONTROL MAGNET VALVE – MV-CC

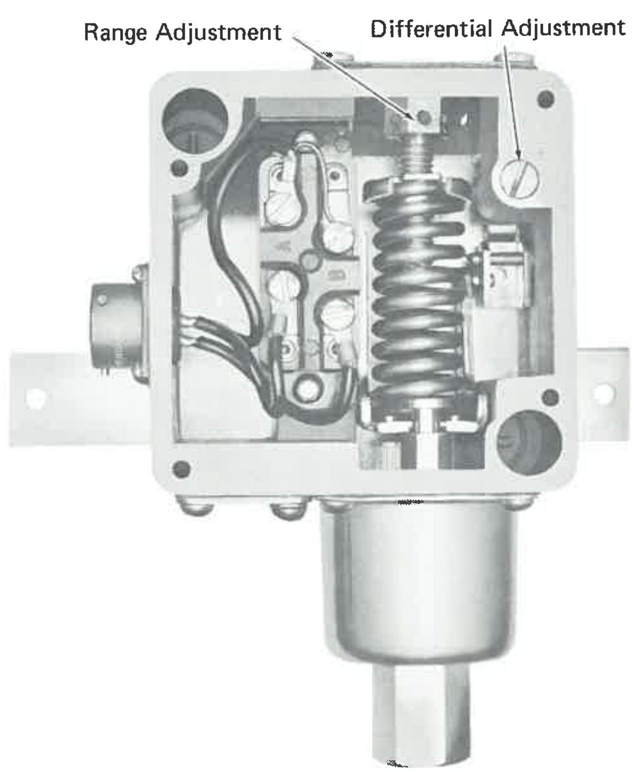
DESCRIPTION

When the compressor control magnet valve, Fig. 5-4, is de-energized, the air compressor unloader piston lifts and the compressor begins to pump. The magnet valve is de-energized when the compressor relay is energized and the compressor relay responds to the compressor control switch in the individual unit or to the compressor control switch in each or any unit of a consist equipped with synchronization.

A manual means is also provided to keep the air compressor unloaded. The compressor magnet valve, MV-CC, can be held open by a manual override handle, which holds the magnet valve in energized position.

MAINTENANCE

If faulty operation of the valve is suspected, check to see that the manual override handle is in the proper position. With the manual override handle pulled out and the magnet valve de-energized, the valve should close causing the compressor to pump. Check the magnet valve and air line to the compressor unloader valve for leaks. Also check the electrical connections on the valve to see that they are tight. If repair is required, remove the magnet valve and replace it with a qualified valve.



17555

Fig. 5-6 – Compressor Control Switch

COMPRESSED AIR PRESSURE GAUGE

DESCRIPTION

A pressure gauge, Fig. 5-4, is located on the compressor control panel next to the AC cabinet. The gauge is connected to the air system in the line from the main reservoir to the compressor control switch and consequently will reflect No. 1 main reservoir pressure.

MAINTENANCE

A test fitting is provided for checking gauge accuracy and compressor control switch settings.

COMPRESSED AIR FILTERS

DESCRIPTION

The compressed air system has three centrifugal type filters, the main reservoir and auxiliary main reservoir filters, Fig. 5-7, and the compressor control filter, Fig. 5-4, to prevent moisture and contaminants from being carried into the air brake and other air systems. Both the main reservoir and auxiliary main reservoir filters are equipped with an automatic electric drain valve which operates on a signal from the compressor control switch each time the compressor unloader valve is actuated. The compressor control filter drain valve opens each time reservoir pressure drops below 20 psi.

The main reservoir and auxiliary main reservoir filters can be equipped with an optional electro-thermo timer to control the interval between blowdowns of the automatic drain.

MAINTENANCE

The No. 2 main reservoir centrifugal filter contains a replaceable type filter element which should be changed at intervals stated in the applicable Scheduled Maintenance Program. See Service Data for correct filter element.

Before removing the sump bowl on the bottom of the filter be sure the cutout located between the main reservoir and the filter is shut off. Once the sump bowl is removed, the element can be removed by unscrewing the wing nut that holds the element in place.

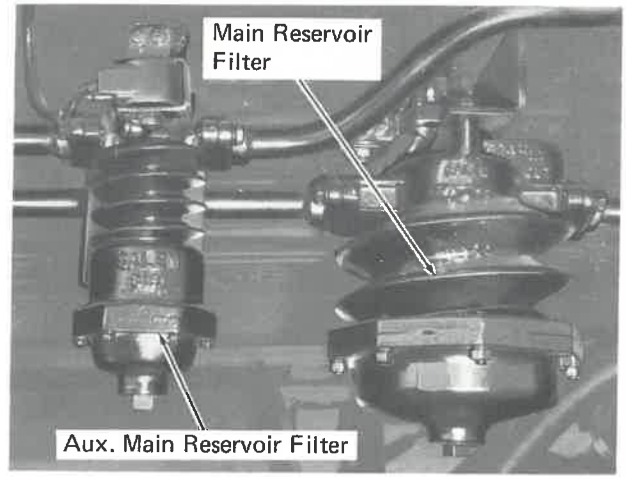


Fig. 5-7 – Compressed Air Filters

The sump bowl on both centrifugal filters may be cleaned out if necessary by removing the bowl. The drain valves should be cleaned and inspected when maintenance is performed on the filters as stated in the applicable Scheduled Maintenance Program.

MAIN RESERVOIR DRAIN VALVES

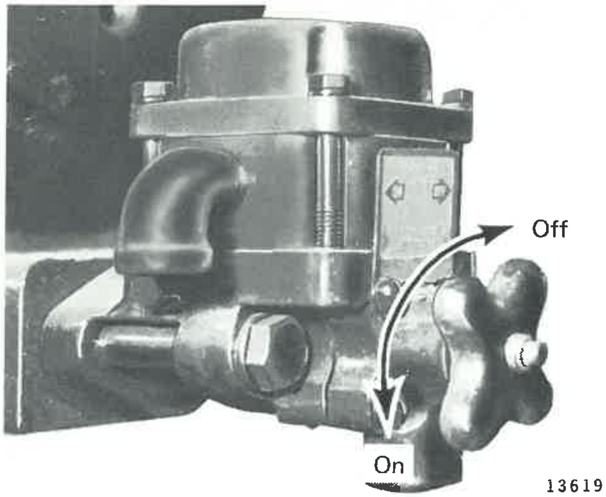
DESCRIPTION

The No. 1 main reservoir is equipped with a combination automatic/manual drain valve. When set on automatic, it operates as the compressor loads or unloads to allow moisture to be drained from the reservoir before it is carried into the air system. The No. 2 main reservoir is basically equipped with a manual drain valve but an automatic/manual valve is optional.

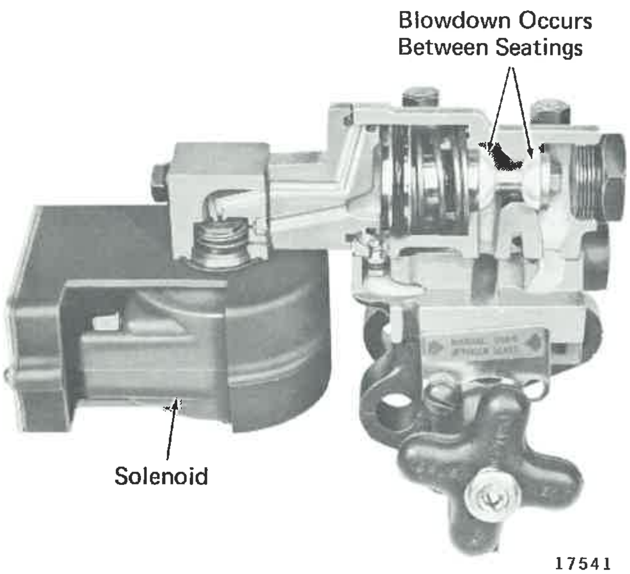
If it is desirable to shut off either the automatic/manual or the solenoid operated drain valves, turn the valve knob clockwise as far as possible. To return the valve to automatic operation turn the valve knob full counterclockwise. Manual drain will occur when the valve knob is midway between the ON and OFF positions.

The electro-thermo timer to control blowdowns of the automatic drains, mentioned earlier under Compressed Air Filters, can be supplied as an option at extra cost.

An additional option which is frequently used with the electro-thermo timer is the solenoid operated automatic drain valve which has the solenoid attached directly to it, Fig. 5-8.



Manual Drain Valve



Solenoid Operated
Automatic Drain Valve

Fig. 5-8 – Main Reservoir Drain

MAINTENANCE

The drain valves should be checked periodically to see that they are seating properly and no air is leaking. The seals and piston should be lubricated at regular intervals with a good grade of air brake grease.

ELECTRO-THERMO TIMER

DESCRIPTION

The electro-thermo timer, EBT, Fig. 5-9, used to control the interval between blowdowns on the automatic drain valves consists of a thermo switch containing a bi-metal disc, a heater, and a relay which is connected to the coil leads on the solenoid operated drain valves. When the relay coil is energized by closing the battery circuit, the heater in the electro-thermo timer is energized and heats the bi-metal disc. When the disc reaches a predetermined temperature, the switch contacts open, shutting off the heater and closing the circuit to the solenoid valve. This causes the drain valve to produce a short blast.

When the bi-metal disc in the thermo switch cools, it closes the contacts in the thermo switch, starts the heater, and energizes the relay which in turn de-energizes the solenoid valves. The drain operates again, producing a short blast.

MAINTENANCE

If faulty operation of the electro-thermo timer is suspected, first check to see that all connections are tight at the timer and at the drain valves. If this does not produce satisfactory results, replace the thermo switch by removing the electro-thermo timer cover and pulling the tape tab on the switch. Plug in a new switch and replace cover.

DRAINING THE AIR SYSTEM

The compressed air system air filters and main reservoir automatic drains should be operated manually at least once a day to ensure operation of the automatic feature.

The drain valves are located at the following locations:

1. Auxiliary main reservoir centrifugal filter drain valve, Figs. 5-10 and 5-11.

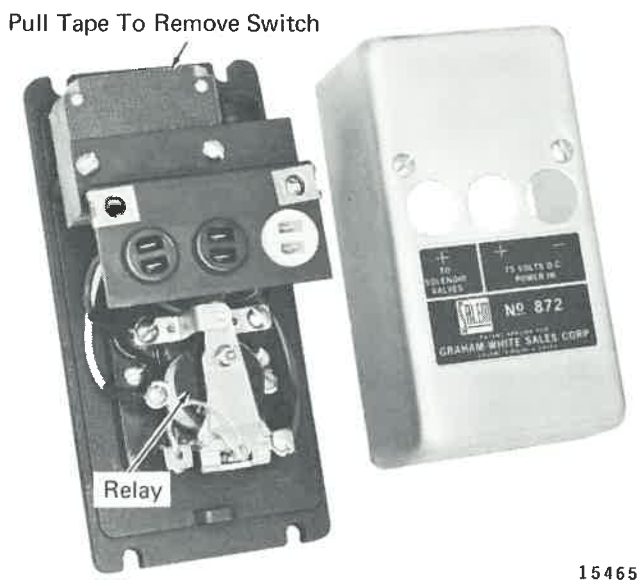


Fig. 5-9 – Electro-Thermo Timer

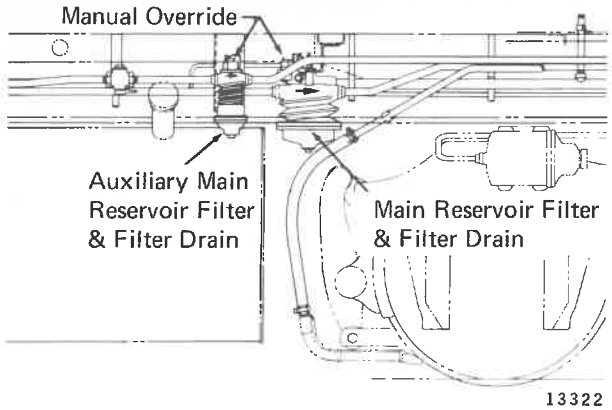


Fig. 5-10– Main And Auxiliary Main Reservoir Centrifugal Filters

2. Main reservoir centrifugal filter drain valve, Figs. 5-10 and 5-11.

3. Main reservoir drain valves, Fig. 5-11.

4. Compressor control strainer drain valve, Fig. 5-11.

RADIATOR SHUTTER CONTROL

SHUTTER OPERATING PISTON

DESCRIPTION

The radiator shutters are opened and closed by the action of an air operated piston, Fig. 5-12, which is mounted to the carbody structure at the front of the shutter assembly on each side of the carbody. The cylinder is actuated when the shutter control magnet valves, MV-SH, are energized.

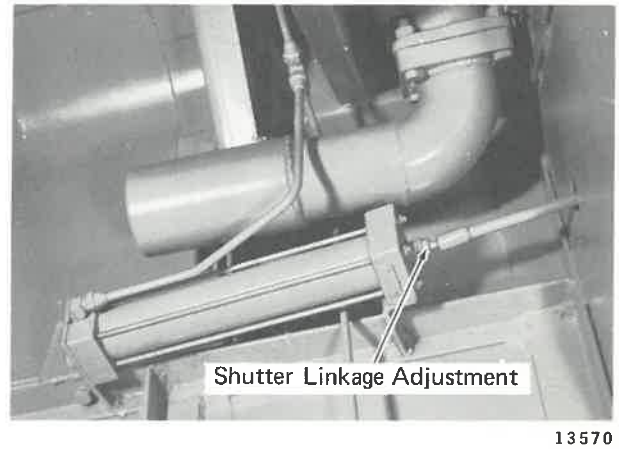
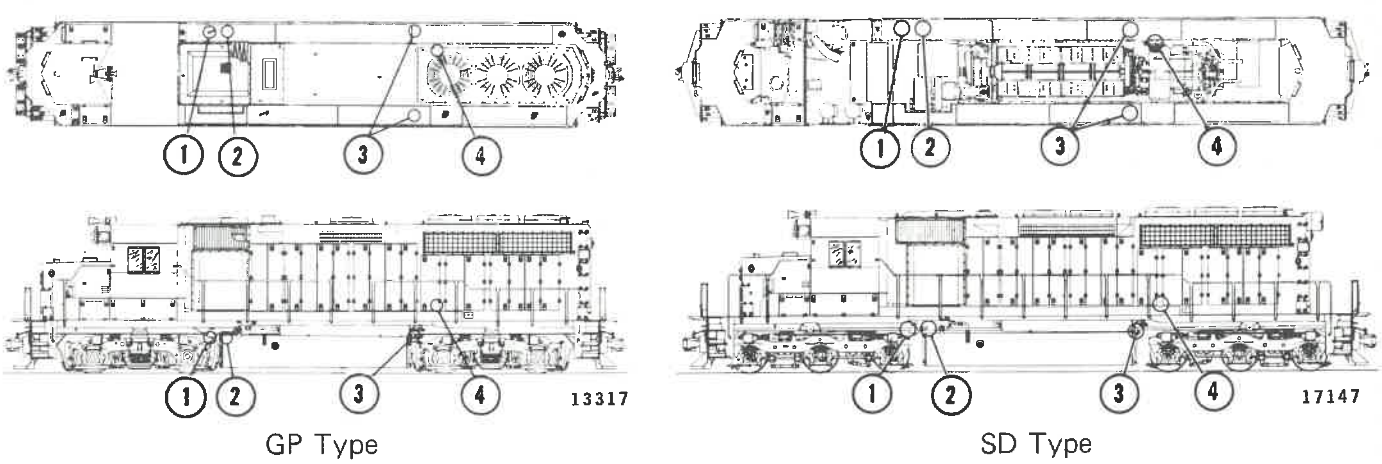


Fig. 5-12 – Shutter Operating Piston

MAINTENANCE

Open the shutters manually by pressing the button on one of the temperature switches or by moving the shutter valve mounted on the front of the water tank to the TEST position. Check for fast, snappy action when opening or closing, and for interference which might be caused by bent linkage or shutter blades. If shutters do not open or close to their full extent, the shutter operating rod may be adjusted by loosening the locknut on the operating rod at the front head of the cylinder, Fig. 5-12, and turning the rod until the desired length is obtained.



1. Main Reservoir Centrifugal Filter And Drain
2. Auxiliary Main Reservoir Centrifugal Filter And Drain
3. Main Reservoir Drain Valve Location
4. Compressor Control Strainer Drain Valve Location

Fig. 5-11 – Compressed Air System Drain Valve Locations

SHUTTER MAGNET VALVE – MV-SH

DESCRIPTION

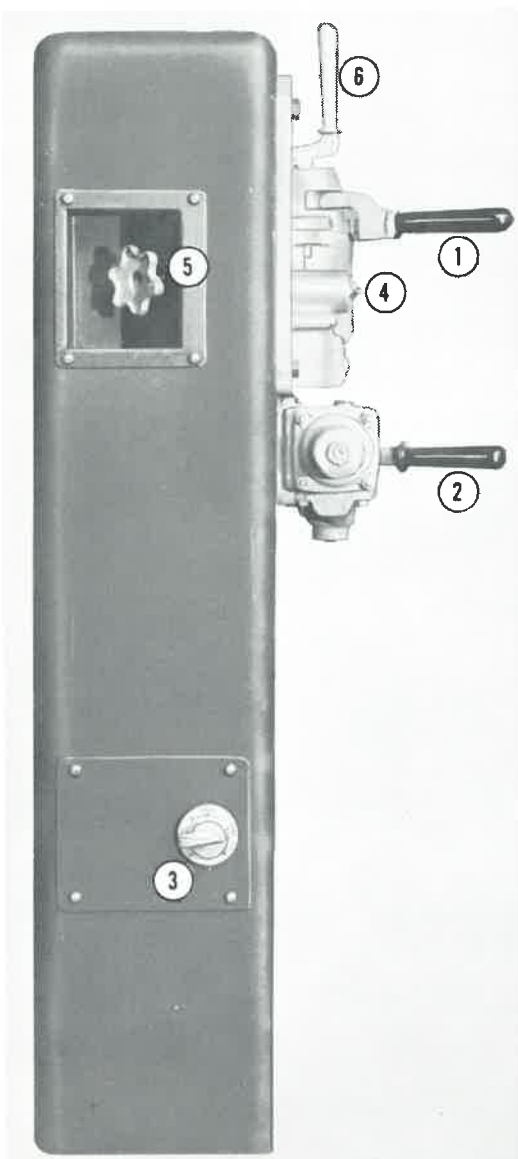
When cooling fan contactors FC1, FC2, and FC3 are de-energized, their interlocks close to energize shutter control magnet valves MV-SH, Fig. 5-4. This allows compressed air to be admitted to the shutter operating pistons to force the spring loaded shutters closed. When the FC1 fan contactor is energized, shutter magnet valves are de-energized, air pressure is released from the shutter operating pistons and the spring loaded shutters open.

The MV-SH assembly consists of two magnet valves connected in tandem by a single manifold. Both magnet valves must be energized and operate before air pressure can force the shutters closed. If either or both valves are de-energized, air pressure is released from the shutter operating piston, exhausted through the valve, and the shutters will open.

MAINTENANCE

If faulty operation of the magnet valve is suspected, check the magnet valve and air line to the operating piston for leaks. Check the filter screens on MV inlet and outlet. Also check the electrical connections on the magnet valve to see that they are tight. If repair is required, remove the magnet valve and replace it with a qualified valve.

CAUTION: This valve is subject to high ambient temperatures and should use only EMD replacement seats and solenoid coil listed in Service Data.



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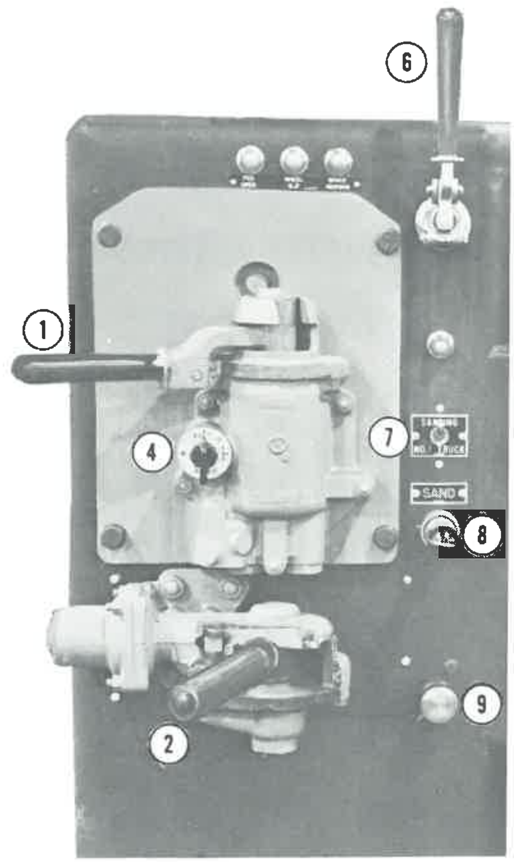


17606

1. Automatic Air Brake Handle
2. Independent Brake Handle
3. Multiple Unit Valve
4. Cut-Off Valve
5. Trainline Air Pressure Knob
6. Air Horn Valve
7. No. 1 Truck Sanding Switch
8. Manual Sanding Lever
9. Bell Ringer

Fig. 5-13 – Air Brake Equipment

AIR BRAKE EQUIPMENT

DESCRIPTION

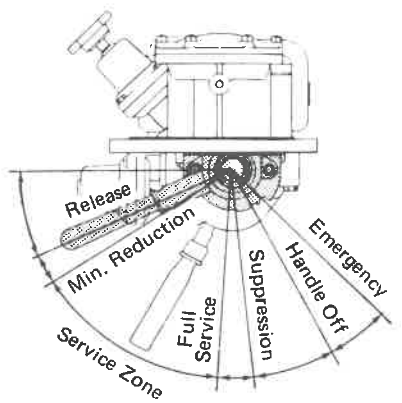
Basic locomotives are equipped with type 26L air brakes. The 26L air brake control equipment consists of an automatic brake, independent brake, multiple unit valve (when MU control is installed), cutoff valve and a trainline air pressure adjustment device. The dead engine feature, a part of the 26L equipment, is shown in Fig. 5-16.

AUTOMATIC BRAKE VALVE

The automatic brake valve handle, which controls the air to the locomotive train brake systems, may be placed in operating positions as shown in Fig. 5-14.

INDEPENDENT AIR BRAKE, Fig. 5-15

The independent air brake handle is located directly below the automatic brake handle. It has two positions; namely, RELEASE and FULL APPLICATION. Between these two positions is the application zone. Since this is a self-lapping brake, it automatically laps off the flow of air and maintains brake cylinder pressure corresponding to the position of the handle in the application zone. Depression of the independent brake valve handle when in the RELEASE position causes release of any automatic brake application on the locomotive.



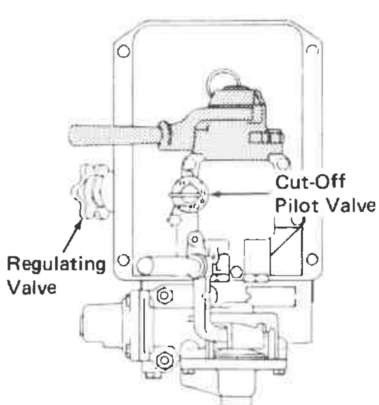
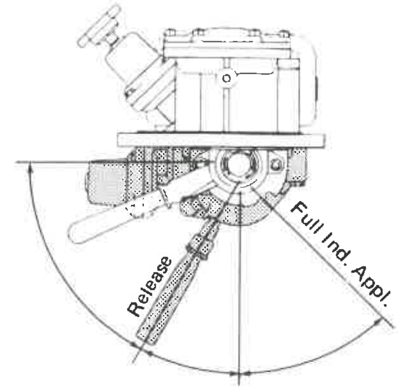


Fig. 5-14 – Automatic Brake Handle Positions



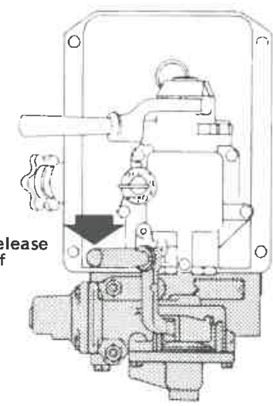


Fig. 5-15 – Independent Brake Handle Positions

MULTIPLE UNIT VALVE

The universal multiple unit (MU-2A) valve is located on the left hand side of the control stand as shown in Fig. 5-13. Its purpose is to pilot the F1 selector valve which is a device that enables the air brake equipment of one locomotive unit to be controlled by that of another unit.

A typical MU-2A valve application has three positions which are:

1. LEAD or DEAD
2. Trail 6 or 26*
3. Trail 24

The valve is positioned by pushing in and turning to the desired setting.

*Whenever the MU-2A valve is in the TRAIL 6 or 26 position, and if actuating trainline is not used, then the actuating end connection cutout cock must be opened to atmosphere. This is necessary to prevent the inadvertent loss of air brakes due to possible pressure buildup in the actuating line.

CUTOFF VALVE

The cutoff valve, Fig. 5-13, is located on the automatic brake valve housing directly beneath the automatic brake valve handle. This valve has the following three positions:

1. CUT-OUT
2. FRT (Freight)
3. PASS (Passenger)

TRAINLINE PRESSURE ADJUSTMENT

The trainline air pressure adjusting knob, Fig. 5-13, is located behind the automatic brake valve at the upper portion of the brake pedestal.

DEAD ENGINE CUTOUT COCK

A dead engine cutout cock, Fig. 5-16, is provided as part of the 26L braking equipment. When a locomotive is to be shipped dead in a train the cutout cock handle should be in the open position.

PRESSURE REGULATOR

The pressure regulator, Fig. 5-16, is provided to regulate the air pressure available for breaking a locomotive being shipped dead in a train.

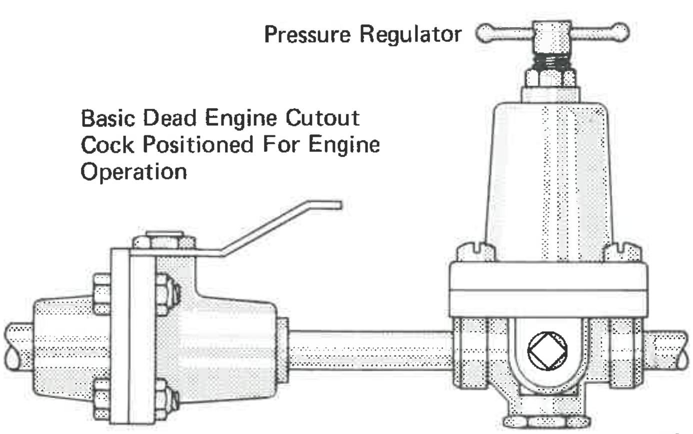


Fig. 5-16 – Dead Engine Cutout Cock And Pressure Regulator

The pressure regulator is pre-set at the value given in the Service Data. At any time the regulator must be reset, loosen the locknut and turn the adjusting handle on top of the regulator until the desired pressure is registered on the brake cylinder gauge when the brake is applied.

The pressure regulator should be cleaned out periodically by unscrewing the cleanout plug in the bottom of the regulator and removing and cleaning the screen.

BRAKE EQUIPMENT POSITIONS

When operating locomotives equipped with 26L air brakes, the brake equipment should be positioned according to the information given in Fig. 5-17.

MAINTENANCE

For maintenance information consult the manufacturer of the specific air brake equipment provided.

SANDING SYSTEM

DESCRIPTION

The basic sanding system for the locomotive is an electrical system that eliminates the need for relay valves and trainlined sanding actuating air pipes. However, if the locomotive is to be used with older locomotives equipped with only pneumatic sanding control, an optional extra pneumatic sanding system, Fig. 5-18, is superimposed upon the electrical sanding system. The two systems operate in parallel, therefore air actuating pipes should be connected whenever a consist contains any units equipped for only pneumatic sanding control.

Sanding circuits are packaged on a plug-in circuit module SA, Fig. 5-19. The circuit module contains provisions for optional extra sanding circuits requested by the railroads, therefore a number of terminals may be unused. For example, the No. 7 terminal is employed when a manual sanding light is required.

Also, part of the sanding module are a static timing device that takes the place of the conventional TDS relay, and a test button and light with which sanding and timing can be checked.

The following controls are employed to accomplish sanding.

An interlock of the RV transfer switch is open when the RV switch is in the forward position and closed when the switch is in the reverse position. The interlock closes to energize a directional sanding relay DSR that is located on the sanding circuit module SA. Contacts of DSR are closed in the forward sanding direction when DSR is de-energized, and they are closed in the reverse sanding direction when DSR is energized.

During primary wheel slip control, power reduction occurs, but no sand is applied to the rail. However, if the wheel slip is relatively severe, the R relay in the WS circuit module operates. A signal is delivered to the timing circuit that is part of the SA module. When the wheel slip is corrected, the transistorized timing circuit continues the signal to the sanding magnet valves for a period of 3 to 5 seconds.

Time delay sanding can be actuated by pressing the test button on the SA module or by pressing the test button on the WS module.

Sanding during an emergency application of the brakes is provided automatically from all sand traps through action of an air operated emergency sanding switch. The circuits from the switch are so arranged that emergency sanding from all traps will continue even though the motors are "plugged" (reverse lever placed to oppose direction of travel). On the basic locomotive, emergency sanding is accomplished electrically. If the locomotive is fitted with the pneumatic option, relay valves and air actuated switches ensure proper sanding even with the motors "plugged."

MAINTENANCE

Before each trip check operation of the sanders by placing the reverser handle in the direction to

Type Of Service	Automatic Brake Valve	Independent Brake Valve	Cutoff Valve	Dead Engine Cutout Cock	26D Control Valve	26F Control Valve	MU2 Valve	Overspeed Cutout Cock	Deadman Cutout Cock
SINGLE LOCOMOTIVE EQUIPMENT									
Lead	Release	Release	Passenger Freight	Closed		Graduated Direct	Lead	Open	Open
Double Heading	Handle Off	Release	Cutout	Closed		Graduated Direct	Lead	Open	Open
Shipping Dead In Train	Handle Off	Release	Cutout	Open	Relief Valve At Control Reservoir 73 ± 2 Lbs.	Direct	Dead	Closed	Closed
Radio Control Lead Unit	Release	Release	Freight	Closed		Direct	Lead	Open	Open
Radio Control Remote Unit	Release	Release	Freight	Closed		Direct	Lead	Closed	Closed
MULTIPLE LOCOMOTIVE EQUIPMENT AND EXTRAS									
Lead	Release	Release	Passenger Freight	Closed		Graduated Direct	Lead	Open	Open
Trail	Handle Off Position	Release	Cutout	Closed		Graduated Direct	*Trail 6 or 26 Trail 24	Open	Open
Shipping Dead In Train	Handle Off Position	Release	Cutout	Open	Relief Valve At Control Reservoir 73 ± 2 Lbs.	Direct	Dead	Closed	Closed
Double Heading	Handle Off Position	Release	Cutout	Closed		Graduated Direct	Lead	Open	Open
Dual Control:									
Operative Station	Release	Release	Passenger Freight	Closed		Graduated Direct	Lead	Open	Open
Non-Operative Station	Handle Off Position	Release	Cutout						

*Whenever the MU2A valve is in "Trail 6 or 26" Position and if the actuating train line is not used, then the actuating end connection cutout cock must be open to atmosphere; so as to prevent the inadvertant loss of air brakes due to possible pressure buildup in the actuating line.

NOTE: By ARR standard all cocks in the brake system except brake pipe end cocks have handles perpendicular to pipe when open.

17548

Fig. 5-17 -- Air Brake Equipment Positions

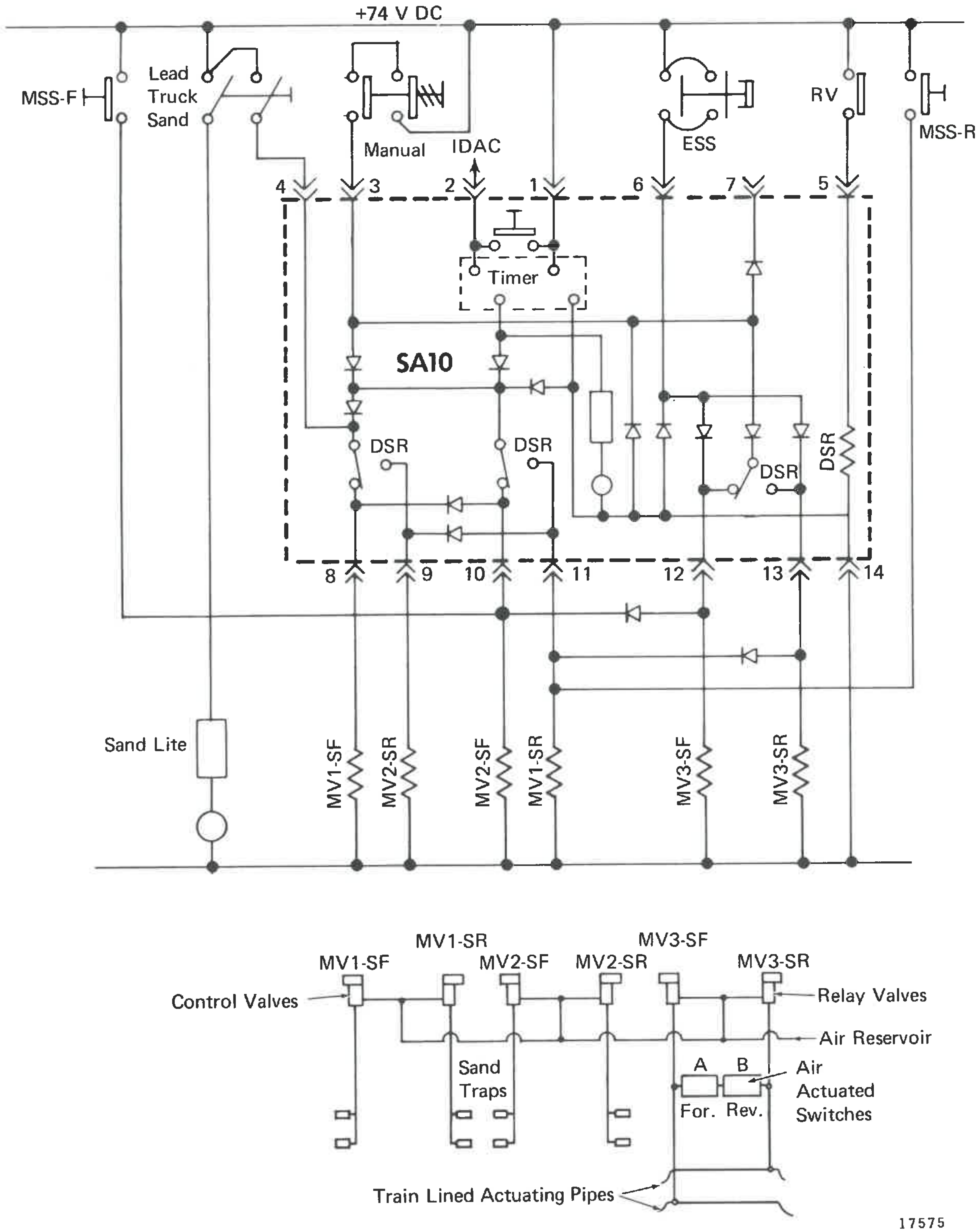


Fig. 5-18 – Sanding Circuit And Air Schematic
Including Pneumatic Sanding Option

17607

Fig. 5-19 – Sanding Circuit Module

be sanded. Close the throttle and move the manual sanding switch to the sand position. Check the sanding nozzles at the rail to make sure they are aligned correctly and that the sand is being delivered to the rail.

Extreme care should be taken that the proper grade of clean dry sand is used. Damp or dirty sand or sand with foreign material in it is likely to clog the traps.

SANDING CONTROL VALVE

DESCRIPTION

Two sanding control valves in each end of the locomotive,· Fig. 5-20, one for forward and one for reverse sanding, provide metered main reservoir air to their respective forward and reverse sand traps. When an electrical signal is received, the magnet valve section is energized to open an air valve which allows the main reservoir air to be admitted to the sand traps. The electrical signal can be initiated by the manual sanding switch, a wheel slip or an emergency brake application.

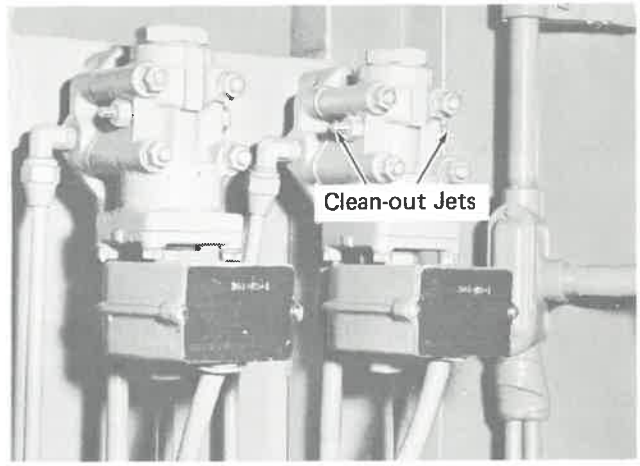


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Fig. 5-20 – Sanding Control Valves

MAINTENANCE

If faulty operation is suspected, inspect the electrical connections for tightness and inspect the air connections for leaks. The control valve is equipped with automatic cleanout jets to clean out the orifice. To operate the cleanout jets push in the plungers on each side of the valve, Fig. 5-21. The plunger will automatically reset at the beginning of the next sanding cycle from the high pressure cleanout blast of air.

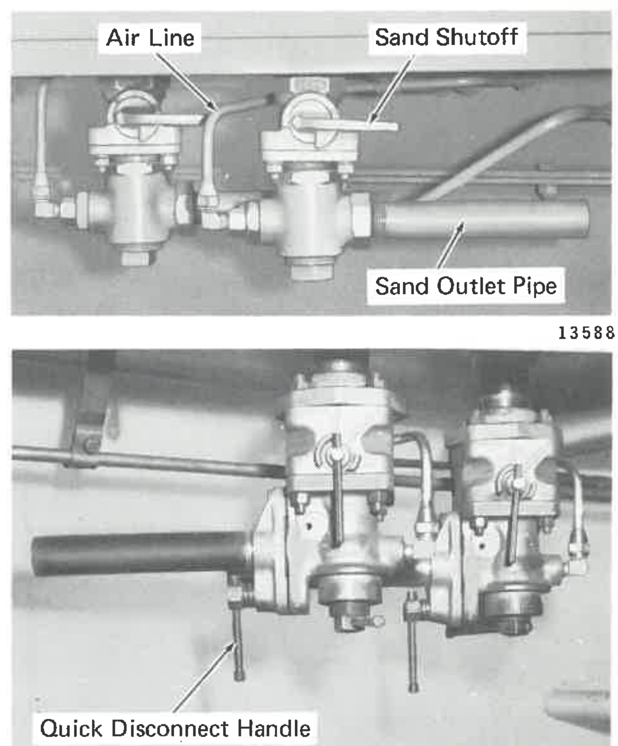

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Fig. 5-21 – Sand Trap

If further repair is required on the valve, remove it from the locomotive and replace with a qualified mechanism.

SAND TRAP

DESCRIPTION

Sand is fed to the trap, Fig. 5-22, by gravity through an inlet at the top of the trap. Actuating air enters the trap through the air nozzle. The nozzle is always covered by sand and therefore the air moves the sand that lies ahead of the discharge end of the nozzle. Sand entering at the trap inlet replaces the sand in front of the nozzle, thus a uniform flow of sand is delivered to the rail through the trap outlet.

A sand shutoff assembly is mounted to the top of the trap at the sand inlet. The valve is in the open position when the hand lever on the side is set at OPEN or is parallel to the sand inlet line. The shutoff can be used when it is desirable to have a particular sanding line inoperative or if work is to be performed on the sand trap.

MAINTENANCE

Before any work is performed on a sand trap, the shutoff valve mounted to the top of the trap should be closed by turning the shutoff valve handle to a horizontal position.

Due to condensation there is always the possibility of getting moisture in the sand trap. To clean out the trap remove the pipe plug at the bottom of the trap. On special order a trap equipped with a quick disconnect delivery tube can be furnished.

The sand trap is set at the time of installation to deliver approximately 20 to 24 oz. of sand per minute. To change the rate of delivery, screw the adjusting nut, Fig. 5-22, in or out depending on whether more or less sand is desired. On the quick disconnect type sand trap use a 7/32" allen wrench to turn the sand control paddle to increase or decrease the rate of delivery.

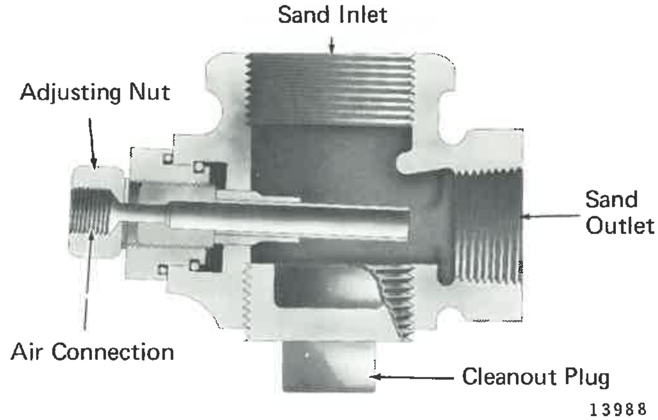

Fig. 5-22 – Sand Trap, Cross-Section

AIR SYSTEM ACCESSORY EQUIPMENT

WINDSHIELD WIPER ASSEMBLY

DESCRIPTION

A separate wiper assembly is provided for each window in front and behind the engineer's and rider's side of the locomotive cab and for the center windshield on the low nose cabs. The air motor, Fig. 5-23, used for the center windshield is identical to the other motors but is set for a longer degree of sweep.

Each air motor is controlled by its own hand operated air valve which is located just above the side windows on each side of the cab. Each motor is equipped with a hand operated lever which can be used to operate the wipers in an emergency.

MAINTENANCE

If a windshield wiper air motor is not operating correctly, check to see that the air connections at the motor and the manual control valve are tight and free from leaks. With the air turned on, operate the air motor with the hand lever attached to the air motor shaft. If this fails, turn

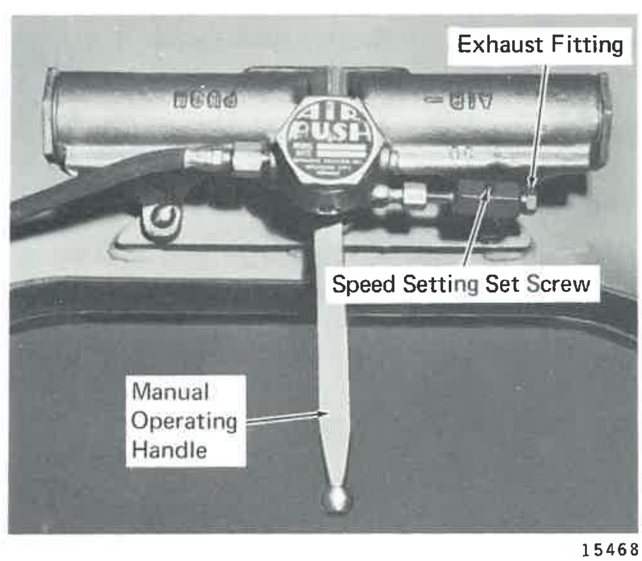

Fig. 5-23 – Windshield Wiper Air Motor

the air off and again try to operate the motor by hand. In most cases this will clean the valve seat of any foreign particles that may have been forced in through the air line.

Remove exhaust fitting, Fig. 5-23, and check for dirty filter or plugged hole. Remove reverser ball housing and check for broken or jammed ball spring.

Check the internal air flow by removing the cylinder end caps and blowing out the holes in the valve chamber. Also blow into the exhaust outlet to make sure the hole is not plugged.

If the air motor still does not operate properly, it will have to be replaced with a qualified motor and taken to the bench to be repaired.

If the wiper connecting arm must be removed from the air motor shaft, remove the acorn nut on the end of the shaft and pull the connecting arm off the splined shaft. When replacing the connecting arm on the shaft, be careful not to overtighten the acorn nut. The wiper motor and wiper mechanism are designed to operate at a maximum speed of 60 - 65 cycles per minute.

The speed of the wiper motor is adjusted by a set screw, Fig. 5-23, located in the exhaust restrictor. The following procedure should be used in making the adjustment:

1. Place a piece of paper between the wiper blade and the glass to simulate a wet glass condition which reduces frictional drag on the blades.

2. Make sure main reservoir air pressure is 130 to 140 psi. Turn operating valve in cab to the fully open position.

3. Turn the adjusting screw in the exhaust restrictor until the wiper motor is running at 60 - 65 cycles (120 - 130 strokes) per minute.

AIR HORN

DESCRIPTION

The basic air horn is a three chime, low profile type, Fig. 5-24. The air horn actuating lever is located on the brake stand at the locomotive control station. When the operating lever is pulled down, compressed air is supplied to the horn.

17646

Fig. 5-24 – Air Horn

Other types of air horns are available on special order including five chime horns.

A valve, located in the air brake stand, provides a means for shutting off the air supply to the horn operating lever.

MAINTENANCE

To inspect and clean the air horn diaphragm, remove back cover bolts and back cover. The diaphragm ring and diaphragm can be removed by taking out the diaphragm ring screws.

Whenever a back cover is removed, it is good practice to blow out the air lines by opening the air horn operating valve wide with full reservoir pressure on the line. This will also clean out the orifice dowel pin.

BELL

DESCRIPTION

The basic locomotive bell is located under the underframe on the left side of the locomotive. A positive action air valve, which activates the bell, is located on the air brake stand at the operator's control station. When the valve is opened, compressed air forces the plunger in the bell ringer assembly down, which causes the clapper to strike the side of the bell.

When the plunger reaches the extended position, the compressed air then returns the plunger to its original position.

To shut off the air supply to the bell operating valve at the control stand, remove the upper panel on the back of the air brake stand and close the valve in the bell ringer air line.

MAINTENANCE

If the bell does not operate when the bell ringer operating valve at the control stand is opened, check to see that the clapper is free to swing and that no air leaks are present in the air lines.

If a new bell ringer cartridge, Fig. 5-25, is needed, remove the old cartridge by loosening the locknut on the side of the bell ringer assembly and backing out the set screw three or four turns. Using the clapper as a lever, unscrew the clevis from the assembly and pull the cartridge out with a pair of pliers. Before installing the new cartridge, actuate the bell ringer operating valve a few times to blow out any dirt or scale which may have accumulated. After installing the new bell ringer cartridge, be sure the "O" rings are in place before applying the clevis. Once the clevis is applied, tighten the set screw and locknut.

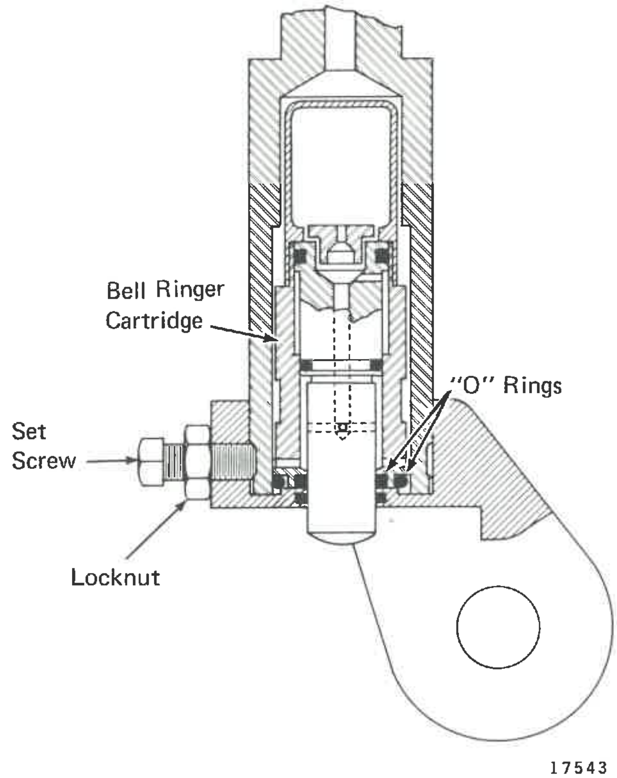

Fig. 5-25 – Bell Ringer, Cross-Section

COMPRESSED AIR SYSTEM

REFERENCES

Air Compressor Maintenance	M.I. 1110 & 1144
Sanding Equipment Maintenance	M.I. 1926
Air Horn Maintenance	M.I. 2926
Magnet Valve Maintenance	M.I. 4707

ROUTINE MAINTENANCE PARTS AND EQUIPMENT

FILTERS

Inlet Compressor Air Filter Element	
(Rectangular Filter)	8347199
(Cylindrical Filter)	8402068
Main Reservoir Air Filter Element	8363343

AIR COMPRESSORS

Lube Oil Pressure Gauge	8127030
Intercooler Air Pressure Gauge	8337561

SHUTTER MAGNET VALVE

Replacement Seats	8251091
Replacement Coil	8468748

SPECIFICATIONS

AIR COMPRESSOR

Type	2 Stage
Number Of Cylinders (Basic)	3
Number Of Cylinders (Optional)	6
Displacement At 900 RPM (3 cylinder)	254 Cu. Ft./Min.
Displacement At 900 RPM (6 cylinder)	401 Cu. Ft./Min.
Lube Oil Capacity (3 cylinder)	10-1/2 Gal.
Lube Oil Capacity (6 cylinder)	18 Gal.
Cooling	Water

Lube Oil

Compressor lube oil must be SAE 10 weight turbine type oil containing anti-rust, anti-oxidation and anti-foam inhibitors and should contain the following properties:

Viscosity-Saybolt Universal (ASTM D88 or D2161)	
@ 100° F. seconds	130 to 180
@ 210° F. seconds	42 to 45
Pour Point (ASTM D97 Degrees F. -- minimum)	0
Rust-Distilled Water (ASTM D665)	No Rust

DEAD ENGINE PRESSURE REGULATOR SETTING

SD – Single Brake (Composition Shoe)	25 ± 1-1/2 psi
GP – Single Brake (Composition Shoe)	25 ± 1-1/2 psi
GP & SD – Clasp Brake (Iron Shoe)	25 ± 1-1/2 psi
GP & SD – Clasp Brake (Composition Shoe)	13 ± 1-1/2 psi

EMD SERVICE DEPARTMENT

LOCOMOTIVE SERVICE MANUAL

ELECTRICAL EQUIPMENT

INTRODUCTION

The locomotive electrical circuits are designed so that no adjustment need be made on the unit. All circuits are bench tested and adjusted before being applied to the locomotive. To facilitate this arrangement, as well as to simplify maintenance procedure and reduce locomotive down time, most control circuits and devices are packaged on plug-in circuit modules. All modules bearing the same identification are interchangeable.

This section of the manual provides a brief description of the circuit module function, along with brief descriptions of other electrical devices and components. For a thorough analysis of the control circuits contained on the modules refer to Section 7 of the Locomotive Service Manual.

ELECTRIC ROTATING EQUIPMENT

MAIN GENERATOR, Fig. 6-1

The main generator is a three-phase alternator equipped with two independent and interwoven sets of stator windings and a rotating field common to the windings. The dual output from the generator stator is supplied to two air cooled rectifier assemblies in an airbox that is an integral part of the main generator. The rectifier assemblies consist of high current, high voltage silicon diodes in three-phase, full wave rectifier circuits. The circuits are provided with delta connected resistors and capacitors for suppression of commutation transients, and are provided with fuses for automatic removal of failed diodes. Each fuse is equipped with a spring loaded indicator that protrudes when a diode failure causes the fuse to blow. Windows for fuse inspection are located in the airbox.

Three current transformers are also mounted in the airbox. The transformers sense output at each of three phases, and provide a proportional signal to circuits that control excitation.

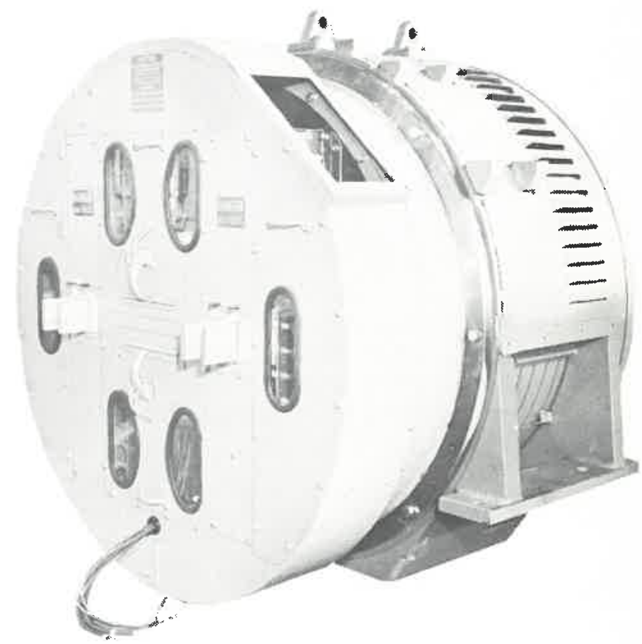

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Fig 6-1 -- AR10 Main Generator

D14 AUXILIARY ALTERNATOR, Fig. 6-2

The D14 alternator is physically connected to but electrically independent of the traction alternator. The D14 rotor (field) is excited by low voltage current which it receives from the DC auxiliary generator through a pair of slip rings adjacent to the slip rings for the main generator.

With the exception of a protective fuse, there are no controls in the D14 excitation circuit, thus the alternator will be excited and developing power whenever the diesel engine is running. Output voltage will vary with speed of rotation, alternator temperature, and load. Nominally D14 output is 215 volts at 120 cycles per second with the engine running at full speed of 900 RPM.

16955

Fig. 6-2 -- D14 Auxiliary Alternator

TRACTION MOTORS, Fig. 6-3

Electrical power from the main generator is distributed to traction motors mounted in the trucks. Each motor is geared to a pair of wheels, with the gear ratio selected for the type of service intended. The motors are cooled by means of an external blower located in the locomotive unit and mechanically driven from the engine.

The motor fields and armatures are connected in series to provide the high starting torque required for locomotive service.

Motor rotation is reversed by reversing the flow of current through the field windings. This is accomplished by switchgear in the locomotive electrical cabinet. Similar switchgear is also used to convert the traction motors to electrical generators for dynamic braking. During braking, the motor fields are connected in series with the main generator output and the motor armatures are connected to heat dissipating resistor grids and fans.

The brush holder assembly is formed with a heavy cross section to minimize flexing and fatigue damage and to enable the assembly to withstand severe flashover. Brush holder cabling is arranged and clamped for increased mechanical strength.

AUXILIARY GENERATOR, Fig. 6-4

All low voltage direct current electricity required during locomotive operation comes from the auxiliary generator. This current is used for battery charging and for excitation of the D14 alternator as well as for energizing control circuits and

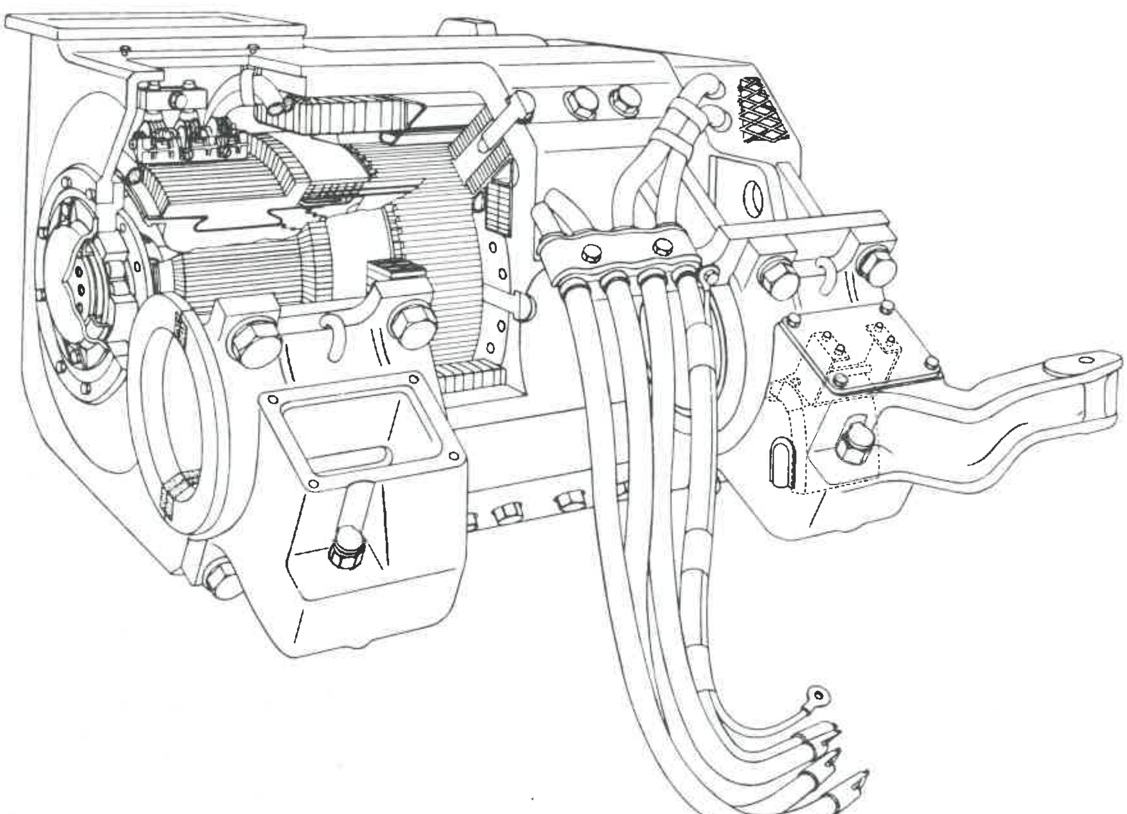

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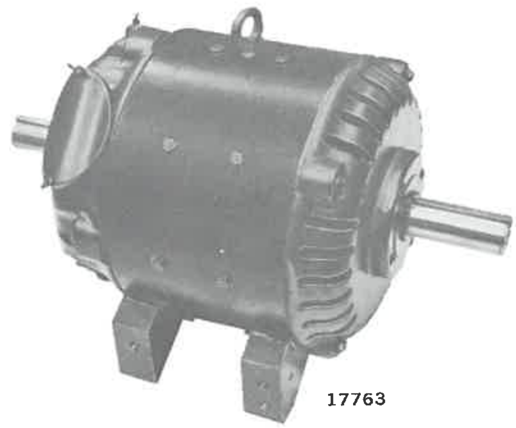
Fig. 6-3 -- Traction Motor

actuating electrical switchgear. The auxiliary generator is a self-excited machine that uses residual magnetism for initial excitation. To hold voltage at a constant 74 volts, a static type voltage regulator is used in the field excitation circuit. The regulator is packaged as a plug-in circuit module VR, and is provided with a voltage adjustment for battery charging purposes.

The locomotive is equipped basically with the 10 KW auxiliary generator, but the power demands of special equipment may require the use of an auxiliary generator of higher capacity. In such case an 18 KW or 24 KW generator is used.



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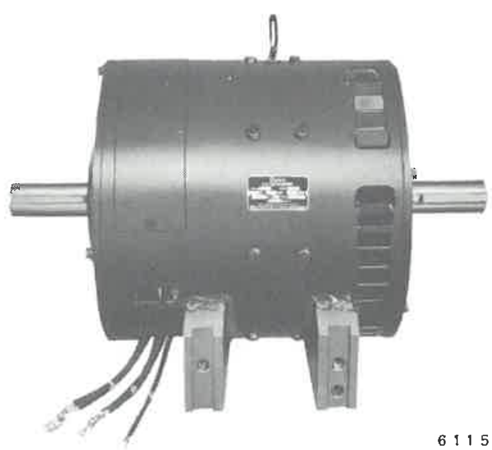
10 KW Generator



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18 Or 24 KW Generator

Fig. 6-4 -- Auxiliary Generator

RADIATOR COOLING FAN MOTORS, Fig. 6-5

These motors are inverted squirrel cage induction type and are an integral part of the cooling fan assembly. The term "inverted" indicates that they differ from the conventional squirrel cage motor in that the rotor is located outside of the stator. Motor and fan rotating speed are directly proportional to the AC frequency of the D14 alternator which in turn is dependent upon engine speed.

15860

Fig. 6-5 -- Cooling Fan Assembly

DYNAMIC BRAKE GRID BLOWER ASSEMBLY, Fig. 6-6

The dynamic brake grid cooling blower assembly consists of a fan powered by a series wound direct current motor. During dynamic braking the locomotive traction motors operate as generators, and the electrical power generated is converted to heat at the braking resistor grids. A portion of the electrical current from the traction motors is shunted around one of the resistor grids and used to power the grid blower motor. Air driven by the grid blower drives grid heat to atmosphere.

15861

Fig. 6-6 -- Dynamic Brake Grid Blower Assembly

TURBO LUBE PUMP MOTOR

This is a 1/4 HP 1200 RPM 64-74 volt DC motor coupled directly to a lubricating oil pump and mounted on the crankcase. At engine start the pump provides lubrication for the turbocharger bearings and at shutdown a time delay relay continues pump operation to carry away residual heat from the turbocharger bearings.

FUEL PUMP MOTOR

This is a 1/4 HP 1200 RPM 64-74 volt DC motor coupled directly to a fuel pump and mounted on the equipment rack. During engine operation the pump supplies fuel oil for combustion and injector cooling. A bypass valve at the primary fuel filter protects the motor against overloading due to filter plugging.

STARTING MOTOR AND SOLENOID, Fig. 6-7

The starting motor solenoid mounted on the starting motor housing contains concentrically wound coils PU and HOLD.

When energized, the low resistance PU coil drives the starter motor pinion into place. The starting contactor then shorts out the PU coil and the high resistance HOLD coil has sufficient energy to hold the pinion engaged. When cranking signal is removed, the starting contactors drop out and reverse polarity current flows through the PU coil to disengage the pinion.

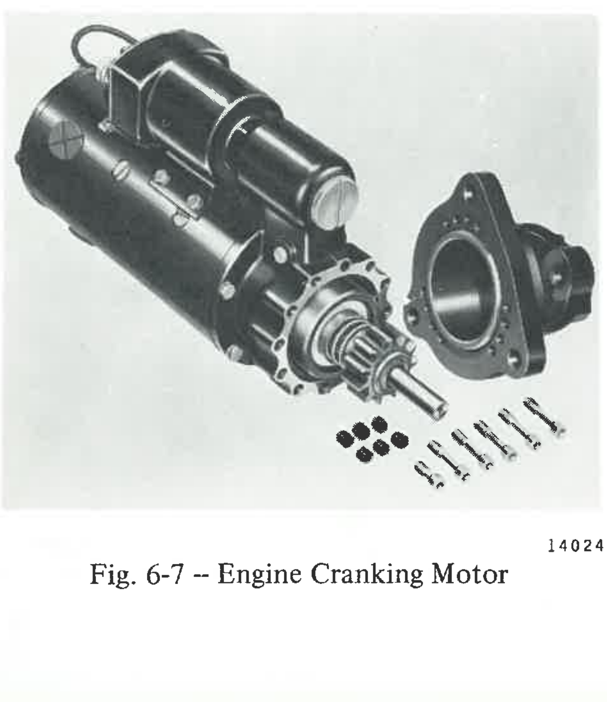

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Fig. 6-7 -- Engine Cranking Motor

The diesel engine is equipped with dual motors for cranking. Power circuits to the motors are interlocked so that the pinions of both cranking motors must be engaged with the engine ring gear before cranking power can be applied.

LOCOMOTIVE CONTROL STAND, Fig. 6-8 And 6-9

The locomotive control stand contains operating handles, switches, and gauges used by the operator of the locomotive. The control panel shown has the operating handles positioned for dynamic braking.

SELECTOR HANDLE

This handle has three positions; left for dynamic braking, centered for off, and right for power. A large illuminated window directly above the operating handle provides indication of handle position; "B" (dynamic braking), OFF, and PWR.

THROTTLE HANDLE

When the selector handle is positioned for power operation, the throttle handle has an idle position and eight operating notches 1 thru 8. The handle can be pulled out from the panel and moved to the right of idle position to stop all engines in a multiple unit consist.

REVERSER HANDLE

This handle has three positions; left, centered, and right. When the handle is moved to the right toward the short hood end of the locomotive, circuits are set up for the locomotive to move in that direction. When the handle is moved to the left toward the long hood end of the locomotive, circuits are set up for movement in that direction. With the reverser handle centered, operation of the throttle handle will not apply power to the traction motors, but a load test may be made when the proper circuit setup is made.

The reverser handle is centered and removed from the panel to lock the throttle handle in IDLE and the selector handle in OFF.

AMM. TM. LOAD CURRENT INDICATING METER

This meter indicates current through the No. 2 traction motor. Since all motors will carry approximately equal current, main generator current will be three times the meter indication during series-parallel operation, and six times the

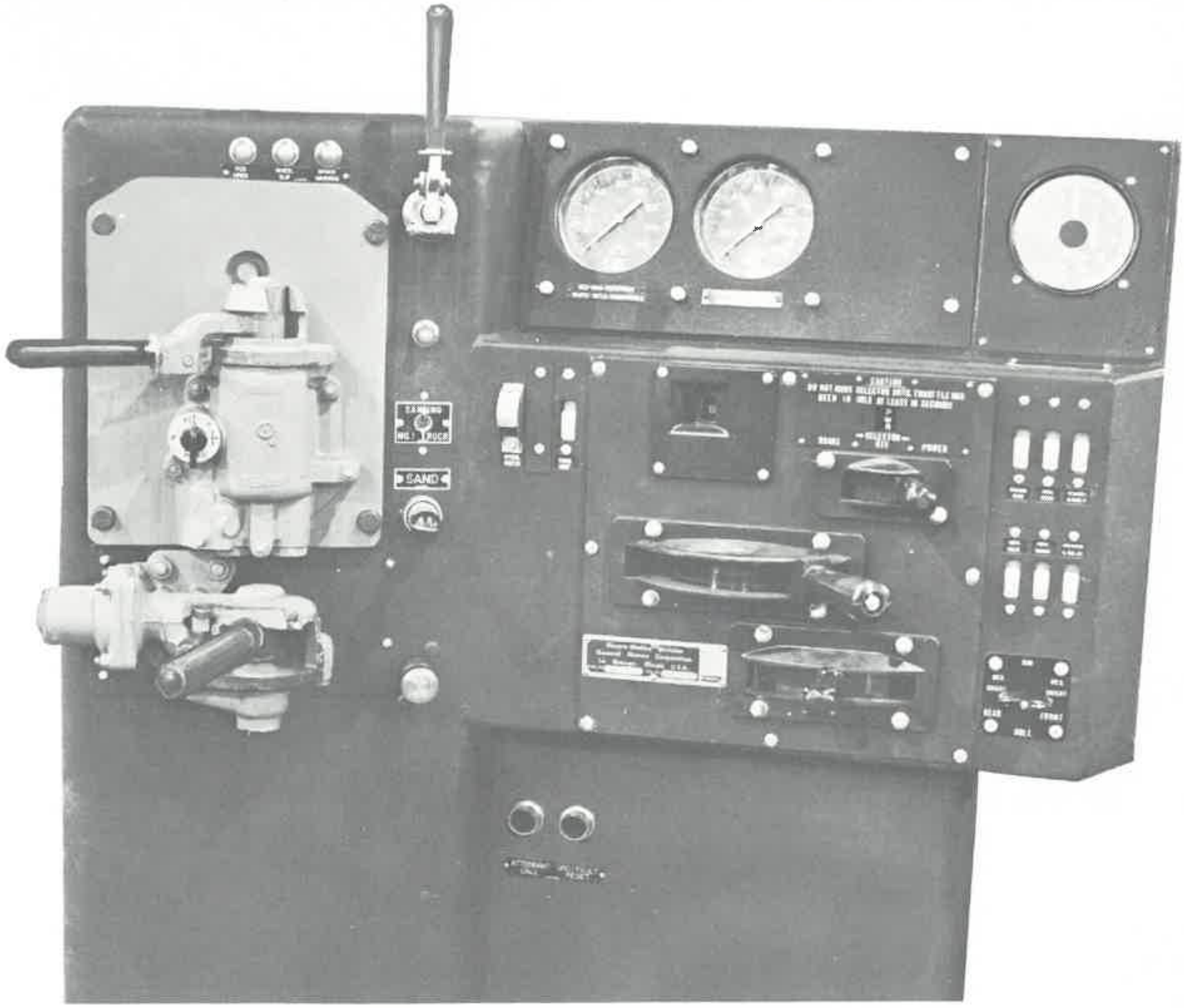

Fig. 6-8 – Locomotive Control Stand

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Fig. 6-9 -- Locomotive Controler With Handles Positioned For Dynamic Braking

indication during full parallel. The meter indicates from zero to 1500 amperes during power operation, with a red zone indicating maximum allowable continuous motor current, beginning at 1050 amperes.

On units equipped with dynamic brakes, the meter has a dial with the zero point located at top center. During power operation the meter needle moves clockwise from zero to indicate increasing motor current. During dynamic braking the meter needle moves counterclockwise from zero to indicate increasing dynamic braking current.

AIR SYSTEM GAUGES

Duplex gauges provide indication of various air brake system pressures.

INDICATING LIGHTS

PCS OPEN light comes on to indicate a safety control or emergency air brake application.

WHEEL SLIP light indicates severe wheel slip, locked-sliding wheels, or circuit difficulty.

BRAKE WARNING light indicates excessive dynamic braking current.

SAND light indicates that the SANDING No. 1 TRUCK switch is closed.

OPERATING SWITCHES

The ENGINE RUN, GENERATOR FIELD, and CONTROL AND FUEL PUMP switches are located at the right side of the control stand. They must be placed ON in the controlling unit of a multiple unit consist and OFF in trailing units.

Other switches at this location control various lights and are placed ON as needed.

HEADLIGHT DIMMING SWITCH

Provides for dim or medium brightness of either front or rear headlights.

GROUND RESET AND ATTENDANT CALL PUSHBUTTONS

These pushbuttons are located at the lower portion of the control stand.

SAND No. 1 TRUCK SWITCH

This switch provides continuous sanding at the leading wheels of the locomotive.

BRAKE VALVE HANDLES

The upper handle controls the automatic or train brakes. The lower handle controls the independent or locomotive brakes.

ELECTRICAL CABINETS

HIGH VOLTAGE CABINET, Figs. 6-10 And 6-11

The high voltage cabinet houses the majority of the locomotive electrical switchgear and static devices. The front of the cabinet forms the rear wall of the locomotive cab, and the rear of the cabinet forms one wall of the central air compartment of the locomotive.

The lower front portion of the electrical cabinet houses heavy duty switchgear used to connect the main generator to the traction motors. Devices that sense current and voltage are generally located in this portion of the cabinet.

ENGINE CONTROL PANEL, Fig. 6-12

The engine control panel contains various switches and warning lights. Brief descriptions of the switch and light functions follow, while descriptions of much of the circuitry involved in engine control is described in other sections of this manual.

LOAD TEST LIGHT

This light comes on when circuits are set up for load testing. On units equipped for automatic loading on the locomotive dynamic braking resistor grids, circuit setup is automatic when the reverser handle is centered and a rotary test switch located on a test panel in the module compartment is properly positioned.

HIGH VOLTAGE GROUND/FAULT LIGHT

Indicates that an electrical path to ground has occurred, or that a group of five diodes in the main generator has failed. The light is held on until a reset button is pressed or an automatic reset is made on locomotives so equipped.

TURBO AUX PUMP LIGHT

Indicates that current is flowing through the turbo lube pump motor. This normally occurs for a timed period after engine start and after engine shutdown. It indicates that the turbocharger is being pre-lubricated during engine starting and oil-cooled after engine shutdown. If the light is not on or fails to come on when a starting attempt is made, interlocking prevents engine cranking.

NO BATT CHARGE NO POWER LIGHT

Indicates that no AC power is being delivered from the auxiliary alternator to a voltage sensing relay. This may be due to a tripped generator field circuit breaker, engine shutdown, alternator failure, or failure of the DC auxiliary generator which excites the alternator. If the light is on for reasons other than engine shutdown, engine speed and power are reduced to idle conditions.

HOT ENGINE LIGHT

Indicates that engine coolant temperature is excessive. Engine speed and power are automatically reduced to a lower level until proper temperature is restored.

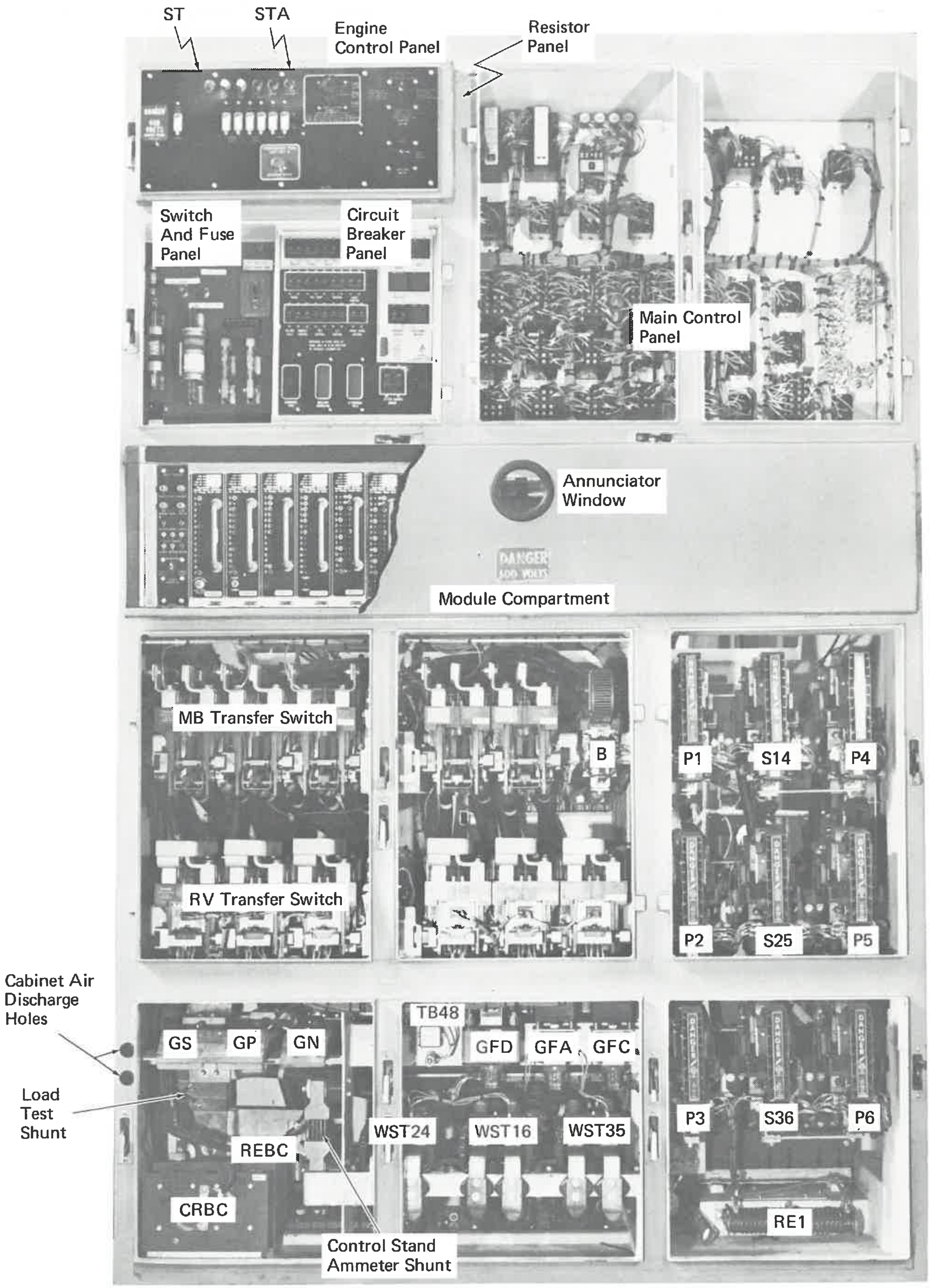

Fig. 6-10 -- Electrical Cabinet, Front

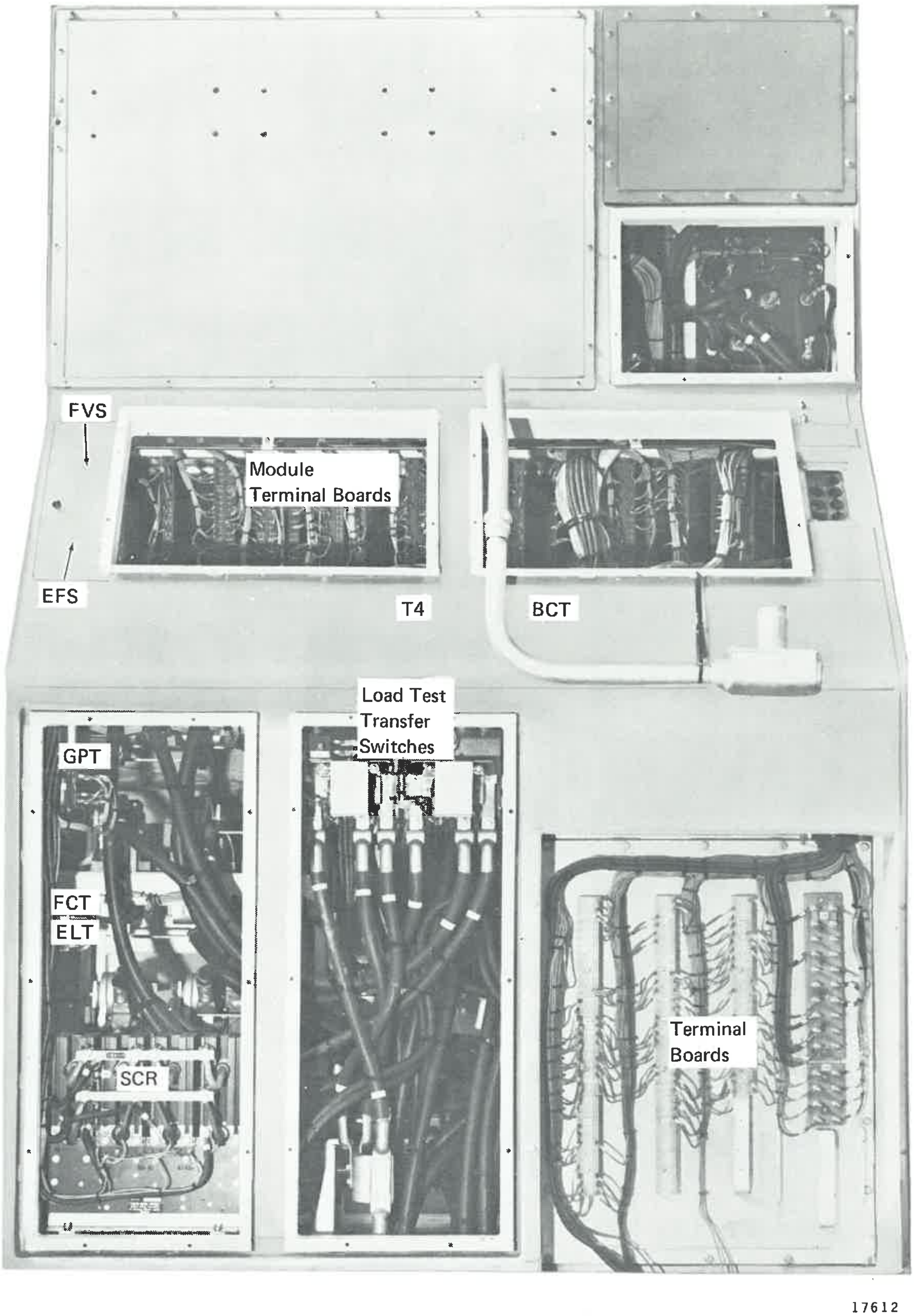

Fig. 6-11 -- Electrical Cabinet, Rear

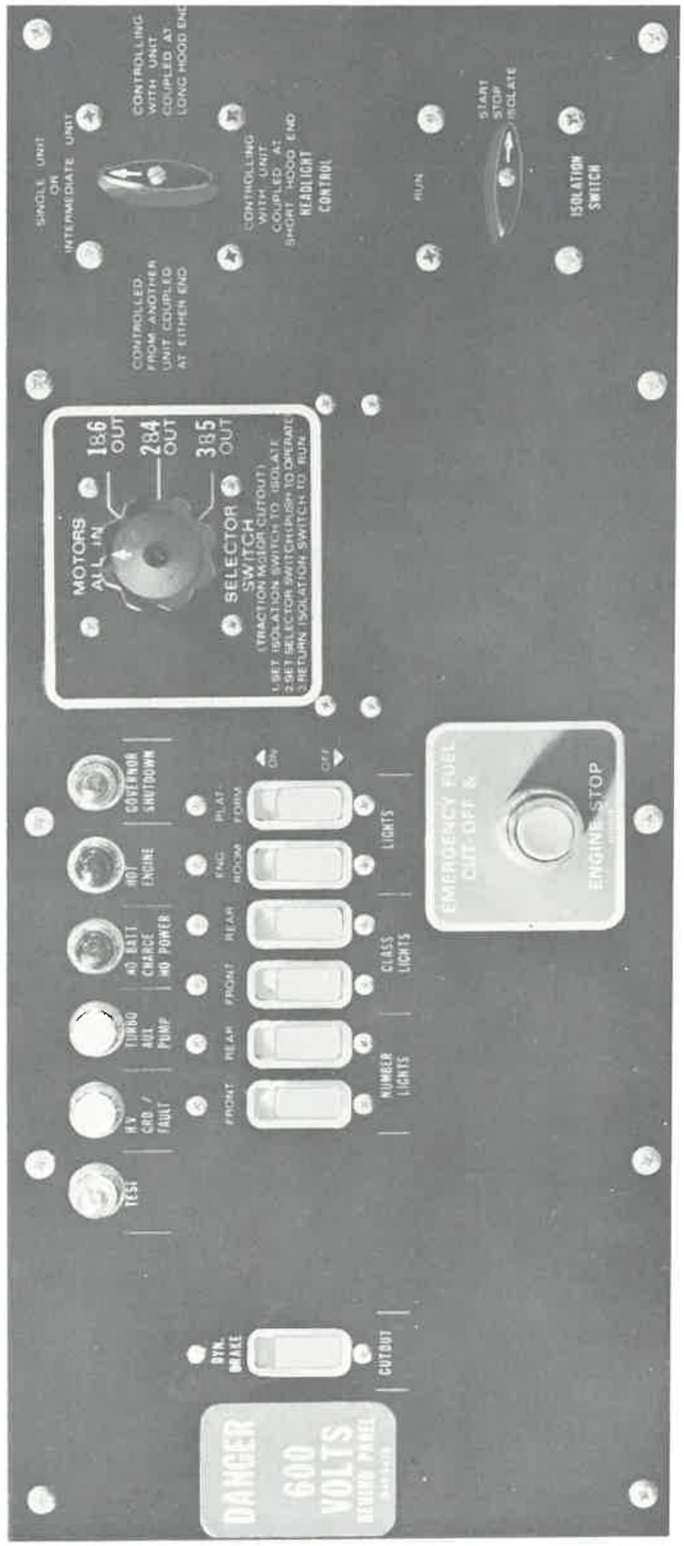

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Fig. 6-12 – Engine Control Panel

GOVERNOR SHUTDOWN LIGHT

Accompanied by engine shutdown for one of the following reasons:

1. Excessively hot lube oil.

   This type of shutdown will normally be preceded by a hot engine light indication. No other indication is given except an extremely hot condition of the engine and cooling system. Do not attempt to restart the engine until it has been allowed to cool down and an engine inspection has been made by qualified personnel.

2. Low engine oil pressure.

   A plugged turbocharger oil filter, low oil level, or failure of the lube oil pump may bring about this type of shutdown. The low oil plunger on the engine governor will protrude, with no other fault indication given.

3. Low water level or low pressure at the water pumps.

   A detector at the engine accessory drive gear housing senses low water pressure and actuates the low oil shutdown mechanism. The low water detector reset button will protrude along with the governor low oil pressure plunger.

4. Crankcase (oil pan) overpressure due to an engine fault.

   Pressure in the crankcase (oil pan) will trip the crankcase overpressure detector and bring about a low oil pressure shutdown. The reset button will protrude along with the governor low oil pressure plunger. Overpressure may be caused by a crankcase explosion, or by a fault allowing cylinder or airbox pressure into the oil pan.

WARNING: When a crankcase overpressure trip indication is observed, leave the engineroom area. Allow a 2 hour cooldown period before making further inspections or taking corrective action.

HEADLIGHT CONTROL SWITCH

Power for both the front and rear headlights is delivered by the lead unit in a locomotive consist. This switch sets up the circuits for control of both the front and rear lights from the lead unit and through any intermediate units. The switch must be properly positioned in all units of a consist.

ISOLATION SWITCH

This switch allows any unit in a locomotive consist to be "taken off the line" regardless of the control signals from the controlling unit. The switch has two positions.

1. START/STOP/ISOLATE Position

   Must be in this position before the engine can be started, but the unit will not develop power. However, if a controlling unit of a multiple unit consist is isolated, all trailing units will still respond to the controls of the controlling unit.

   It is recommended that the isolation switch be placed in this position before stopping the engine, but the switch in no way negates any engine stopping switch or device.

2. RUN Position.

   When the switch is in this position, the unit will respond to controls and will develop power. If the engine is shut down with the switch in this position, the alarm bell will sound.

EMERGENCY FUEL CUTOFF AND ENGINE STOP SWITCH

Momentary pressure on this pushbutton de-energizes governor speed setting solenoids and independently energizes the governor shutdown solenoid. The governor brings the fuel injector racks to no fuel position and the engine shuts down immediately from lack of fuel. Two other switches, each with identical function, are located at the locomotive underframe near each fuel filler opening.

On units equipped with steam generators the Emergency Fuel Cutoff switch will stop the steam generator as well as the engine. On such units a second switch labeled only ENGINE STOP is provided to shut down only the engine.

DYNAMIC BRAKE CUTOUT SWITCH

In the cutout position this switch prevents the individual unit from going into dynamic braking, yet allows the unit to operate under power. The switch is used to limit the amount of braking effort available in a multiple unit consist or to cut out a faulty dynamic braking system while allowing operation under power.

LIGHT SWITCHES

Switches are provided for various lights employed on the locomotive.

TRACTION MOTOR CUTOUT SWITCH

When the locomotive unit is isolated, an unlock solenoid is energized when the cutout switch handle is pressed in. This also causes the reversing switchgear motor to operate and repeatedly drive the switchgear from one position to another until the handle is released. While the handle is pressed in and turned to a position to cut out a suspected faulty motor, the appropriate switches move to center and become locked in neutral position. Appropriate power contactors are also dropped out. Control circuits are rearranged for safe operation at a lower power level.

CIRCUIT BREAKER PANEL, Fig. 6-13

The following circuit breakers must be closed for locomotive operation.

TURBO

Two-pole breaker protects the turbo lube pump motor and STA contactor circuits. Must remain on after engine shutdown to ensure delivery of cooling oil to the turbocharger bearings.

FUEL PUMP

Three-pole breaker protects the fuel pump motor and contactor circuits. Engine will shut down from lack of fuel if this breaker trips.

CONTROL

Two-pole breaker protects circuits supplying low voltage trainlined control power to all units in a consist.

LOCAL CONTROL

Two-pole breaker protects circuits supplying low voltage control power to the individual locomotive unit.

AUX. GEN. FIELD

Single pole breaker protects the field circuit to the auxiliary generator.

MODULE CONTROL

Two-pole breaker protects low voltage DC circuits to control modules.

REV CONTROL

Two-pole breaker protects motor operated switchgear motor circuit.

AC CONTROL

Two-pole breaker protects circuit supplying D14 AC power to control modules, various transductors, and the no voltage relay NVR.

BRAKE TRANS. CONTROL

Two-pole breaker protects motor operated switchgear motor circuit.

GENERATOR FIELD

Two-pole breaker protects circuit supplying D14 AC power to the main generator controlled rectifier SCR.

AUXILIARY GENERATOR

On special order this single pole breaker is used in place of the auxiliary generator fuse.

ALTERNATOR FIELD

On special order this single pole breaker is used in place of the alternator field fuse.

FILTER BLOWER MOTOR

Two-pole breaker protects the inertial filter exhaust blower motor circuit.

The following circuit breakers are placed on as required.

CAB HTR.

Two pole breaker protects cab heater fan motor circuit.

LIGHTS

Two-pole breaker protects the various light circuits.

HDLTS.

Two-pole breaker protects the headlight circuits.

RADIO

Two-pole breaker for radio circuits.

AUTO WATER DRAIN

On special order the cooling system will drain automatically when coolant temperature in the area of the cab heaters approaches freezing. This two-pole breaker protects the circuits.

A.T.C.

Two-pole breaker protects automatic train control circuits.

UTILITIES

Protects miscellaneous special equipment.

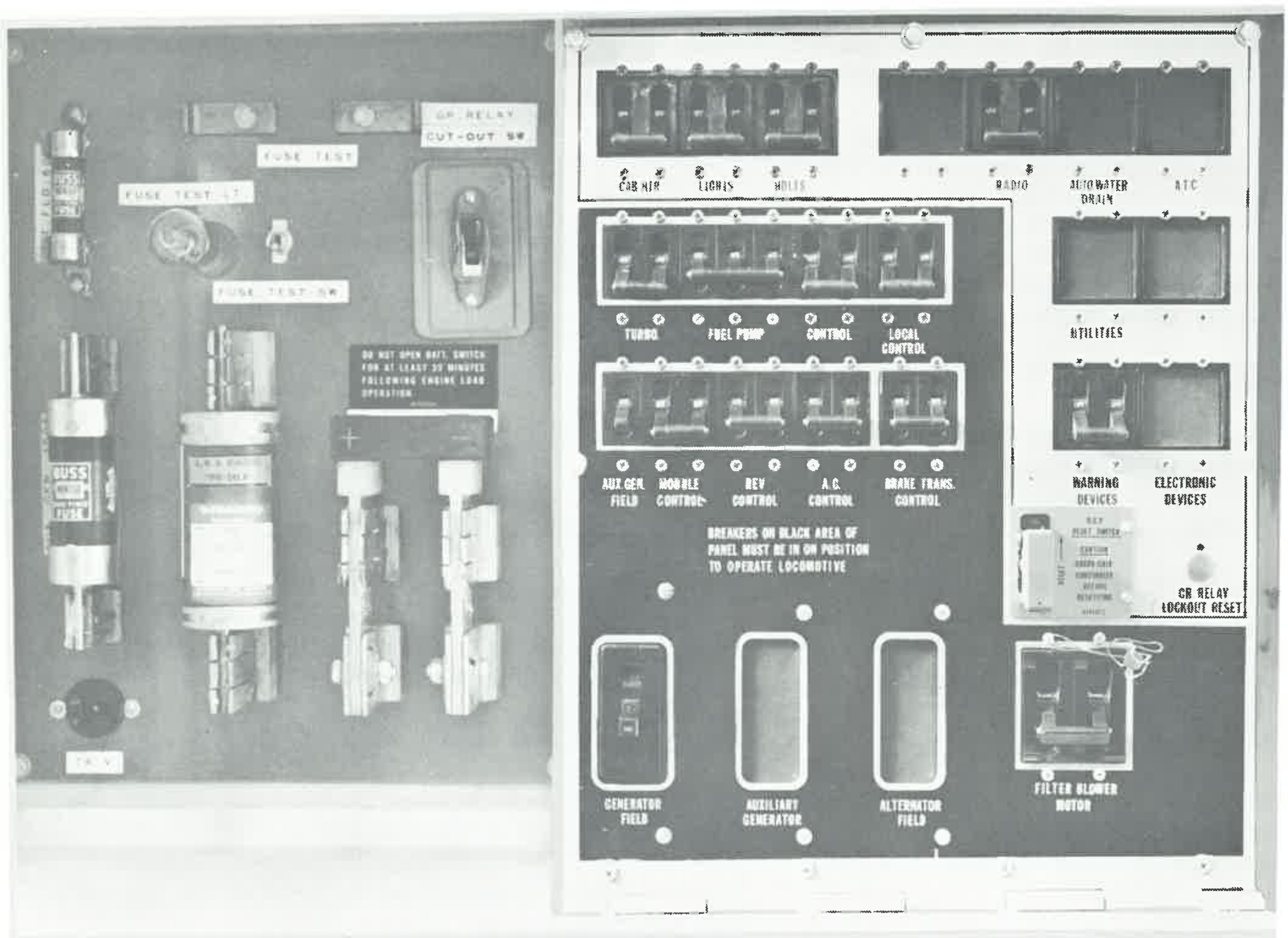

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Fig. 6-13 -- Switch And Fuse Panel And Circuit Breaker Panel

SWITCH AND FUSE PANEL, Fig. 6-13

D14 ALTERNATOR FIELD FUSE

The D14 alternator receives its excitation through a pair of slip rings connected to the low voltage DC auxiliary generator output. This fuse protects the field windings. If the fuse is blown, the no power alarm will be given and engine speed and power will be reduced to idle condition.

FUSE TEST EQUIPMENT

A fuse test block and test lamp are provided, with a switch to test the lamp. Always test fuses before installing them.

GROUND RELAY CUTOUT SWITCH

The purpose of the ground relay cutout switch is to eliminate the ground protective relay from locomotive circuits during certain shop maintenance inspections. The switch is a three-pole device, with one pole performing the cutout function. The other poles prevent locomotive operation with the ground relay cut out.

AUXILIARY GENERATOR FUSE

A 150 ampere fuse is installed to protect the basic auxiliary generator. A 250 ampere fuse is used for the heavy duty auxiliary generator.

CAUTION: The 250 ampere fuse is the same physical size as the higher rated starting fuse. Do not interchange the fuses.

STARTING FUSE

A 400 ampere fuse is installed to protect the starting motors. The fuse is in use only during engine cranking.

CAUTION: On some locomotives the cranking motors are connected in parallel and require an 800 ampere starting fuse. Do not install an 800 ampere fuse in locomotives with cranking motors connected in series.

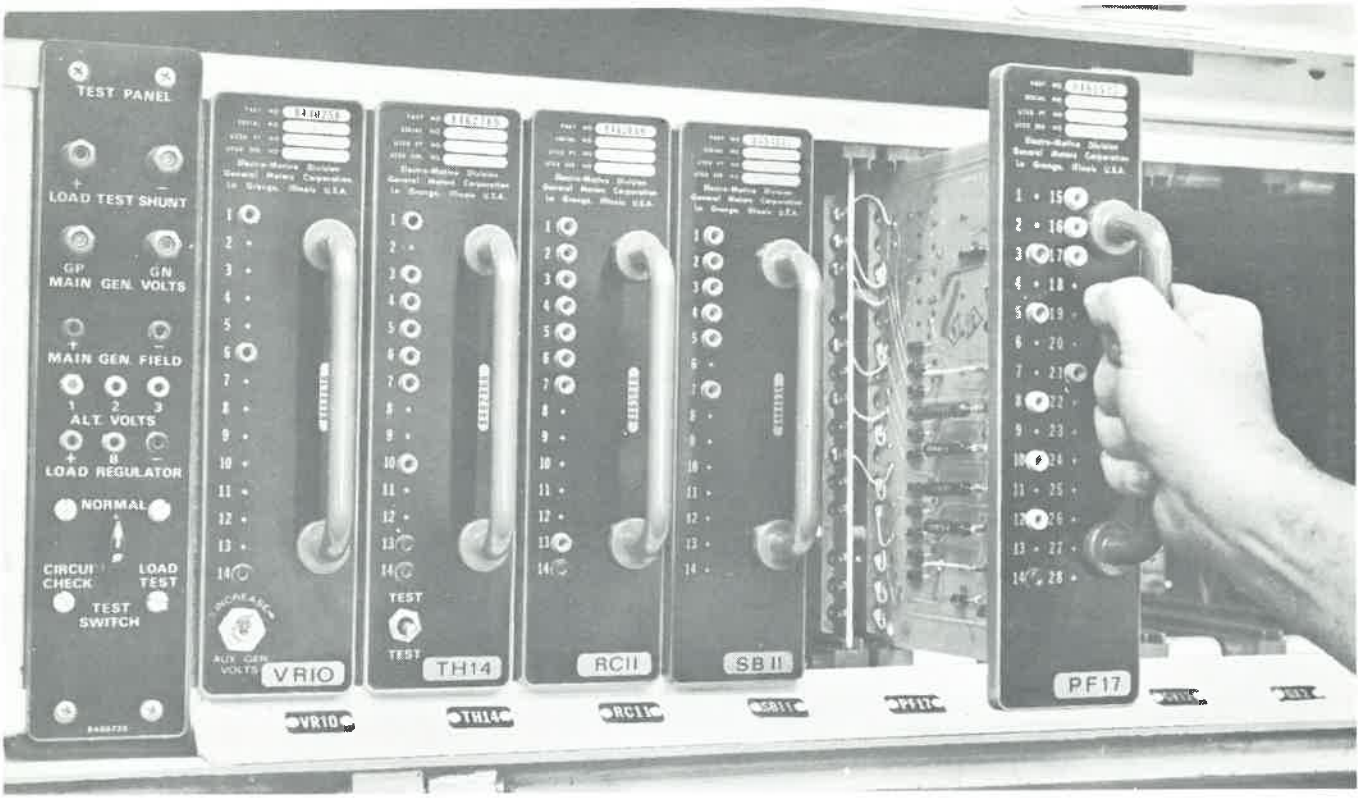
MAIN BATTERY KNIFE SWITCH

This switch connects the battery to the locomotive low voltage system. The switch must always be closed during locomotive operation. It may be opened during shop inspections and locomotive layover.

CIRCUIT MODULES, Fig. 6-14

Each circuit module contains components and wiring for one or more locomotive control functions. The components are mounted on one or more circuit boards. All circuit boards are of the same size, and terminals on the boards are placed on a common grid pattern. The boards are fitted with receptacle strips arranged in a vertical plane, and as the board is inserted into guideways and fully seated, the receptacles mate with pins that are connected to terminal strips. Cabinet wiring completes the circuit connection.

Face plates and handles are attached to the circuit boards, and test points are located on the face plates. In addition to the test points the face plates may contain test buttons and lights.



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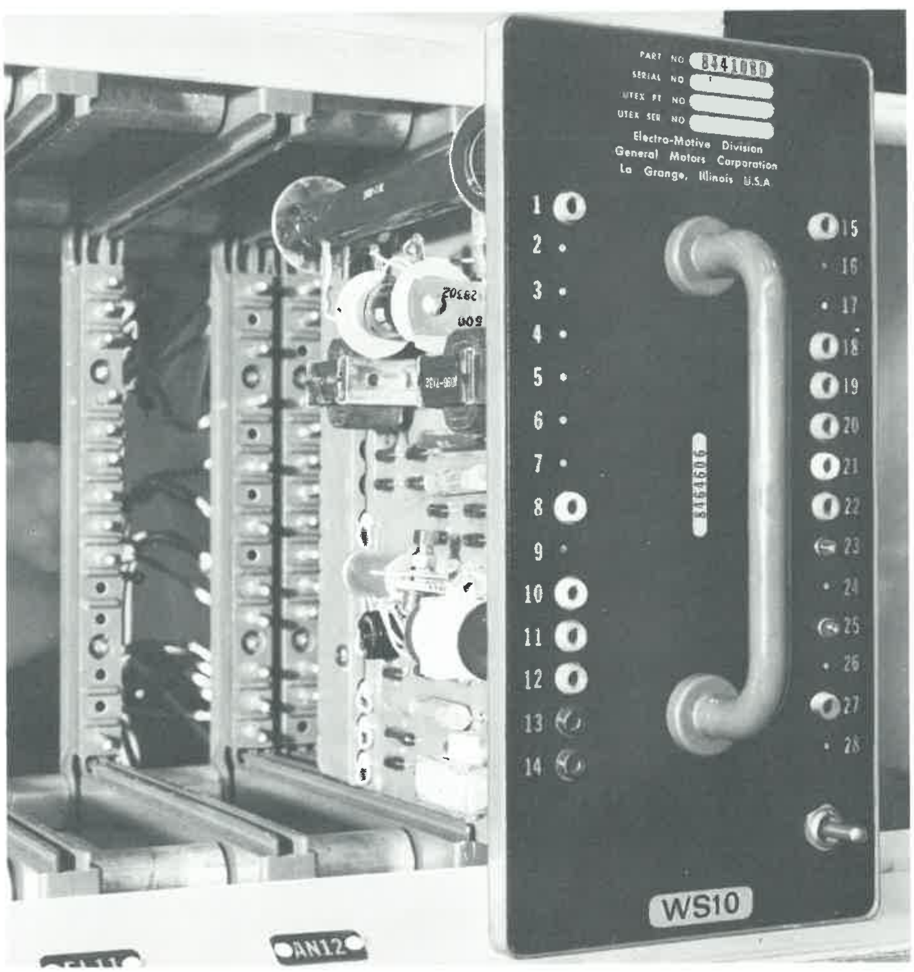

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Fig. 6-14 – Module Compartment And Typical Circuit Modules

AN CIRCUIT MODULE, Fig. 6-15

Fault Annunciator

The annunciator records, by means of latching relays and lights, faults or abnormal operating conditions that occur during locomotive operation. Once lit, the annunciator lights will stay on until a guarded reset switch is operated by a qualified maintenance man. Correction of a fault or resetting of protective devices does not reset the annunciator.

The basic annunciator provides the following indications.

1. Hot Engine
2. Engine Air Filter Plugged.
3. Ground Relay Operated.
4. Excitation Limit Operated.

Units with dynamic brakes provide additional indications.

5. Grid Overcurrent.
6. Motor Overexcitation.

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Fig. 6-15 – Typical Annunciator Module

7. Grid Open Circuit. (Operative only on units with extended range brakes.)

On special order the following indication may be applied.

8. Grid Blower Failure.

DE CIRCUIT MODULE - Extended Range Brake Control

During dynamic braking a signal from the brake control rheostat is compared at the SB module with the main generator feedback signal from the PF module. Main generator excitation is regulated as a result of this comparison and main generator regulation results in motor field and braking current regulation. During extended range dynamic braking the feedback signal from the PF module is compared also with a signal from brake current transductor BCT, and when the BCT signal falls below the PF feedback signal (indicating less dynamic braking grid current than called for by braking lever position) the DE circuits operate to energize a grid shorting contactor. The grid shorting contactor decreases total dynamic braking grid resistance, and more current flows in the grids.

The DE circuit module also compares the BCT signal with the brake rheostat signal during extended range braking. When the BCT signal exceeds the level called for by the brake rheostat, a DE circuit activates the brake regulator circuit in the DR module and holds dynamic braking current at a maximum established by braking handle position.

DG CIRCUIT MODULE - Grid Blower Protection

Excessive current, as with a stalled grid blower motor; or lack of motor current, as with an open motor or cable will be detected by the dynamic grid current transductor. The transductor signal will trigger a latching circuit in the DG module. The braking power contactor "B" is dropped out to prevent dynamic brake operation. A reset button on the DG module allows resetting of the circuit after inspection and correction has been made. A test button is provided on the DG module to test the DG circuit function. The button provides a DC signal to test windings on the transductor in order to simulate a current unbalance at the transductor.

DP CIRCUIT MODULE-
Brake Warning
Motor Field Protection

The dynamic brake protective module provides backup protection should normal regulating devices fail. Should the dynamic brake regulator fail, the brake warning circuit of the DP module will provide rough backup regulation and an annunciator signal. Should motor fields become too hot, the motor field protection circuit of the DP module will protect the motors, provide rough backup regulation, and provide an annunciator signal.

DR CIRCUIT MODULE - Brake Regulator

The DR circuit senses voltage across a dynamic braking resistor grid. When that voltage reaches a value indicative of the maximum allowable amperes in the grids, a transistor in the DR circuit acts to shunt the input to the rate control capacitor of the RC module directly to negative. The rate control capacitor then discharges through a fixed resistance in the RC module. Main generator excitation is thereby controlled to maintain traction motor field excitation for maximum braking current.

A further modification of braking current regulation is in effect during extended range dynamic braking. The turn on point of the DR transistor is controlled not by maximum allowable current in the grids, but by braking handle position. In other words, maximum braking current at lower braking handle positions is low, regardless of train speed. This type of regulation is required to snub braking current surges that occur when grid shorting contactors pickup or drop out.

On special order, control of maximum grid current by braking handle position is available for the entire speed range of the locomotive with or without the extended range dynamic brake extra. When applied, this type of control is trainlined and will be effective on all units so equipped in a consist.

EL CIRCUIT MODULE - Excitation Limit

The excitation limit transductor senses main generator field current, and provides a signal to the EL module. When an overcurrent condition occurs, the EL module causes dropout of the generator field contactor. In this manner the EL module provides backup protection in case of GX module failure, and allows rough regulation of generator current to allow the locomotive to operate under power to reach a maintenance point.

The test button on the EL module is used to energize a test winding on the ELT transductor and simulate an overcurrent condition.

GV CIRCUIT MODULE - Voltage Regulation

The normal condition of the GV circuit module during locomotive operation is full on. There is very slight voltage drop across the 8 and 4 terminals. When the GV module regulates there is a large drop across the terminals. Regulation occurs when a signal from generator potential transformer GPT is great enough to bias the GV transistor off. The function of GV is to maintain main generator voltage at a safe level.

GX CIRCUIT MODULE - Excitation Regulation

The normal condition of the GX circuit module during locomotive operation is full on. There is a very slight voltage drop across the 8 and 4 terminals. When the GX module regulates there is a large voltage drop across the terminals. Regulation occurs when a signal from excitation limit transductor FCT is great enough to bias the GX transistor Off. FCT senses generator field excitation current.

PF CIRCUIT MODULE - Performance Control

Current transformers within the main generator apply a signal to PF proportional to main generator current. Potential transformers in the electrical cabinet apply a signal proportional to main generator voltage. These AC signals are rectified and loaded on precisely determined values of resistance within the PF module. DC voltages across the resistors are combined, added, and applied to the SB module for comparison with the reference signal from the load regulator.

The ohmic values of the PF resistors are selected to obtain performance control characteristics desired for locomotive response to throttle position during train starting, and to obtain a suitable balance point for the load regulator during normal operating service.

RC CIRCUIT MODULE - Rate Control

The response of the main generator and the main generator control system is so fast that sudden changes in the level of reference voltage would result in rough train handling. The RC module makes use of an RC (resistance-capacitance) circuit to smooth out power changes even though an abrupt change in reference signal occurs.

SA CIRCUIT MODULE - Sanding

The sanding circuit module is designed to accommodate a variety of sanding circuits selected by the railroads. A timing circuit is part of the module. It provides for time delay sanding when a wheel slip is signaled. The test button on the module is used to check time delay sanding.

SB CIRCUIT MODULE -
Sensor Bypass (Feedback - Reference Comparison)

The primary SB circuit compares the current-plus-voltage feedback signal from the main generator with the reference voltage signal from the load regulator. The SB uses the comparison to control current in the control winding of the SE circuit module.

SE CIRCUIT MODULE - Sensor

This magnetic amplifier provides shaped signal pulses to turn on the silicon controlled rectifier assembly that provides excitation current to the main generator. Small amounts of current in the control windings of the magnetic amplifier control large amounts of current in the main generator field. The ability to use signals to control large currents simplifies the construction of protective and regulating devices related to main generator excitation, and allows rapid and precise control.

TH CIRCUIT MODULE -
Throttle Response -
Reference Voltage Regulator

The voltage reference regulator section of the TH circuit module provides extremely stable reference voltage for the excitation control system.

The throttle response section of the TH module provides reference voltage directly related to throttle position. This reference voltage is impressed upon power control circuits and locomotive power is precisely controlled by throttle position.

A test button on the TH module is provided to energize the ORS solenoid in the engine governor. This is merely to provide test control of the load regulator.

TR CIRCUIT MODULE -
Transition

Transition is required in order to stay within current limitations of the main generator at low track speeds and within voltage limitations at high track speed. This is accomplished by using 3 parallel motor paths each with two motors in series at low speeds and 6 parallel single motor paths at high speeds.

The TR module is essentially two E-I type relay circuits mounted on a single circuit board. The relay circuits are energized by main generator voltage signals from a generator potential transformer GPT and are restrained (reverse biased) by main generator current signals derived from generator current transformers and the PF module. The voltage and current signals are compared at transistors in the TR circuits. When the voltage signals as calibrated by circuit components exceed the current signals, the transistors are turned on to pick up FTR and BTR pilot relays. FTR pickup at a higher value than BTR pickup initiates forward transition. BTR dropout at a lower value than FTR dropout initiates backward transition.

VR CIRCUIT MODULE - Voltage Regulator

The locomotive low voltage system and equipment are designed for operation on 74 volt DC power supplied by the auxiliary generator. This voltage must be kept constant regardless of changes in engine (and generator) speed.

The voltage regulator is used in the auxiliary generator field excitation circuit and functions to vary excitation as needed to hold output voltage constant despite speed changes. This device functions entirely automatically and should never be disturbed during operation. The regulator utilizes solid state electronic components to regulate auxiliary generator voltage. The regulator does this by rapidly turning the generator field circuit on and off. Time "on" in relation to time "off" establishes auxiliary generator voltage. The regulator is called a static voltage regulator because with the exception of a starting relay it uses no moving parts.

The face of the VR module is provided with a slotted-shaft rheostat to adjust generator voltage between 72 and 76 V DC. This adjustment is provided for battery charging purposes only.

NOTE: The VR circuit module does not provide stable reference voltage for the excitation system. The stable reference voltage is provided by a regulating circuit located on the TH module.

CAUTION: The diesel engine must be completely stopped before the VR module is removed or inserted.

WS CIRCUIT MODULE - IDAC

The IDAC wheel slip control circuits are housed in the WS module. The components are smaller than earlier IDAC configurations, but the functions are essentially the same. Wheel slip correction is based upon acceleration of slipping wheels in the first and second stages. The first stage being immediate power reduction and immediate return to power in small increments. The second stage involves essentially a first stage reduction of power followed by a slower return to power. The third stage of correction is based upon a level value of wheel slip signal rather than a rate of change.

The WS module is provided with a test button that is operative with the unit isolated or with the throttle in idle. When the test switch is operated a green light on the face of the module indicates with a high degree of probability that the wheel slip system is functioning properly. A red test lamp indicates that the WS module is faulty.

TEST PANEL, Fig. 6-16

The test panel located in the module compartment contains terminals and receptacles that provide an easy place to read significant test voltages during operation or test. The test selector switch has the following positions.

1. NORMAL for locomotive operation.
2. CIRCUIT CHECK, which allows control circuits to function when the generator field circuit breaker is opened.
3. LOAD TEST, which allows control and excitation circuits to operate when the reverser is centered, but prevents delivery of power to the traction motors.

CAUTION: The CIRCUIT CHECK position does not prevent excitation of the main generator.

The LOAD TEST position open-circuits the main generator unless an external grid load is connected or the unit is equipped for automatic self loading.

Do not operate above throttle Run 1 with main generator open circuited.

Never return test switch to NORMAL while operating under load.

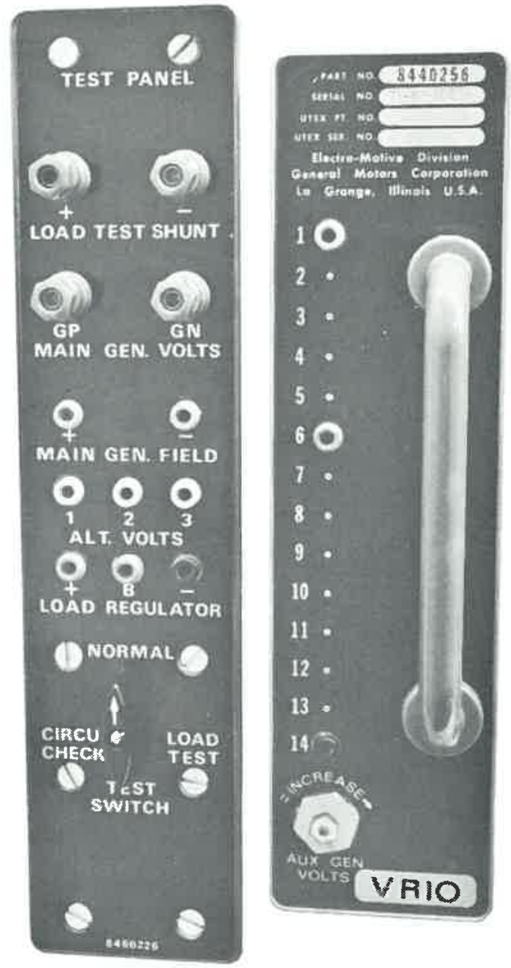

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Fig. 6-16 -- Test Panel

ELECTRICAL DEVICES

The following devices are listed alphabetically for ease of reference. For the most part the devices are located within the main electrical cabinet.

B; BRAKING POWER CONTACTOR, Fig. 6-17

During dynamic braking this contactor is connected in series with traction motor fields and the main generator. It has high current interrupting capability, and must always open before transfer switchgear operates. Interlocks prevent operation of transfer switches while the "B" contactor is closed.

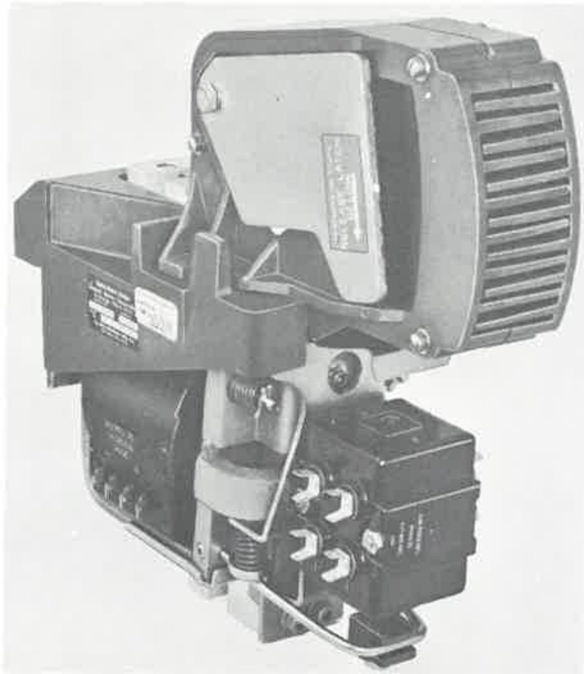

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Fig. 6-17 – Braking Power Contactor

BCT; BRAKING CURRENT TRANSDUCTOR

On locomotives equipped for grid current trainline control and those equipped for extended range dynamic brakes, this transductor is used to provide a signal proportional to current in the dynamic brake resistor grids. The transductor consists of coils wound on iron cores. A cable that carries braking current passes through the cores.

The transductor coils are connected in series with a transformer T4 and across the D14 alternator. The strength of dynamic braking current controls the impedance of the BCT coils, and the output transformer T4 provides a signal that is proportional to braking current. This signal is applied to dynamic brake control circuits in the DR and DE modules.

The DR and DE modules use the signal to regulate maximum braking grid current according to braking handle position. The DE module uses the signal to bring about pickup of grid shorting contactors at given values of braking current.

BR1, BR2; BRAKE RELAYS

These relays are energized when the selector handle is indexed to the brake position. BR relay contacts set up dynamic braking circuits and nullify power circuits. BR1 contacts are made of gold alloy material and are located in control circuits that carry small amounts of current. BR2 contacts are located in circuits carrying greater amounts of current.

When transfer from power to brake is made, a time delay interlock in the feed to the BR coils ensures the decay of generator residual before circuit transfer is initiated by pickup of the BR relays.

CA; CAPACITORS

CA30

Connected around the operating coil of the GFD contactor to suppress arcing at circuit interrupting interlocks.

CA31

Connected in series with a resistor around the operating coil of contactor delay relay CDR to delay dropout of the relay.

CA32

When the controlled rectifier SCR is turned on, this capacitor in conjunction with RE32 suppresses the voltage spike that occurs when the "free-wheeling" diode around the generator field is turned off.

CA33

Suppresses arcing at CDR contacts which operate to drop out power contactors.

CA34

When dynamic braking current is rapidly rising to the regulated value, charging current in CA34 anticipates the approach of full current and triggers the DR transistors. This anticipation effect results in stable DR function with little or no overshoot.

CA37

Acts to suppress a transient generated upon GFC contactor dropout.

CCR, CRL; COMPRESSOR RELAYS

On units equipped with synchronization of all compressors in a consist, the compressor relays in all units of the consist are energized when the main air reservoir pressure in any unit falls below a preset level. The compressor relays in the individual units will remain energized until all reservoir pressures build up to the normal level.

CCS; COMPRESSOR CONTROL SWITCH

The compressor control switch senses main reservoir pressure. It trips to energize the compressor control magnet valve when main reservoir falls below the desired pressure.

On special order a second sensing device can be included in the compressor control switch. This device will de-energize the compressor relay in any individual unit if main reservoir pressure in that unit approaches the safety valve setting of that unit.

An additional function of the compressor control switch is the pickup (through compressor relay CR contacts) of magnet valves at main and auxiliary strainer drains. The strainer drains will blow free for a moment whenever the magnet valves are energized or de-energized.

CDR; CONTACTOR DELAY RELAY

Contacts of CDR are connected in the feed to power contactor operating coils. A resistor-capacitor combination connected around the operating coil of CDR delays dropout and prevents interruption of the feed to power contactor operating coils. CDR dropout is initiated by direction transfer, motor-brake transfer, isolation, or intermittent trainline feed. CDR delay prevents the power contactors from interrupting high voltage and current, with resulting increase in contactor life and elimination of high voltage transients that can damage main generator diodes.

One set of CDR contacts latches the CDR relay in against dropout of the MR relay when the throttle is placed in idle position. This prevents unnecessary operation of power contactors and requires return of the throttle to idle position before power contactors will pick up after a circuit change is made.

COR; MOTOR CUTOUT RELAY

On units equipped for motor cutout the contacts of this relay perform a variety of functions to ensure proper operation with two traction motors cut out. This involves disabling the "S" power contactors and certain wheel slip control circuits, changing the slope and position of power control lines and transition operating points, and picking up "P" power contactors and providing circuits around the interlocks that are not positioned because the related motors are cut out.

CR; RECTIFIERS

CR17

This rectifier is connected as a discharge rectifier around the D14 field to stabilize D14 output. The "free-wheeling" characteristic smooths out fluctuations resulting from variations in field current.

CR30

Blocks backfeed from the turbo lube pump relay coil power supply.

CR31 THRU CR33 AND CR38 THRU CR40

Perform blocking functions in circuits to governor and throttle response coils.

CR34

Blocks backfeed from the alarm circuit to the ER relay coil.

CR35

Delays dropout of fuel pump control relay FPCR to ensure against engine shutdown due to transient circuit interruption.

CR36

Suppresses voltage spikes to transistorized TR module circuits connected in parallel with the TDR relay coil.

CR37

Blocks backfeed from the SA module test circuit to the governor overriding solenoid ORS.

CR41

Blocks rate control capacitor discharge through the TH module.

CR45

Blocks backfeed from ORS circuit.

CR49

Blocks feedback through the hot engine (THL) and plugged engine air filter (EFL) protective circuits.

CR60

Acts to suppress a transient generated upon ORS dropout.

CR-BC, BATTERY CHARGING RECTIFIER, Fig. 6-18

The battery charging rectifier consists of a pair of heat sink mounted silicon diodes in parallel with a selenium suppression rectifier that protects the silicon diodes from high voltage spikes. The rectifier prevents battery current from flowing through the windings of the auxiliary generator and D14 alternator when the diesel engine is stopped.

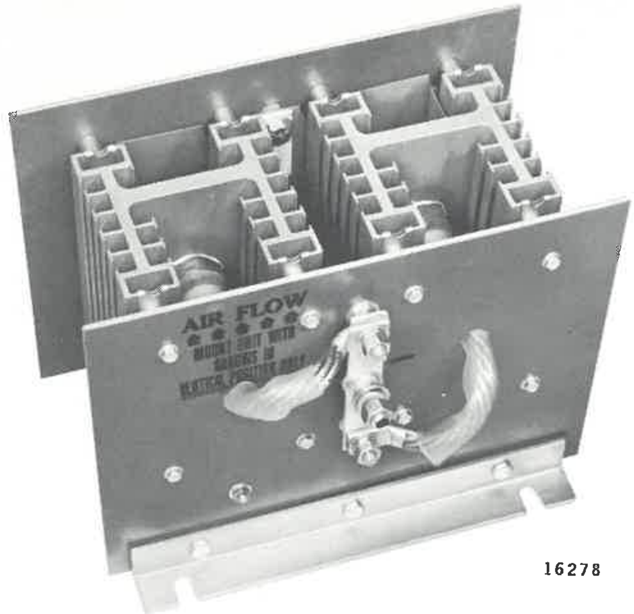


Fig. 6-18 -- Battery Charging Rectifier

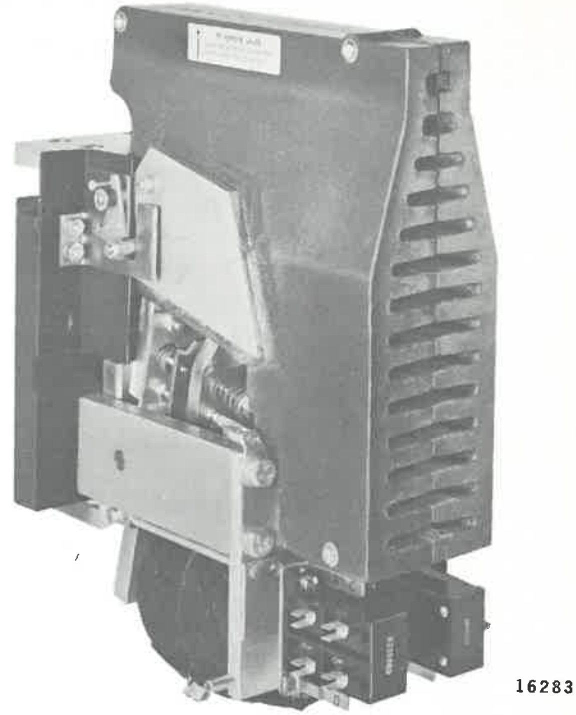


Fig. 6-19 -- Dynamic Brake Grid Shorting Contactor

CR-GR; GROUND RELAY RECTIFIER

It is the function of the ground relay to detect high voltage DC and AC grounds and AC phase unbalance at the main generator. The fast acting relay uses an operating coil of high impedance, consequently the relay will not respond properly to alternating current. The ground relay rectifier changes AC signals to DC at the ground relay operating coil, thus ensuring rapid operation of the relay.

CT; CURRENT TRANSFORMERS

Current transformers are located within the main generator airbox. Three cables, one from each phase of the three-phase AC output, pass through the CT's before connecting to the main generator rectifier assembly. The cable from phase A passes through CTA, from phase B through CTB, and from phase C through CTC. The signals from the CT's are proportional to main generator DC output. They are applied to the performance control module PF from which a feedback signal is derived and used for locomotive control.

DC1, 2, 3; DYNAMIC BRAKE GRID SHORTING CONTACTORS, Fig. 6-19

On locomotives equipped with extended range dynamic brakes, the DC power contactors close in sequence to each short out approximately one-fourth dynamic braking grid resistance. This reduction of braking grid resistance allows current flow through the remaining grids to continue at a high level as locomotive speed decreases.

The contactors are rated to carry more than 2000 amperes continuously, and are equipped with arc chutes that contain, expand, and extinguish arcs by action of a permanent magnet blowout structure. The contactor is rated to open in parallel with dynamic braking grids on volts up to 350 and currents up to 2400. Contactor operation is controlled by the DE module and pilot relays.

DGT; DYNAMIC GRID TRANSDUCTOR

This transductor is constructed of the same basic parts as the wheel slip transductors, but in addition is equipped with a spool to accept and firmly hold several turns of a cables leading to braking grid fan motors. In the event of a stalled fan or motor, or an open in the motor circuit, currents at the transductor create an unbalance. The unbalance is sensed at the DG circuit module, and the braking power contactor is locked out. A reset button on the DG circuit module will reset the lockout after the fault has been corrected.

DP1, 2, 3; DYNAMIC BRAKE PILOT RELAYS

These relays are controlled by the extended range dynamic brake control circuit module DE. They pilot the extended range dynamic brake power contactors DC1, 2, and 3.

DP1A; AUXILIARY PILOT RELAY

Establishes grid current control during extended range dynamic braking. Units with extended range dynamic brakes and no DP1A relay are equipped for full range grid current control.

EBT, ELECTRO-THERMAL BLOWDOWN TIMER

This device is applied on special order to time the operation of the automatic drain valves in the compressed air system of the locomotive. With the system, automatic drain valve blowdown occurs at approximately 3 minute intervals regardless of locomotive circumstances (operation, standby, or shutdown) as long as the control circuits are energized.

EFL; ENGINE FILTER LATCHING RELAY

If the engine air filter becomes plugged, a filter vacuum switch trips to energize the EFL relay. Relay contacts operate to restrict engine speed and power and to provide an annunciator signal.

ELT; EXCITATION LIMIT TRANSDUCTOR

If generator field current exceeds a safe level, ELT actuates the EL circuit module. The equipment protective relay is dropped out, which in turn drops out the generator field contactor GFC until current falls to a safe level. The action protects equipment, yet allows rough regulation to get the locomotive over the road to a maintenance point.

EQP; EQUIPMENT PROTECTIVE RELAY

It is the function of the EQP relay to drop out the generator field contactor GFC when protective devices operate to back up faulty regulating devices. EQP dropout can occur through operation of the following:

1. DP circuit module brake warning and motor field protective relays.
2. Through pickup of the excitation limit relay of the EL circuit module.
3. Through pickup of the FTR relay after forward transition has been made.
4. Through dropout of the generator field decay relay that is piloted by the ground relay.

All of the above accomplish rough regulation to enable the locomotive to get over the road to a maintenance point. On the basic locomotive none of the devices lock in after pickup. However, on special order the ground relay can be made to latch after a specific number or a specific rate of GR operations.

ER; ENGINE RUN RELAY

The function of the engine run relay is to set up control circuits to the governor speed setting solenoids. Therefore, if the engine run relay is de-energized by placing the engine run switch in the OFF position or by operation of safety devices, the diesel engine will not run above idle speed. Throttle response relays in the TH module will, however, still respond to throttle position.

On the basic locomotive the engine run switch on the locomotive control stand must be in the on position before the engine run relay can be energized. On special order the engine run switch may be eliminated. On such units, operator's control of the engine run relay is provided by the isolation switch and the ground relay cutout switch only.

ETS; ENGINE TEMPERATURE SWITCH

This switch is located in a water manifold on the equipment rack. It senses engine water temperature and picks up to indicate excessive temperature. Upon pickup it turns on the HOT ENGINE light and energizes the TH relay which operates to reduce engine speed and power. Contacts of ETS also protect against failure of other temperature sensing switches by providing a backup feed to a cooling fan contactor.

FCT; FIELD CURRENT TRANSDUCTOR

This transductor consists of two toroidal iron cores, each with a 1000 turn test winding is also common to both cores. The cores and windings are completely enclosed and hermetically sealed. D14 AC is impressed upon the windings, and a hole in the molded enclosure admits a cable carrying current through the transductor and to the generator field. When field current reaches a specific level, output from the transductor causes the GX module to go into a blocking state. Control current ceases to flow in the SE module (sensor) control windings and generator excitation is reduced.

FC1, 2, 3; COOLING FAN CONTACTORS, Fig. 6-20

The cooling fan contactors operate to supply D14 AC power to the radiator cooling fan motors. They are controlled by temperature switches mounted in a water manifold on the equipment rack.

FOR; DIRECTIONAL RELAY, FORWARD

This relay along with RER controls the direction in which the locomotive will move. The designation FOR is related to the short hood end of the unit. The relay is energized by trainlined control current when the reversing lever on the controller is placed in the appropriate position. Contacts of the relay make or break circuits using local control current to actuate heavy duty motor driven transfer switches. The transfer switches establish the direction of high voltage main generator current flow through traction motor fields.

Crossover wires at each of the jumper cable receptacles between units of a consist are so arranged that whatever the makeup of the consist, the appropriate relays in trailing units will be energized.

FPC; FUEL PUMP CONTACTOR

Use of this contactor relieves the fuel prime-engine start switch of fuel pump motor current load. Pickup and dropout of the fuel pump contactor are piloted by the fuel pump control relay FPCR.

FPCR; FUEL PUMP CONTROL RELAY

When the fuel prime engine start switch FP/ES is placed in the START position, the FPCR is energized. FPCR contacts pick up to provide a holding circuit for FPCR and to establish a circuit between the FPC coil and the auxiliary generator side of the battery charging rectifier when the FP/ES switch is released. FPCR contacts also enable the circuit to the engine run relay ER and set up the engine shutdown circuit to the governor "D" solenoid.

FPR; FUEL PUMP RELAY

The primary purpose of the fuel pump relay is to provide the locomotive operator with the means of shutting off the fuel pump from a switch on the control stand. Before the engine is running, the relay performs no function, but it must be picked up to set up the fuel pump contactor circuit.

CAUTION: The control and fuel pump switch must always remain in the ON position while the engine is running. If an engine shuts down from lack of fuel, damage to the engine injectors is possible.

FTX; FORWARD TRANSITION AUXILIARY RELAY

This relay is piloted by the FTR relay in the TR module. Its contacts operate to initiate the transition sequence and also initiate corrective action when FTR signals a wheel overspeed by pickup during parallel operation.

FUSE, RADIATOR FAN MOTOR, Fig. 6-20

These 200 ampere bolted lug type fuses protect the radiator fan motors. The lugs are affixed to tubular insulating bodies made of reinforced melamine. Fast acting fusible links within the tube connect the fuse lugs. The links are surrounded with silicon sand that acts to absorb arc energy. A small indicating fuse is affixed to the main fuse body, and is connected in parallel with the main fuse elements. When the main elements open, the indicator link also burns open, and a spring loaded indicator pin protrudes to indicate a blown fuse.

If an inspection reveals a single blown fuse, remove and discard both fuses used to protect the motor. This is done because the second fuse, while not indicated as blown, will in all probability be degraded and will blow open the next time the fan is called upon to start.

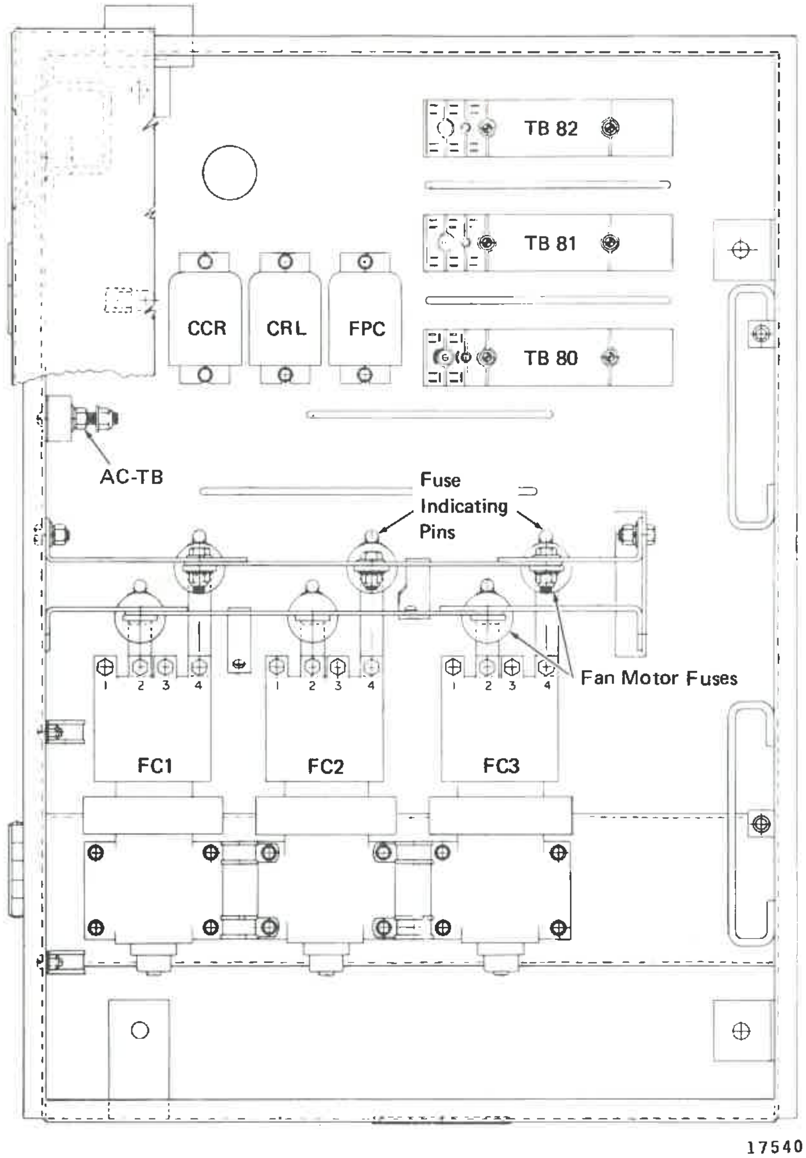
CAUTION: If for some reason a single fuse is to be removed, always remove the other fuse to completely isolate the motor.

GFA; GENERATOR FIELD AUXILIARY CONTACTOR

This contactor is energized during dynamic braking. Its purpose is to accomplish more precise control of low level main generator excitation required during dynamic braking. It does this by inserting resistance in series with the main generator field and by limiting input to the main generator excitation SCR to a single phase from the D14 alternator.

GFC; GENERATOR FIELD CONTACTOR

The main contacts of this device are located in the AC supply from the D14 alternator to the main generator excitation rectifier SCR. The contactor will pick up to close the main contacts when circuits are complete for power operation, dynamic braking, or load testing. A GFC interlock pilots an auxiliary relay GFX whose contacts perform interlocking functions associated with GFC operation.



CAUTION

Whenever a single blown fuse is indicated, always remove and discard both fuses in the fan circuit. Replace with two new fuses.

Fig. 6-20 – AC Cabinet

GFD; GENERATOR FIELD DECAY CONTACTOR

During ground relay action, GFD operates to drop out equipment protective relay EQP which in turn drops out generator field contactor GFC. GFD main contacts open to insert resistance in series with generator field discharge circuit, and thereby increase the field decay rate by limiting the duration of circulating current.

GFX; GENERATOR FIELD AUXILIARY RELAY

This relay is piloted by operation of the GFC contactor. Its primary function is to complete the throttle reference voltage circuit from the throttle response function of the TH circuit module to the rate control function of the RC circuit module. Secondary functions nullify various module test circuits during power or braking operation.

GPT; GENERATOR POTENTIAL TRANSFORMER(S)

Voltage from the AC side of the main generator rectifier assembly is applied to the primary windings of GPT. An output signal proportional to main generator voltage is applied from GPT to the generator voltage regulating module GV, to performance control module PF, and to transition module TR.

GR; GROUND RELAY

The ground relay detects AC and DC high voltage grounds or the loss of five paralleled main generator diodes in a group. It does not detect low voltage grounds. When the relay is tripped, the

H.V. GRD/FAULT light comes on. This light is located on the engine control panel and on the annunciator module within the electrical cabinet. The engine control panel light goes out when the ground relay is reset, but the annunciator light remains on until the annunciator is reset.

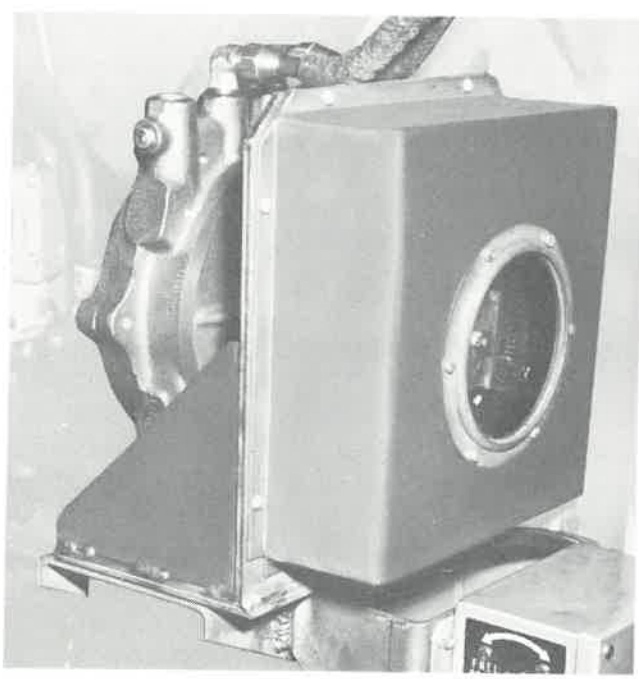
The ground relay is held in its tripped position by a mechanical latch in the relay. It is reset by either manually pressing the ground relay reset button on the control stand or by an automatic reset device on locomotives so equipped. The automatic resetting devices also provide a reset lockout that prevents further resetting after a specific number of resets or after a specific number of resets within a specific time period.

IPS; INDEPENDENT PRESSURE SWITCH

Application of the locomotive air brake during extended range dynamic braking will actuate this switch and will nullify extended range dynamic braking. This is done to prevent the possibility of sliding wheels.

LR; LOAD REGULATOR, Fig. 6-21

The load regulator is a plate type rheostat driven by a hydraulically operated vane motor. A pilot valve in the engine governor controls a flow of engine oil under pressure to drive the vane motor clockwise or counterclockwise through a maximum arc of about 300 degrees, thereby positioning the rheostat brush arm and regulating the



16176

Fig. 6-21 -- Load Regulator

output of the main generator by varying a signal to a system that controls excitation of the generator field. Control of generator field excitation results in control of the load on the engine. Load control of the engine by the governor permits the governor to maintain engine speed with regulation of power at the correct level for a given speed.

LTT; LOAD TEST TRANSFER SWITCHES, Fig. 6-22

When the test panel switch is rotated to the LOAD TEST position, these switches operate to connect the main generator to the dynamic braking resistor grids. They are located toward the back of the electrical cabinet and are applied on special order when automatic load testing is desired.

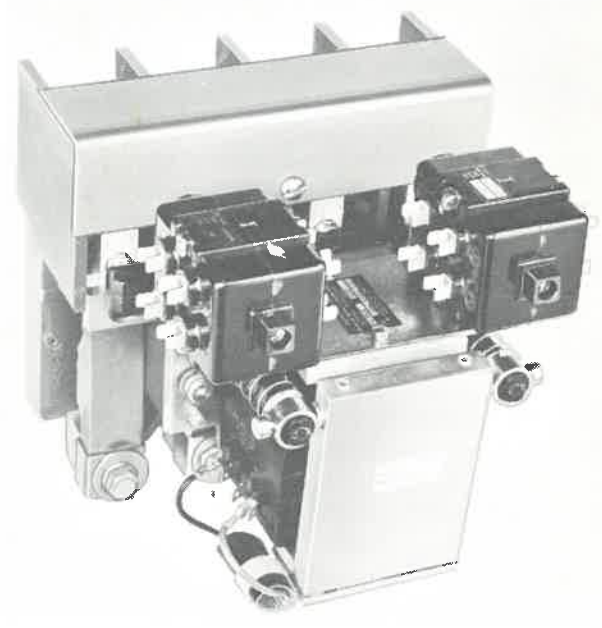


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Fig. 6-22 -- Load Test Transfer Switch

MB; MOTOR BRAKE TRANSFER SWITCH, Fig. 6-23

This switchgear is used to transfer circuits from the power mode of operation to the dynamic braking mode on locomotives so equipped. The device is made up of motor driven gang operated switches rated at 1200 amperes and 1500 volts. There can be from two to six double-pole double-throw switches per device. Being motor driven, once the switch is positioned, it will not drop out. A positive feed is required to move the contacts. When they do move, all poles operate together, and a single interlock suffices to indicate the position of all switches. This increases interlock availability and allows complete protective interlocking.

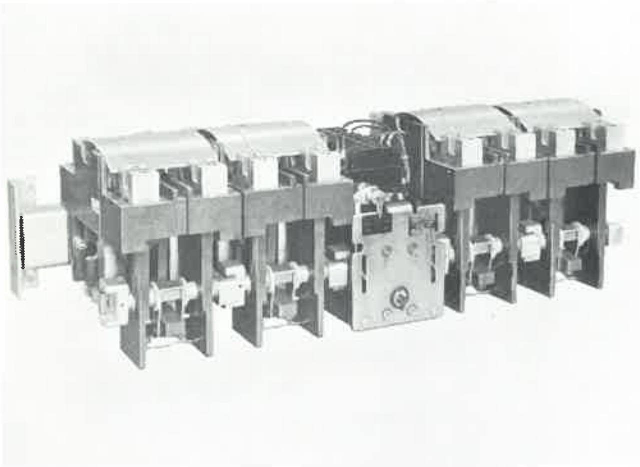

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Fig. 6-23 -- Typical Motor Operated Transfer Switch

MCOX; MOTOR CUTOUT AUXILIARY RELAY

MCOX operates in conjunction with relay RVF to drive the motor operated transfer switches RV from one position to another when the rotary cutout switch in the cab is operated. This allows MCO relays to lock transfer switch contacts at an open centered position and cut out the power circuits to the appropriate traction motor(s).

MCO_; MOTOR CUTOUT MAGNET COIL AND LIMIT SWITCH

On units equipped for traction motor cutout, an MCO magnet coil is mounted on each RV transfer switch. Two MCO coils are energized whenever the rotary cutout switch in the cab is operated to cut out a faulty motor and its electrically related motor. When the rotary switch is operated, the motor operated transfer switch assembly will cycle between forward and reverse positions. As the switches to be cut out pass through centered position, the MCO locks the contact operator in the centered or neutral position, and the MCO armature operates a limit switch assembly to pick up the COR relay which functions to set up control circuits for operation with motors cut out. The limit switch contacts also hold the appropriate "P" power contactors dropped out.

MR; MOTORING RELAY

This relay performs functions formerly assigned to the relay identified as GFR. It is energized when the throttle is opened for power. It is dropped out during dynamic braking. Contacts of the MR relay perform functions associated with excitation of the main generator field.

MV-CC; MAGNET VALVE, COMPRESSOR CONTROL

When the compressor control magnet valve is de-energized, the air compressor unloader valve opens and the compressor begins to pump. The magnet valve is de-energized on the basic system by action of the compressor control switch CCS. On units equipped for synchronization of all compressors in a consist, the magnet valve is de-energized when the compressor relay responds to the compressor control switch in the individual unit or to the compressor control switch in each or any unit of a consist.

MV-SH; MAGNET VALVES, SHUTTER CONTROL, Fig. 6-24

When cooling fan contactors FC1, FC2, and FC3 are de-energized, their related fans are not powered. Interlocks of FC1, FC2, and FC3 close to energize shutter control magnet valves MV-SH. Compressed air is admitted to the shutter operating pistons to work against shutter spring pressure and drive the shutters closed. When the FC1 fan contactor picks up shutter magnet valves are de-energized, air pressure is released from the shutter operating pistons and the spring pressure drives the shutters open.

The two magnet valve assemblies are connected in tandem at a single manifold. Both magnet valves must be energized and operate before air pressure can drive the shutters closed. If either or both valves are de-energized, air pressure is released from the shutter operating piston, exhausted through the valve, and the shutters open. Refer to the air flow sketch in Fig. 6-25.

MV-818; FILTER BLOWDOWN VALVE

When this magnet valve is energized and again when it is de-energized an operating spool briefly releases air and accumulated water from the auxiliary main reservoir centrifugal filter. On the basic locomotive blowdown occurs when the air compressor loads or unloads. If the locomotive is equipped with electric blowdown timer EBT, blowdown occurs approximately every three minutes.

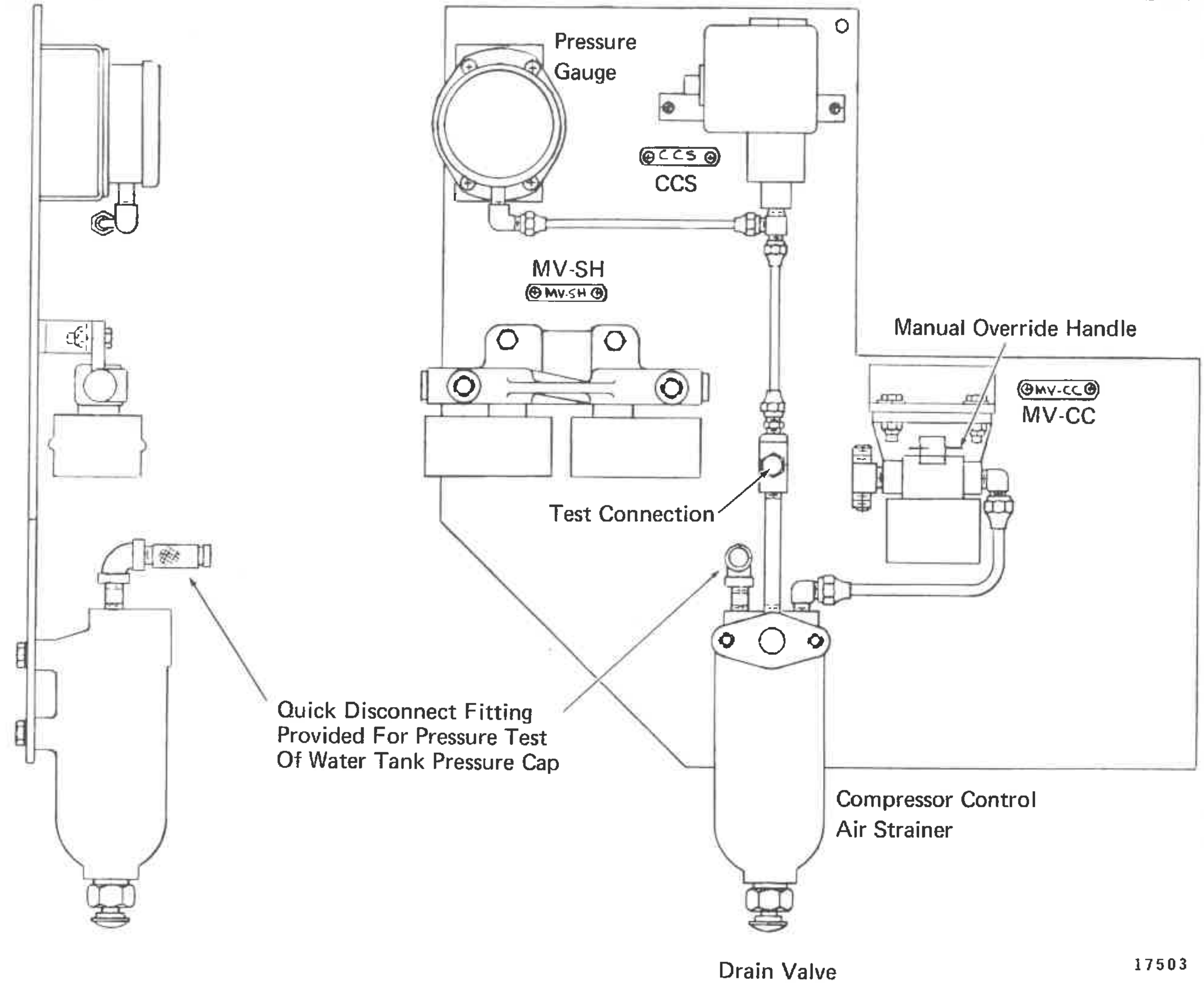

Fig. 6-24 – Air Equipment Mounting Panel

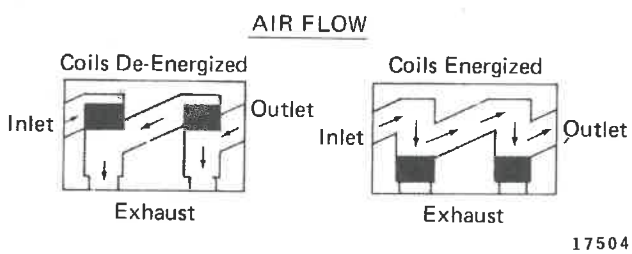

Fig. 6-25 – Shutter Magnet Valve Air Flow

MV-824; FILTER BLOWDOWN VALVE

When this magnet valve is energized and again when it is de-energized an operating spool briefly releases air and accumulated water from the main reservoir centrifugal filter. It operates in the same manner as the MV-818.

MV-880; MAIN RESERVOIR BLOWDOWN VALVE

When this magnet valve is energized and again when it is de-energized an operating spool briefly releases air and accumulated water from the main and auxiliary main reservoir tanks. On the basic electrical blowdown system this occurs whenever the compressor loads or unloads. If the locomotive is equipped with electric blowdown timer EBT, blowdown occurs approximately every three minutes.

NVR; NO VOLTAGE RELAY

This relay is energized by AC current from the D14 alternator when the engine is running. In the event that auxiliary AC power is somehow lost, NVR drops out. This sets up circuits to sound an alarm, restrict the diesel engine to idle speed and start the turbocharger auxiliary lube oil pump. The turbocharger auxiliary pump light and the no power light will come on.

Loss of AC to NVR can be caused by the engine stopping, by tripped main generator field or AC control circuit breakers, by trip of the auxiliary generator field circuit breaker, or by failure of the D14 alternator or the auxiliary generator fuses.

OCP; OPEN CIRCUIT PROTECTIVE RELAY

On units equipped with extended range dynamic brakes, this latching relay is bridge connected between motor armatures and dynamic braking resistor grids during dynamic braking. If an open occurs in the grids or cables, the relay picks up and latches in. It can not be reset by the locomotive operator, and should only be reset by maintenance personnel after a thorough examination of the dynamic braking grids and cables. The reset button is located within the electrical cabinet.

CAUTION: Do not reset the OCP until a thorough inspection has been made to ensure that dynamic braking grids and cables are in satisfactory condition.

ORS; OVERRIDING SOLENOID

This solenoid is located within the engine governor. When energized it operates the load regulator pilot valve, and causes governor oil pressure to drive the load regulator to minimum field position.

ORS is energized when protective devices operate, and during transition on units that require transition. A test button on the TH module provides the means for checking governor control of the load regulator by energizing ORS.

PCR; PNEUMATIC CONTROL RELAY

The function of the pneumatic control relay is to reduce engine speed and power to idle when an emergency or penalty application of the brakes occurs.

PCS: PNEUMATIC CONTROL SWITCH

Contacts of the pneumatic control switch are normally closed in the circuit to the magnet coil of the pneumatic control relay. When a penalty or emergency application of the air brakes occurs the PCS switch operates to interrupt the circuit to PCR. Engine speed and power go to idle. When control of the air brakes is recovered, PCS drops out, and PCR will pick up if the throttle is at idle position.

PR; PARALLEL RELAY

The contacts of PR operate in the transition sequence circuits to ensure proper transition from series-parallel to parallel and back. They also control generator excitation during transition and they recalibrate performance control characteristics.

PRA; PARALLEL RELAY AUXILIARY

This relay is used to set up the wheel overspeed detection and correction circuits.

P_; POWER CONTACTORS, Fig. 6-26

Power contactors are rated at 1200 amperes 1500 volts continuous, and can successfully interrupt current at this value repeatedly without damage; however, during normal operation current and voltage values are far less when the power contactor opens. The contactors are equipped with continuous duty series electro-magnetic blowout and arc chutes that accomplish arc blowout without arcing to ground. The arc chutes are positive latching. They cannot be misapplied, and power contactor interlocks will not function if the arc chute is removed. Contact tips are trifurcated (the movable tip is made up of three movable fingers) for greater contact surface and are made of alloy material with good conductivity that resists oxidation and erosion and maintains a low operating temperature.

These contactors are energized and closed to connect all of the traction motors in full parallel with the main generator. Auxiliary contacts perform various functions in control circuits.

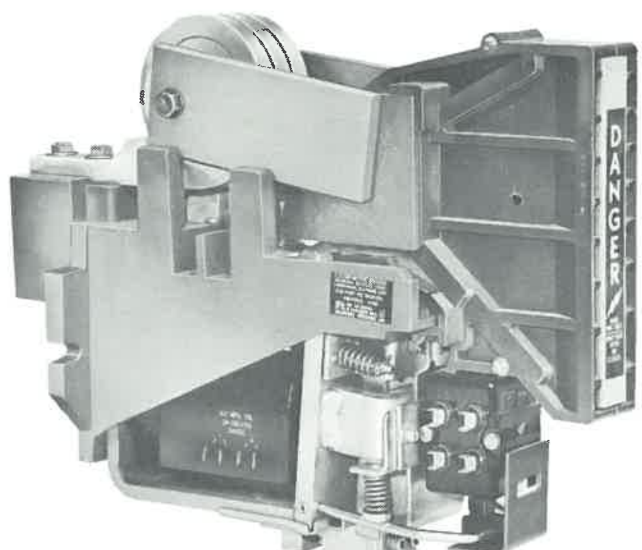

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Fig. 6-26 – Power Contactor

RE-BC; BATTERY CHARGING RESISTOR

This limiting resistor is installed to protect the auxiliary generator and battery charging circuit against high currents in the event that the battery has a very low charge.

RE-DB; DYNAMIC BRAKING RESISTORS

The faceplate type dynamic braking rheostat RH50 employs this resistor assembly to extend the capability of the rheostat.

RE; RESISTORS

RE1

Provides limiting resistance between the SCR assembly and the AR10 field during dynamic braking. This is done to obtain improved control of the low field current required during dynamic braking.

RE2

This resistance is inserted in series with the main generator field to increase the rate of field decay when ground relay action occurs.

RE3A - B

Provide limiting resistance in the circuits for the ground relay.

RE4A - B

Wheel slip relay WSR bridge circuit resistors.

RE5A - B

Tapped resistances to control headlight intensity are inserted in circuit by means of switch on the control stand.

RE6

Provides the load for the output from the wheel slip transductors. The voltage drop across this resistor is the wheel slip signal to the WS circuit module.

RE10A - B; RE20A - B

These adjustable resistors provide proper voltage for the headlights.

RE31

With CA31 establishes the time delay dropout of contactor delay relay CDR.

RE32

With CA32 acts to suppress voltage spikes at the SCR.

RE33

With CA33 acts to suppress arcing at CDR relay contacts.

RE34

Protects against accidental pickup of S14 in case of transient fault condition.

RE39

Used to modify SE operating characteristics during dynamic braking.

RE41

With CA37 acts to suppress a transient generated upon GFC contactor dropout.

RER; DIRECTIONAL RELAY, REVERSE

This relay along with FOR controls the direction in which the locomotive will move. The designation RER is related to the long hood end of the unit. The relay is energized by trainlined control current when the reversing lever on the controller is placed in the appropriate position. Contacts of the relay make or break circuits using local control current to actuate heavy duty motor driven transfer switches. The transfer switches establish the direction of high voltage main generator current flow through traction motor fields.

Crossover wires at each of the jumper cable receptacles between units of a consist are so arranged that whatever the make up of the consist, the appropriate relays in trailing units will be energized.

RH50; DYNAMIC BRAKE RHEOSTAT

During dynamic braking this rheostat is operated by the throttle lever. It consists of a plate type potted assembly. Its resistance is used in combination with RE-DB.

RVF; TRANSFER SWITCH FORWARD RELAY

On units equipped for traction motor cutout, this relay operates in conjunction with motor cutout auxiliary relay MCOX to drive the motor operated transfer switches RV from one position to another to allow the motor cutout relays to lock transfer switch contacts at an open centered position and cut out the power circuits to the appropriate traction motor(s).

RV_; DIRECTIONAL TRANSFER SWITCH

This switch is used to change the direction of current flow through the traction motor fields. The device is made up of motor driven gang operated switches rated at 1200 amperes and 1500 volts. There are from two to six double-pole double-throw switches per device. Being motor driven, once the switch is positioned, it will not drop out. A positive feed is required to move the contacts. When they do move, all poles operate together, and a single interlock suffices to indicate the position of all switches. This increases interlock availability and allows complete protective interlocking.

SCR; SILICON CONTROLLED RECTIFIER

AC power from the D14 alternator is rectified and applied to the main generator in controlled amounts by this rectifier assembly. A triggering device in the power control system signals the amount of power that SCR sends to the generator field.

ST; STARTING CONTACTOR

The cranking motor assemblies are equipped with heavy duty contact tips that make contact when the starting solenoid has operated to engage the cranking motor pinion with the starting gear. Such contacts are normally used to carry current to the cranking motors; however, to ensure reliability of the cranking devices, the locomotive uses the solenoid operated contacts to pilot a still heavier duty contactor ST. Use of this starting contactor also ensures engagement of each of the paired cranking motor pinions before power is applied to the cranking motors.

STA; STARTING AUXILIARY CONTACTOR

When the fuel prime-engine start switch is placed in the ENGINE START position, the STA contactor closes to apply battery power to starting solenoids that are part of the cranking motor assembly. The solenoids drive the cranking motor pinions in to mesh with the starting ring gear. When the pinions are meshed, solenoid, operated contacts close to energize cranking contactor ST, which applies battery power to the cranking motors.

S_; SERIES POWER CONTACTORS

These electro-magnetic contactors are energized and closed to connect the traction motors in series-parallel with the main generator during operation under power. During dynamic braking these contactors close to connect traction motor armatures to braking resistor grids. Auxiliary contacts of these contactors perform various functions in the control circuits.

TA, TB, TC; TEMPERATURE SWITCHES

These switches are located in a manifold on the equipment rack. They sense engine water temperature and operate to activate cooling fan contactors.

TDR; TRANSITION DELAY RELAY

During transition from series-parallel to parallel, the TDR operating coil is energized while power contactors are sequencing. When the transition sequence is completed, the TDR coil is de-energized, but dropout of TDR contacts is delayed by an air dashpot. These time delay contacts pilot a relay in the TR module which acts to hold BTR in against transient low voltage and to prevent inadvertent FTR pickup. TDR times out after system voltage has stabilized.

THL; THROTTLE LIMIT RELAY

When for any reason a hot engine occurs, the engine temperature switch ETS contacts close to sound the alarm bell, turn on the hot engine light on the engine control panel, and energize the THL relay coil. THL contacts turn on the hot engine light on the annunciator, and act to reduce engine speed and power to accomplish engine cooling if the hot engine was caused by a transient condition. If the hot engine was due to an engine or system fault, the hot engine condition may persist until engine shutdown is brought about by engine protective devices.

TLPR; TURBO LUBE PUMP RELAY

The function of TLPR is to energize the turbine auxiliary lube oil pump at engine start and shutdown, and to prevent engine start until it (TLPR) is picked up.

TLTD; TURBINE LUBE TIME DELAY RELAY

The TLTD is energized whenever the main battery switch is moved from open to closed position and the turbocharger auxiliary lube pump motor circuit breaker is closed. TLTD contacts close for a period of approximately 35 minutes to energize the turbocharger auxiliary lube oil pump contactor TLPC, which in turn controls the turbocharger auxiliary lube oil pump. TLTD is recycled if the circuit is interrupted by the engine start or stop switch or if an engine shutdown causes NVR interlocks to close.

TSR; TRANSFER SWITCH RELAY

The transfer switch relay is energized only when all power contactors have dropped out. Its interlocks prevent operation of the transfer switches until all power contactors are dropped out. The transfer switches will therefore not open while they are carrying current.

T4; BRAKING CURRENT SIGNAL TRANSFORMER

This transformer provides a signal of usable value from braking current transductor BCT that is proportional to current in the dynamic braking grids. On units equipped for extended range dynamic braking, the signal is applied to the DE module to bring about pickup of dynamic brake grid shorting contactors. On units equipped for trainlined control of dynamic brake grid current, the signal is applied to bring about regulation of braking effort according to braking handle position.

WL; WHEEL SLIP LIGHT RELAY

This relay is energized by pickup of either the WSR or "L" relays in the WS circuit module or by pickup of the FTX relay after transition to parallel motor connection has been made. "L" relay pickup indicates a large steady current differential at the traction motors, such as would occur with a locked sliding wheel. WSR relay pickup can indicate simultaneous slip of wheels on one truck. FTX pickup during parallel motor connection indicates wheel overspeed such as during six-axle simultaneous slip.

In the event of a locked-sliding wheel set, pickup of WL contacts opens the wheel slip circuit feed to the governor ORS coil. This is to prevent driving the load regulator near minimum field position where it would be held by wheel slip rate circuits, thus preventing the required WL pickup and wheel slip light indications.

WST; WHEEL SLIP TRANSDUCTORS

The transductor consists of two coils wound on independent iron cores. The coils are in series across an alternating current source - the D14 alternator. Cables carrying traction motor current pass within the frame of the iron cores. The current in the cables is normally of equal value and in opposite direction. When wheel slip occurs the currents are unbalanced, causing a change in magnetic fluxes in the cores. This results in a decrease in the impedance of the coils and the impedance change is seen as a wheel slip signal at the WS module.

PNEUMATIC DEVICES IN THE ELECTRICAL CABINET

EFS: ENGINE FILTER SWITCH

This switch senses the pressure drop across the inertial plus the pleated paper engine air filters. When the pressure drop across the combined filters reaches 24 inches of water, the switch operates to energize latching relay EFL. EFL contacts act to limit engine speed and power, and provide a backup signal to the AN module.

FVS: FILTER VACUUM SWITCH

This switch senses the pressure drop across the inertial plus the pleated paper engine air filters. When the pressure drop across the combined filters reaches 14 inches of water, the switch operates to provide a signal to the AN module.

HOSE STEMS FOR MANOMETER CONNECTION

Three hose stems are provided at the front of the electrical cabinet.

Air Filters - Engine Plus Inertials

This opening is piped to the turbocharger inlet side of the engine air filter. It is used to measure the pressure drop across the carbody mounted inertial filters plus the engine air filter.

Electrical Cabinet

This hose stem opens directly to the inside of the electrical cabinet. It is used to measure the pressure drop across the electrical cabinet filters.

Inertial Filters

This opening is piped to the central air compartment. It is used to measure the pressure drop across the carbody inertial filters.

GUIDE TO THE EXCITATION AND POWER CONTROL SYSTEM

CAUTION

The data appearing in this section is intended only as a guide in explaining the locomotive excitation and power control system. The circuits shown in this section represent typical components and do not necessarily agree with the wiring diagrams of specific locomotives. Consult the applicable locomotive wiring diagrams and the troubleshooting section of this manual when performing troubleshooting on the excitation and power control system.

INTRODUCTION

The purpose of this section is to describe the locomotive excitation and power control system. A block diagram of the excitation and power control system is provided in Fig. 7-1.

The excitation and power control system is designed for high reliability, high performance, and minimum down time. Minimum down time is assured by using top quality components mounted on plug-in modules. The modules are centrally located in the electrical cabinet on the cab side. Each module contains components that are functionally related. For example, the wheel slip module contains components that initiate correction for a wheel slip condition and the sanding module contains components that initiate application of sand to the rails.

The modules are provided with test jacks for making voltage measurements when performing troubleshooting. Some of the modules are equipped with press-to-test pushbuttons for performing functional checks on the modules. The modules are designed to be adjusted on the test bench in the shop. Therefore, when a module is changed out it is not necessary to adjust the module while installed on the locomotive. This feature greatly reduces locomotive down time.

Some of the other significant characteristics of the excitation and power control system includes:

1. Use of the AR10 alternating current generator with integral solid-state rectifier assembly to provide DC power to the traction motors.
2. Use of solid-state components to match the reference signal from the load regulator with feedback signals from the AR10 main generator.
3. Use of a silicon controlled rectifier assembly to apply power from the D14 alternator to the field of the AR10 main generator.
4. Use of throttle controlled variable resistance during locomotive starting to reduce reference voltage signals from the load regulator, which rests in maximum output position at the time of locomotive start. Locomotive response to throttle change is thereby rapid but smooth, and power is held at a low level during low throttle position.

GENERAL

When the diesel engine starts to turn, the DC auxiliary generator is initially self excited by residual magnetism. As engine speed increases, generated voltage builds up and part of the auxiliary generator output is fed back through the static voltage regulator. Output from the voltage regulator is used to control excitation to the auxiliary generator and maintain constant voltage.

Part of the auxiliary generator output is used to excite the field of the D14 alternator. When the diesel engine is running, the D14 field excitation is maintained at a nominally constant level.

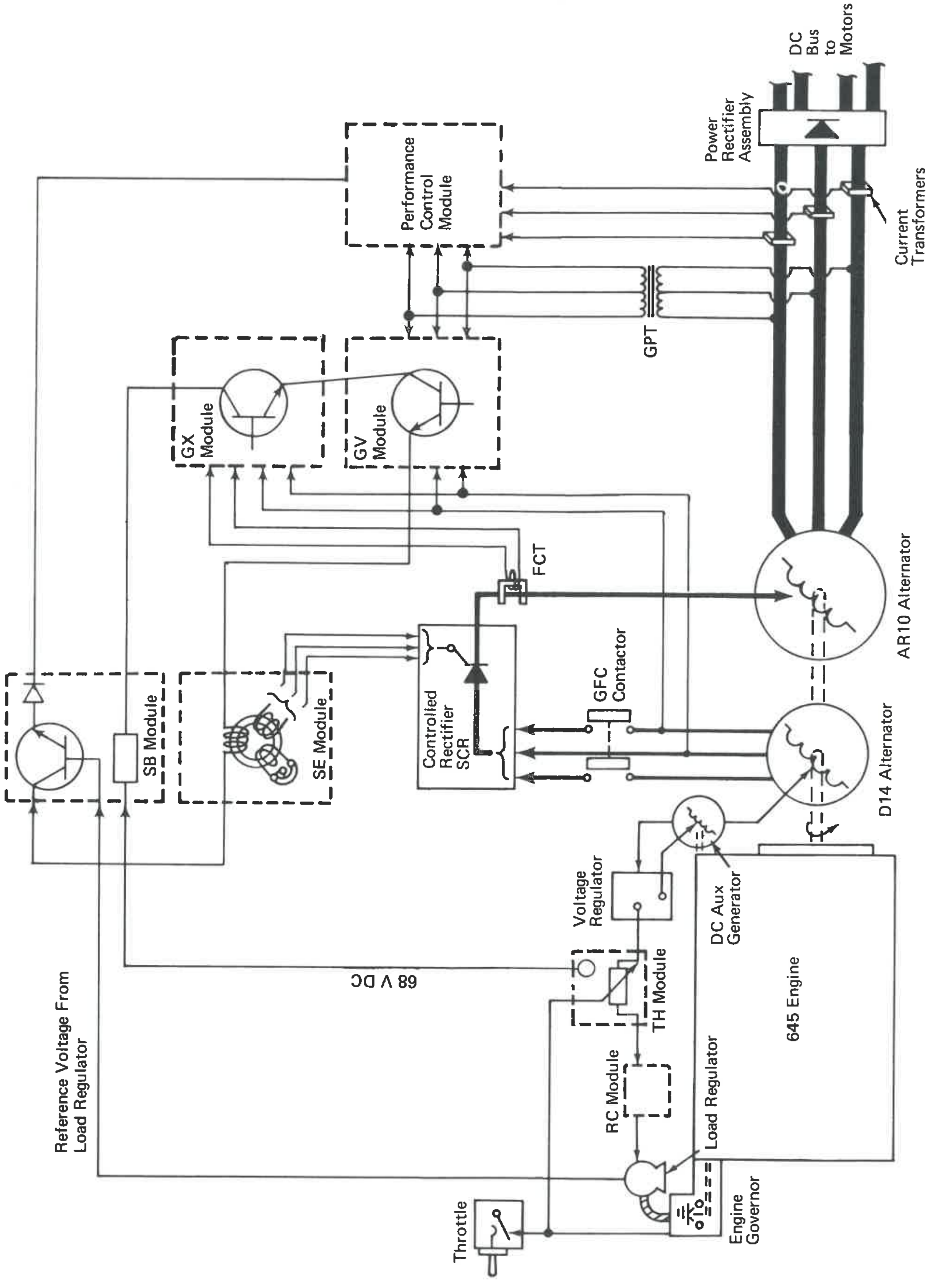

Fig. 7-1 -- Excitation System Block Diagram

Three phase alternating current is taken from the D14 alternator and fed through a silicon controlled rectifier assembly to excite the field of the AR10 main generator. The output from the silicon controlled rectifier assembly is determined by a magnetic amplifier type SENSOR and solid-state components that respond to signals related to AR10 main generator output, throttle position, or load regulator position.

Three phase alternating current from the stator of the AR10 main generator is applied to a power rectifier assembly located within the AR10 main generator housing. DC power from the rectifier assembly is applied to the traction motors.

CONTENTS

This section is divided into the following parts:

Part A -- Generators and Voltage Regulator

Description of the auxiliary generator, voltage regulator, AR10 main generator, and the D14 alternator.

The contents of Section 7 Part A are presented in the following order:

1. AG - Auxiliary Generator
2. AR10 - AR10 Main Generator
3. D14 - D14 Alternator
4. VR - Voltage Regulator Module

Part B -- Excitation and Power Control System

General description of the excitation and power control system and a detailed description of each module or assembly used in the excitation and power control system.

The contents of Section 7 Part B are presented in the following order:

1. EL - Excitation Limit Backup Protection System (EL Module)
2. GV - Generator Voltage Regulator Module
3. GX - Generator Excitation Regulator Module
4. LR - Load Regulator Assembly
5. PF - Performance Control Module
6. RC - Rate Control Module
7. SB - Sensor Bypass Module
8. SE - Sensor Module
9. SCR - Silicon Controlled Rectifier Assembly
10. TH - Throttle Response And Voltage Reference Regulator Module
11. TR - Transition Module

Part C -- Wheel Slip Detection and Correction System

General description of the wheel slip detection and correction system and detailed description of each module or assembly used in the wheel slip detection and correction system.

The contents of Section 7 Part C are presented in the following order:

1. SA - Sanding Module
2. WSBC - Wheel Slip Bridge Circuit
3. WS - Wheel Slip Module
4. WST - Wheel Slip Transductor

Part D -- Dynamic Braking System, Excitation and Control

General description of the dynamic braking system excitation and control. Includes a detailed description of each module or assembly used in the dynamic braking system.

The contents of Section 7 Part D are presented in the following order:

1. DE - Extended Range Dynamic Brake Module
2. DG - Dynamic Brake Grid Protection Module
3. DP - Dynamic Brake Protection Module
4. DR - Dynamic Brake Regulator Module

Part E -- Indicating Lights and Devices

Description of the use and location of indicating lights and devices such as indicating lights on the engine control panel, the load indicating meter, and the annunciator module.

GENERATORS AND VOLTAGE REGULATOR

Part A of Section 7 provides a general description of the auxiliary generator, auxiliary generator voltage regulator, D14 alternator, and AR10 main generator assembly.

The auxiliary generator provides a nominal output voltage of 74 volts for excitation of the D14 alternator field and other low voltage DC circuits.

The auxiliary generator voltage regulator is a solid-state voltage regulator that maintains a constant output of approximately 74 volts from the auxiliary generator.

The D14 alternator provides three-phase AC power for the radiator blower motors, the filter blower motor, various control circuits, and the silicon controlled rectifier assembly. The rectified output of the silicon controlled rectifier is applied to the field of the AR10 main generator for excitation.

The AR10 main generator assembly provides DC power for the traction motors.

CONTENTS

The contents of Section 7 Part A are arranged in the following order:

1. Auxiliary Generator
2. AR10 Main Generator
3. D14 Alternator
4. Voltage Regulator Module

AUXILIARY GENERATOR

The auxiliary generator is a variable speed, self excited, shunt wound, direct current generator with an output of 10 kilowatts, Fig. AG-1. An 18 kilowatt auxiliary generator, Fig. AG-2, is available on special order. A solid state voltage regulator is used to regulate the output voltage at 74 volts nominal at generator speeds of 825 to 3,000 RPM.

The auxiliary generator is driven by the diesel engine through a flexible coupling and provides direct current power for lighting circuits, control circuits, excitation for the D14 alternator, charging storage batteries, and other miscellaneous low voltage direct current requirements. The auxiliary generator rotates at a speed approximately three times as fast as the diesel engine.

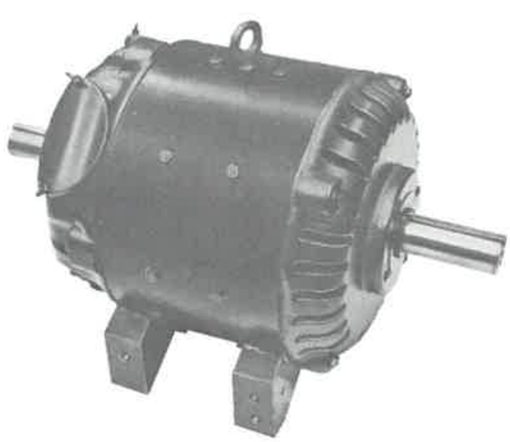

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Fig. AG-1 -- 10KW Auxiliary Generator

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Fig. AG-2 -- 18KW Auxiliary Generator

AR10 MAIN GENERATOR

In the diesel electric locomotive, mechanical power developed by the diesel engine is converted to electrical power by a rotating electrical machine. The construction of rotating electrical generators is such that alternating current is produced, but since alternating current will not efficiently power variable speed motors, the alternating current is converted to direct current before being applied to the traction motors. In conventional direct current generators, commutator bars and brushes are used to convert the alternating current to direct current. This method of converting alternating current to direct current has mechanical and electrical limitations that become more pronounced as the amount of usable electrical power is increased. The conventional direct current generator has been replaced by the AR10 main generator that uses silicon diodes to convert the alternating current to direct current.

The AR10 main generator assembly consists of two mechanically coupled, but electrically independent, air cooled, three phase generators – the D14 alternator and the AR10 main generator. The D14 alternator is described in Part A – D14 of this section. The three major components of the AR10 main generator are shown in Figs. AR10-1, AR10-2, and AR10-3.

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Fig. AR10-1 -- AR10 Rotor Assembly

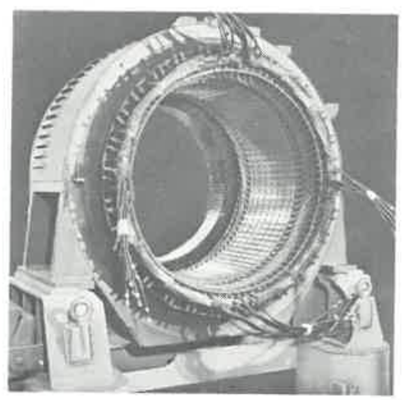

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Fig. AR10-2 – AR10 Stator Assembly

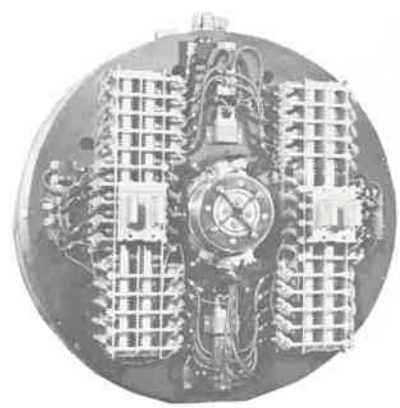

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Fig. AR10-3 -- AR10 Rectifier Bank Assembly

The main generator consists of 10 field poles and the required stator windings for generating three phase AC power. The AC power is rectified by two banks of air cooled silicon diodes that are an integral part of the AR10 main generator assembly. The resulting DC power is applied to the traction motors.

The operating principle of the AR10 main generator is illustrated in Fig. AR10-4. Direct current from the silicon controlled rectifier assembly is applied to the rotating field through a pair of slip rings. The magnetic lines of force developed by the rotating field induce a voltage in the stationary armature windings as the rotor turns.

One three phase group of armature windings and a three phase waveform are shown in Fig. AR10-4. There are ten groups of these "wye" connected armature windings distributed about the circumference of the stator. Five of the groups are connected to the left bank of rectifiers and the other five groups are connected to the right bank of rectifiers. A separate positive and negative bus is provided for each bank of rectifiers. A simplified schematic diagram of the stator windings, bridge rectifiers, and DC buses is provided in Fig. AR10-5.

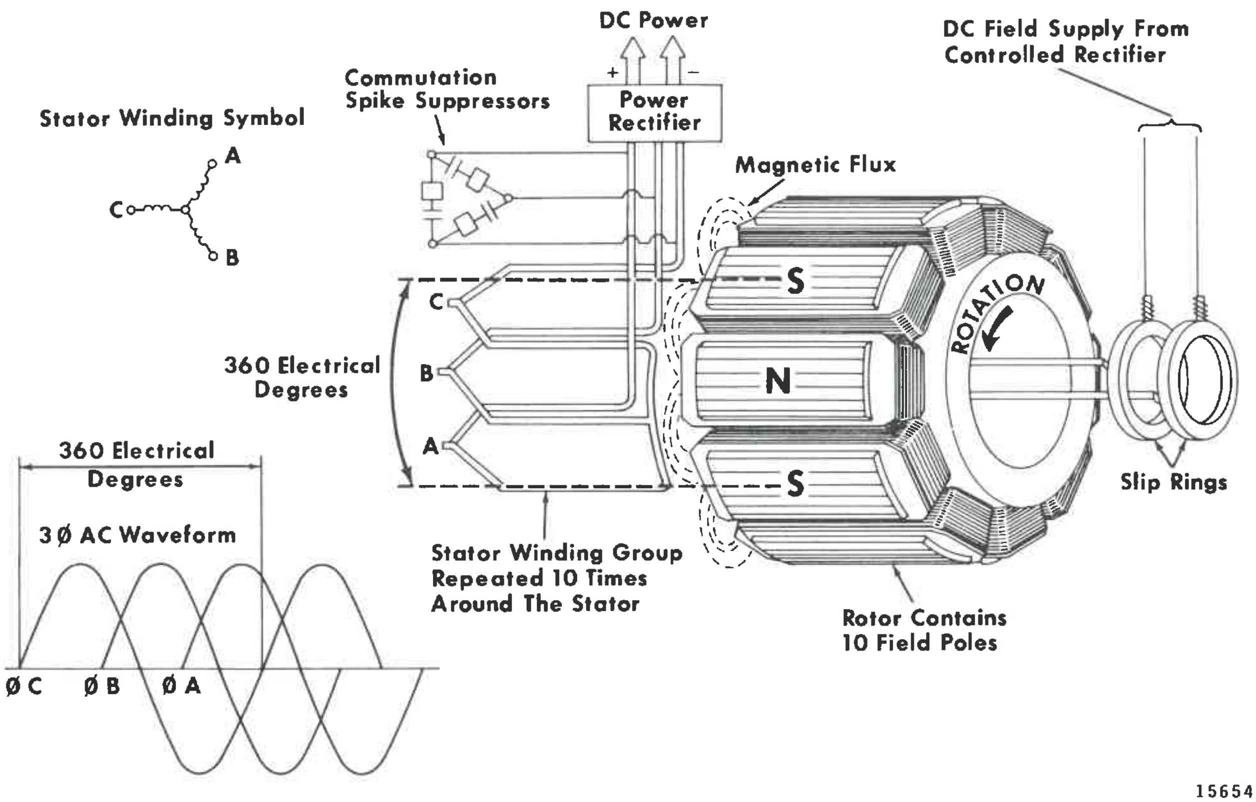

Fig. AR10-4 -- Main Generator Pictorial Diagram

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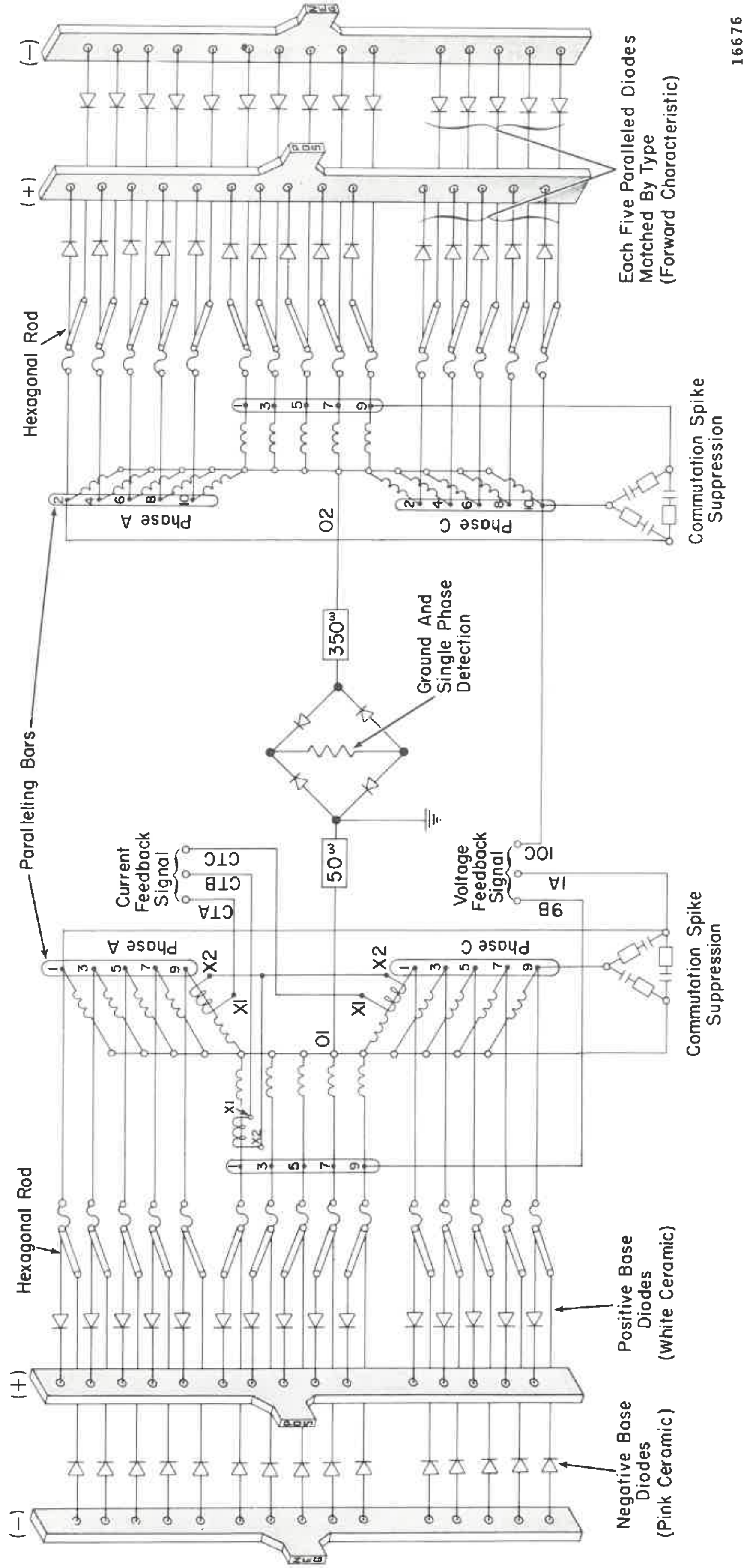

Fig. AR10-5 -- AR10 Wiring Diagram

Fig. AR10-6 illustrates rotor pole position at an instant called the "V." Pole position is in respect to a single stator winding group. By applying the right-hand rule for generators, current flow in the stator windings can be determined, and the conditions existing at a given point of time determined.

Note that the phase A winding is centered over the poles (point of greatest flux density) and is at negative potential. Note also that the potential at phase C is decreasing while the potential at phase B is increasing. At the moment depicted, the potentials at C and B are equal and positive. Therefore, current at equal potential flows to the rectifier bridge, and two diodes at the positive side of the bridge conduct. Total current then flows through the load and from there through a single diode back to the phase A winding, which is at negative potential.

Generator potential can be observed at the waveform in Fig. AR10-6.

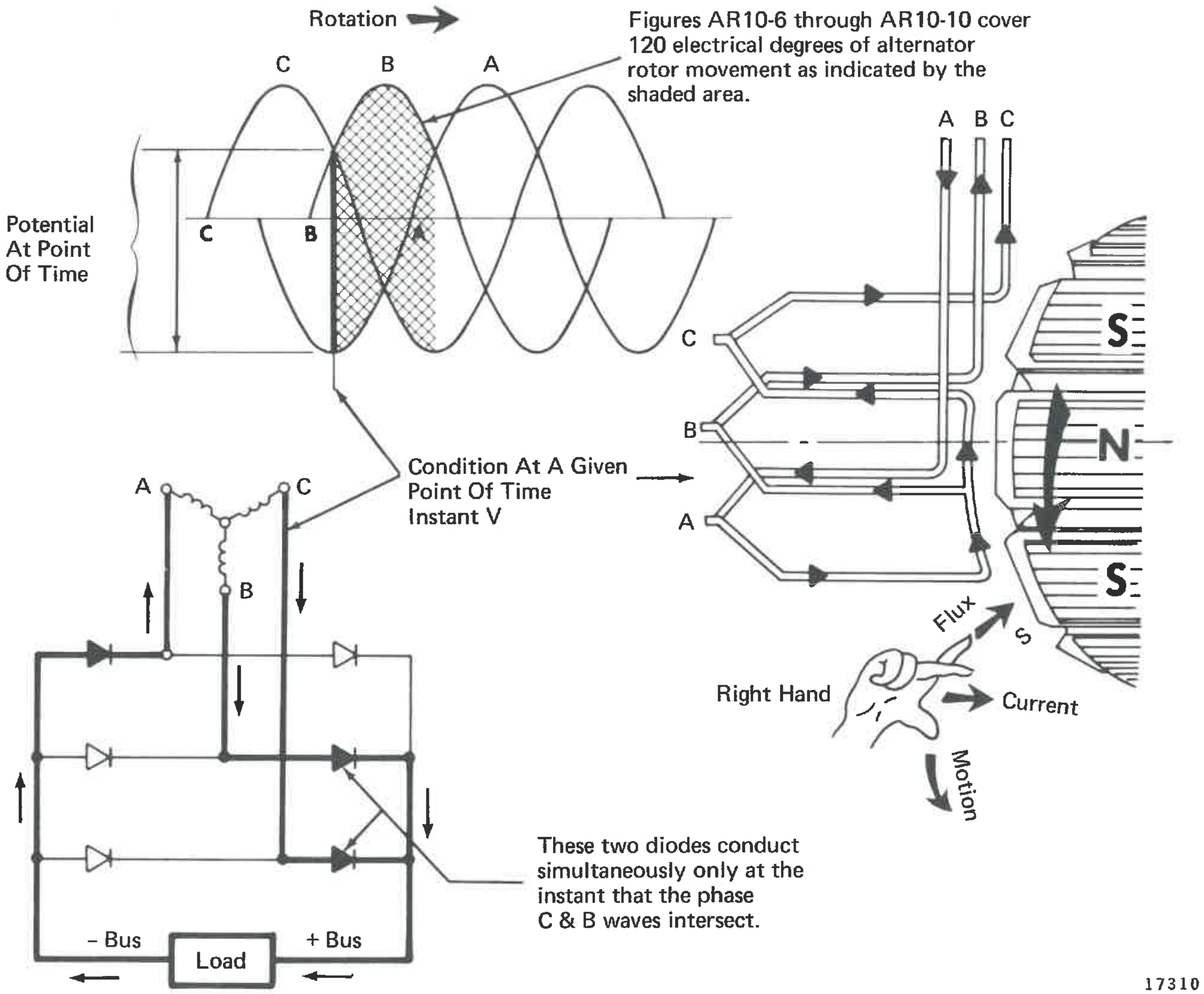

Fig. AR10-6 -- Current Flow In Stator Windings And Rectifier Bridge - Instant "V"

In Fig. AR10-7, instant "W," the alternator rotor has turned nominally 20 electrical degrees. Phase A is still negative, but of decreasing potential. Phase B is now more positive than phase C. The change in potential has turned off the phase C diode, and no current flows in the phase C winding. Total current at potential slightly greater than that at instant "V" now flows out of phase B winding, through the load, and back to the phase A winding which is still negative.

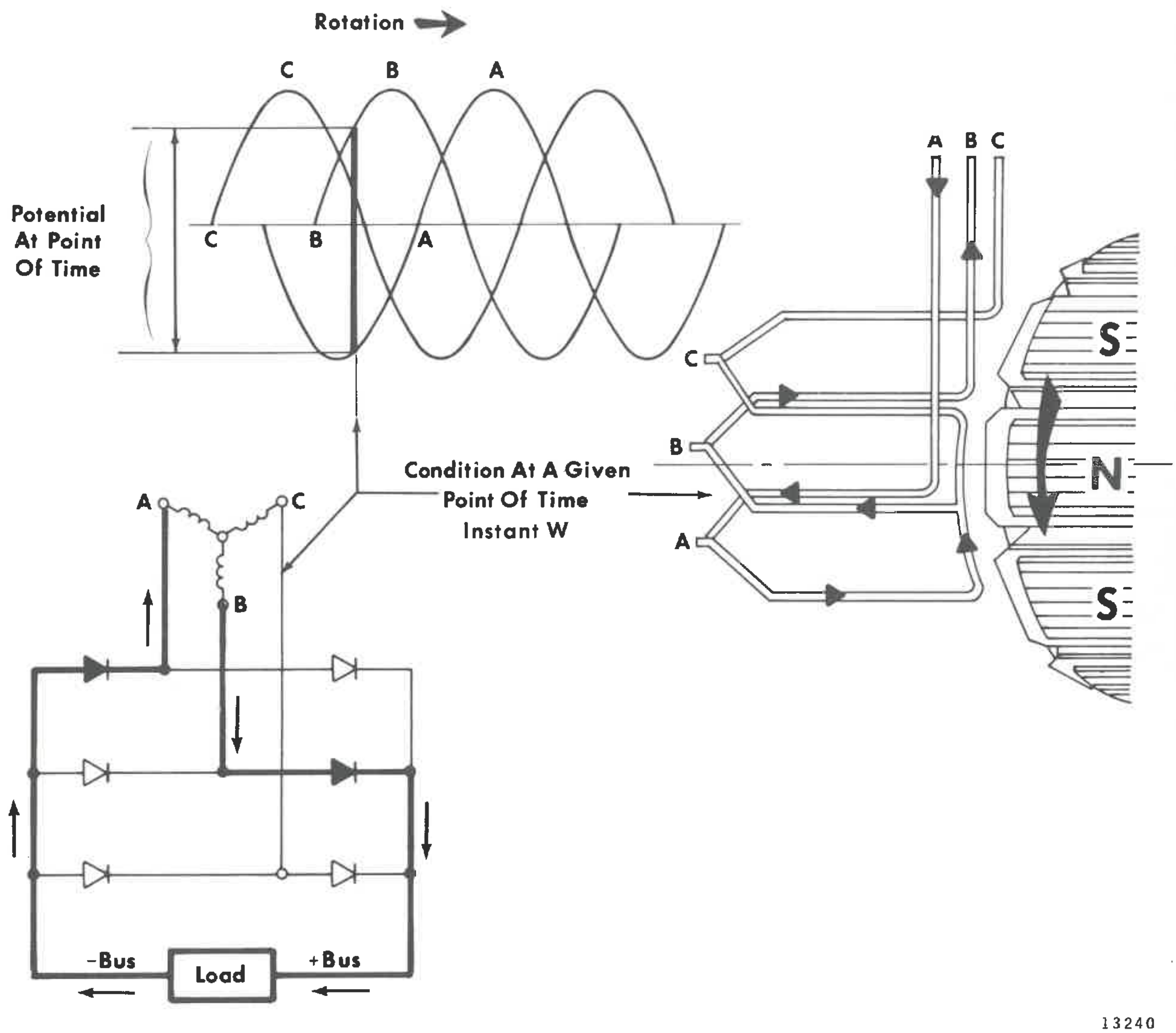

Fig. AR10-7 -- Current Flow In Stator Windings And Rectifier Bridge - Instant "W"

At instant "X" in Fig. AR10-8, the alternator rotor has turned about 60 electrical degrees. Phase C and Phase A are at equal negative potential, and phase B is at positive potential. The direction of current flow in the C winding has reversed, and since potentials at the negative side of the rectifier bridge are equal, both the phase A and phase C diodes conduct. Total winding current at potential equal to that at instant "V" now flows out of phase B winding through the load and back through two diodes at the negative side of the rectifier bridge.

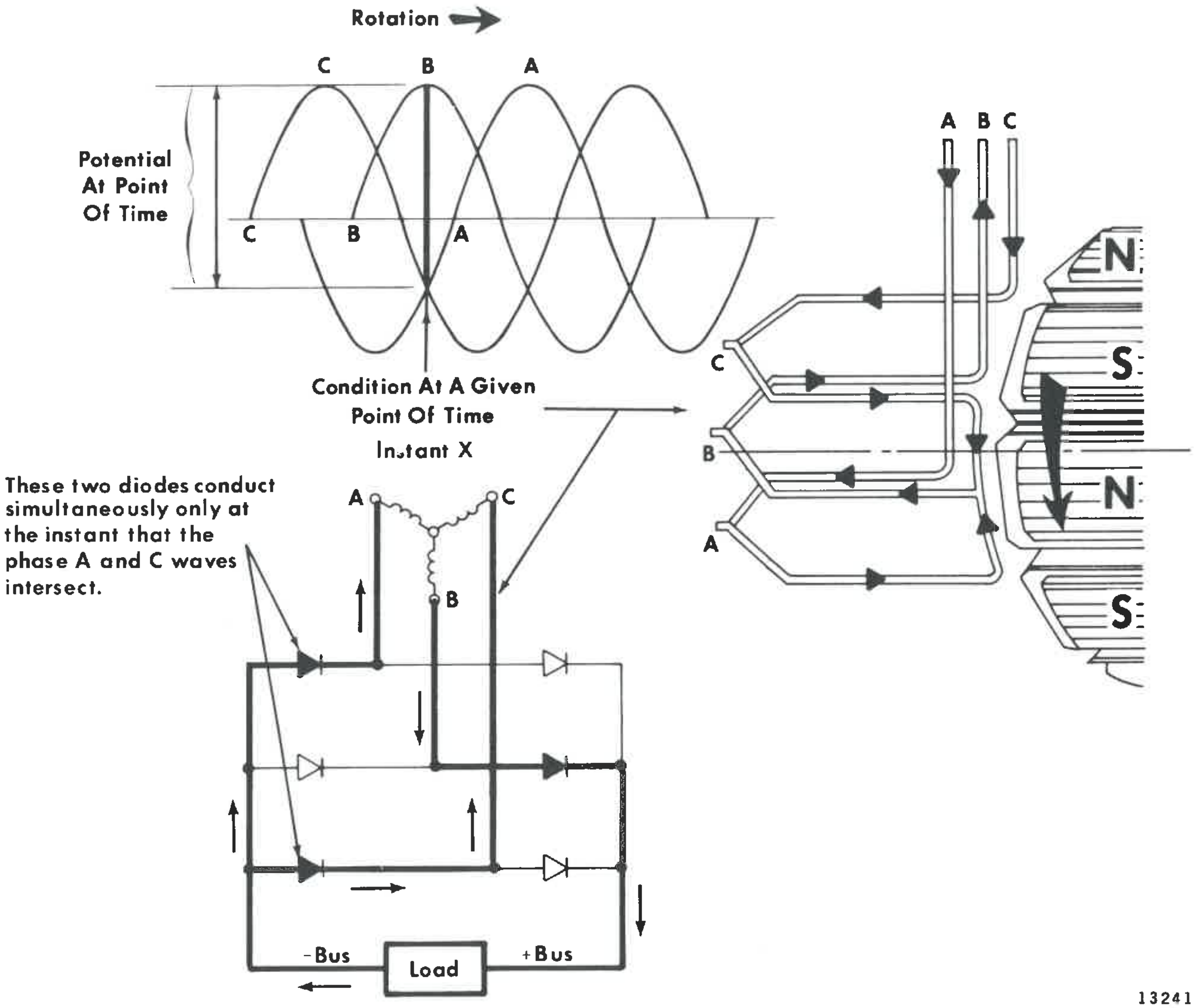

Fig. AR10-8 -- Current Flow In Stator Windings And Rectifier Bridge - Instant "X"

At instant "Y," Fig. AR10-9, the alternator rotor has turned about 100 electrical degrees. Phase C is now more negative than phase A. The change in potential has turned off the phase A diode at the negative side of the bridge, and no current flows in the phase A winding. Total current at potential slightly greater than that at instant "V" now flows out of phase B winding, through the load, and back to phase C winding which is negative.

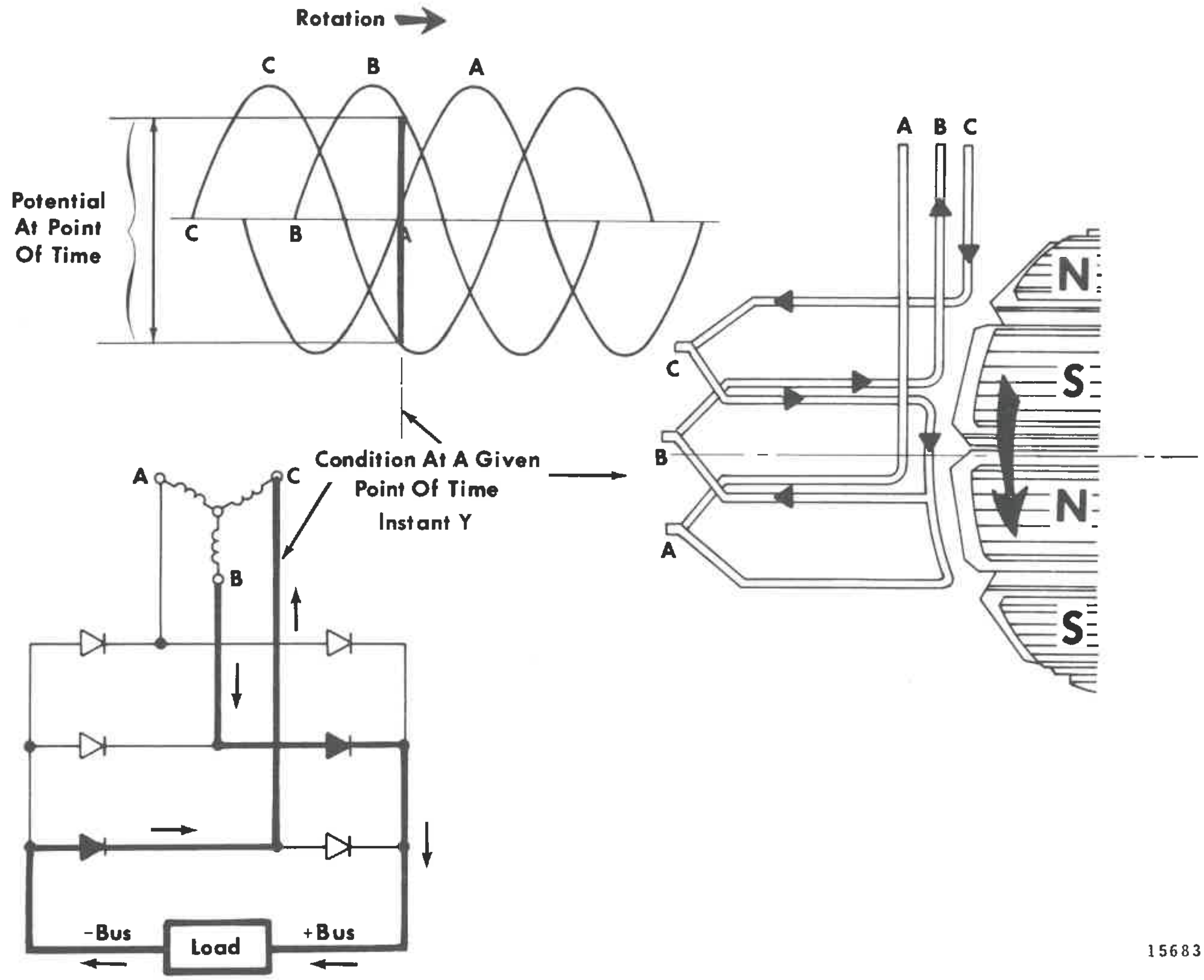

Fig. AR10-9 -- Current Flow In Stator Windings
And Rectifier Bridge - Instant "Y"

In Fig. AR10-10, the alternator rotor has turned 120 degrees. Phases A and B are at equal positive potential, and phase C is negative. Since potentials at the positive side of the rectifier bridge are equal, both the phase A and B diodes conduct. Total winding current at potential equal to that at instant "V" now flows out of the phase A and B windings, through the load, and back through the phase C diode at the negative side of the bridge.

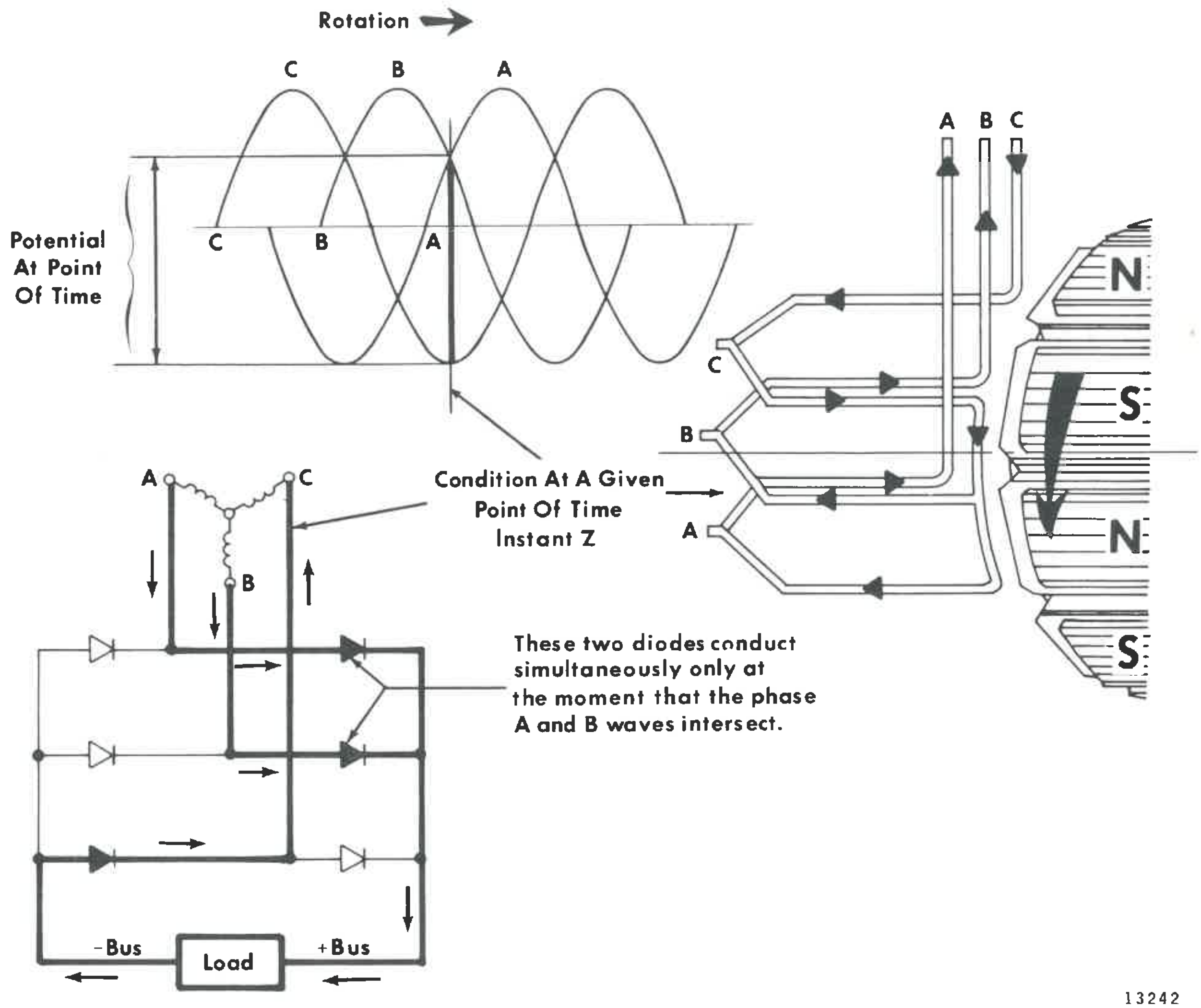

Fig. AR10-10 -- Current Flow In Stator Windings And Rectifier Bridge - Instant "Z"

AR10 COMMUTATION TRANSIENT VOLTAGE SUPPRESSION

During commutation voltage transients are produced. The action of diodes switching from a conducting to a blocking state in the AR10 generator is called commutation. During commutation high reverse current flows in the diodes for a few microseconds, after which time the value of reverse current flow in the diode suddenly drops to almost zero. The rate at which current flow changes from a high value to almost zero, multiplied by circuit inductance determines the magnitude of the transient voltage spike. If this transient voltage exceeds the reverse rating of the diode, the diode will immediately fail.

The AR10 generator is provided with a system for capacitive storage of energy from circuit inductance during commutation. The system is called the commutation transient voltage suppression system. It utilizes a total of six 2 microfarad capacitors and six 5 ohm resistors. The resistors and capacitors are connected in delta fashion, Fig. AR10-11, between the "A," "B," and "C" phase paralleling bars on both the left and right banks of the generator.

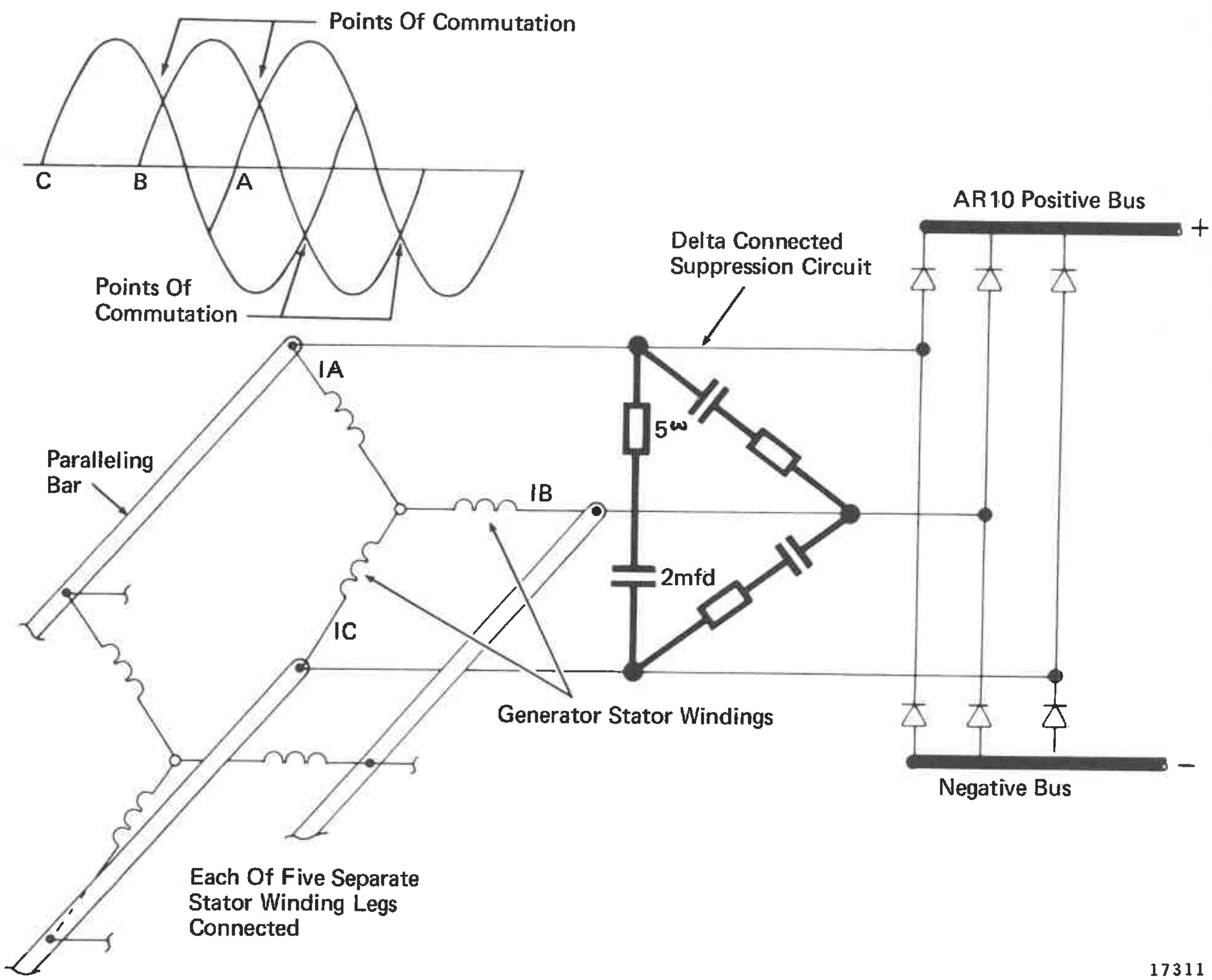

Fig. AR10-11 – Delta Connected Suppression Circuit - Simplified Diagram

D14 ALTERNATOR

The D14 alternator, Fig. D14-1, is a variable frequency, variable voltage, rotating field, stationary armature, three phase, wye connected AC generator with a rating of 100 KVA at 0.8 power factor. Nominal output of the D14 alternator is 215 volts at 120 cycles per second when the diesel engine is rotating at a speed of 900 RPM. The D14 alternator is physically connected to, but electrically independent of the main generator. The D14 alternator and main generator rotating assembly is directly coupled to the crankshaft of the diesel engine.

The D14 alternator provides power for the filter blower motor, radiator blower motors, excitation for the main generator, and for various control circuits. The maximum output of the D14 alternator is approximately 15 amperes for each ampere of field excitation. The auxiliary generator provides approximately 30 amperes of field excitation current to the D14 alternator when the field is hot. The 30 amperes of field excitation current is determined by dividing the nominal output voltage of the auxiliary generator (74 volts) by the nominal hot resistance of the D14 alternator field (2.46 ohms). The D14 alternator can provide an output of approximately 450 amperes with the 30 amperes of field excitation. With the exception of a protective fuse there are no controls in the D14 alternator excitation circuit. Therefore, the D14 alternator will be excited and developing power whenever the diesel engine is running.

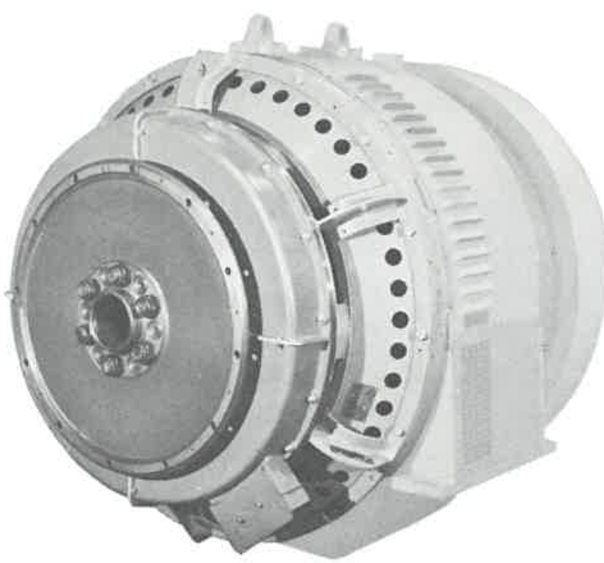

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Fig. D14-1 – D14 Alternator

VOLTAGE REGULATOR MODULE, VR

INTRODUCTION

The voltage regulator module VR is a solid-state voltage regulator designed to maintain output voltage of the auxiliary generator to within ±1 volt of the "set point." The VR module is usually adjusted for a nominal output voltage of 74 volts from the auxiliary generator, but can be adjusted for any output between 71 and 77 volts. The VR module will maintain the output to within ±1 volt of the "set point" at auxiliary generator rotating speeds between 825 and 3,000 RPM, at any load between no load and full rated load and within a temperature range of -40° C. to +80° C.

The VR module contains a starting circuit, a detector circuit, a power circuit, and an oscillator circuit. A simplified schematic diagram of a typical VR module, Fig. VR-1, should be used for reference only. The locomotive wiring diagram should be used when performing troubleshooting or maintenance.

The output voltage of the auxiliary generator is regulated by opening and closing the power circuit to the generator field. This is accomplished by controlling conduction of the silicon controlled rectifier SCR1. Conduction of SCR1 is controlled by the detector circuit and the oscillator circuit. SCR1 is gated on by the detector circuit if the output voltage of the generator is below the "set point." After being turned on SCR1 will continue to conduct until a positive pulse is applied to its cathode. The oscillator circuit provides a positive pulse to the cathode of SCR1 once during each cycle of oscillation. SCR1

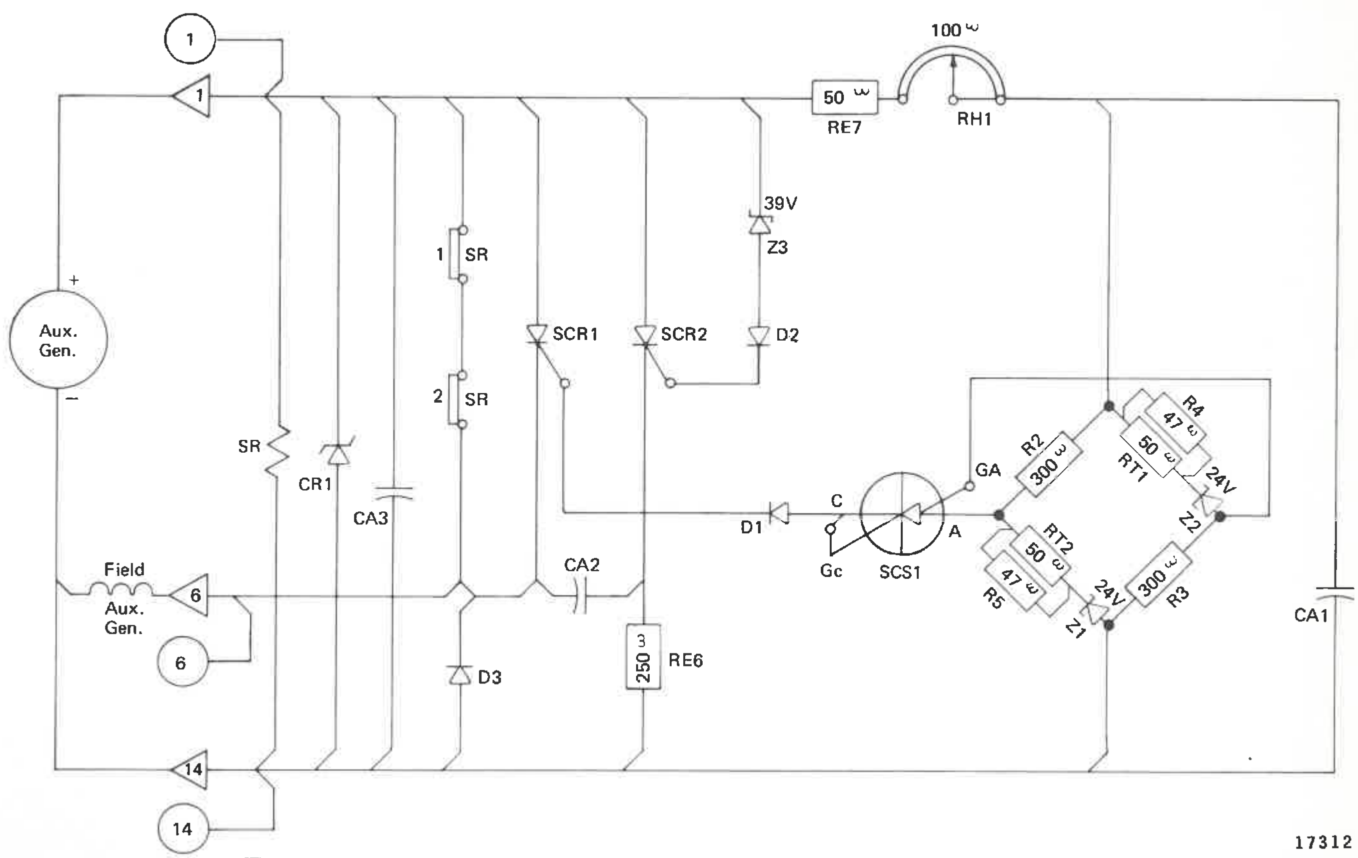

Fig. VR-1 – Voltage Regulator Module, Simplified Schematic Diagram will remain off if the output voltage of the generator is above the "set point" when the positive pulse is received from the oscillator. If the output is below the "set point" SCR1 will be turned on by the detector circuit as soon as the positive pulse from the oscillator is removed.

The positive pulses from the oscillator circuit occur often enough to prevent any noticeable difference in field strength between pulses. When SCR1 is turned off, generator field tends to collapse, however, the current generated by the decaying field flows through diode D3 causing a gradual decay instead of a sudden collapse. The gradual decay of the field, frequency of oscillations from the oscillator, and the response of the detector and power circuits result in a stable output from the auxiliary generator.

STARTING CIRCUIT, Fig. VR-2

The starting circuit consists of a starting relay SR with two sets of normally closed contacts. The SR coil is connected to the output of the auxiliary generator. The SR contacts, in series with the auxiliary generator field, is also connected to the output of the auxiliary generator.

During normal operation, excitation current to the field is supplied through a silicon controlled rectifier SCR1. However, during start up generator excitation is provided by residual magnetism and the output is not large enough to cause turn on of SCR1. Therefore, the normally closed contacts of SR are connected so that SCR1 is bypassed during voltage build up. The SR relay is designed to pick up after the generator output voltage is large enough to turn on SCR1. After pickup of SR the bypass circuit is open and excitation to the field is supplied through SCR1.

DETECTOR CIRCUIT, Fig. VR-3

The detector circuit consists of a silicon controlled switch SCS1 and a voltage divider consisting of resistor RE7, rheostat RH1, and a zener diode bridge circuit with temperature compensating resistors.

The silicon controlled switch SCS1 remains off until forward bias is applied between the anode and cathode and a negative potential is applied to the anode gate in respect to the anode. After conduction starts the anode gate loses control and conduction will continue as long as the anode is positive in respect to the cathode.

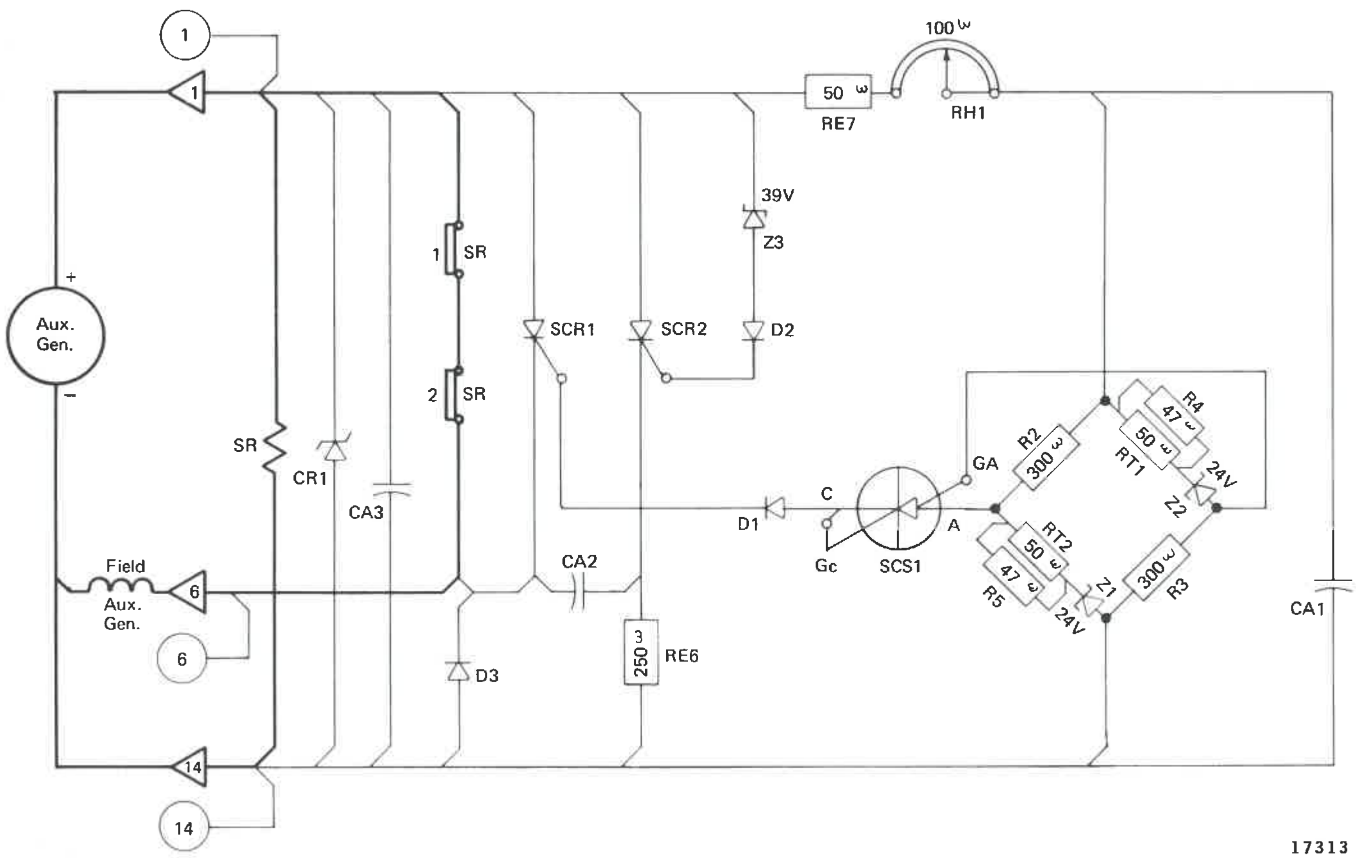

Fig. VR-2 – Voltage Regulator Starting Circuit, Simplified Schematic Diagram

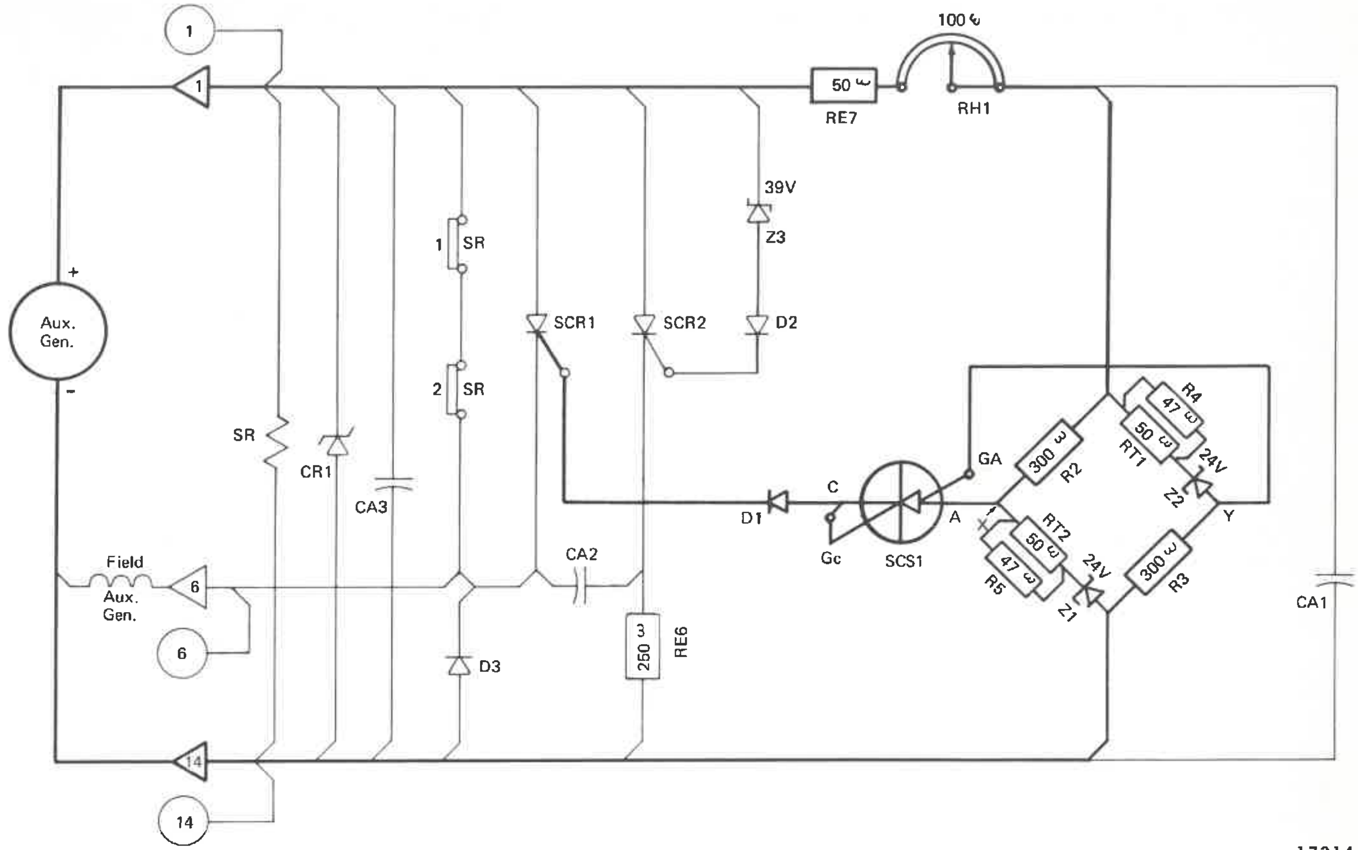

Fig. VR-3 -- Voltage Regulator Detector Circuit, Simplified Schematic Diagram

The gating signal, potential between anode "A" and anode gate "GA" is provided by the zener bridge. The zener bridge is balanced, potential at "X" is equal to the potential at "Y," when output voltage of the generator is at the "set point." When the bridge is balanced, potential at the anode is equal to the potential at the anode gate and no gating signal is applied to SCS1.

If generator output voltage decreases, the bridge will become unbalanced. The potential at "Y" decreases and the potential at "X" will remain almost constant. The decrease in potential at "Y" with respect to "X" places a negative potential on the anode gate in respect to the anode. This causes SCS1 to conduct. Conduction of SCS1 places a positive potential on the gate of SCR1 causing SCR1 to conduct.

Conduction of SCR1 causes the potential on its cathode to rise to a value which is almost equal to the positive potential of the generator. This positive potential places reverse bias on SCS1 causing SCS1 to turn off. SCR1 continues to conduct until the oscillator circuit places reverse bias on SCR1. Reverse bias from the oscillator circuit results in turn off of SCR1, but SCS1 will apply a gating signal to SCR1 causing turn on if the anode gate of SCS1 is still negative with respect to the anode of SCS1. This process continues until output voltage of the generator rises to the "set point." The bridge is balanced when generator output voltage reaches the "set point" and no gating signal is applied to SCS1 or to SCR1. Therefore, the detector circuit tends to maintain generator output voltage at the "set point."

Negative temperature coefficient resistors, RT1 and RT2, are used in the bridge circuit to provide thermal compensation. The resistance of RT1 and RT2 decreases as temperature increases, whereas resistance of R2, R3, R4, R7, and RH1 increases as temperature increases. Therefore, the decrease in resistance of RT1 and RT2 compensates for increase in resistance R2, R3, R4, R5, R7, and RH1 as temperature increases and the increase in resistance of RT1 and RT2 compensates for a decrease in resistance as temperature decreases.

GENERATOR FIELD EXCITATION POWER CIRCUIT, Fig. VR-4

Excitation current for the auxiliary generator field is supplied through the silicon controlled rectifier SCR1. SCR1 is turned on by conduction of SCS1 in the detector circuit when the output voltage of the generator falls below the "set point" of the voltage regulator. After turn on, SCR1 continues to conduct until a positive pulse from the oscillator circuit applies reverse bias to SCR1.

This positive pulse from the oscillator circuit results in turn off of SCR1. However, SCS1 in the detector circuit will apply a gating pulse to SCR1 causing turn on, as soon as the positive pulse is removed, if generator output voltage is below the "set point." When output voltage is equal to or greater than the "set point," SCS1 will not conduct and no gating pulse is applied to SCR1 until the output voltage falls below the "set point."

The generator field tends to collapse when SCR1 is turned off. However, self inductance of the field induces a voltage into the field windings which causes current flow through diode D3 and results in a gradual decay of the field instead of a sudden collapse. The gradual decay of the field, frequency of oscillations from the oscillator, and the response of the detector and power circuits result in a stable output from the auxiliary generator.

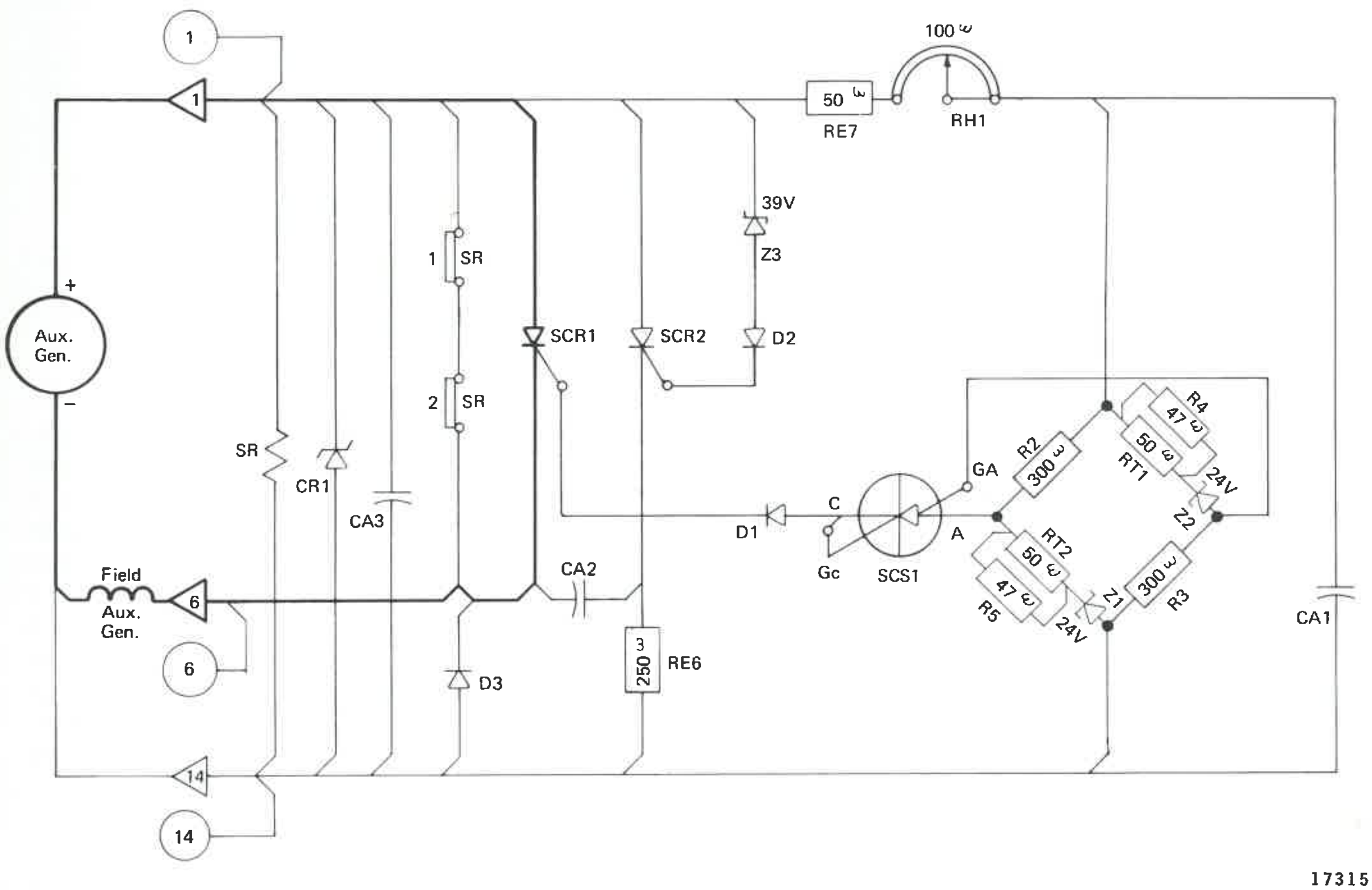

Fig. VR-4 -- Voltage Regulator Power Circuit, Simplified Schematic Diagram

OSCILLATOR CIRCUIT, Fig. VR-5

After SCR1 starts conducting it continues to conduct until the cathode becomes positive with respect to the anode. If SCR1 remained on, the output voltage of the generator would increase to the saturation level. The oscillator circuit consisting of silicon controlled rectifier SCR2, diode D2, zener diode Z3, capacitor CA2, and resistor R6 provides a positive pulse to the cathode of SCR1 once during each oscillation. These positive pulses from the oscillator apply reverse bias at intervals of three milliseconds or less causing SCR1 to turn off. SCR1 will be turned on again by a pulse from SCS1 in the detector circuit if the output voltage of the generator is below the "set point" when the positive pulse is removed from the cathode of SCR1. If the output voltage of the generator is equal to or greater than the "set point," SCS1 in the detector circuit remains off and no gating pulse is applied to turn on SCR1.

Assume that SCR1 is conducting and capacitor CA2 has a positive charge of 74 volts on plate 1 in respect to plate 2. Zener diode Z3 fires and applies a positive pulse to the gate of SCR2. This positive pulse causes SCR2 to turn on. Turn on of SCR2 causes the voltage on the cathode of SCR2 and on plate 2 of CA2 to rise to approximately 74 volts. This forces Z3 to cut off and removes the gating signal, but SCR2 will continue to conduct as long as the anode is positive with respect to the cathode.

The sudden increase in voltage on plate 2 of CA2 causes a corresponding momentary increase in the voltage on plate 1 and on the cathode of SCR1. The reason for the momentary increase in voltage on plate 1 of CA2 is that the difference in the voltage across the plates cannot change instantaneously. Therefore, the voltage on plate 1 and on the cathode of SCR1 increases to a value higher than the output voltage of the generator. This results in turn off of SCR1 and permits capacitor CA2 to charge up so that plate 2 is positive with

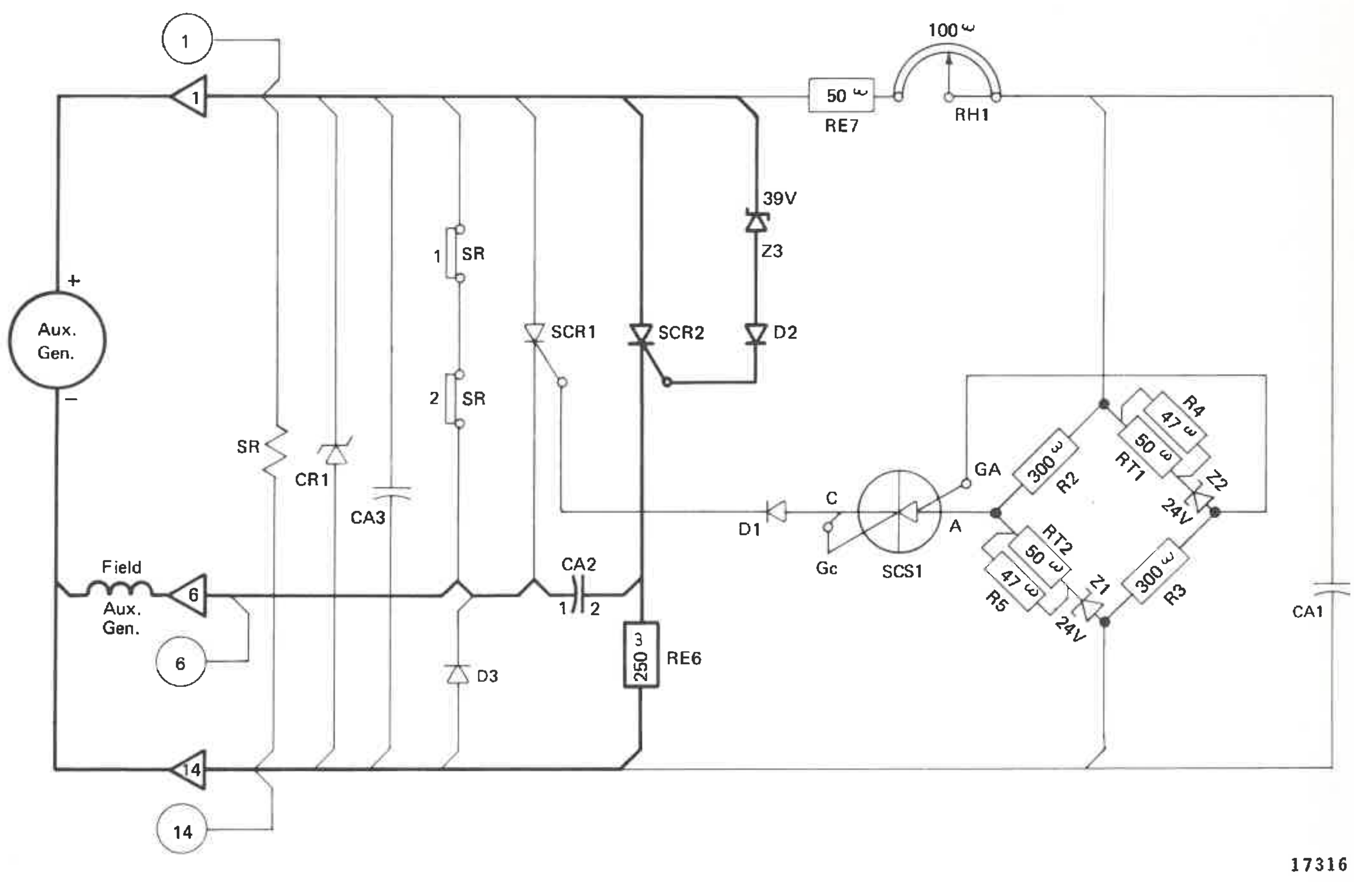

Fig. VR-5 – Voltage Regulator Oscillator Circuit, Simplified Schematic Diagram respect to plate 1. SCR1 will turn on again as soon as the cathode is negative with respect to the anode provided SCS1 applies a gating signal to the gate of SCR1.

The average nominal output voltage of the generator is 74 volts, but the actual output contains commutation ripples that rise above and fall below the 74 volt value. With SCR2 turned on CA2 will charge up to a value near the peak of the commutation ripple. SCR2 will be reversed biased causing turn off when the generator output falls below the value of the charge on CA2. Capacitor CA2 discharges through R6 when SCR2 is turned off.

Zener diode Z3 turns on when the charge on CA2 falls below 39 volts. Turn on of Z3 results in a repeat of the cycle. The cycle is repeated at intervals of 3 milliseconds or less.

EXCITATION AND POWER CONTROL SYSTEM

This section provides a general description of the excitation and power control system. Description of the system is followed by a detailed description of typical modules and assemblies used in the system. Simplified schematic diagrams of the modules are provided for convenient reference. The locomotive wiring diagram should be used when performing troubleshooting or maintenance.

GENERAL DESCRIPTION

A flow diagram of the excitation and power control system is provided in Fig. 7B-1. Electrical power and electrical control signals are represented in the flow diagram by solid interconnecting lines. Mechanical and hydraulic signals are represented by broken interconnecting lines.

The voltage reference regulator VRR, located in the TH module, and the throttle switches receive 74 volts DC input from the auxiliary generator. The 74 volts applied to the throttle switches is used to energize the speed setting solenoids in the engine speed governor and to energize the throttle response relays located in the throttle response circuit of the TH module.

The speed setting solenoids in the engine speed governor are energized individually or in combination depending upon throttle position. The speed setting solenoids change the speed characteristics of the engine speed governor so that the governor will maintain a different engine speed for each throttle position. The nominal engine speed for each throttle position is given in Fig. 7B-1.

The throttle response relays, located in the throttle response circuit of the TH module, are energized individually or in combination depending upon throttle position. The throttle response relays control the magnitude of the reference signal output from the throttle response circuit. This is accomplished by shorting out resistance in the throttle response circuit.

The voltage reference regulator VRR provides a very stable 68 volts DC output to the throttle response circuit and to the sensor bypass module SB.

The throttle response circuit of the TH module provides an output reference signal related to throttle position. The nominal value of the throttle response circuit output reference signal for each throttle position is given in Fig. 7B-1.

The reference signal from the throttle response circuit is applied to the load regulator assembly LR, through the rate control module RC. The rate control module limits the rate of change in the reference signal. Limiting the rate of change results in a fast, but smooth, increase or decrease in the reference signal as the throttle position is changed. The reference signal is also decreased as it passes through the rate control module. An input reference signal of 68 volts DC to the rate control module, in throttle 8 position, provides an output reference signal of 50 volts to the load regulator. The nominal value of the rate control reference signal from the RC module for each throttle position is given in Fig. 7B-1.

The reference signal from LR is applied to the sensor bypass module SB as an input to the excitation and power control servo loop consisting of the sensor bypass module SB, the generator excitation current regulator module GX, the generator voltage regulator module GV, sensor module SE, silicon controlled rectifier SCR, main generator, current transformer CT, generator potential transformer GPT, and the performance control module PF. Excitation to the main generator is determined by the reference signal from the load regulator LR. The LR wiper arm position is controlled by the engine speed governor so that the load on the diesel engine as well as engine RPM is determined by throttle position.

THROTTLE POSITION	* ENGINE RPM	THI3 USED WITH RCII		THI4 USED WITH RCII	
		* THI3 OUTPUT	* RCII OUTPUT	* THI4 OUTPUT	* RCII OUTPUT
IDLE	315				
1	315	9.35	7.3	9.2	7.2
2	395	22.5	16.9	21.6	16.2
3	480	31.2	23.2	28.6	21.3
4	560	43.0	31.8	35.7	26.5
5	650	51.2	37.8	43.3	32.0
6	735	57.3	42.2	51.2	37.8
7	815	63.2	45.6	61.4	45.2
8	900	68.0	50.0	68.0	50.0

* Approximates Nominal Values (With SB Module Disconnected Or During Normal Operation)

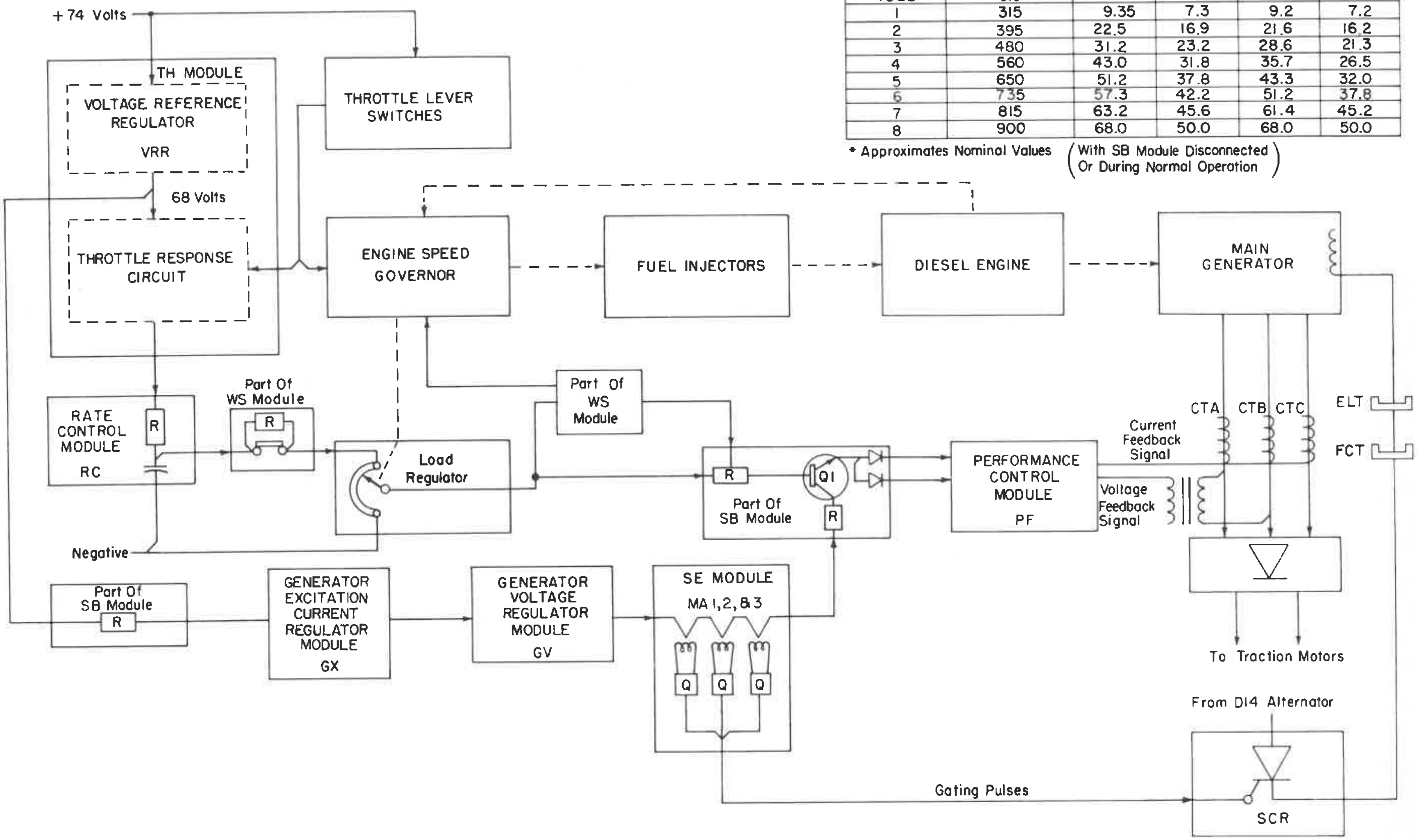

Fig. 7B-1 – Excitation And Power Control System, Simplified Flow Diagram

The SB module compares the input reference signal with feedback signals which are proportional to main generator output. Main generator output is sensed by a current transformer CT and generator potential transformer GPT1. Current transformer CT provides a feedback signal to the performance control module PF, proportional to main generator output current. The generator potential transformer GPT1 provides a feedback signal to the performance control module PF, proportional to main generator output voltage. Some locomotives are equipped with a second potential transformer GPT2. The current feedback signal and the voltage feedback signal from GPT1 are combined by the PF module to provide a power control feedback signal. When applicable, a performance control feedback signal is obtained by combining the voltage feedback signal from GPT2 with the current feedback signal. Both the power control feedback signal and the performance control feedback signal are proportional to main generator voltage and main generator current. However, the power control feedback signal is smaller than the performance control feedback signal during low current, high voltage operation. The performance control feedback signal is smaller than the power control feedback signal during low voltage high current operation. The two signals are applied to the sensor bypass module SB.

The SB module compares the reference signal from the load regulator with the feedback signals from the PF module. The load regulator reference signal is relatively constant for a given throttle position, provided operating conditions such as track, terrain, altitude, temperature, and fuel are constant. However, the feedback signals contain ripples having peaks and valleys. Transistor Q1 of the SB module, Fig. 7B-1, is forward biased whenever instantaneous value of the reference signal is larger than the instantaneous value of either of the feedback signals. Therefore, Q1 will be forward biased at intervals even when the average value of the reference signal is smaller than the average value of the feedback signals.

With forward bias on Q1, a control signal is applied to the sensor module SE, through the generator excitation current regulator module GX and the generator voltage regulator module GV. The GX and GV modules pass the control signal as long as the main generator output voltage and excitation current remains below the maximum safe value. The GX module blocks the control signal if generator excitation current rises above a safe value. The GV module blocks the control signal if generator output voltage rises above a safe value.

The control signal applied to the SE module causes the SE module to apply gating pulses to the silicon controlled rectifier assembly SCR. The SCR is forward biased during each positive alternation of output voltage from the D14 alternator, however, the SCR will not conduct until gating pulses are applied to the gate of the SCR. When the SCR is forward biased and a pulse of the proper magnitude is applied to the SCR gate, conduction occurs as in a regular diode. After conduction starts, the pulse loses control and conduction continues as long as the SCR is forward biased. When forward bias is removed, the SCR is cut off until the next pulse is applied to the SCR gate along with forward bias between anode and cathode.

Excitation to the main generator field, from the D14 alternator, is controlled by the gating pulses. When the gating pulses are applied to SCR, excitation and main generator output increase until the instantaneous difference between the reference signal and the feedback signal is just large enough to maintain the control signal from SB to SE.

When the locomotive is operating with a constant quality of fuel and at a constant load, speed, and temperature, the reference signal will stabilize at some value. The feedback signal will also stabilize, so that a constant control signal will be applied to SE and constant excitation will be applied to the main generator field. However, the track, terrain, temperature, and fuel quality are variables. Therefore, the reference signal varies to compensate for the changing conditions and the feedback signal also varies in attempting to match the reference signal.

When operating in throttle 8 position, the reference signal from the load regulator LR has a maximum value of 50 volts with LR in maximum field position. However, during normal operation the actual value of the reference signal is usually less than 50 volts. The maximum value of the reference signal decreases as the throttle position is decreased. Assume that the locomotive is operating in throttle 8 position, the consist is moving at high speed, main generator output current is low, main generator output voltage is high and the load regulator is below maximum field position. This condition may be represented by point "A" on the constant horsepower curve of Fig.

7B-2. Note that the feedback signal at point "A" on the constant horsepower curve of Fig. 7B-2 is approximately 40 volts. This value was selected for descriptive purposes only and does not necessarily indicate the actual value of the feedback signal under the stated conditions.

If the locomotive now starts climbing a grade, the load on the traction motors increases. The increased load causes a decrease in traction motor speed. The decrease in traction motor speed results in an increase in traction motor current due to less counter-electromotive force. An increase in traction motor current results in a decrease in voltage applied to the traction motors. This decrease in voltage is partly due to the increased I^2R and IZ losses in the main generator. If the reference signal did not change, the horsepower output of the main generator would decrease by following the 40 volt signal line from point "A" to point "B" in Fig. 7B-2.

A decrease in horsepower tends to cause an increase in speed of the diesel engine. This increase in speed is sensed by the engine speed governor. The governor reacts to temporarily decrease the amount of fuel injected into the diesel engine and thereby maintains a constant engine speed. At the same time the fuel is decreased, a pilot valve in the engine speed governor directs hydraulic pressure into the load regulator vane motor which causes the load regulator to move toward maximum field position.

Movement of the load regulator toward maximum field position results in an increase in the reference signal. Increasing the reference signal results in an increase of excitation to the main generator field and an increase in main generator horsepower output. This increased horsepower tends to decrease diesel engine speed, however, the governor again reacts to maintain a constant engine speed. The pilot valve in the governor also causes a slight adjustment in load regulator position so that the main generator output moves along the constant horsepower curve of Fig. 7B-2 from point "A" to point "C" instead of moving from point "A" to point "B." The response of the engine speed governor and the load regulator is fast enough to prevent any noticeable difference in diesel engine speed or main generator output during the corrective action. This corrective action continues until the locomotive is operating at point "D" on the constant horsepower curve of Fig. 7B-2.

At point "D" the load regulator is in maximum field position and providing a 50 volt reference signal. A further increase in main generator output current causes the horsepower output to follow the 50 volt signal line from point "D" toward point "E." As the operating point moves toward point "E," the horsepower output of the diesel engine decreases. This decrease in horsepower tends to increase engine speed, but the governor reacts to decrease fuel in order to maintain a constant engine speed. At the same time that fuel is decreased, the pilot valve in the governor opens and applies a hydraulic pressure to the load regulator vane motor. The vane motor tries to drive the load regulator to increase the reference signal, but the load regulator is already in maximum field position and cannot move. Therefore, the locomotive will operate along the 50 volt signal line from point "D" to point "E."

At point "E" the main generator current is at the maximum continuous operating value for the traction motors. This value may be exceeded, but only for a short period of time. If the system is not equipped with a performance control feedback signal, the locomotive will operate along the line from point "E" toward point "G." If equipped with a performance control feedback signal, the 50 volt performance control feedback signal line crosses the 50 volt power control feedback signal line at point "E." At this point locomotive operation will shift to the performance control feedback signal line and operate from point "E" toward point "F" instead of operating from point "E" toward point "G." This shift permits operation at a higher horsepower output during the short time current rating of the traction motors.

When operating in a throttle position lower than throttle 8, the feedback signals, reference signal, and constant horsepower curve will have lower values than in throttle 8. However, the general operating description is the same for all throttle positions.

Refer to description of individual modules and components for a more detailed description of components used in the excitation and power control system.

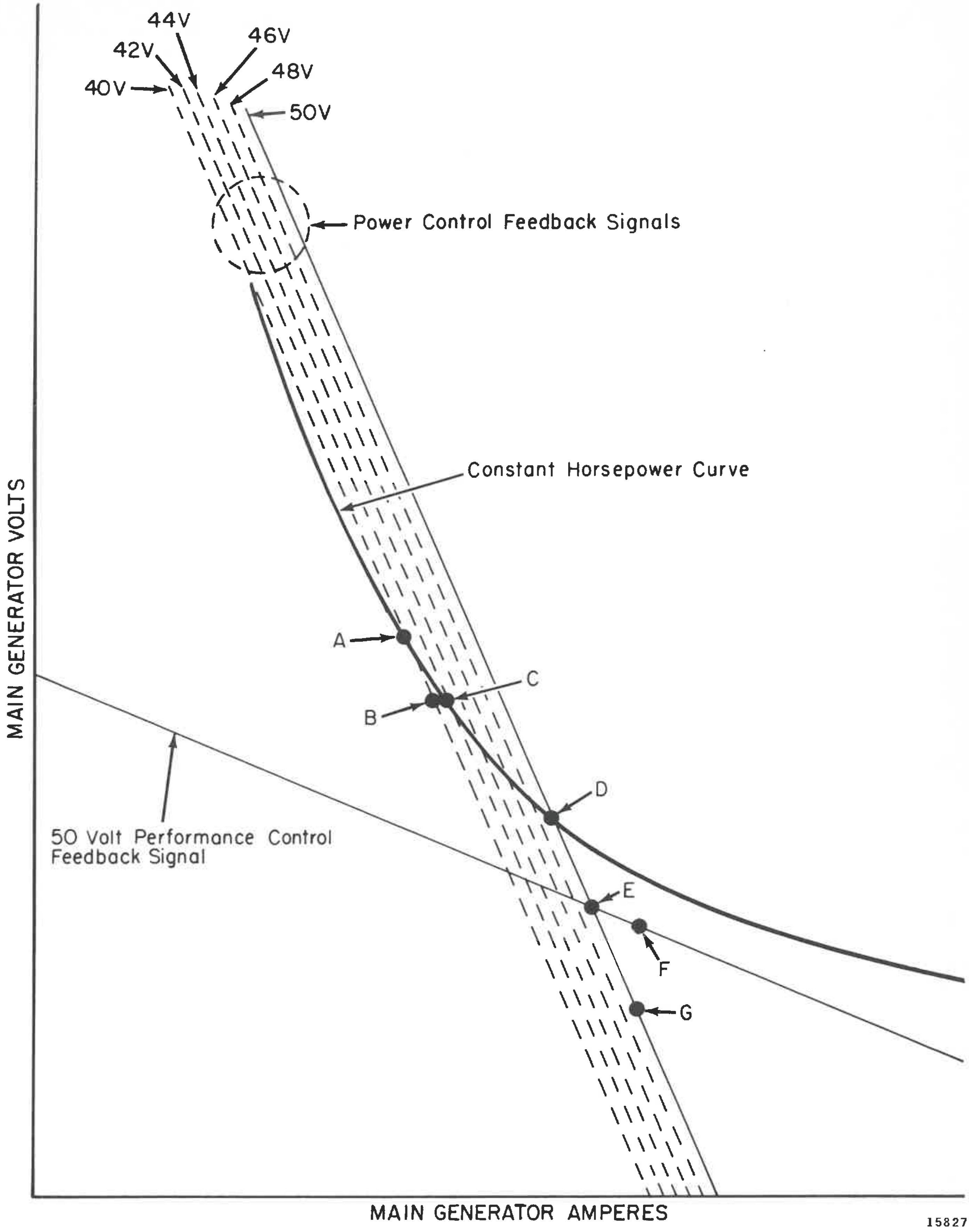

Fig. 7B-2 -- Constant Horsepower Curve With Power Control Feedback Signals And Performance Control Feedback Signals

CONTENTS

The contents of Section 7 Part B are presented in the following order:

1. Excitation Limit Backup Protection System
2. Generator Current Regulator Module
3. Generator Voltage Regulator Module
4. Load Regulator Assembly
5. Performance Control Module
6. Rate Control Module
7. Sensor Bypass Module
8. Sensor Module
9. Silicon Controlled Rectifier Assembly
10. Throttle Response and Voltage Reference Regulator Module
11. Transition Module

EXCITATION LIMIT BACKUP PROTECTION SYSTEM

INTRODUCTION

The excitation limit backup protection system consists of an excitation limit module EL11 and an excitation limit transductor ELT. The ELT provides an input signal to the EL module which is proportional to main generator field current. The EL module provides protection against excessively high excitation current to the main generator field by dropping the feed to the equipment protection relay EQP in case a fault in the GV or GX module allows excitation current to rise above a safe value. A simplified schematic diagram of the excitation limit backup protection system, Fig. EL-1, is provided for reference only. The applicable locomotive wiring diagram should be used when performing troubleshooting or maintenance on the excitation limit backup protection system.

EXCITATION LIMIT TRANSDUCTOR, ELT

The excitation limit transductor ELT consists of two laminated iron cores, two AC windings, a field current bias winding, and a test winding. The two cores are magnetically isolated from each other by an air gap and each core contains an AC winding. The bias winding and the test winding are common to both cores. A simplified schematic diagram of the ELT is provided in Fig. EL-1.

The two AC windings are connected series opposing so that the magnetic lines of force (flux lines) in the two cores travel in opposite directions. The AC windings, in series with the primary of transformer T1 on the EL module, are energized by current from the D14 alternator.

The reactance of the AC windings is much larger than the reactance of T1, when no current is flowing in the main generator field. Therefore, with no main generator field current practically all of the input AC voltage is developed across the AC windings and very little voltage appears across T1. Transformer T1 provides an input signal to the EL module. Consequently, the input signal to the EL module is very small when no current is flowing in the main generator field.

The field current bias winding consists of a single conductor passing through both cores and is connected in series with the main generator field windings. The flux lines set up by the bias winding aids the flux lines set up by the AC winding in one of the cores and opposes the flux lines set up by the AC windings in the other core. The core in which the flux lines aid moves toward magnetic saturation which reduces the reactance of the AC winding on this core. The core in which the flux lines oppose moves away from saturation, but the reactance of the AC winding on this core is affected by only a very small amount. Therefore, the combined reactance of the two AC windings decreases as current increases through the field current bias winding. The current through the field current bias winding controls the current in the AC winding according to the ampere-turns ratio between the bias winding and the AC winding. Therefore, an increase of current in the bias winding results in an increase of current through the AC windings and through transformer T1, located on the EL module. The increase in current through T1 causes an increase in the signal applied to the EL module. If the field current in the main generator rises above a safe value, the signal from T1 is sufficient to cause the EL module to operate. Operation of the EL module results in drop out of EQP, which opens the feed to the GFC contactor coil. Dropout of GFC results in disconnecting the D14 alternator from the main generator field.

The test winding on ELT provides a means for testing the excitation limit backup protection system. Closing the test switch on the EL module allows current to flow through the test winding. Current flow through the test winding causes one of the cores of ELT to move toward saturation and results in an increase of current through T1.

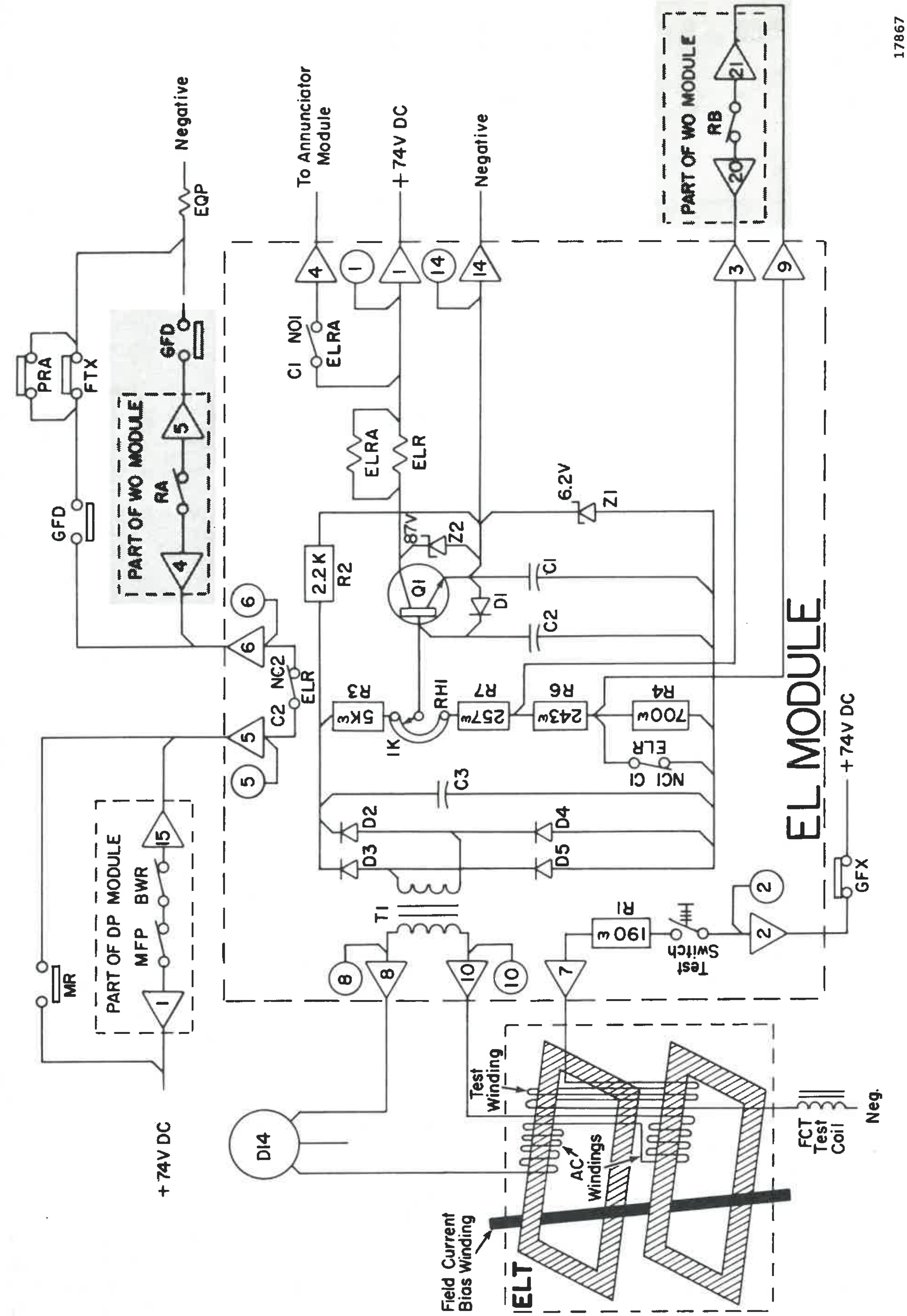

Fig. EL-1 -- Excitation Limit Protection System, Simplified Schematic Diagram

This increase in current through T1 causes the EL module to operate, thereby testing ELT and the EL module. The excitation limit light on the annunciator module should light and stay on until the annunciator module is reset.

EXCITATION LIMIT MODULE, EL Fig. EL-1

An input signal, which is proportional to the main generator field current is applied to transformer T1. The rectified output of T1 is applied to a voltage divider consisting of resistors R3, R4, R6, R7, and rheostat RH1. Capacitor C2 which is connected to the base of transistor Q1 prevents turn on of Q1 due to transient voltage output from T1. Transistor Q1 is forward biased when the output of T1 is large enough to charge C2 to a value in excess of 6.2 volts. This forward bias causes Q1 to turn on and results in a current flow from terminal 1 of the EL module, through ELR and ELRA relays, from collector to emitter of Q1, then to negative. This results in pickup of ELR and ELRA.

Pickup of ELRA provides a feed to the excitation limit light on the annunciator module AN. Pickup of ELR drops the feed to EQP by opening the ELR contacts between terminals 5 and 6 on the EL module. Pickup of ELR also recalibrates the voltage divider biasing circuit by inserting resistor R4 in series with R3, R6, R7, and RH1. Recalibrating the voltage divider biasing circuit increases forward bias on Q1. Increasing forward bias on Q1 prevents dropout of ELR and ELRA until field current decreases several amperes below the safe value. Dropout of EQP removes the feed from generator field contactor GFC which results in disconnecting the D14 alternator from the main generator field. Disconnecting the D14 alternator from the main generator field causes field current to decrease. The decrease in field current reduces the signal to transformer T1 causing Q1 to turn off. Turn off of Q1 results in dropout of ELR and ELRA. Dropout of ELR re-establishes feed to EQP which in turn re-establishes feed to GFC and results in reconnecting the D14 alternator to the main generator field. The locomotive will now operate in a normal manner, provided the condition that caused over excitation has cleared up. However, if the condition still exists, excessive current will flow through the field and again cause the EL module to operate. This cycling will continue as long as the over excitation condition exists. The cycling results in very rough regulation of power and also causes undesirable wear on the generator field contactor GFC. Therefore, the condition should be corrected as soon as practicable.

Refer to shaded area near terminal 6 on Fig. EL-1. The shaded area between the EQP relay and terminal 6 of the EL module is applicable to GP model locomotives. The non-shaded area between EQP relay and terminal 6 is applicable to SD model locomotives.

On SD model locomotives, the EL module provides backup protection at 114 amperes field current at all track speeds. Refer to the following paragraph for backup protection on GP model locomotives.

GP MODEL LOCOMOTIVES

During low speed operation resistor R6 is shorted out by closed RB relay contacts on the WO module. Refer to shaded area near terminals 3 and 9 on Fig. EL-1. The EL module provides backup protection at 155 amperes field current when R6 is shorted out. The RB relay picks up when track speed increases. Pickup of RB recalibrates the EL module by removing the short circuit from R6. The EL module provides backup protection at 114 amperes field current while RB is energized. The shaded area near terminals 3 and 9 is not applicable to SD model locomotives. Therefore, the EL module provides backup protection at 114 amperes field current at all speeds for SD model locomotives.

GENERATOR VOLTAGE REGULATOR MODULE, GV

INTRODUCTION

The generator voltage regulator module GV11 or GV12 limits the maximum output voltage of the main generator to a safe value. This regulation is provided by modulating the control signal to the sensor module SE in the event that main generator output voltage tends to rise above a safe value. Decreasing the control signal to the SE module results in a decrease of excitation to the main generator field and a corresponding decrease in main generator output voltage.

A simplified schematic diagram of the GV module, Fig. GV-1, is included for reference only. The applicable locomotive wiring diagram should be used when performing troubleshooting or maintenance. The GV11 and GV12 modules differ only in the ohmic value of resistors RE6 and RE7. Refer to the shaded area of Fig. GV-1 for values of RE6 and RE7.

GENERAL DESCRIPTION

During normal operation, transistor Q1 on the GV module is forward biased. With forward bias applied to Q1, the control signal passes through the GV module from terminal 8 to terminal 4 then to the SE module. The control signal applied to the SE module causes gating pulses to be applied to the silicon controlled rectifier SCR. The gating pulses turn on the SCR so that excitation is applied to the main generator field. The amount of excitation applied to the main generator field is proportional to the magnitude of the control signal applied to the SE module. If main generator output voltage tends to rise above a safe value, the GV module modulates the control signal to the SE module as necessary to limit the main generator voltage to a safe value.

Output of the D14 alternator is applied to transformer T3 on the GV module. The rectified output of T3 is applied to resistor RE5 and capacitor CA1 in series causing a voltage to be developed across CA1. The voltage developed across CA1 is applied to the base of transistor Q1. The series combination of capacitors CA2 and CA3 is connected in parallel with CA1. The emitter is connected to the junction of CA2 and CA3, therefore the voltage applied to the emitter of Q1 is less than the voltage applied to the base and Q1 is forward biased. With forward bias on Q1, the control signal passes through the GV module from terminal 8, through Q1 from collector to emitter, to terminal 4, then to the SE module. The control signal applied to the SE module results in gating pulses to the silicon controlled rectifier SCR and excitation to the main generator field. This excitation causes build up of main generator voltage.

An input signal, which is proportional to main generator output voltage, is applied to transformers T1 and T2. The rectified output of T1 and T2 is applied to the series combination of resistor RE4, diode D2, and capacitor CA1. The voltage developed across CA1 is applied to the base of Q1. The rectified output of T1 and T2 is also applied to a voltage divider consisting of resistor RE1, rheostat RH1, resistors RE2, RE6 and RE7. The wiper arm of RH1 is connected to the emitter of Q1. During normal operation, an increase in main generator voltage results in a proportional increase in voltage at the base and at the emitter of Q1.

As the main generator output voltage increases, the voltage applied to T1 and T2 increases and the voltage developed across CA1 increases until the breakdown voltage of zener diode Z1 is reached. After breakdown of Z1 the voltage applied to the base of Q1 assumes a constant value which is equal to the breakdown voltage of Z1. A further increase in main generator output voltage results in an increase of voltage applied to the emitter of Q1, but the voltage on the base remains constant at the breakdown value of Z1.

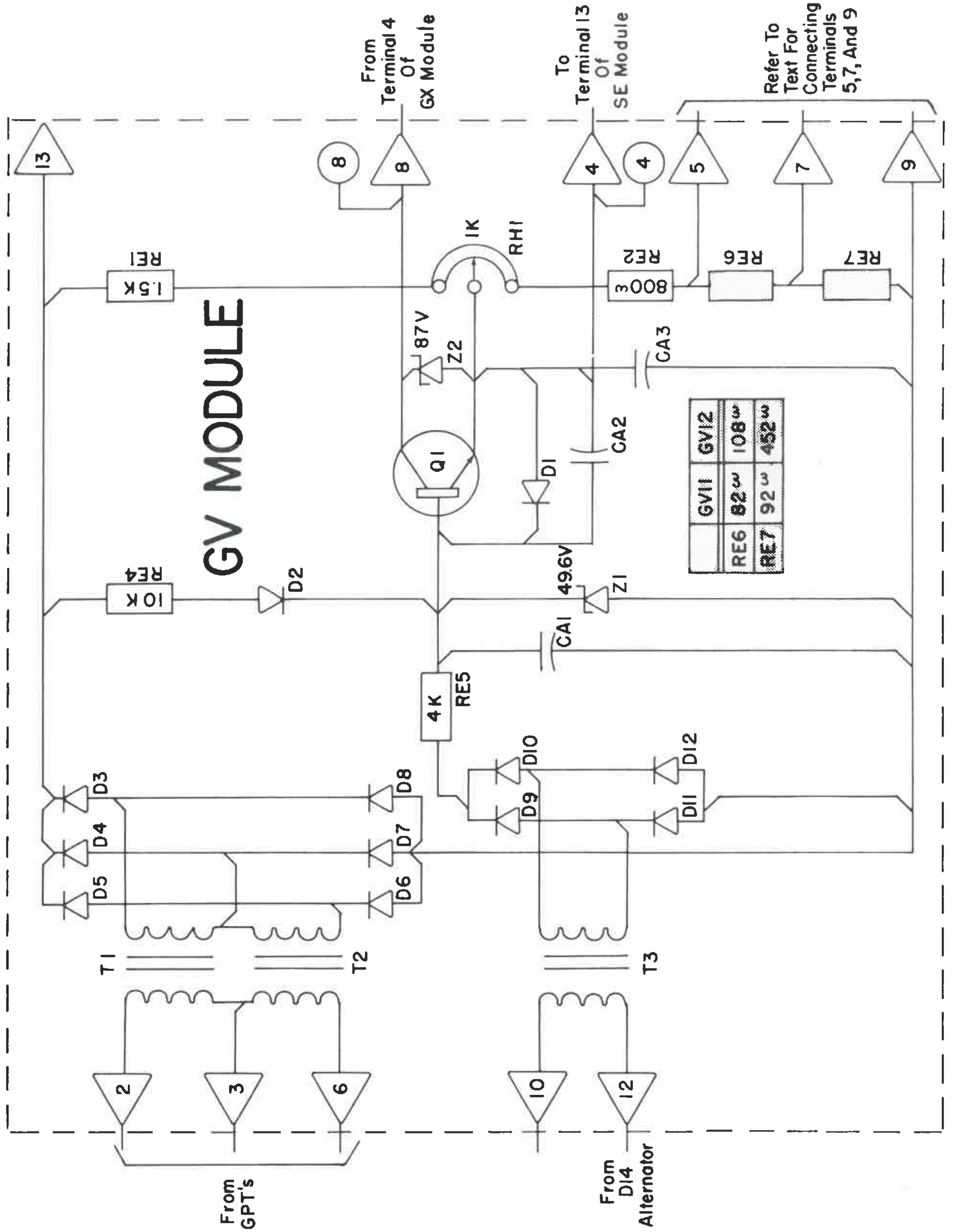

Fig. GV-1 – Generator Voltage Regulation Module GV Simplified Schematic Diagram

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If the main generator voltage tends to rise above a safe value, the voltage at the emitter of Q1 increases causing a decrease in forward bias on Q1. The decrease in forward bias, or a reverse bias, causes a decrease in the control signal to the SE module and consequently a decrease in excitation to the main generator field and a decrease in output voltage of the main generator. Therefore, the output voltage of the main generator is limited to a safe value by applying a signal to the GV module that is proportional to the output voltage of the main generator.

REGULATION FOR DIFFERENT VALUES OF MAIN GENERATOR OUTPUT VOLTAGE

The maximum output voltage of the main generator may be regulated, by the GV11 module, to any one of three different values. The specific value is determined by the external connections applied to terminals 5, 7, and 9 of the GV11 module. Refer to Fig. GV-1. The GV11 module will limit main generator output voltage to 1300 volts when no external connections are applied to terminals 5, 7, and 9. Main generator voltage will be limited to 1350 volts when terminal 5 is connected to terminal 7 and terminal 9 is left open. Main generator voltage will be limited to 1400 volts when terminal 5 is connected to terminal 9. The GP40-2 locomotive is equipped with the GV11 module with terminals 5, 7, and 9 open. This provides for a maximum output voltage of 1300 volts.

The maximum output voltage of the main generator may be regulated, by the GV12 module, to any one of three different values. The specific value is determined by the external connections applied to terminals 5, 7, and 9 of the GV12 module. Refer to Fig. GV-1. The GV12 module will limit main generator output voltage to 1050 volts when no external connections are applied to terminals 5, 7, and 9. Main generator voltage will be limited to 1200 volts when terminal 7 is connected to terminal 9 and terminal 5 is left open. Main generator will be limited to 1250 volts when terminal 5 is connected to terminal 9. The GP38-2 and SD38-2 model locomotives are equipped with the GV12 module with terminal 5 connected to terminal 9 and terminal 7 is left open. This provides for a maximum output voltage of 1250 volts for GP38-2 and SD38-2 model locomotives. The SD40-2 and SD45-2 model locomotives are equipped with the GV12 module with terminal 5 connected to terminal 9. This provides for a maximum output voltage of 1250 volts for SD40-2 and SD45-2 model locomotives.

GENERATOR EXCITATION REGULATING SYSTEM

INTRODUCTION

The generator excitation regulating system consists of the generator excitation regulating module GX2 and a field current transductor FCT. The FCT provides an input signal to the GX module proportional to main generator field current. The GX module provides protection against excessively high excitation current to the main generator field by modulating the control signal to the sensor module SE in the event that excitation to the main generator field tends to rise above a safe value. A simplified schematic diagram of a typical generator excitation regulating system, Fig. GX-1, is included for reference only. The applicable locomotive wiring diagram should be used when performing troubleshooting or maintenance.

FIELD CURRENT TRANSDUCTOR, FCT

The field current transductor FCT consists of two laminated iron cores, two AC windings, and a field current bias winding. The two cores are magnetically isolated from each other by an air gap and each core contains an AC winding. The bias winding is common to both cores. Fig. GX-1 contains a simplified schematic diagram of FCT.

The two AC windings are connected series opposing so that the magnetic lines of force (flux lines) in the two cores travel in opposite directions. The AC windings, in series with the primary of transformer T1 on the GX module, are energized by current from the D14 alternator.

The reactance of the AC windings is much larger than the reactance of T1, when no current is flowing in the main generator field. Therefore, with no main generator field current, practically all of the input AC voltage is developed across the AC windings and very little voltage appears across T1. Transformer T1 provides an input signal to the GX module. Consequently, the input signal to the GX module is very small when no current is flowing in the main generator field.

The field current bias winding consists of a single conductor passing through both cores and is connected in series with the main generator field windings. The flux lines set up by the bias winding aids the flux lines set up by the AC winding in one core and opposes the flux lines set up by the AC winding in the other core. The core, in which the flux lines aid, moves toward magnetic saturation which reduces the reactance of the AC winding on this core. The core in which the flux lines oppose, moves away from saturation, but the reactance of the AC winding on this core is affected only by a very small amount. Therefore, the combined reactance of the two AC windings decrease as the field current increases. The decrease in reactance results in an increase in current through the AC windings and through transformer T1, located on the GX module. If the main generator field current rises above a safe value, the signal from T1 is sufficient to cause transistor Q1, on the GX module, to modulate the control signal to the SE module. Modulating the control signal to the SE module results in decreasing the main generator field current.

GENERATOR EXCITATION REGULATING MODEL GX

Fig. GX-1 contains a simplified schematic diagram of GX2.

During normal operation, transistor Q1 on the GX module is forward biased. With forward bias applied to Q1, the control signal is passed through the GX module from terminal 8 to terminal 4. This control signal is applied through the GV module, to terminal 13 of the SE module. The control signal applied to the SE module causes gating pulses to be applied to the silicon controlled rectifier SCR. The gating pulses turn on the SCR and excitation current flows through the SCR to the main generator field. The amount of excitation applied to the main generator field is proportional to the magnitude of the control signal applied to SE. If the main generator field current tends to rise above a safe value, the GX module modulates the control signal to the SE module as necessary to limit the main generator field current to a safe value.

Output voltage of the D14 alternator is applied to transformer T2 on the GX module. The rectified output of T2 is applied to resistor RE4 and capacitor CA1 in series, causing a voltage to be developed across CA1. The voltage developed across CA1 is applied to the base of transistor Q1. The series combination of capacitors CA2 and CA3 is connected in parallel with CA1. The emitter is connected to the junction of CA2 and CA3, therefore the voltage applied to the emitter is less than the voltage applied to the base. This places forward bias on Q1. With forward bias on Q1, the control signal passes through the GX module from terminal 8, through Q1 from collector to emitter, to terminal 4, then through the GV module to the SE module. The control signal applied to SE results in gating pulses to the silicon controlled rectifier SCR and excitation to the main generator field. This excitation causes build up of main generator voltage.

An input signal, which is proportional to main generator field current, is applied to transformer T1. The rectified output of T1 is applied to the series combination of resistor RE3, diode D2, and capacitor CA1. The voltage developed across CA1 is applied to the base of Q1. The rectified output of T1 is also applied to a voltage divider consisting of rheostat RH1, resistor RE1, RE2, and RE5. The wiper arm of RH1 is connected to the emitter of Q1. During normal operation, an increase in main generator field current results in a proportional increase in voltage at the base and at the emitter of Q1 which maintains forward bias on Q1.

As the main generator field current increases, the voltage applied to T1 increases and the voltage developed across CA1 increases until the breakdown voltage of zener diode Z1 is reached. After breakdown of Z1, the voltage applied to the base of Q1 assumes a constant value which is equal to the breakdown voltage of Z1. A further increase in main generator field current results in an increase of voltage to T1 which results in an increase in voltage applied to the emitter of Q1, but the voltage on the base remains constant at the breakdown value of Z1.

If the main generator field current tends to rise above a safe value, the voltage at the emitter of Q1 increases, and this causes a decrease in forward bias on Q1. The voltage at the emitter of Q1 may increase to a value that results in reverse bias on Q1. The decrease in forward bias, or reverse bias, causes a decrease in the control signal to SE and consequently a decrease in main generator field current. Therefore, the field current of the main generator is limited to a safe value by applying a signal to the GX module that is proportional to the main generator field current.

REGULATION FOR DIFFERENT TYPES OF LOCOMOTIVES

The GX2 module is designed so that main generator field current may be regulated at a maximum limit of any one of three different values. Refer to Fig. GX-1. The GX2 module will limit field current to 103 amperes when no external connections are applied to terminals 5, 6, and 7. Field current will be limited to 108 amperes when terminal 5 is connected to terminal 6 and terminal 7 is left open. Field current will be limited to 144 amperes when terminals 5, 6, and 7 are connected together.

GP MODEL LOCOMOTIVES

On GP model locomotives, resistor RE2 is shorted out by external connection between terminals 5 and 6. During low speed operation resistor RE5 is shorted out by closed RB relay contacts on the WO module. Refer to shaded area of Fig. GX-1. Field current is limited to a maximum of 144 amperes when RE2 and RE5 are shorted out. The RB relay picks up when track speed increases. Pickup of RB recalibrates the GX module by removing the short circuit from RE5. Field current is limited to 108 amperes after recalibration.

SD MODEL LOCOMOTIVES

On SD model locomotives, resistor RE2 is shorted out by external connection between terminals 5 and 6 and terminal 7 is left open. Under these conditions field current is limited to 108 amperes. Recalibration of the GX module is not applicable to SD locomotives. Therefore, field current is limited to 108 amperes regardless of track speed.

FCT TEST WINDING

A test winding on FCT provides a means for testing GX module operation. The winding is connected in series with a test winding on excitation limit transductor ELT, Fig. EL-1. When the locomotive throttle is at idle with the engine running, closing the test switch on the EL module allows current to flow through both the ELT and FCT test windings, causing one FCT core to move toward saturation. This results in an increase of current through T1 of GX. The increased current causes the GX module to regulate, and voltage can be seen across GX-TP8 to GX-TP4.

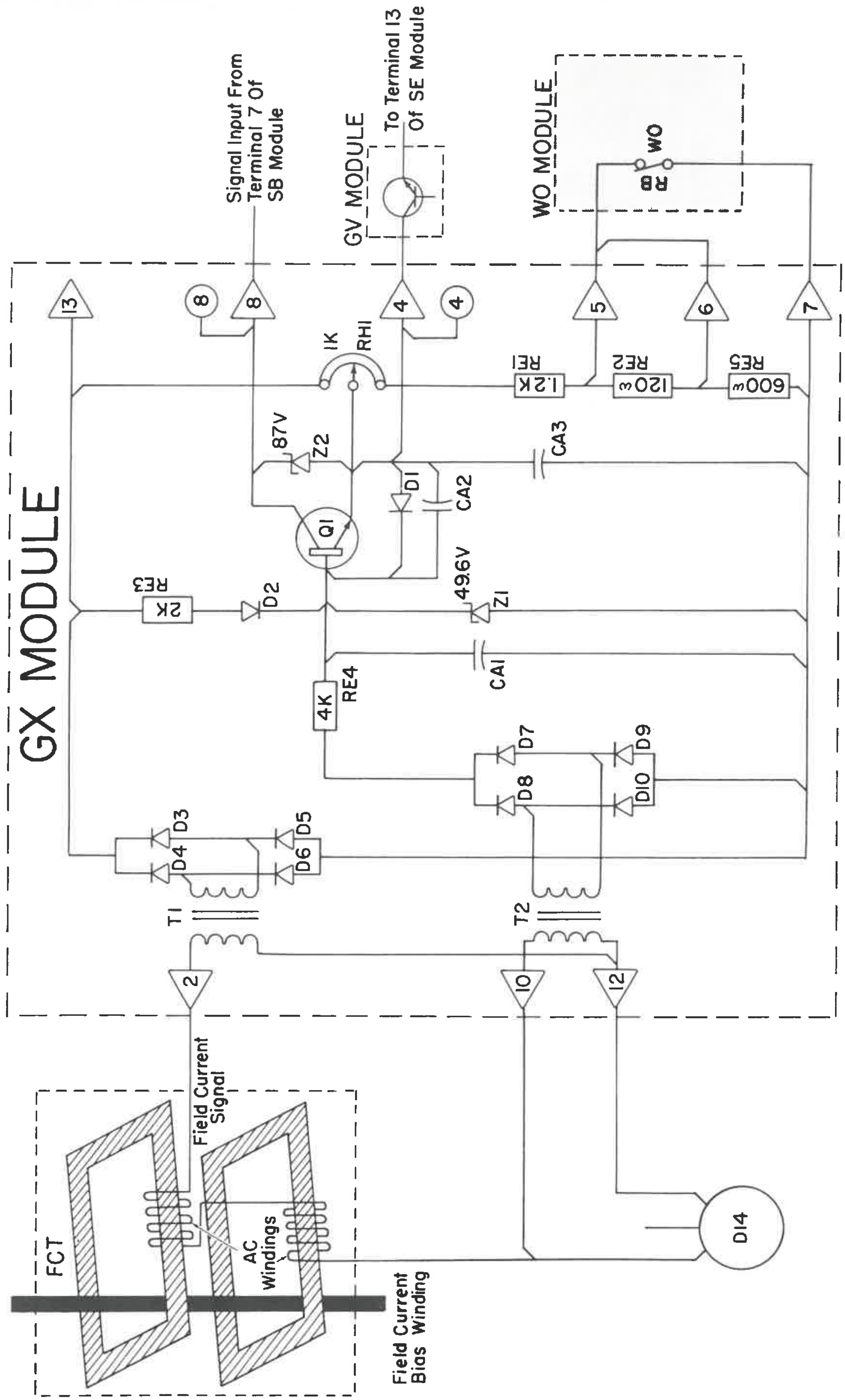

Fig. GX-1 -- Generator Excitation Regulating Module -- Simplified Schematic Diagram

LOAD REGULATOR ASSEMBLY

The load regulator assembly LR consisting of a 1500 ohm tapered plate-type rheostat and a hydraulically operated vane motor, receives an input voltage from the rate control module RC and provides a reference voltage to the sensor bypass (feedback comparison) module SB. The wiper arm of the load regulator, which may be moved through an arc of 300 degrees, is attached to the vane motor. A pilot valve, located in the engine speed governor, controls the flow of engine oil under pressure to drive the vane motor clockwise or counterclockwise to position the wiper arm. Refer to Fig. LR-1.

The input voltage applied to the load regulator depends upon the throttle setting and the state of charge on the rate control capacitors on the rate control module. When operating in throttle 8 position, and with rate control capacitors fully charged, the input voltage applied to the load regulator is 50 volts. The input voltage applied to the load regulator decreases as the throttle position is decreased.

The output voltage available at the load regulator wiper arm depends upon the input voltage applied to the load regulator and the position of the wiper arm. At locomotive standstill and during initial startup, the load regulator is in maximum field position. Output voltage of the load regulator when in maximum field position is approximately equal to input voltage.

During normal operation, with the throttle in a fixed position, the output voltage from the load regulator is determined by the input voltage to

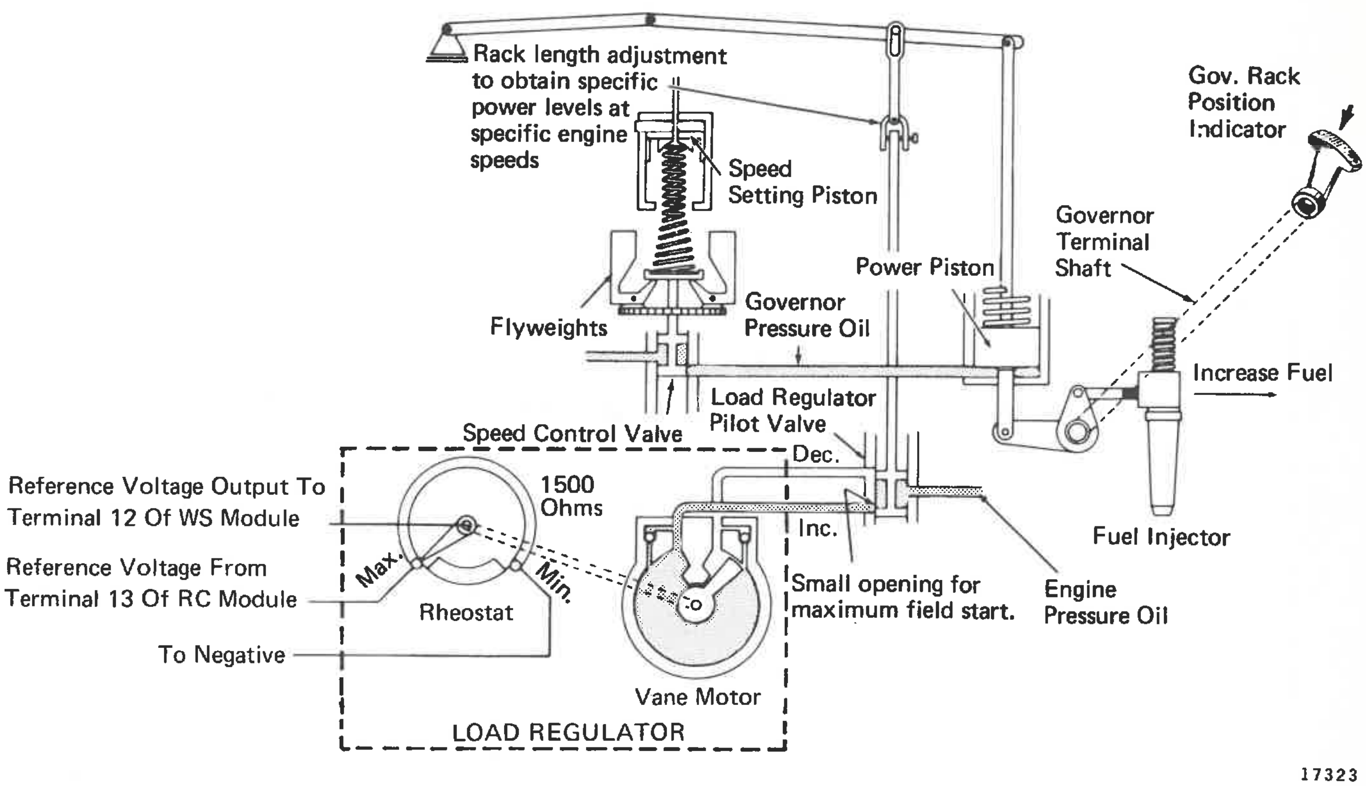

Fig. LR-1 -- Load Regulator, Simplified Diagram the load regulator and main generator current. Assume that the locomotive is operating in throttle 8 position with a 40 volt reference signal from LR as shown in Fig. LR-2. If load is increased, such as when starting up a grade, the speed of the traction motors will decrease due to the increased load.

With decrease in traction motor speed, the load current increases due to a decrease in counter electromotive force. An increase in traction motor current results in a decrease in voltage. This decrease in voltage is partly due to the increased I_2R and IZ losses in the main generator.

If the reference signal from LR remains at 40 volts, the horsepower applied to the traction motors would follow the 40 volt reference line from point "A" toward point "B" in Fig. LR-2. However, to follow the 40 volt reference line the operating point would fall below the constant horsepower curve and less horsepower would be applied to the traction motors.

The decrease in horsepower tends to cause an increase in diesel engine speed. This increase in speed is sensed by the engine speed governor. The governor reacts to temporarily decrease the amount of fuel injected into the engine and thereby maintains a constant engine speed. At the same time that the fuel is decreased a pilot valve in the engine speed governor directs hydraulic pressure to the load regulator vane motor which causes the load regulator to move toward maximum field position. This action can be followed by referring to Fig. LR-1. The increase in speed causes the governor fly weights to pivot outward which results in raising the speed control valve plunger. This allows some of the oil under the power piston to escape below the lower land on the speed control valve plunger causing the power piston to move downward. The escaped oil returns to the oil sump in the governor. Downward movement of the power piston causes a downward movement of the load regulator pilot valve plunger and also moves the governor rack to decrease the fuel to the engine. Downward movement of the load regulator pilot valve plunger directs engine oil, under pressure, to the increase port of the load regulator vane motor. This causes the vane motor to drive the wiper arm of the load regulator rheostat toward maximum field position.

Movement of the load regulator toward maximum field position results in an increase in the reference signal from LR. Increasing the reference signal results in an increase of excitation to the main generator field and an increase in main generator horsepower output. This increased horsepower tends to decrease diesel engine speed, however, the governor again reacts to maintain a constant engine speed. The pilot valve in the governor also causes a slight adjustment in load regulator position so that the main generator output moves along the constant horsepower curve from point "A" to point "C" instead of

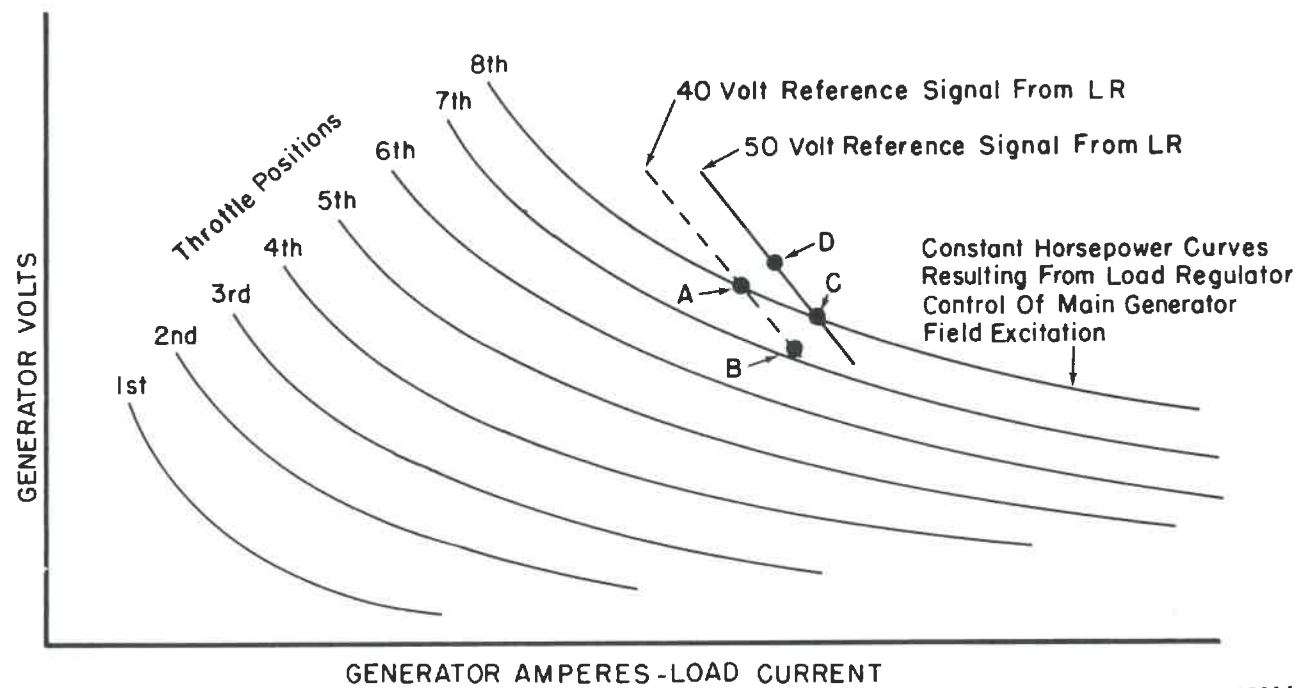

Fig. LR-2 – Constant Kilowatt (Horsepower) Curves - Nominal from point "A" to point "B" in Fig. LR-2. Refer to Fig. LR-1. The decrease in engine speed causes the governor fly weights to move inward which results in lowering the speed control valve plunger. This allows the governor oil, under pressure, to be forced under the power piston causing the power piston to move upward. Upward movement of the power piston causes an upward movement of the load regulator pilot valve plunger and also moves the governor rack to increase the fuel to the engine. Upward movement of the load regulator pilot valve plunger allows the oil from the increase port to drain into the engine oil sump and also opens the decrease port to engine oil pressure. Oil pressure at the decrease port causes the vane motor to drive the load regulator wiper arm toward minimum field position. Therefore, the engine speed governor maintains a constant engine speed and the load regulator maintains a constant horsepower output within the normal operating range of the locomotive. The response of the engine speed governor and the load regulator is fast enough to prevent any noticeable difference in diesel engine speed or main generator output.

Assume that the locomotive is operating in throttle position 8 with a 50 volt reference signal from LR as shown at point "C" of Fig. LR-2. If load is decreased, such as when starting down a grade, the speed of the traction motors will increase due to the decreased load.

With an increase in traction motor speed, the load current decreases due to an increase in counter electromotive force. A decrease in traction motor current results in an increase in voltage. If the reference signal from LR remained at 50 volts with a decrease in current, the horsepower applied to the traction motors would follow the 50 volt reference line from point "C" toward point "D" in Fig. LR-2. However, to follow the 50 volt reference line, the operating point would rise above the constant horsepower curve and more horsepower would be applied to the traction motors.

The increase in horsepower tends to decrease diesel engine speed. This decrease in speed is sensed by the engine speed governor. The governor reacts to temporarily increase the amount of fuel injected into the engine and thereby maintains a constant engine speed. At the time that the fuel is increased, a pilot valve in the engine speed governor directs hydraulic pressure to the load regulator vane motor which causes the load regulator to move toward minimum field position. Refer to Fig. LR-1. The decrease in speed causes the governor fly weights to move inward which results in lowering the speed control valve plunger. This allows the governor oil, under pressure, to be forced under the power piston causing the power piston to move upward. Upward movement of the power piston causes an upward movement of the load regulator pilot valve plunger and also moves the governor rack to increase the fuel to the engine. Upward movement of the load regulator pilot valve plunger allows the oil from the increase port to drain into the engine oil sump and also opens the decrease port to engine oil pressure. Oil pressure at the decrease port causes the vane motor to drive the load regulator wiper arm toward minimum field position.

Movement of the load regulator toward minimum field position results in a decrease in the reference signal from LR. Decreasing the reference signal results in a decrease of excitation to the main generator field and a decrease in main generator output. This decreased horsepower tends to increase diesel engine speed, however, the governor again reacts to maintain a constant engine speed. The pilot valve in the engine speed governor also causes a slight adjustment in load regulator position so that the main generator output moves along the constant horsepower curve from point "C" to point "A" instead of moving from point "C" to point "D" in Fig. LR-2.

The load regulator operation described above tends to cause the locomotive to operate along the horsepower curves shown in Fig. LR-2. Notice that a different horsepower curve is provided for each throttle position. The horsepower curves shown in Fig. LR-2 are general horsepower curves and do not indicate specific values of main generator current or voltage. When the locomotive is operating in the lower speed range, the operation will not follow the horsepower curves shown in Fig. LR-2, but will be modified by the action of the performance control module PF. A description of the performance control module PF is provided later in this section.

PERFORMANCE CONTROL MODULE, PF17

INTRODUCTION

The performance control module PF17 consists of two rectifier assemblies connected to loading resistors. One of the rectifier assemblies is connected to generator potential transformer GPT1 so that the feedback signal developed across its loading resistor is proportional to main generator output voltage. The other rectifier assembly is connected to current transformers CTA, CTB, and CTC so that the feedback signal developed across its loading resistors is proportional to main generator output current.

The current feedback signal and the voltage feedback signal is combined to provide a feedback signal to the sensor bypass module SB. The feedback signal applied to the SB module is proportional to main generator output voltage and output current. The SB module compares the reference signal from the load regulator with the feedback signal from the PF module. Excitation is applied to the main generator field when the reference signal from LR is larger than the instantaneous value of the feedback signal from the PF module. Excitation is removed from the main generator field when the reference signal from LR is smaller than the instantaneous value of the feedback signal from the PF module. The maximum value of the reference signal from LR is approximately 50 volts.

A simplified schematic diagram of the PF module is provided later in this section for convenient reference. The applicable locomotive wiring diagram should be used when performing troubleshooting or maintenance.

MAIN GENERATOR VOLTAGE FEEDBACK SIGNAL

The rectifier assembly consisting of diodes D13 through D18 is connected to generator potential transformer GPT1. The rectified output of this assembly is applied to resistors R5A, R5B, R5C, and R6A connected in series. The resistance values are selected so that an output voltage of approximately 1950 volts from the main generator would result in a feedback signal of 50 volts across R6A. The main generator voltage is limited to much less than 1950 volts, however, the 1950 volts is used in calculating the desired slope of the 50 volt voltage feedback signal line and to establish the desired relationship between the voltage feedback signal and main generator output voltage within the operating range of the main generator. This relationship is shown in Fig. PF-1.

MAIN GENERATOR CURRENT FEEDBACK SIGNAL

The rectifier assembly consisting of diodes D7 through D12 is connected to current transformers CTA, CTB, and CTC. The rectified output of this assembly is applied to resistors R4A, R4B, R4C, and R8 connected in series. Resistor R8 is shorted out by BR1 contacts during power operation.

The resistance values of R4A, R4B, and R4C are selected so that:

1. An output current of approximately 5700 amperes from the main generator would result in a 50 volt feedback signal across R4A, R4B, and R4C during series-parallel operation.

2. An output current of approximately 6100 amperes from the main generator would result in a 50 volt feedback signal across R4C plus R4A and R4B in parallel with R10 during parallel operation.

The normal output current is limited to less than 5700 amperes, however, the 5700 and 6100 values are used in calculating the desired slope of the 50 volt current feedback signal line and to establish the desired relationship between the current feedback signal and main generator output current within the operating range of the main generator. The relationship of main generator output current and the feedback signal is shown in Fig. PF-2.

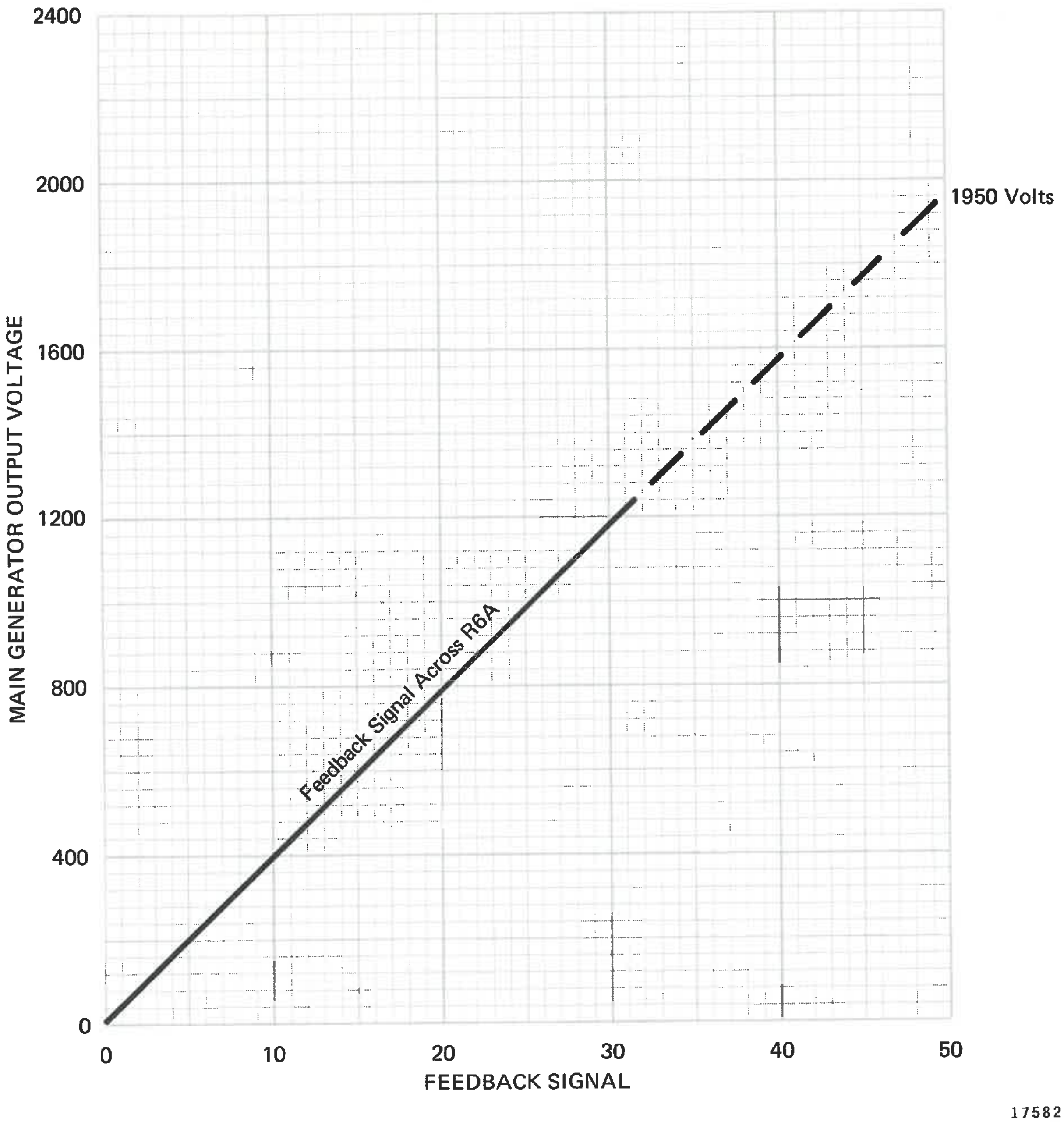

Fig. PF-1 – Relationship Between Feedback Signal And Main Generator Voltage

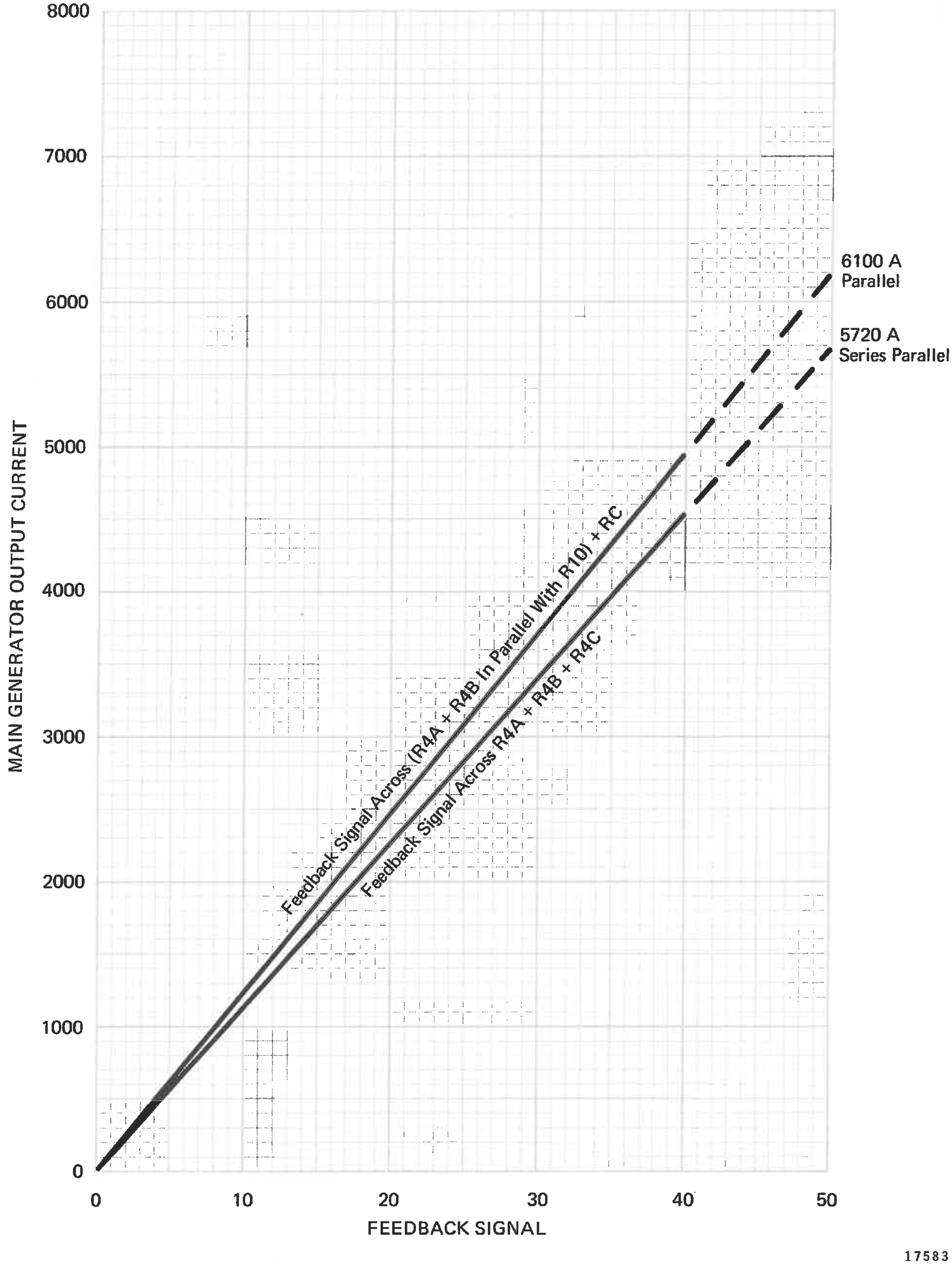

Fig. PF-2 – Relationship Between Feedback Signal And Main Generator Current

During dynamic brake operation, resistor R8 is placed in the circuit to obtain the desired relationship between the dynamic braking lever position and the current feedback signal developed across R4A, R4B, R4C, and R8.

POWER CONTROL FEEDBACK SIGNAL

The power control feedback signal is obtained by combining the main generator voltage feedback signal developed across R6A with the main generator current feedback signal developed across R4A, R4B, and R4C. The relationship between main generator output voltage and current and the 50 volt power control feedback signal is shown in Fig. PF-3. The 3000 horsepower curve, 108 ampere maximum excitation limit line as established by the GX module, and the 1250 volt maximum voltage line as established by the GV module are also shown in Fig. PF-3.

POWER CONTROL OPERATION

The power control feedback signal is applied to transistor Q1 in the SB module where it is compared with the reference signal from the load regulator LR. Forward bias is applied to Q1 if the reference signal is larger than the feedback signal.

In throttle 8 position and at low track speeds, the reference signal from LR has a maximum value of 50 volts. This condition is represented by point B on the constant horsepower curve in Fig. PF-3. The reference signal is less than 50 volts when operating at higher track speeds. This condition occurs between points A and B on the constant horsepower curve. The reference signal from LR decreases as the throttle is reduced.

When operating in throttle 8 position, the engine speed governor and load regulator tends to cause the locomotive to operate along the constant horsepower curve from point A to point C as locomotive speed decreases. However, the instantaneous value of the reference signal from LR must be slightly larger than the instantaneous value of the feedback signal in order to provide excitation to the main generator. The power control feedback signal increases as it moves to the right. Therefore, operation on the constant horsepower curve between points B and C cannot occur as the reference signal has a maximum value of 50 volts and the power control feedback signal would be above 50 volts between B and C on the constant horsepower curve.

A decrease in speed from point B causes the operating point to move below the 3000 horsepower curve. The operating point tends to move along the 50 volt power control line toward point D. However, main generator excitation current is limited to 108 amperes by the generator excitation regulation module GX. Therefore, the operating point actually moves along the 108 ampere excitation line toward point E.

When operating at point A, an increase in track speed causes the operating point to move toward point F. However, main generator voltage is limited to approximately 1250 volts by the generator voltage regulator module GV. This prevents the operating point from moving above point G. If the GV module fails to limit operation to point G, the GX module provides backup protection to limit operation to point H.

When operating in a throttle position lower than throttle 8, the feedback signals, the reference signal, and constant horsepower curve will have lower values than when operating in throttle 8 position. However, the general description is the same for all throttle positions.

Refer to Fig. PF-4 for simplified schematic diagram of the performance control module.

When operating with a pair of traction motors cut out, resistor R12 on the PF module is inserted between the TH module and the RC module. This reduces horsepower output of the locomotive by reducing the maximum reference signal from the load regulator LR.

Main generator output voltage is very low during dynamic brake operation and the voltage feedback signal is not combined with the current feedback signal. However, resistor R8 is inserted in series with R4A, R4B, and R4C to increase the current feedback signal. Therefore, during dynamic brake operation, the power control signal consists entirely of the current feedback signal. This power control signal is applied to the SB module for comparison with the reference signal from the load regulator LR.

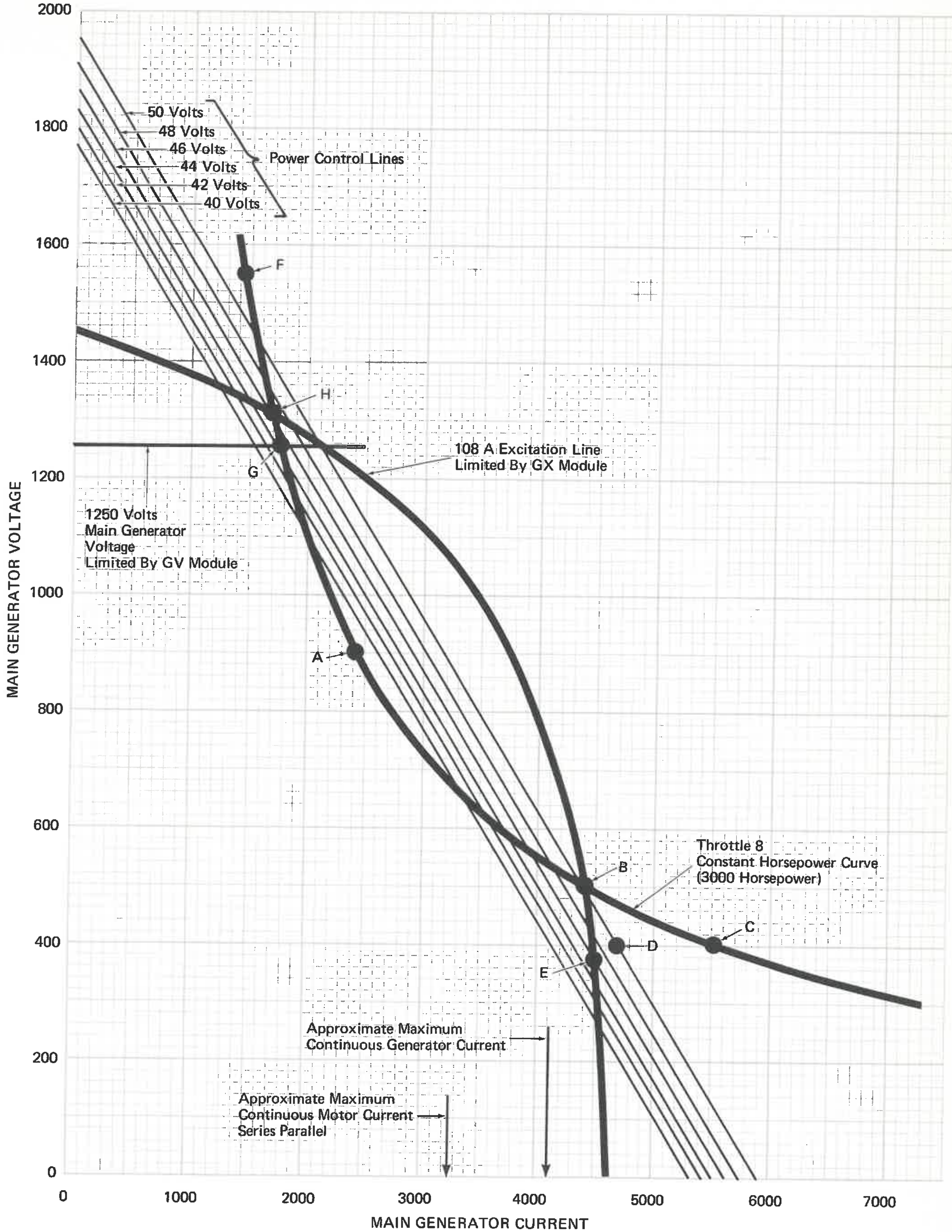

Fig. PF-3 -- Power Control And Constant Horsepower Curves

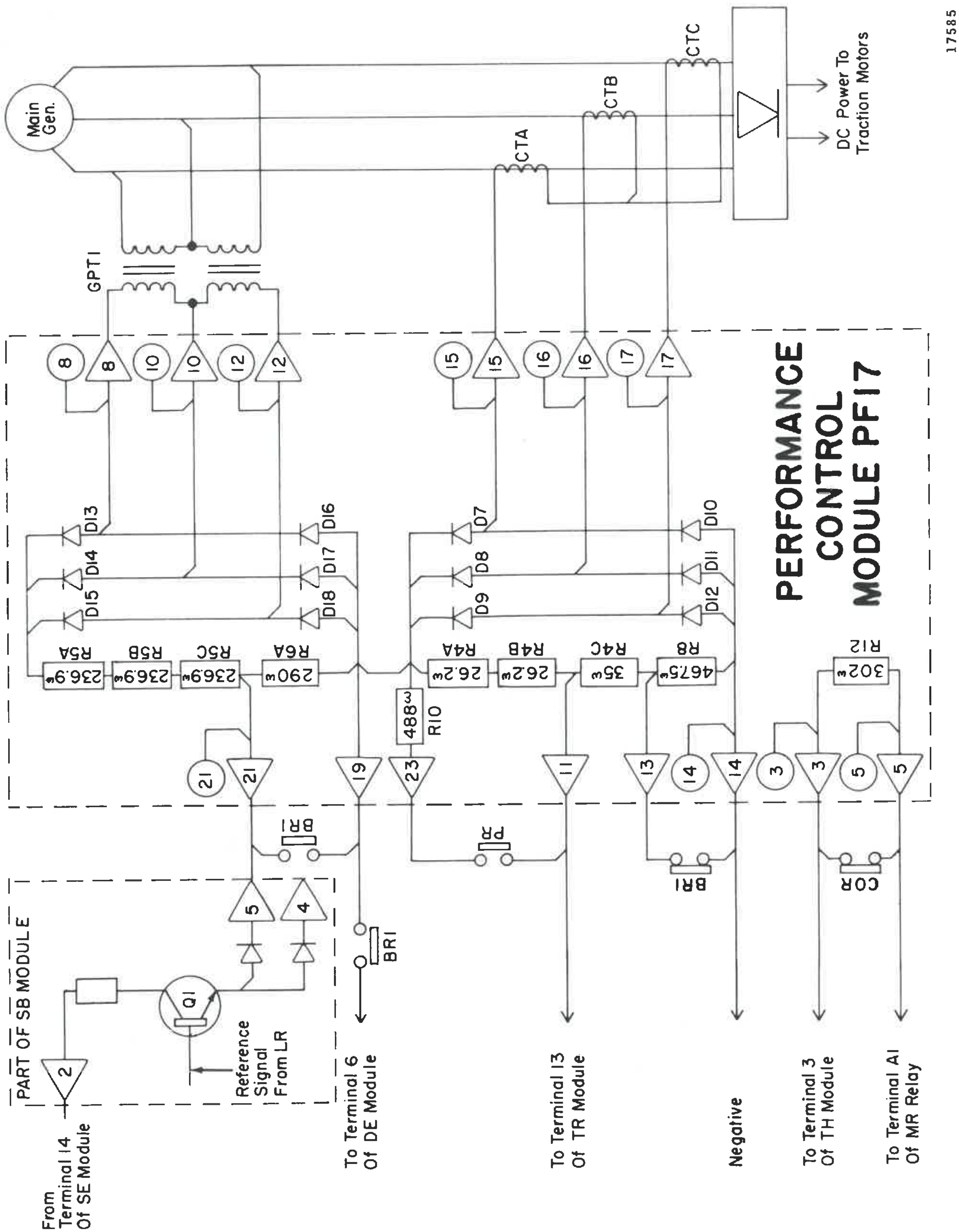

Fig. PF-4 – Performance Control Module, Simplified Schematic Diagram

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PERFORMANCE CONTROL MODULE, PF18 (SPECIAL ORDER)

INTRODUCTION

This special order performance control module is designed to provide optimum power within adhesion considerations at low speed and to operate in consists with less powerful locomotives. Performance control module PF18 consists of three rectifier assemblies connected to loading resistors. Two of the rectifier assemblies are connected to generator potential transformers, GPT1 and GPT2, so that the feedback signals developed across their loading resistors are proportional to main generator output voltage. The other rectifier assembly is connected to current transformers CTA, CTB, and CTC so that the feedback signal developed across its loading resistors is proportional to main generator output current.

The current feedback signal and the two voltage feedback signals are combined to provide two separate feedback signals to the sensor bypass module SB. The feedback signals applied to the SB module are proportional to main generator output voltage and output current. The SB module compares the reference signal from the load regulator with the feedback signals from the PF module. Excitation is applied to the main generator field when the reference signal from LR is larger than the instantaneous value of either of the feedback signals from the PF module. Excitation is removed from the main generator field when the reference signal from LR is smaller than the instantaneous value of both feedback signals from the PF module.

A simplified schematic diagram of the PF module is provided later in this section for convenient reference. The applicable locomotive wiring diagram should be used when performing troubleshooting or maintenance.

MAIN GENERATOR VOLTAGE FEEDBACK SIGNALS DURING SERIES-PARALLEL OPERATION

The rectifier assembly consisting of diodes D1 through D6 is connected to generator potential transformer GPT2. The rectified output of this assembly is applied to resistors R1A, R1B, R1C, and R2 connected in series. The resistance values are selected so that an output voltage of approximately 2800 volts from the main generator would result in a feedback signal of 50 volts across R2. The main generator voltage is limited to much less than 2800 volts, however, the 2800 volts is used in calculating the desired slope of the 50 volt feedback signal line and to establish the desired relationship between the feedback signal and main generator output voltage within the operating range of the main generator. This relationship is shown in Fig. PF-1.

The rectifier assembly consisting of diodes D13 through D18 is connected to generator potential transformer GPT1. The rectifier assembly output is applied to resistors R7, R5A, R5B, R6A, and R11 connected in series. The resistance values are selected so that an output voltage of approximately 850 volts from the main generator would result in a feedback signal of 50 volts across R6A and R11. The relationship between main generator output voltage and the feedback signal developed across R6A and R11 is shown in Fig. PF-1.

MAIN GENERATOR CURRENT FEEDBACK SIGNALS DURING SERIES-PARALLEL OPERATION

The rectifier assembly consisting of diodes D7 through D12 is connected to current transformers CTA, CTB, and CTC. The rectifier assembly output is applied to resistors R3A, R3B, R3C, R4A, R4B, R4C, and R8. Resistor R8 is shorted out by BR1 contacts during power operation.

The resistor values are selected so that:

1. An output current of approximately 6800 amperes from the main generator would result in a 50 volt feedback signal across R4C + (R4A and R4B in parallel with R3A, R3B, R3C, and R10).

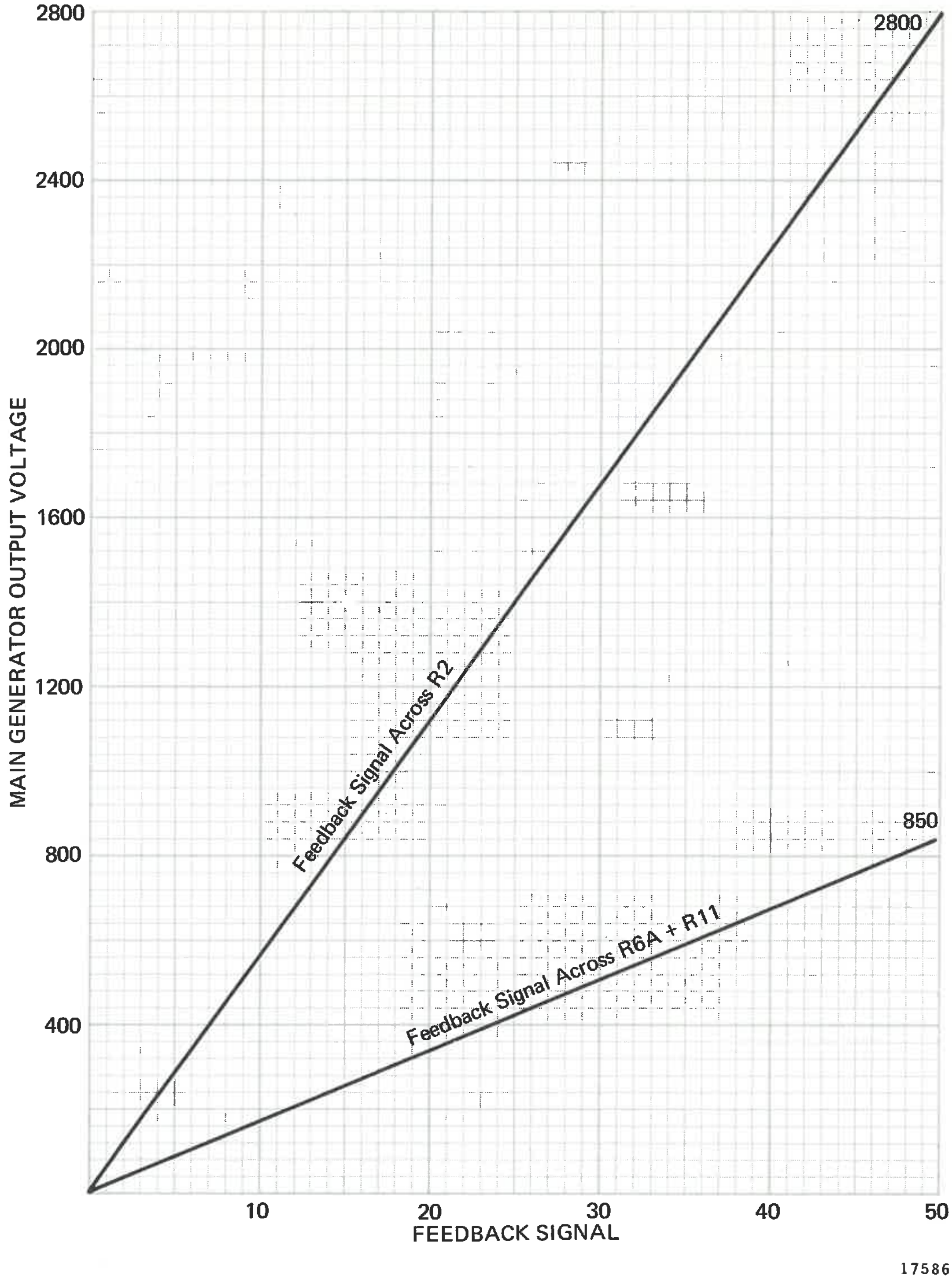

Fig. PF-1 – Relationship Between Feedback Signal And Main Generator Voltage (Series-Parallel Operation)

2. An output current of approximately 3800 amperes from the main generator would result in a 50 volt feedback signal across R4C + (R3A, R3B, R3C, R4A, and R4B in parallel with R10).

The normal output current is limited to less than 6800 amperes, however, the 6800 and 3800 values are used in calculating the desired slope of the 50 volt feedback signal line and to establish the desired relationship between the feedback signal and main generator output current within the operating range of the main generator. The relationship of main generator output current and the feedback signals are shown in Fig. PF-2.

During dynamic brake operation, resistor R8 is placed in the circuit to obtain the desired relationship between the dynamic braking lever position and the feedback signal.

POWER CONTROL FEEDBACK SIGNALS DURING SERIES-PARALLEL OPERATION

The power control feedback signal is obtained by combining the main generator voltage feedback signal developed across R2 with the main generator current feedback signal developed across R3A, R3B, R3C, R4A, R4B, and R4C. The relationship between main generator output and the 50 volt power control feedback signal is shown in Fig. PF-3.

Any combination of main generator current and voltage that intersects at a point above or to the right of the 50 volt power control feedback signal line will provide a feedback signal greater than 50 volts. Any combination of current and voltage that intersects at a point below or to the left of the 50 volt power control feedback signal line will provide a feedback signal less than 50 volts. Power control lines of 40, 42, 44, 46, 48, and 50 volts are shown in Fig. PF-3.

PERFORMANCE CONTROL FEEDBACK SIGNAL DURING SERIES-PARALLEL OPERATION

The performance control feedback signal is obtained by combining the main generator voltage feedback signal developed across R6A and R11 with the main generator current feedback signal developed across R4A, R4B, and R4C. The relationship between main generator output and the performance control feedback signal is shown in Fig. PF-3.

Any combination of main generator current and voltage that intersects at a point above or to the right of the 50 volt performance control feedback signal line will provide a performance control feedback signal greater than 50 volts. Any combination of voltage and current that intersects at a point below or to the left of the 50 volt performance control feedback signal line will provide a performance control feedback signal less than 50 volts.

POWER CONTROL AND PERFORMANCE CONTROL OPERATION DURING SERIES-PARALLEL OPERATION

The power control and performance control feedback signals are applied to transistor Q1 in the SB module where they are compared with the reference signal from the load regulator LR. Forward bias is applied to Q1 when the instantaneous value of the reference signal is larger than the instantaneous value of either the power control feedback signal or the performance control feedback signal.

In throttle 8 position, the reference signal from LR has a maximum value of 50 volts. This condition is represented by point B on the constant horsepower curve in Fig. PF-3. The reference signal is less than 50 volts when operating at higher track speeds. This condition occurs between points A and B on the constant horsepower curve. The reference signal from LR decreases as the throttle is reduced.

When operating in throttle 8 position, the engine speed governor and load regulator tend to cause the locomotive to operate along the constant horsepower curve from point A to point C as locomotive speed decreases. However, the reference signal from LR must be slightly higher than the feedback signal in order to maintain excitation to the main generator. The power control feedback signal increases as it moves to the right. Therefore, operation on the constant horsepower curve between points B and C cannot occur as the reference signal has a maximum value of 50 volts and the power control feedback signal would be above 50 volts between B and C on the constant horsepower curve.

A decrease in speed from point B causes the operating point to move toward point D and results in a decrease in horsepower output from the locomotive. A further decrease in speed from point D causes the operating point to move

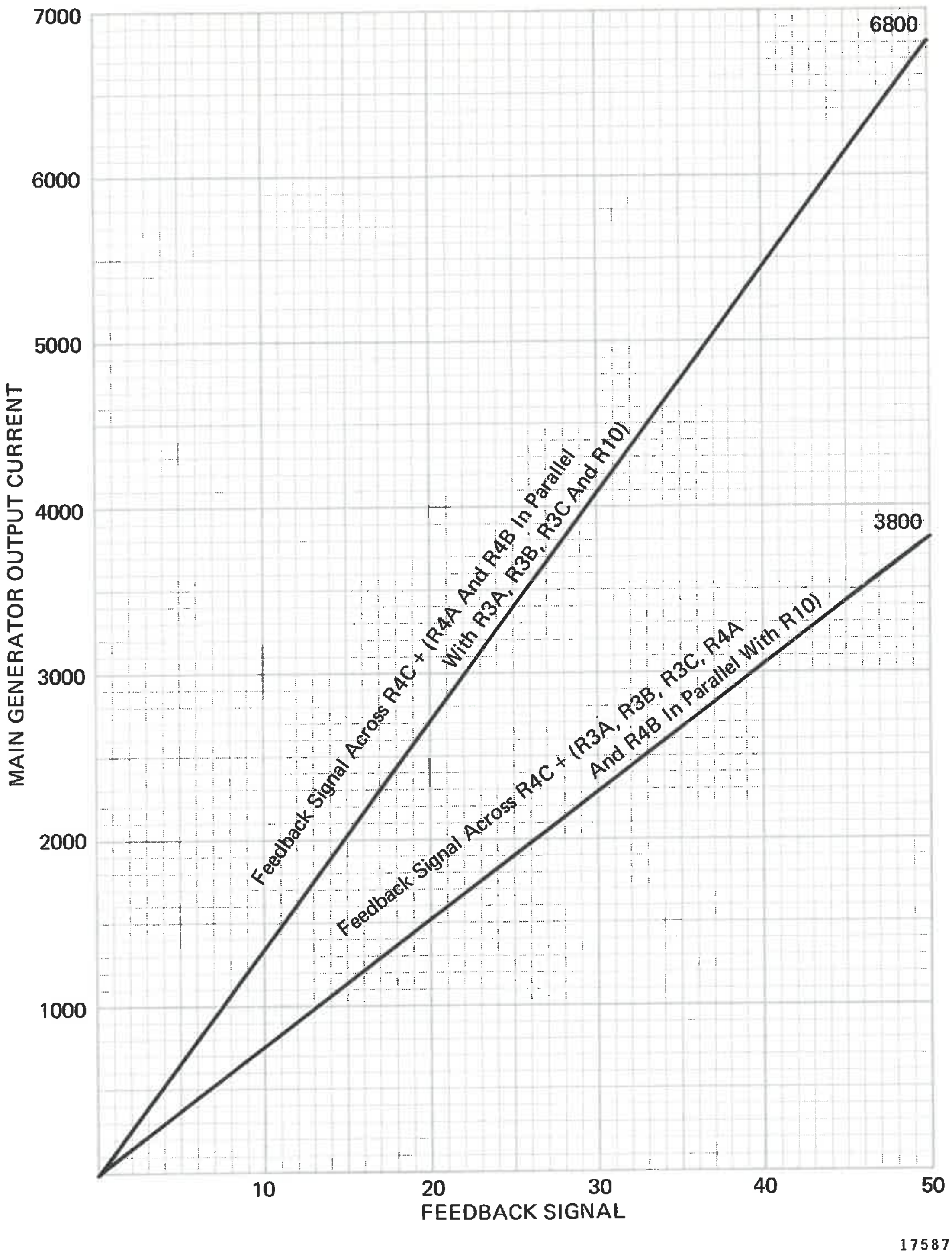

Fig. PF-2 – Relationship Between Feedback Signal And Main Generator Current (Series-Parallel Operation)

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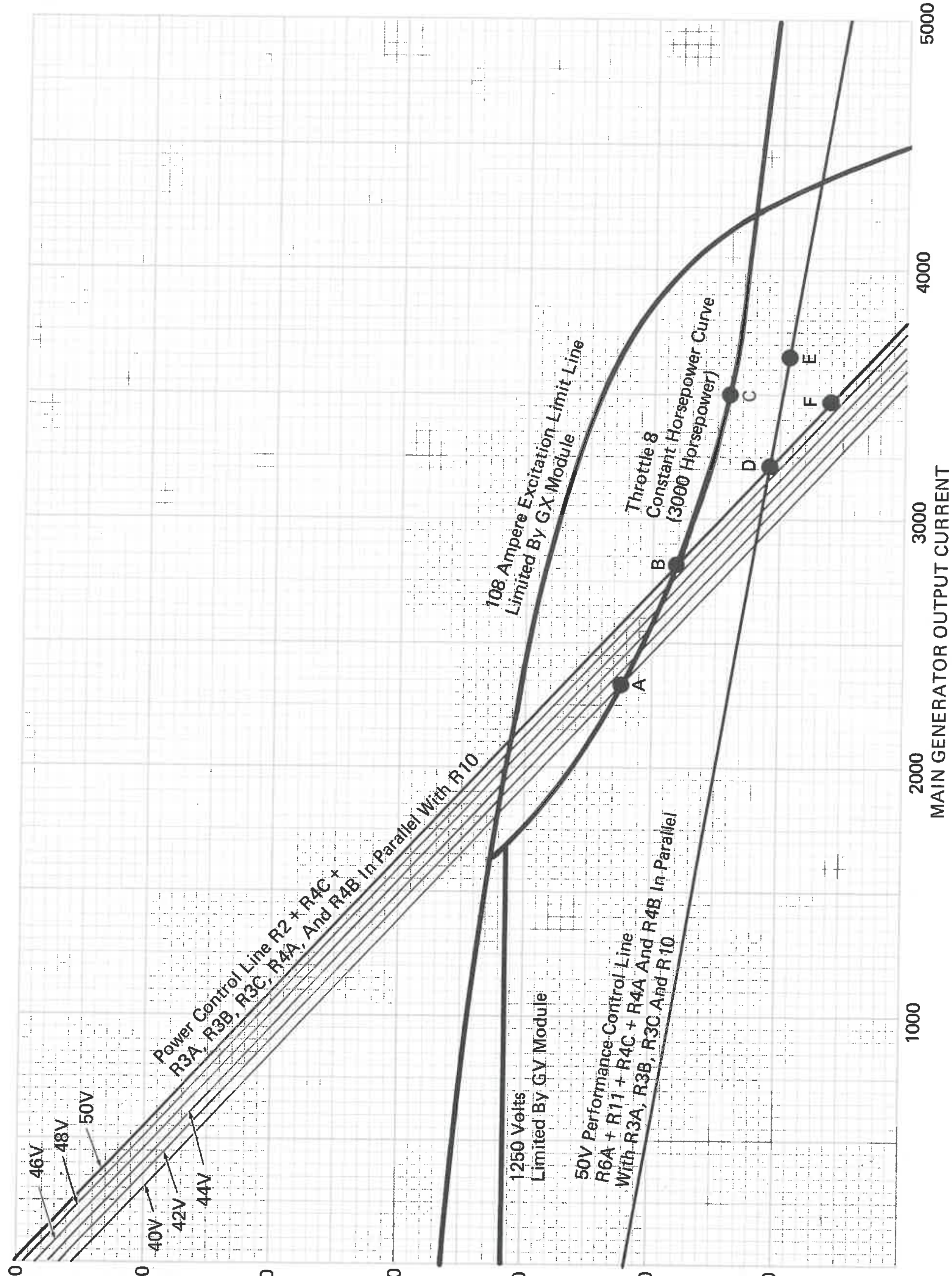


Fig. PF-3 – Relationship Of Power Control Feedback Signal, Performance Control Feedback Signal And Main Generator Output (Series-Parallel Operation) toward point E instead of toward point F. Movement of the operating point toward point E provides for a larger horsepower output than movement toward point F, but any increase in current from point D should be for a short time only. The purpose of the performance control line is to provide optimum power within adhesion considerations at low speed and to operate in consists with less powerful locomotives.

MAIN GENERATOR VOLTAGE FEEDBACK SIGNALS DURING PARALLEL OPERATION

The rectifier assembly consisting of diodes D1 through D6 is connected to generator potential transformer GPT2. This rectifier assembly output is applied to resistors R1A, R1B, R1C, and R2 connected in series. The resistance values are selected so that an output voltage of approximately 2800 volts from the main generator would result in a feedback signal of 50 volts across R2. The main generator voltage is limited to much less than 2800 volts, however, the 2800 volts is used in calculating the desired slope of the 50 volt feedback signal line and to establish the desired relationship between the feedback signal and main generator output voltage within the operating range of the main generator. This relationship is shown in Fig. PF-4.

The rectifier assembly consisting of diodes D13 through D18 is connected to generator potential transformer GPT1. The rectifier assembly output is applied to resistors R7, R5A, R5B, R6A, and R11 connected in series. The values of these resistors are selected so that an output voltage of approximately 1750 volts from the main generator would result in a feedback signal of 50 volts across R6A. The main generator voltage is limited to much less than 1750 volts, however, the 1750 volts is used in calculating the desired slope of the 50 volt feedback signal line and to establish the desired relationship between the feedback signal and main generator output voltage within the operating range of the main generator. This relationship is shown in Fig. PF-4.

MAIN GENERATOR CURRENT FEEDBACK SIGNALS DURING PARALLEL OPERATION

The rectifier assembly consisting of diodes D7 through D12 is connected to current transformers CTA, CTB, and CTC. The rectifier assembly output is applied to resistors R3A, R3B, R3C, R4A, R4B, R4C, and R8 in series. Resistor R8 is shorted out by BR1 contacts during power operation.

The resistance values are selected so that:

1. An output current of approximately 6000 amperes from the main generator would result in a 50 volt feedback signal across the series combination of R4A, R4B, and R4C.

2. An output current of approximately 2200 to 2700 amperes from the main generator would result in a 50 volt feedback signal across the series combination of R3A, R3B, R3C, R4A, R4B, and R4C.

The normal output current is limited to much less than 6000 amperes, however, the 6000 and 2200 to 2700 values are used in calculating the desired slope of the 50 volt feedback signal line and to establish the desired relationship between the feedback signal and main generator output current within the operating range of the main generator. The relationship of main generator output current and the feedback signals are shown in Fig. PF-5.

During dynamic brake operation, resistor R8 is placed in the circuit to obtain the desired relationship between the dynamic braking lever position and the feedback signal.

POWER CONTROL FEEDBACK SIGNALS DURING PARALLEL OPERATION

The power control feedback signal is obtained by combining the main generator voltage feedback signal developed across R2 with the main generator current feedback signal developed across the series combination of R3A, R3B, R3C, R4A, R4B, and R4C. The relationship between main generator output and the 50 volt power control feedback signal line is shown in Fig. PF-6.

Any combination of main generator current and voltage that intersects at a point above or to the right of the 50 volt power control feedback signal line will provide a feedback signal greater than 50 volts. Any combination of current and voltage that intersects at a point below or to the left of the 50 volt power control feedback signal line will provide a feedback signal less than 50 volts.

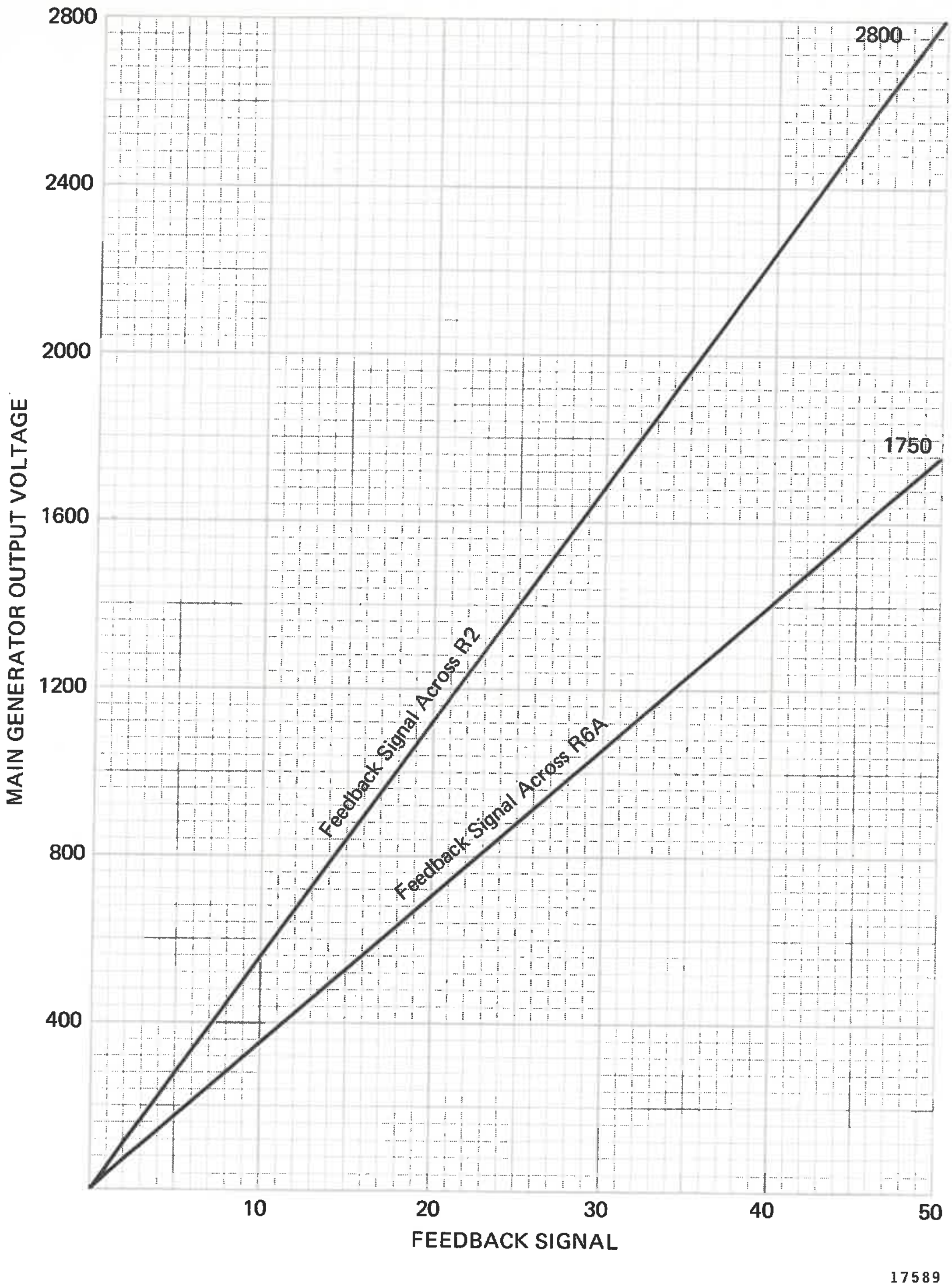


Fig. PF-4 -- Relationship Between Feedback Signal And Main Generator Voltage (Parallel Operation)

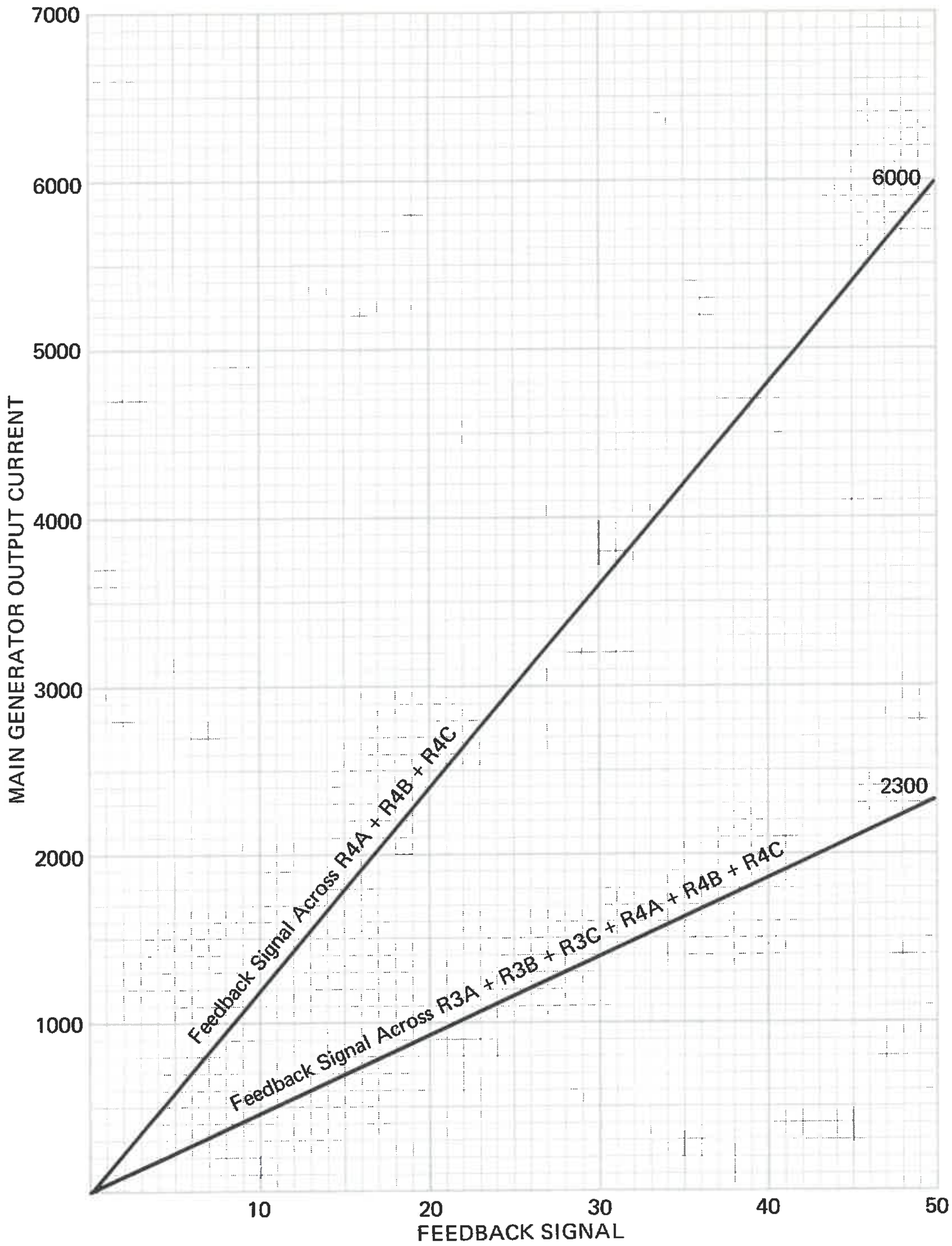


Fig. PF-5 – Relationship Between Feedback Signal And Main Generator Current (Parallel Operation)

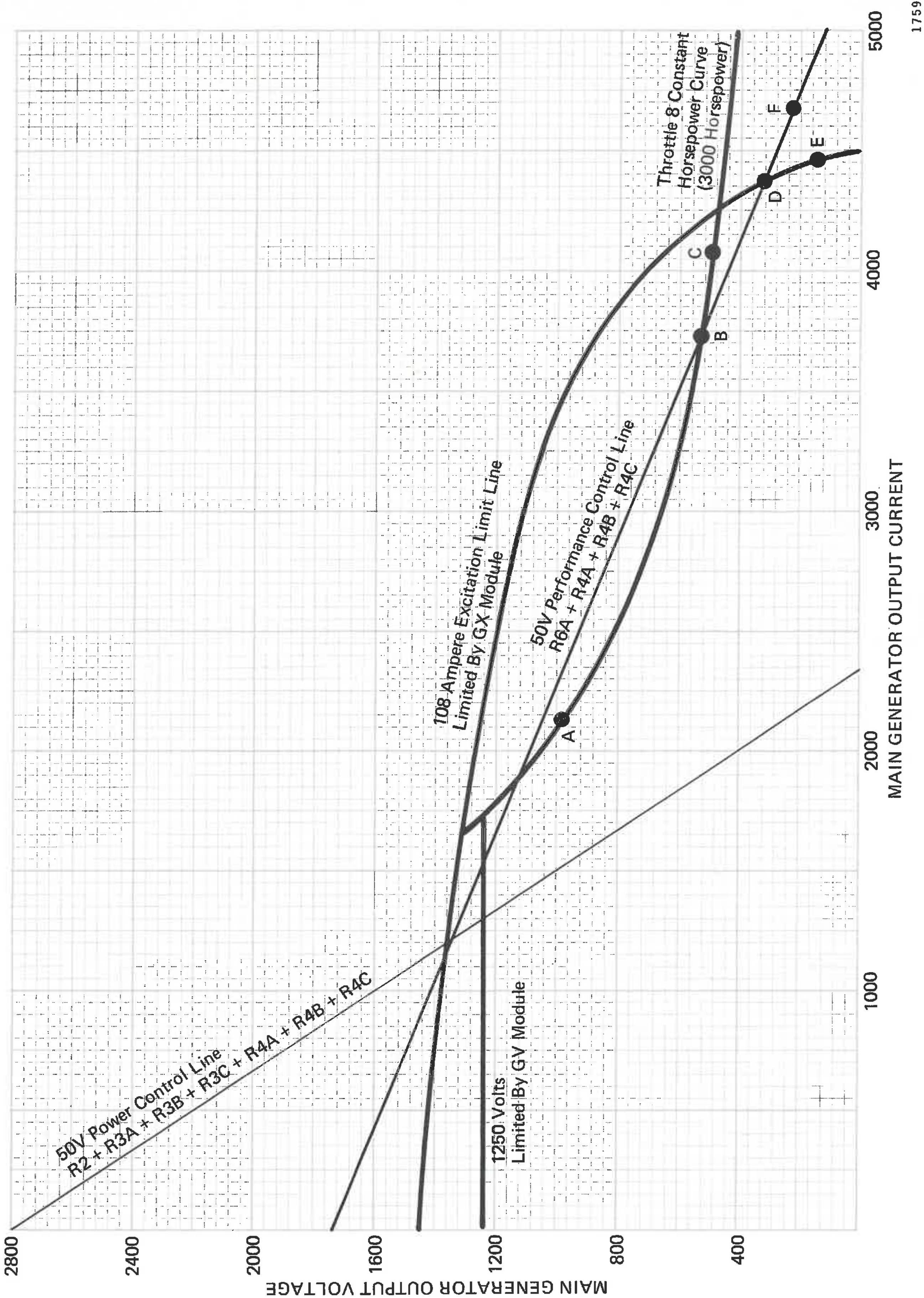


Fig. PF-6 -- Relationship Between Power Control Feedback Signal, Performance Control Feedback Signal, And Main Generator Output (Parallel Operation)

PERFORMANCE CONTROL FEEDBACK SIGNAL DURING PARALLEL OPERATION

The performance control feedback signal is obtained by combining the main generator voltage feedback signal developed across R6A with the main generator current feedback signal developed across the series combination of R4A, R4B, and R4C. The relationship between main generator output and the performance control feedback signal is shown in Fig. PF-6.

Any combination of main generator current and voltage that intersects at a point above or to the right of the 50 volt performance control feedback signal line will provide a performance control feedback signal greater than 50 volts. Any combination of voltage and current that intersects at a point below or to the left of the 50 volt performance control feedback signal line will provide a performance control feedback signal less than 50 volts.

POWER CONTROL AND PERFORMANCE CONTROL OPERATION DURING PARALLEL OPERATION

The power control and performance control feedback signals are applied to transistor Q1 in the SB module where they are compared with the reference signal from the load regulator LR. Forward bias is applied to Q1 when the instantaneous value of the reference signal is larger than the instantaneous value of either the power control feedback signal or the performance control feedback signal.

In throttle 8 position, the reference signal from LR has a maximum value of 50 volts. This condition is represented by point B on the constant horsepower curve in Fig. PF-6. The reference signal is less than 50 volts when operating at higher track speeds. This condition occurs between points A and B on the constant horsepower curve. The reference signal from LR decreases as the throttle is reduced.

When operating in throttle 8 position, the engine speed governor and load regulator tend to cause the locomotive to operate along the constant horsepower curve from point A to point C as locomotive speed decreases. However, the reference signal from LR must be slightly higher than the feedback signal in order to maintain excitation to the main generator. The feedback signal increases as it moves to the right. Therefore, operation on the constant horsepower curve between points B and C cannot occur as the reference signal has a maximum value of 50 volts and the feedback signal would be above 50 volts between B and C on the constant horsepower curve.

A decrease in speed from point B causes the operating point to move toward point D and results in a decrease in horsepower output from the locomotive. A further decrease in speed from point D causes the operating point to move toward point E instead of toward point F. Operation between point D and point E is the result of excitation limit by the GX module. Notice that locomotive operation is controlled by the constant horsepower curve and the performance control feedback signal line. The power control feedback signal line lies to the left of the horsepower line and performs no function during parallel operation.

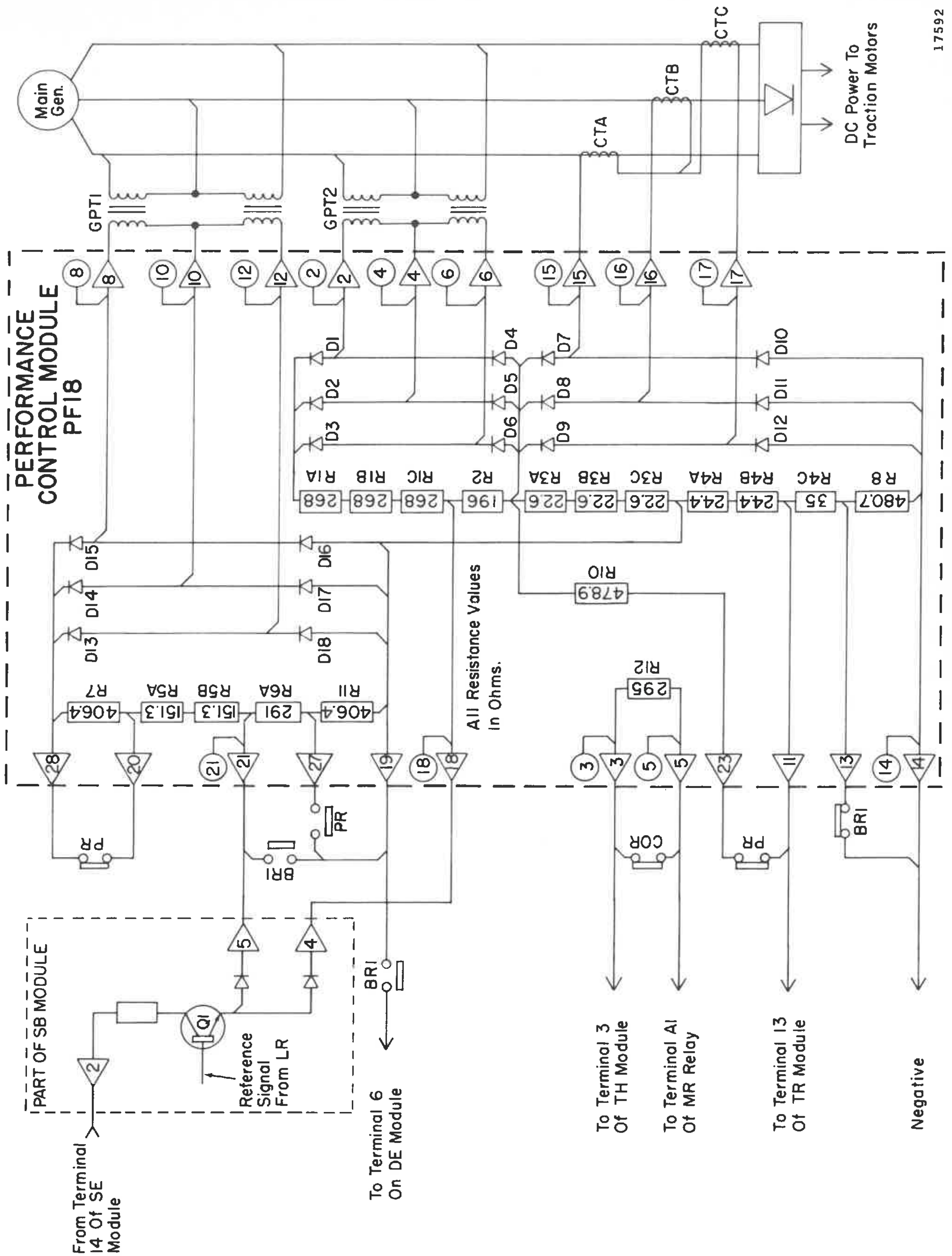


Fig. PF-7 – Performance Control Module, Simplified Schematic Diagram

RATE CONTROL MODULE, RC11

INTRODUCTION

The main generator excitation system has a very fast response. Therefore, an increase in throttle position tends to cause a sudden increase in power. The rate control module RC11 provides for a fast, but smooth, increase in power instead of a sudden increase. This response is accomplished by limiting the rate of increase in power by modifying the reference signal, between the throttle response circuit and the load regulator, during changes in throttle position. The rate of change is limited by controlling the bias at the base of transistor Q1 on the RC module, through a resistor-capacitor timing circuit. Operation of the RC module during power and during dynamic braking is described in the following paragraphs. A simplified schematic diagram of the RC module, Fig. RC-1, is provided for reference only. The applicable locomotive wiring diagram should be used when performing troubleshooting or maintenance on the system.

OPERATION OF RATE CONTROL MODULE WITH THROTTLE IN IDLE POSITION

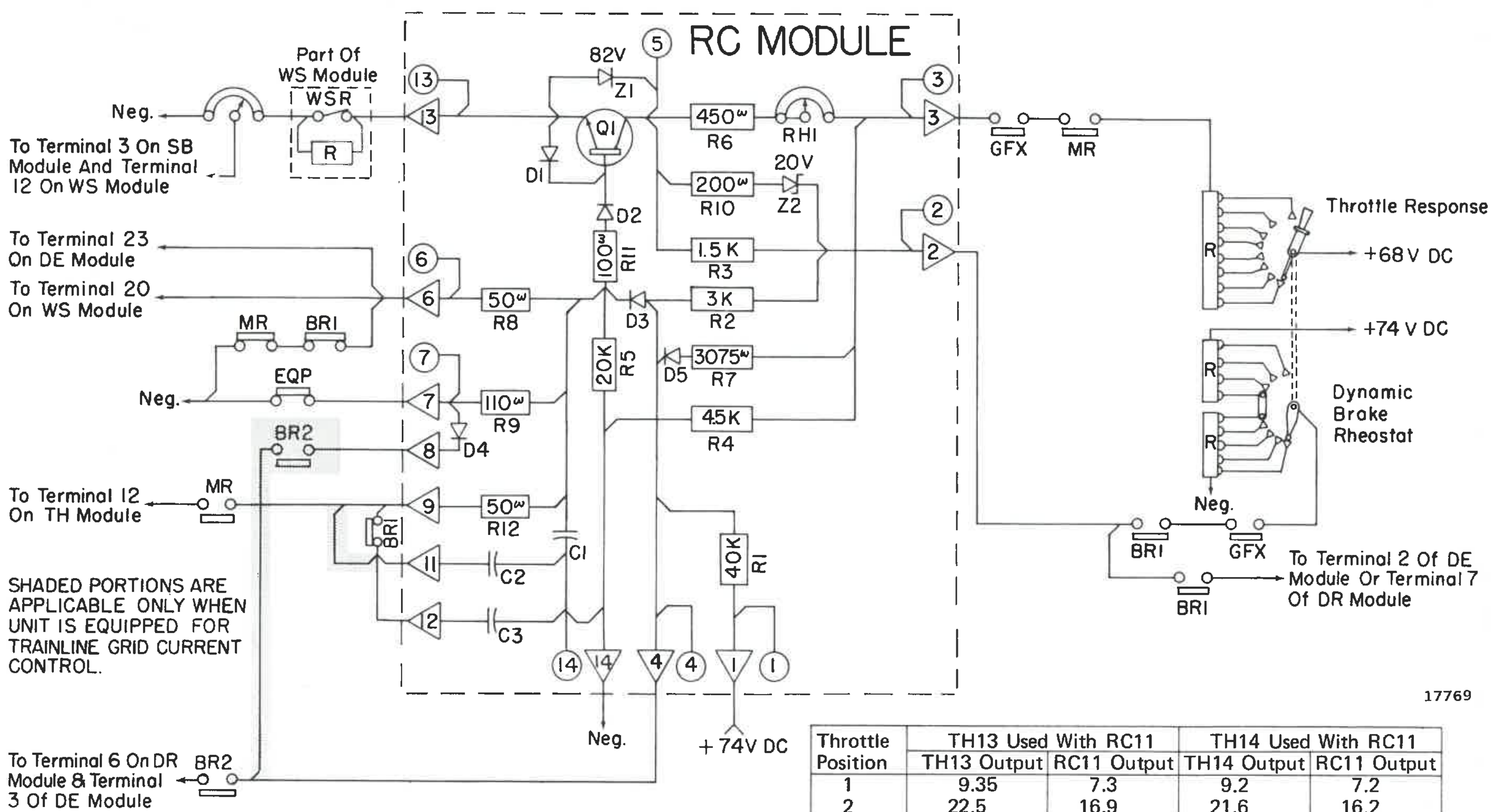
With the throttle in IDLE, there is no reference signal input to the RC module. However, a potential of 74 volts is applied between terminals 1 and 14. This 74 volts provides a current flow from terminal 1 through resistor R1 and diode D3 to capacitor C1 and resistors R5 and R8. The resistance ratio of R1 to R8 permits a very small charge on C1. This very small charge provides an initial forward bias for Q1 and results in a very small current flow through resistors R1, R2, and R3, from collector to emitter of Q1 and then through the load regulator LR to negative. Therefore, the 74 volts applied between terminals 1 and 14 provides an initial forward bias for Q1 and maintains a very small amount of conduction through Q1. This initial conduction is not sufficient to provide excitation to the main generator field, but it decreases turn on time of Q1.

OPERATION OF RATE CONTROL MODULE DURING POWER APPLICATION

The MR relay picks up when the throttle is advanced to Run 1 position. Pickup of MR provides a feed of approximately 9 volts to terminal 3 of the RC module. Pickup of MR also provides a small potential (approximately 4 to 6 volts) from terminal 12 of the TH module to terminals 9, 11, and 12 on the RC module. This 4 to 6 volts provides an immediate charge on capacitors C1, C2, and C3 and immediate power response. Otherwise, there would be a short time delay in power response while charging C1, C2, and C3 through R7 from terminal 3. The initial charge on C1, C2, and C3 from terminal 12 of the TH module is less than the potential applied to terminal 3. Therefore, capacitors C1, C2, and C3 will continue to charge through R7, D5, and D3 until the full charge for Run 1 position is attained.

It should be noted that the voltage across the load regulator LR increases at the same rate as the increase in forward bias applied to the base of Q1. There is an immediate low level response when the throttle is advanced to Run 1 position, due to the initial charge on C2 and C3. After this initial response, the rate of increase in forward bias is determined by the resistance of R7 and the capacitance of C1, C2, and C3. The values of R7, C1, and C3 are selected to provide a fast and smooth response instead of a sudden increase.

Advancing the throttle results in an increase in reference voltage applied to terminal 3 from the TH module, an increase in bias, an increase in current flow through Q1, and an increase in voltage developed across the load regulator LR. With the throttle in Run 8 position, the voltage applied to terminal 3 is 68 volts and the voltage across LR and the bias applied to the base of Q1 is approximately 50 volts. The ratio of applied reference voltage to the LR voltage is approximately 1.36 to 1 for all throttle positions. The



Throttle Position	TH13 Used With RC11		TH14 Used With RC11	
	TH13 Output	RC11 Output	TH14 Output	RC11 Output
1	9.35	7.3	9.2	7.2
2	22.5	16.9	21.6	16.2
3	31.2	23.2	28.6	21.3
4	43.0	31.8	35.7	26.5
5	51.2	37.8	43.3	32.0
6	57.3	42.2	51.2	37.8
7	63.2	46.5	61.4	45.2
8	68.0	50.0	68.0	50.0

Table gives nominal values for normal operation or with SB module removed.

Relationship Between Throttle Position, Input Voltage From TH Modules, And Output From The RC Module.

Fig. RC-1 – Rate Control Module Simplified Schematic Diagram relationship between throttle position, input voltage from TH modules, and output from the RC module is shown in Fig. RC-1.

Reducing the throttle from Run 8 to Run 7 position results in reducing the applied reference voltage. This reduction of applied voltage results in a discharge of capacitors C1, C2, and C3 to a value proportional to the input reference voltage. Capacitors C1, C2, and C3 discharge through R5 and from base to emitter of Q1. The MR relay drops out when the throttle is reduced to IDLE. Dropout of MR provides a fast discharge path for C1, C2, and C3 through R8.

Terminal 6 of the RC module is connected to the WS module. If wheel slip is detected, terminal 6 will be connected to negative through the WS module. With terminal 6 connected to negative, C1, C2, and C3 will discharge rapidly through R8 to terminal 6 of the RC module then through the WS module to negative. Discharging C1, C2, and C3 results in less excitation to the main generator and less power is applied to the traction motors. Capacitors C1, C2, and C3 will continue to discharge until the wheel slip is corrected. For a more detailed description of wheel slip correction refer to coverage of the wheel slip control circuit.

OPERATION OF RATE CONTROL MODULE ON LOCOMOTIVES EQUIPPED WITH BASIC DYNAMIC BRAKES

When dynamic brakes are applied, the reference signal from the dynamic brake rheostat is applied to terminal 2 of the RC module. The signal applied to terminal 2 of RC causes a current flow through R2 and D3 to capacitors C1, C2, and C3 and resistor R5. This current flow results in voltage build up across capacitors C1, C2, and C3 and consequently forward bias on the base of Q1. The increased forward bias results in an increase of current from collector to emitter of Q1 and a larger voltage is developed across load regulator LR. This increase in current is supplied from terminal 2 through R3 and to the collector of Q1.

The voltage developed across LR as determined by collector to emitter current does not increase suddenly as the braking lever is advanced, but increases at the same rate as the increase in bias applied to the base of Q1. The rate of increase in bias is determined by the resistance of R2 and the capacitance of C1, C2, and C3.

Advancing the braking lever results in an increase in the signal applied to terminal 2 of the RC module. Resistor R3 and load regulator LR form a voltage divider for the input signal. The voltage across R3 is approximately equal to the voltage across LR for all values of signal input voltage up to 40 volts. This voltage divider action provides close control of excitation during low braking effort. Zener diode Z2, connected across R3, has a breakdown voltage rating of 20 volts. Therefore, Z2 breaks down when the voltage across R3 reaches 20 volts. After breakdown of Z2, any further increase in signal input to terminal 2 of the RC module results in a corresponding increase in voltage developed across LR and results in a faster increase in excitation during high braking effort.

When the braking lever is reduced, the input signal decreases and capacitors C1, C2, and C3 slowly discharge through R5 and from base to emitter of Q1. If the braking lever is rapidly reduced from high braking effort to low braking effort, the voltage at the base of Q1 will be much higher than the voltage at the collector. This difference in potential tends to cause a reverse discharge current flow from base to collector then through the dynamic brake rheostat to negative. The 200 ohm resistor R10 prevents excessive current flow through zener diode Z2. Therefore, the reverse current from collector of Q1 to the dynamic brake rheostat must flow through R3 and R10. The resistance of R10 limits the reverse current and thereby protects Q1 from breakdown due to the reverse current.

If the braking lever is positioned to release the brakes, the BR relay drops out and capacitors C1, C2, and C3 will rapidly discharge through the 50 ohm resistance of R8 to terminal 6 and then to negative. Capacitors C1, C2, and C3 will discharge through R9 to terminal 7 and then to negative if the EQP relay drops out.

LIMITING BRAKING GRID CURRENT TO 700 AMPERES

Terminals 4 and 8 of the RC module are connected, through BR2 contacts, to terminal 6 on the dynamic brake regulator module DR. If the braking grid current increases above 700 amperes, terminals 4 and 8 of the RC module will be connected to negative through the DR module. With terminal 4 connected to negative, the brake control input signal is removed from C1, C2, and C3 allowing rapid discharge through R9 of the RC module. Discharging of C1, C2, and C3 results in less voltage across LR and less braking effort. When braking grid current decreases below 700 amperes, terminals 4 and 8 are disconnected from negative and the brake control signal is again applied to C1, C2, and C3. This regulating action protects the dynamic braking grids by limiting braking current to a maximum of 700 amperes. For a more detailed description of the dynamic brake regulating action refer to coverage of the dynamic brake regulator module DR.

REGULATING BRAKING GRID CURRENT PROPORTIONAL TO BRAKING LEVER POSITIONS ON LOCOMOTIVES EQUIPPED WITH BASIC DYNAMIC BRAKES

As an optional extra, the locomotive may be designed to regulate braking grid current at a value proportional to braking lever position. The following paragraphs describe the operation of the RC module when this option is requested by the customer.

A signal proportional to braking lever signal is provided from terminal 2 of the RC module to terminal 7 of the DR module. A signal proportional to braking grid current is applied to terminals 9 and 11 of the DR module. The braking grid current signal is compared to the braking lever signal by the DR module. If the braking grid current signal tends to rise above the braking lever signal, the DR module operates to rapidly discharge capacitors C1, C2, and C3 through resistor R9 and terminal 8 on the RC module and through the DR module to negative. Refer to coverage of the DR module for detailed description of this regulating action.

OPERATION OF THE RC MODULE ON LOCOMOTIVES EQUIPPED WITH EXTENDED RANGE DYNAMIC DYNAMIC BRAKES

On locomotives equipped with extended range dynamic brakes, terminal 6 of the RC module is connected to terminal 23 of the DE module and terminal 2 of the RC module is connected to terminal 2 of the DE module.

The connection between terminal 2 of RC and terminal 2 of the DE module applies the braking lever signal from the dynamic brake rheostat to the DE module for comparison with the braking grid current signal from transformer T4. If the braking grid current signal rises above the braking lever signal, the DE module operates to provide an input between terminals 4 and 5 of the DR module. This signal results in discharging capacitors C1, C2, and C3 through R9 and terminal 8 on the RC module then to negative through the DR module. Refer to coverage of the DR module for detailed description of this regulating action.

The connection between terminal 6 of the RC module and terminal 23 of the DE module provides a fast discharge path for C1, C2, and C3 during the time interval between pickup of the extended range dynamic brake pilot relay DP and pickup of the dynamic brake shorting contactor. Discharging C1, C2, and C3 causes a decrease in voltage across LR which results in less excitation to the fields of the traction motors. This reduced excitation prevents excessive braking current after pickup of the dynamic brake shorting contactor. The discharge path for C1, C2, and C3 is through R8 to terminal 6 on the RC module, then through the DE module to negative.

SENSOR BYPASS MODULE, SB11

INTRODUCTION

The sensor bypass module SB11 limits main generator output to a value proportional to throttle position. This is accomplished by comparing the load regulator reference signal with main generator feedback signals from the performance control module PF. A simplified schematic diagram of the SB module, Fig. SB-1, is included for reference only. The applicable locomotive wiring diagram should be used when performing troubleshooting or maintenance.

GENERAL DESCRIPTION

The sensor bypass module, Fig. SB-1, compares the reference signal from the load regulator LR with main generator feedback signals from the performance control module PF. The reference signal from LR is proportional to throttle position and the feedback signals from PF are proportional to main generator output voltage plus main generator output current.

Some PF modules are designed to provide two feedback signals, a power control feedback signal and a performance control feedback signal, to the emitter of Q1 on the SB module. Other PF modules provide only the power control feedback signal. The following description applies to the SB module as used with PF modules providing two feedback signals. However, operation of the SB module is basically the same for one feedback signal as for two feedback signals. Refer to description of the PF module for detailed description of the feedback signals.

If the reference signal from LR is smaller than both of the feedback signals from PF, transistor Q1 in the sensor bypass module SB is turned off and no current flows through the magnetic amplifier control windings on the SE module. With current through the magnetic amplifier control winding cut off, gating pulses to the silicon controlled rectifier SCR are also cut off and no excitation is applied to the main generator field.

If the reference signal from LR is instantaneously larger than either of the feedback signals from PF, transistor Q1 on the SB module is turned on and allows current flow through the magnetic amplifier control windings of the SE module. With current flowing through the magnetic amplifier control windings, gating pulses are applied to the silicon controlled rectifier SCR. The gating pulses result in applying excitation to the main generator field. The amount of excitation applied to the main generator field is proportional to the magnitude of current flowing through the magnetic amplifier windings. The magnitude of current flowing through the magnetic amplifier control windings and consequently the strength of the main generator field is proportional to the value of the reference signal from LR.

The reference signal from LR is applied through terminal 3 and resistors R1 and R4 to the base of Q1. The emitter of Q1 is connected to the power control feedback signal and the performance control feedback signal through diodes D2 and D3. The power source that supplies current to the magnetic amplifier control windings in the SE module is applied to terminal 1 of the SB module.

When Q1 is forward biased, current flows from terminal 1 through R3 to terminal 7, through the GX module, through the SE module magnetic amplifier control windings to terminal 2 of the SB module, through R2 and Q1, then through diode D2 or diode D3 to the PF module.

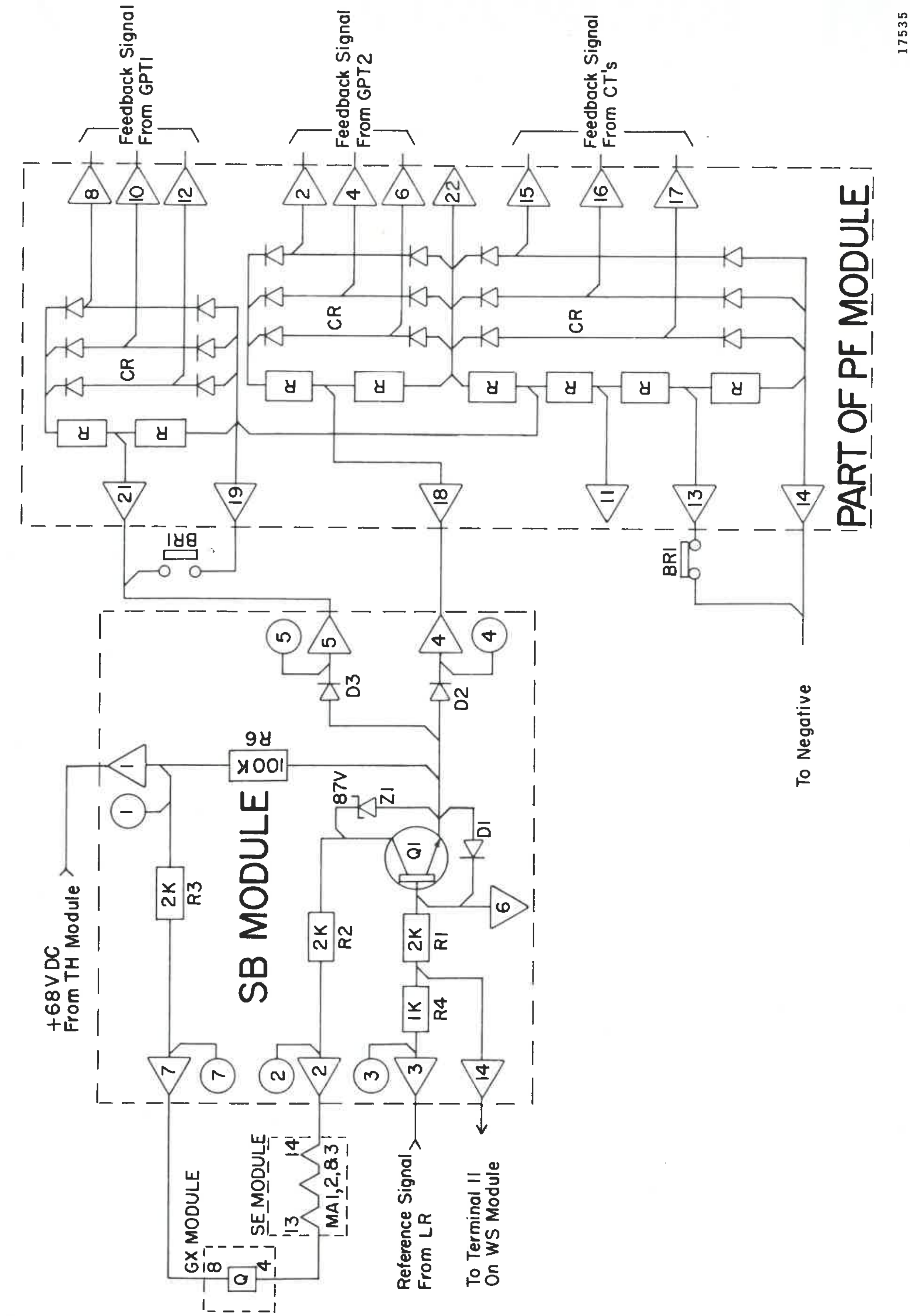


Fig. SB-1 – Sensor Bypass Module, Simplified Schematic Diagram

SILICON CONTROLLED RECTIFIER ASSEMBLY, SCR

Excitation to the main generator field is provided by the D14 alternator through the three phase silicon controlled rectifier assembly SCR. A simplified schematic diagram of the SCR assembly, Fig. SCR-1, is provided for convenient reference only. The locomotive wiring diagram should be used when performing troubleshooting or maintenance.

One silicon controlled rectifier is connected in series with each of three phases of the D14 alternator. Therefore, one of the silicon controlled rectifiers is forward biased during each positive alternation of output voltage from the D14 alternator. However, the silicon controlled rectifier will not conduct until the forward bias is accompanied by a gating signal to the cathode gate. The gating signal is a voltage, applied to the cathode gate, which is positive in respect to the voltage applied to the cathode. Therefore, the potential on both the anode and cathode gate must be positive in respect to the cathode in order to turn on the silicon controlled rectifier. After conduction starts, the gating signal loses control and conduction continues as long as the anode is positive in respect to the cathode. The silicon controlled rectifier turns off due to reverse bias between anode and cathode at the completion of the positive alternation. After turn off, conduction will not start until forward bias is accompanied by the gating signal.

Gating pulses are applied to the silicon controlled rectifiers from the SE module as necessary to maintain the required excitation current to the main generator field. The amount of excitation required is determined by comparing the reference signal from the load regulator with feedback signals from the PF module. This comparison is made in the SB module. If the reference signal is instantaneously larger than the feedback signal, the transistor in the SB module is forward biased causing the transistor to turn on and results in current flow through the SE module magnetic amplifier control windings. If the feedback signal is instantaneously larger than the reference signal, the transistor in the SB module is reverse biased and no current flows through the magnetic amplifier windings.

Current flow through the control windings drives the core of the magnetic amplifier into saturation. Saturating the core causes turn on of the transistor in the SE module and results in providing gating signals to the SCR assembly. The point at which the core becomes saturated is determined by the amount of current flow through the control windings. The amount of current flow through the control windings is determined by the value of the reference signal from LR.

If the reference signal is small, a small amount of current flows through the control windings and the core is saturated late in the positive half cycle. Therefore, the gating signal occurs late in the positive half cycle and excitation current flows for only a short period of time during the positive half cycle. If the reference signal increases, the current flow through the control windings increases and the core is saturated earlier in the positive half cycle and the gating signal occurs earlier in the positive half cycle. This results in flow of excitation current for a longer period of time and increases the average amount of excitation to the main generator field.

Excitation current passes through the silicon controlled rectifiers only during a portion of the positive half cycle. However, the current through the main generator field is relatively stable. Resistor RE32 and capacitor CA32 are used for spike suppression. The flux lines from the main generator field tend to collapse during the negative half cycles. However, the decaying flux field induces a voltage into the field windings which causes a current to flow through the free wheeling diode FWD and through the main generator field. This results in a slowly decaying flux field instead of a sudden collapse and maintains a relatively stable field strength.

Refer to the description of the SE module for a more detailed description of the gating signals.

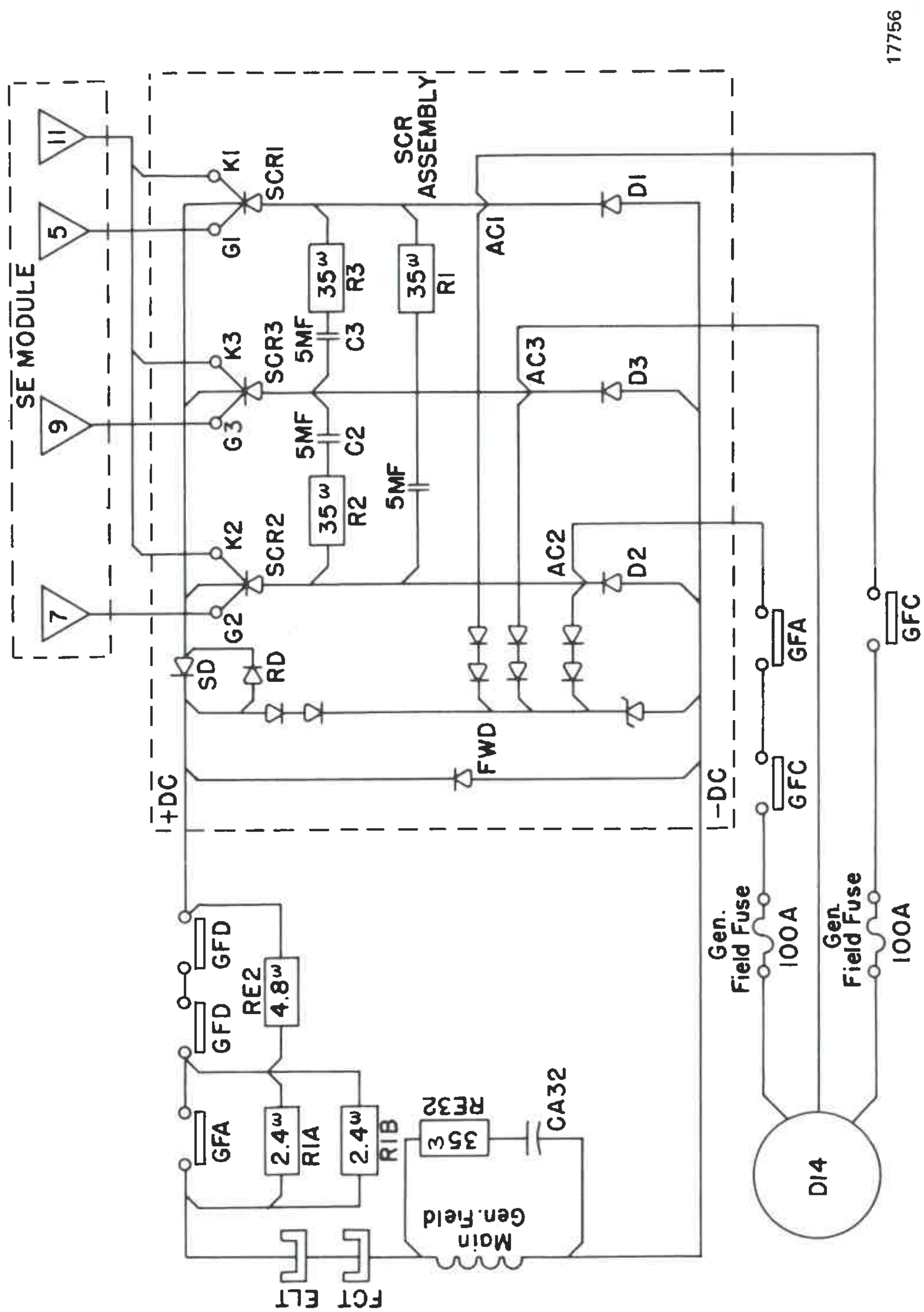


Fig. SCR-1 -- SCR Assembly, Simplified Schematic Diagram

SENSOR MODULE, SE

The sensor module SE provides gating signals to the silicon controlled rectifiers in the SCR assembly as necessary to maintain proper excitation of the main generator field. The SE module contains three identical channels, one for each phase of output from the D14 alternator. Since all three channels operate in the same manner, only one channel will be described in this section. A simplified schematic diagram of channel B, Fig. SE-1, is provided for reference only.

A simplified schematic diagram of a typical SE module, Fig. SE-2, is shown for convenient reference. The locomotive wiring diagram should be used when performing troubleshooting or maintenance.

The main generator field excitation current is provided by the D14 alternator through silicon controlled rectifiers SCR1, SCR2, and SCR3 on the SCR assembly. The silicon controlled rectifiers will not conduct until they are forward biased and a gating signal is applied to the cathode gate. The gating signal is a voltage, applied to the cathode gate, which is positive in respect to the cathode. After conduction starts, the gating signal loses control and conduction continues as long as the anode is positive in respect to the cathode.

Forward bias is applied to SCR1 during each positive half cycle of phase B voltage from the D14 alternator. Therefore, the gating signal from terminal 5 of the SE module must be positive in respect to terminal 11 at some time during the positive half cycle of phase B voltage in order to turn on SCR1. Terminal 5 is positive in respect to terminal 11 only when current flows through R4 and Q1.

When phase B is negative, the top of the secondary of transformer T1 is positive and current flows through diode D1, resistor R1, and the output winding of magnetic amplifier MA1. This current flow through the output winding causes the core of MA1 to reset (magnetic lines of force reduced to zero). Current also flows through diode D2 to charge capacitor C1. Section C of T1 applies reverse bias to transistor Q1 so that Q1 cannot conduct during the half cycle when phase B is negative. Therefore, the charge remains on capacitor C1 until transistor Q1 turns on. Zener diode Z1 limits the voltage on the emitter of Q1 to 9.1 volts.

When phase B is positive, the bottom of the secondary of T1 is positive and current flows through the output winding of MA1, then through D3, R8, and R6. Inductance of the output winding is very high and practically all of the output voltage from section C of T1 is developed across the output winding of MA1 until the core of MA1 is driven into magnetic saturation. The lines of force from the output winding are not sufficient to saturate the core and the forward bias on Q1 is too small to turn on Q1.

Transistor Q1 in the sensor bypass module SB is turned on when the reference signal from the load regulator is larger than the feedback signal from the PF module. Turn on of Q1 in the SB module provides a path for current flow through control winding No. 1 of MA1 in the SE module. The lines of force set up by current flow through control winding No. 1 aids the lines of force set up by the current flow through the output winding of MA1 during the positive half cycle of phase B voltage and results in driving the core of MA1 into magnetic saturation. Driving the core of MA1 into saturation causes a decrease in the voltage developed across output winding No. 1 of MA1 and results in an increase of forward bias of Q1 on the SE module. This increase in forward bias causes Q1 to turn on and results in discharge of C1 through R2, R3, R4, and from collector to emitter of Q1. The voltage developed across R4 provides the gating signal to SCR1 on the SCR assembly. The gating signal causes SCR1 to turn on and provide excitation current to the main generator field during the remainder of the positive half cycle of phase B voltage.

The average amount of excitation current applied to the main generator is determined by the instant in the cycle when the core of MA1 is driven into saturation. Excitation is large if saturation occurs early in the positive half cycle and small if saturation occurs late in the positive half cycle. The point of saturation is determined by the amount of current flow through control winding No. 1. If the reference signal from the load regulator is smaller than the feedback signal from the PF module, no current flows through control winding No. 1 and SCR1 is not gated on. If the reference signal from the load regulator is larger than the feedback signal, current will flow through control winding No. 1. The amount of this current flow is directly proportional to the difference between the reference signal and the feedback signal. Saturation of the MA1 core occurs early in the positive half cycle, if the current flow is large. Saturation occurs late in the positive half cycle, if the current flow is small.

During dynamic braking, a resistor (not shown in Fig. SE-2) in series with control winding No. 1 is shorted out by pick up of BR-1 contacts. This results in an increase in current flow through control winding No. 1. Pickup of BR-1 also connects control winding No. 2 across the main generator output. The lines of force set up by control winding No. 2 oppose the lines of force set up by control winding No. 1. Increasing the current flow through control winding No. 1 and energizing control winding No. 2 shifts the operating point of MA1 to a more stable region during dynamic braking.

The values of resistors R1, R7, and R8 are selected as necessary to provide proper operation of the SE module.

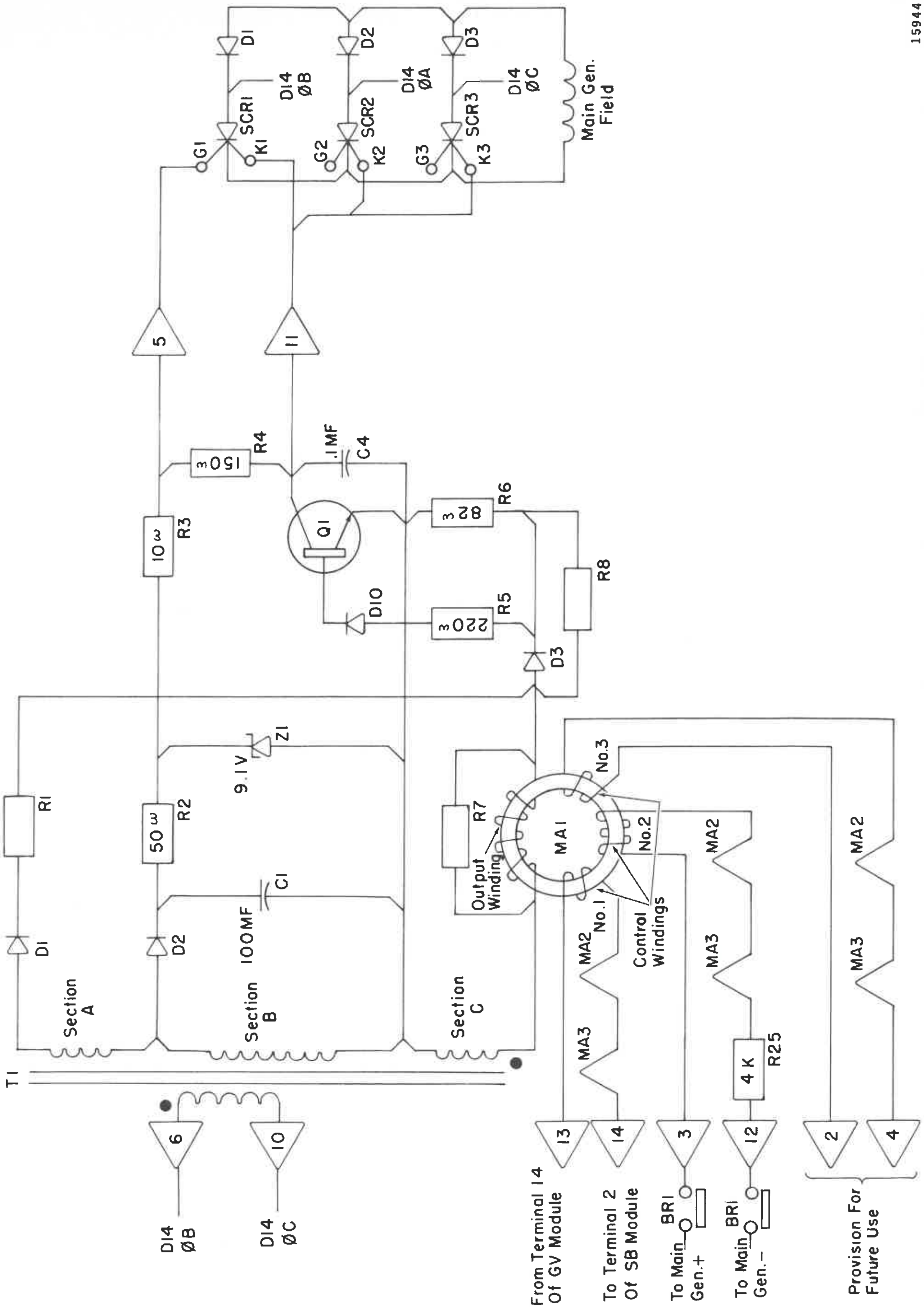


Fig. SE-1 – Channel B Of SE Module – Simplified Schematic Diagram

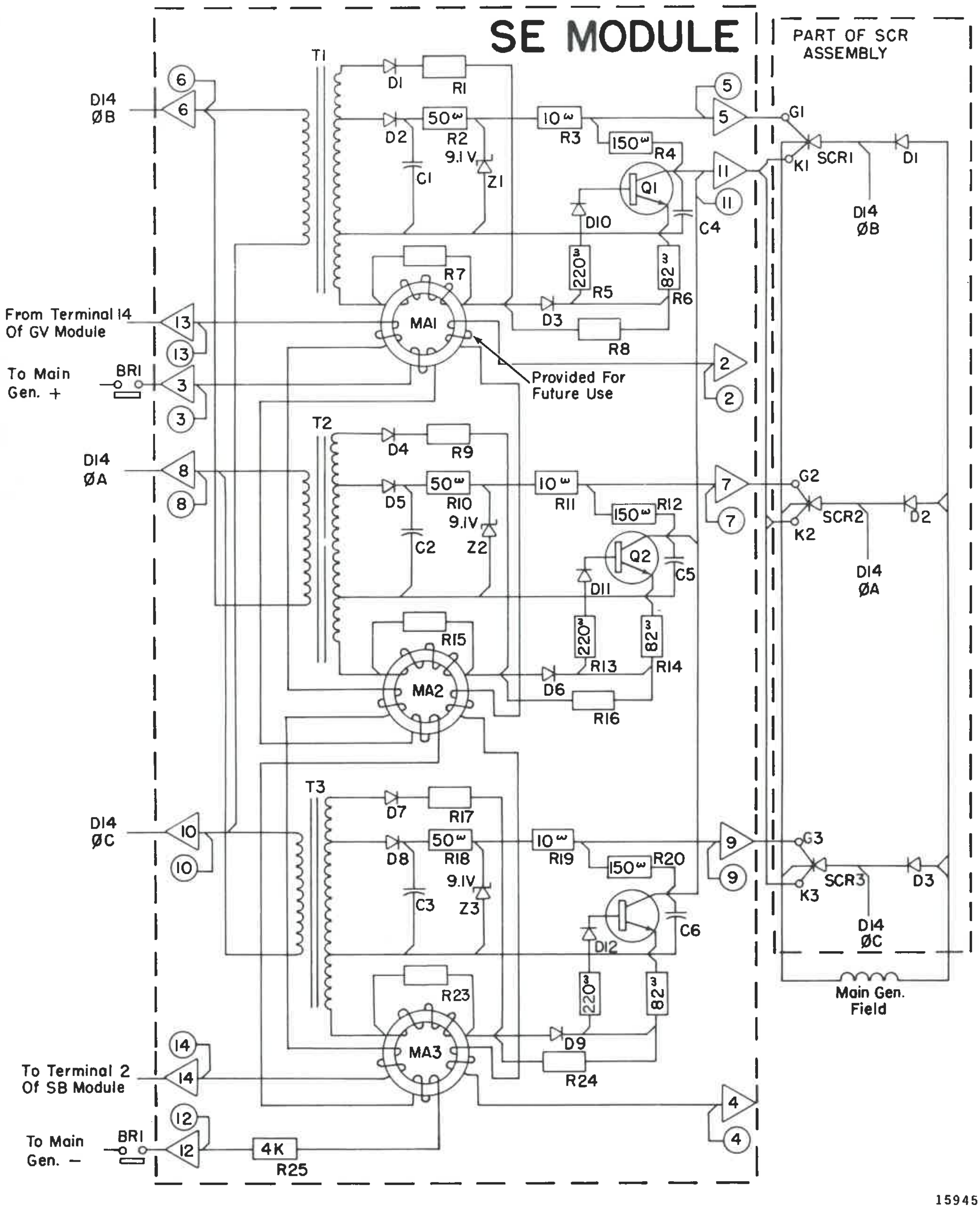


Fig. SE-2 – Sensor Module - Simplified Schematic Diagram

VOLTAGE REFERENCE REGULATOR AND THROTTLE RESPONSE MODULE

INTRODUCTION

The voltage reference regulator and throttle response modules TH13 and TH14 contain a voltage reference regulator circuit and a throttle response circuit. Output of the voltage reference regulator provides a very stable 68 volts DC to the throttle response circuit and to the sensor bypass module SB. Output of the throttle response circuit, which is proportional to throttle position, is applied to the rate control module for controlling locomotive power in accordance with throttle position.

The same voltage reference regulator circuit is used on both TH modules. The throttle response circuit is the same on both TH modules, except for resistance values of the throttle response resistors R1 through R7. A simplified schematic diagram of the TH module, Fig. TH-1, with resistance values of R1 through R7 for TH13 and TH14, is provided for reference only.

VOLTAGE REFERENCE REGULATOR CIRCUIT

The voltage reference regulator VRR provides a stable 68 volts DC input reference voltage to the throttle control circuit and to the sensor bypass (feedback comparison) module SB. Nominal input voltage to VRR is 74 volts DC from the auxiliary generator. The output voltage of VRR is equal to the input voltage minus the collector to emitter voltage E_{ce} of transistor Q4. VRR is designed so that E_{ce} of Q4 varies with changes in input voltage and changes in load to maintain a very stable 68 volts DC output voltage.

When the input voltage is exactly 74 volts, E_{ce} of Q4 will be 6 volts and the output voltage of VRR will be 68 volts. If the input voltage of VRR increases above 74 volts, E_{ce} of Q4 will increase to maintain a 68 volt output. If the input voltage decreases below 74 volts, E_{ce} of Q4 will decrease to maintain a 68 volt output provided the input voltage remains above 68 volts. E_{ce} of Q4 is controlled by the bias applied to the base of Q4. A change in load applied to the output of VRR tends to change the output voltage of VRR, but E_{ce} changes to compensate for variable loads and thus maintains a stable output voltage with changes in input voltage or changes in load.

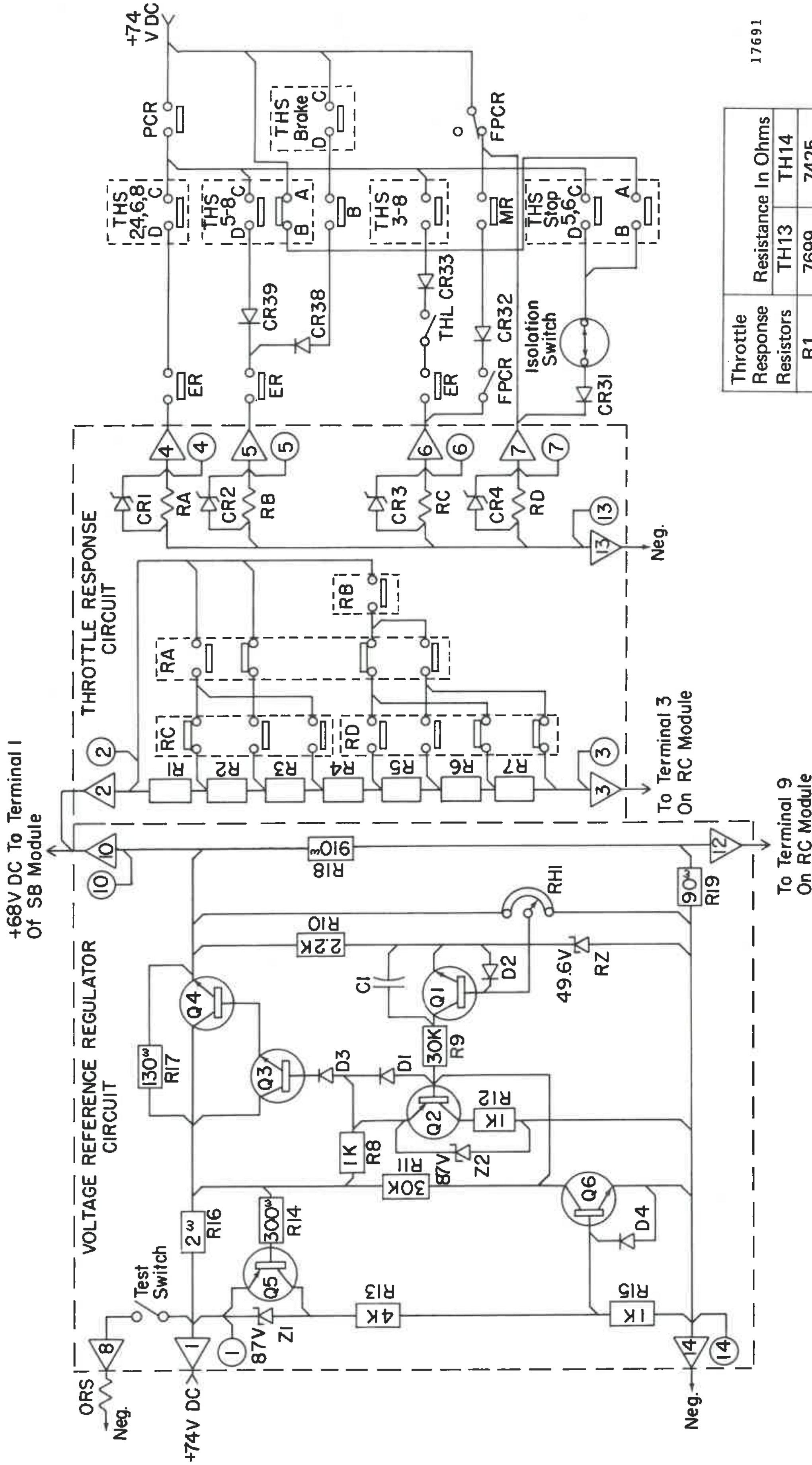
Transistor Q1 with rheostat RH1, reference zener diode RZ, and resistors R9, R10, and R11 monitor the output voltage of VRR and controls the operation of transistor Q2. Transistor Q2 and resistor R8 control operation of transistor Q3 and transistor Q3 controls operation of Q4.

Reference zener diode RZ is connected to the emitter of transistor Q1. The voltage across a zener diode tends to drift slightly as current through it changes. Resistor R10 provides a stabilizing current to RZ. With the stabilizing current established, the very small additional emitter current I_e of Q1 will have no effect on the voltage across RZ. Therefore, RZ maintains a constant positive voltage at the emitter of Q1.

Rheostat RH1 provides a positive voltage at the base of Q1. This positive voltage increases with an increase in output voltage of VRR and decreases with a decrease in output voltage of VRR.

Resistor R11 places a positive voltage at the base of Q2 when Q1 is not conducting. Current flows through resistor R11, diode D1, diode D3, and from base to emitter of Q3 and Q4. This current flow results in reverse bias on Q2 and prevents conduction of Q2 when Q1 is not conducting.

Resistors R9 and R11 are used as voltage dividers when Q1 is conducting. The current flowing through R11 also flows through R9, Q1, and RZ. This voltage divider action reduces the positive voltage at the base of Q2. The reduction in positive voltage at the base of Q2 is sufficient to cause the base of Q2 to become negative with respect to the emitter of Q2, thus placing a forward bias on Q2. This forward bias causes Q2 to conduct.



Throttle Response Resistors	Resistance In Ohms TH13	TH14
R1	7699	7425
R2	1058	1155
R3	844	683
R4	354	472
R5	192	336
R6	150	302
R7	103	144

Fig. TH-1 – Voltage Reference Regulator And Throttle Response Module, Simplified Schematic Diagram

Transistor Q2 and resistor R8 provide the bias control for Q3 and Q4. When Q2 is not conducting, a large positive voltage is applied to the base of Q3 through R8. This large forward bias causes Q3 to conduct heavily and apply a large forward bias to the base of Q4. This high forward bias on Q4 results from low E_{ce} of Q3 when Q3 is operating with a large forward bias. The large forward bias on Q4 causes Q4 to go into saturation which results in a small E_{ce} for Q4.

When Q2 is conducting, current flows through R8 and Q2 causing a voltage drop across R8. This voltage drop reduces the forward bias on Q3 which reduces conduction of Q3 and reduces forward bias on Q4. The reduced forward bias on Q4 results in a larger E_{ce} for Q4.

An increase in the input voltage to VRR or a decrease in the load applied to VRR tends to increase the output voltage of VRR. The rise in output voltage results in increasing the voltage drop across RH1 which increases the forward bias on the base of Q1 and causes I_{ce} of Q1 to increase. An increase in I_{ce} of Q1 results in a larger voltage drop across R11 and decreases the positive voltage applied to the base of Q2. The decrease in positive voltage at the base of Q2 causes I_{ce} of Q2 to increase. This increase in I_{ce} of Q2 results in a larger voltage drop across R8 causing a decrease in forward bias at the base of Q3. This decrease in forward bias on Q3 causes E_{ce} of Q3 to increase. The increase of E_{ce} of Q3 results in decreasing the forward bias on Q4. This decrease in forward bias on Q4 causes E_{ce} of Q4 to increase. The increase in E_{ce} of Q4 results in a decrease in the output voltage of VRR (output voltage equals input voltage minus E_{ce} of Q4). The sequence of events occurring from the initial increase in output voltage to the resulting decrease in output voltage is instantaneous so that change in the output voltage is very small.

VRR CIRCUIT PROTECTION

Protection of the VRR circuit from excessive input voltage and excessive overload is provided by transistors Q5 and Q6, and resistors R13, R14, R15, and R16. Normal current flow through R16 is not sufficient to provide forward bias for Q5. However, an excessive load or excessive input voltage results in an increase of current flow through R16. This increased current flow provides forward bias for Q5. Turn on of Q5 results in current flow through R13 and R15. Current flow through R15 provides forward bias for Q6. Turn on of Q6 provides reverse bias for Q3 and Q4. This results in turn off of Q4 so that output current is limited by R16 and R17.

THROTTLE RESPONSE CIRCUIT

The throttle response circuit contains seven resistors and four relays with suppression diodes. A simplified schematic diagram of the throttle response circuit, Fig. TH-1, is shown for reference only.

The input voltage to the throttle response resistors at terminal 2 is obtained from the voltage reference regulator at terminal 10. This input voltage is modified by the throttle response resistors, as determined by throttle position and is applied to the rate control module as a reference for controlling excitation to the main generator field.

The throttle response relays in the throttle response circuit are energized singly or in combination, depending upon throttle position. The throttle response resistors are connected to the contacts of the relays so that the arrangement of resistors and relays provides an output voltage to the rate control module RC, which is related to throttle position. Output voltage to the RC module increases as the throttle is advanced and excitation to the main generator field is directly proportional to the output voltage of the TH module.

The relationship of throttle position to output voltage is given in Table TH-1 for the TH13 and TH14 modules.

Throttle Position	Relays Energized	Approximate Output Voltage TH13 Module	Approximate Output Voltage TH14 Module
STOP	D		
1	NONE	9.4	9.2
2	A	22.5	21.6
3	C	31.2	28.6
4	A C	43.0	35.7
5	B C D	51.2	43.3
6	A B C D	57.3	51.2
7	B C	63.2	61.4
8	A B C	68.0	68.0

Table gives nominal values for normal operation or with SB module removed.

Table TH-1 – Relationship Of Throttle Position And Output Voltage Of The Throttle Response Control Circuit

TRANSITION MODULE

INTRODUCTION

SD locomotives are equipped with six traction motors and utilize one step of transition. Motor field shunting is not employed. At low track speeds, the traction motors are connected in series-parallel across the main generator output. This series-parallel connection consists of three parallel groups with two series connected motors in each group. As track speed increases transition occurs to connect the six traction motors in parallel across the main generator output. This transition sequence is initiated by the transition module TR11.

This section provides a description of the TR11 module and a step-by-step description of forward transition, simultaneous wheel overspeed correction, and backward transition.

GENERAL DESCRIPTION

The TR module consists of a backward transition BTR section and a forward transition FTR section. A simplified block diagram, Fig. TR-1, of the BTR section is provided for convenient reference only. The BTR and FTR sections are similar. Each section contains a detector stage and a power stage. The detector stage is designed to apply forward bias to the solid state switch in the power stage as necessary to initiate forward transition at the proper time, or to turn off the solid state switch in the power stage as necessary to initiate backward transition at the proper time. Each detector stage and each power stage consists of a biasing circuit, a solid state switch, and an output circuit.

DETECTOR STAGE OF BTR SECTION

The detector biasing circuit consists of two input signals and a voltage divider. One of the input signals is proportional to main generator output voltage. The other input signal is proportional to main generator output current. The generator voltage signal is rectified and applied to the voltage divider which contains a rheostat. The wiper arm of the rheostat is connected through a diode to the base of the solid state switch. Therefore, a potential proportional to main generator output voltage is applied to the base of the solid state switch. The generator current signal is applied through a diode to the emitter of the solid state switch. Forward bias is applied to the solid state switch when the voltage signal applied to the base is larger than the current signal applied to the emitter.

The detector output circuit consists of an input transformer T3, an output transformer T5, and four diodes. The output transformer is energized only when the solid state switch in the detector stage is forward biased. Output of the detector output transformer is applied to the bias circuit of the power stage.

POWER STAGE OF BTR SECTION

The biasing circuit of the power stage consists of a rectifier, filter, and voltage divider. An input voltage is applied to the rectifier when the detector stage is forward biased. The rectified input is applied to a voltage divider which places forward bias on the solid state switch in the power stage. This forward bias turns on the power stage solid state switch to initiate forward transition. Reverse bias on the detector stage solid state switch results in turn off of the power stage solid state switch to initiate backward transition. Forward bias on the power stage of the FTR section initiates forward transition. Reverse bias on the power stage of the BTR section initiates backward transition.

OPERATION

A signal proportional to main generator output voltage is applied to transformers T1 and T2 on the TR module. Refer to Figs. TR-2 and TR-3. This signal is rectified by diodes D1 through D6 and filtered by capacitors C1 and C2 and resistor R1. This rectified output is applied to a voltage divider in the BTR section, Fig. TR-2, and to a voltage divider in the FTR section, Fig. TR-3.

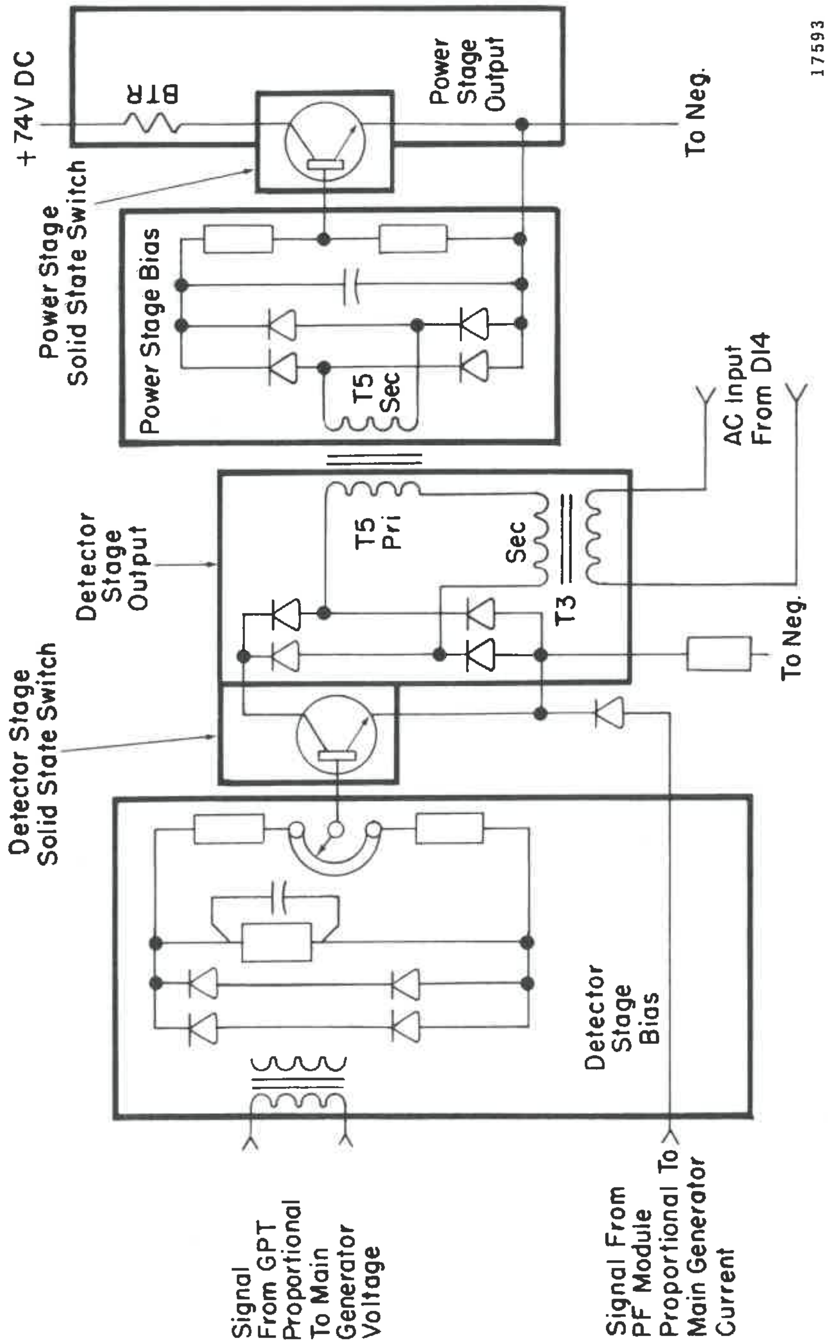


Fig. TR-1 – TR Module BTR Section, Block Diagram

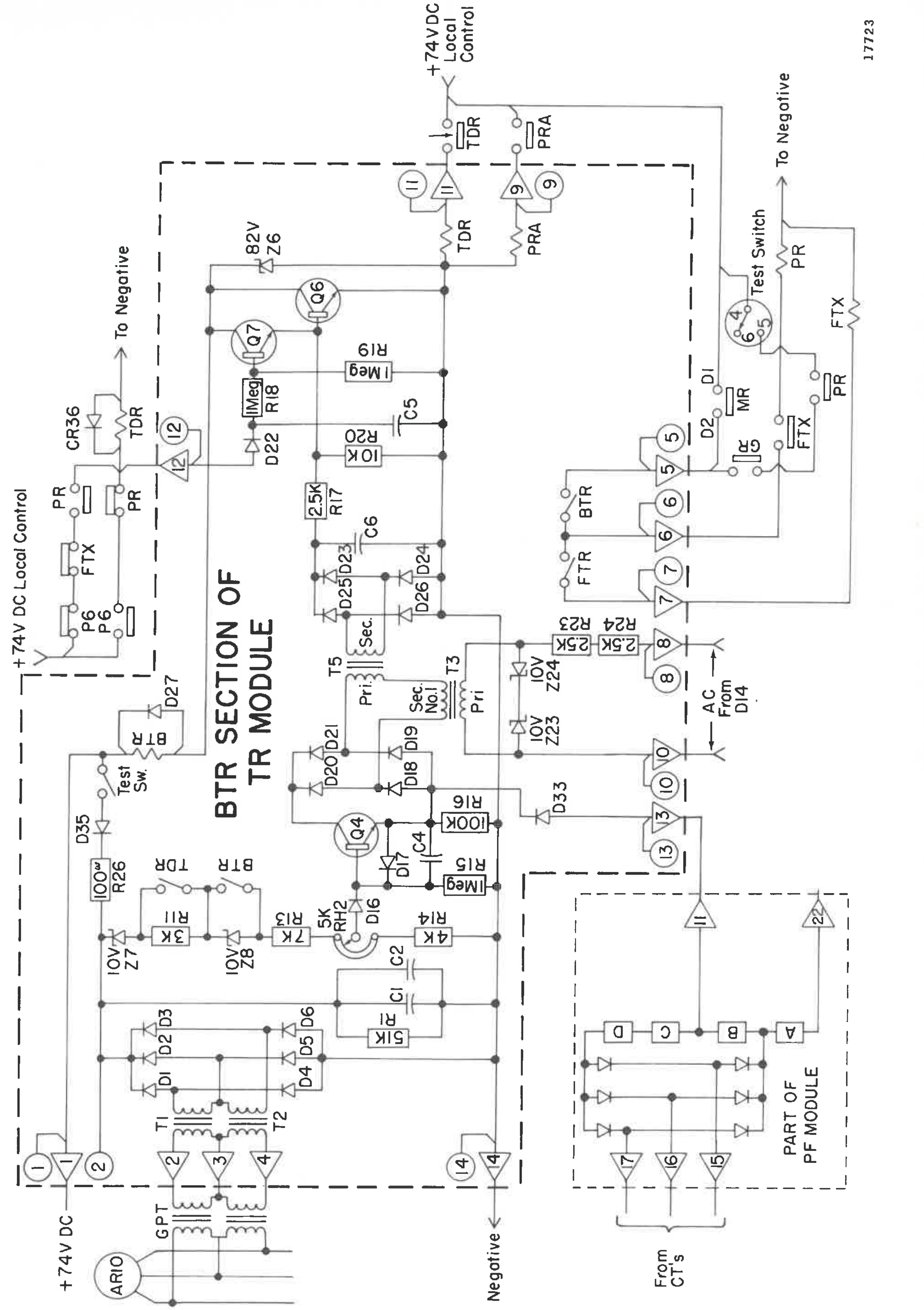


Fig. TR-2 -- BTR Section Of TR Module, Simplified Schematic Diagram

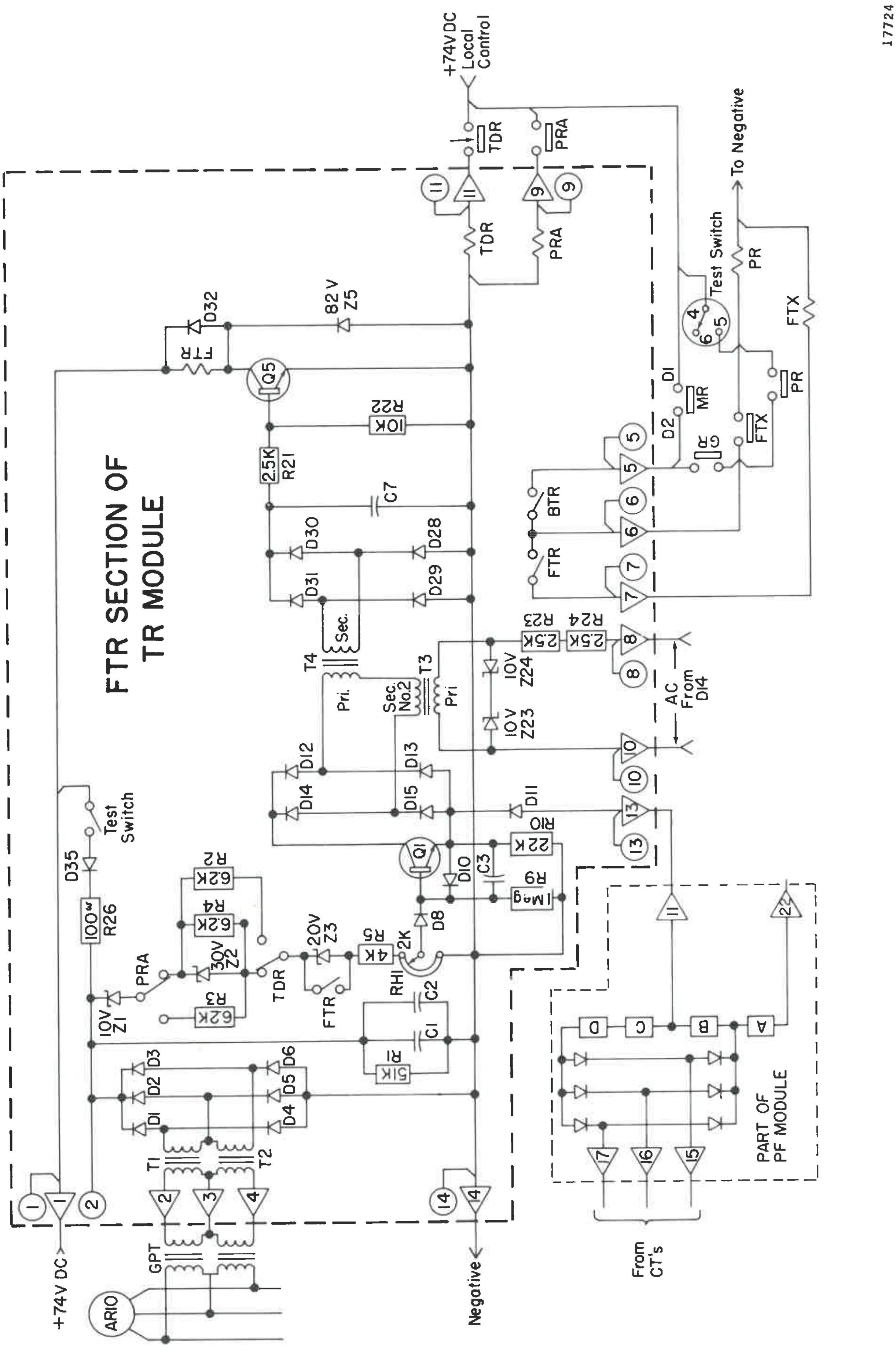


Fig. TR-3 – FTR Section Of TR Module, Simplified Schematic Diagram

The voltage divider in the BTR section consists of zener diodes Z7 and Z8, resistors R11, R13, and R14, and rheostat RH2. The wiper arm of RH2 is connected, through diode D16, to the base of Q4. Therefore, a voltage proportional to main generator output voltage is applied to the base of Q4.

The voltage divider in the FTR section consists of zener diodes Z1, Z2, and Z3, resistors R2, R3, R4, and R5, and rheostat RH1. The wiper arm of RH1 is connected, through diode D8, to the base of Q1. Therefore, a voltage proportional to main generator output voltage is applied to the base of Q1.

A signal, from the PF module, proportional to main generator output current is applied through diode D11 to the emitter of Q1 and through diode D33 to the emitter of Q4. At low track speeds the current signal applied to the emitter is larger than the voltage signal applied to the base. This results in reverse bias on Q1 and Q4.

As track speed increases, the voltage signal increases and the current signal decreases. This results in a decrease of reverse bias. A further increase in speed results in forward bias on Q4. The voltage signal applied to the base of Q1 is less than that applied to the base of Q4. Therefore, a higher track speed must be attained before forward bias is applied to Q1.

The primary of transformer T3 is energized by output voltage from the D14 alternator. Turn on of Q4 permits current flow through secondary No. 1 of T3 and through the primary of T5. The output of T5 is rectified by diodes D23 through D26 and filtered by capacitor C6. The rectified output is applied to a voltage divider consisting of R17 and R20. The voltage developed across R20 provides forward bias for Q6.

Turn on of Q6 provides a feed to BTR. Pickup of BTR increases forward bias applied to Q4 by recalibrating the voltage divider connected to the base of Q4. This ensures against dropout of BTR until track speed decreases to a lower value than the pickup value. Pickup of BTR also sets up the circuit to FTX and sets up a holding circuit for PR. Refer to applicable Charts and Graphs Drawing for BTR pickup value.

A further increase in track speed results in forward bias on Q1. Turn on of Q1 permits current flow through secondary No. 2 of T3 and through the primary of T4. The output of T4 is rectified by diodes D28 through D31 and filtered by capacitor C7. The rectified output is applied to a voltage divider consisting of resistors R21 and R22. The voltage developed across R22 provides forward bias for Q5.

Turn on of Q5 provides a feed to FTR. Pickup of FTR increases forward bias applied to Q1 by recalibrating the voltage divider connected to the base of Q1. This ensures against dropout of FTR until forward transition is initiated. Pickup of FTR also provides a feed to FTX. Refer to applicable Charts and Graphs Drawing for pickup value of FTR.

Step	Procedure Or Condition	Result Of Procedure Or Condition
	ACCELERATION AND FORWARD TRANSITION	
1	Advance throttle	MR ↑.
2	MR ↑.	CDR ↑.
3	CDR ↑.	S14 ↑, S25 ↑, and S36 ↑.
4	S14 ↑, S25 ↑, and S36 ↑.	Connects traction motors in series-parallel across main generator. Opens feed to TSR to prevent reversal of motor fields while contactors are closed. Opens circuit to P1 through P6 to ensure against pickup of parallel contactors while series contactors are closed. Provides feed to GFC to provide excitation to main generator field. Activates wheel slip bridge circuit while operating in series-parallel. Sets up circuit to B contactor to ensure series-parallel motor connections during dynamic brake operation. NOTE: Main generator is excited and motors are connected in series-parallel across main generator. Locomotive starts out from standstill (high current and low voltage).
5	Locomotive starts out from Standstill.	Main generator output voltage is low and output current is high. NOTE: A signal from GPT is applied to terminals 2, 3, and 4 of TR module. This signal is proportional to main generator output voltage. A signal from the PF module is applied to terminal 13 of the TR module. This signal is proportional to main generator output current.

Fig. TR-4 – Sequence Of Events During Acceleration, Forward Transition, Wheel Overspeed, And Backward Transition (Sheet 1 of 9)

Step	Procedure Or Condition	Result Of Procedure Or Condition
6	Signal proportional to main generator output voltage is applied to terminals 2, 3, and 4 of TR module.	This signal is applied to transformer T1 and T2 on TR module. The output of T1 and T2 is rectified and filtered. This rectified output is applied to two voltage dividers. One of the voltage dividers consists of zener diodes Z7 and Z8, rheostat RH2, and resistors R11, R13, and R14. The base of Q4 is connected, through diode D16, to the wiper arm of RH2. The other voltage divider consists of zener diodes Z1, Z2, and Z3, resistors R2, R3, R4, and R5, and rheostat RH1. The base of Q1 is connected, through diode D8, to the wiper arm of RH1.
7	Signal proportional to main generator output current is applied to terminal 13 of the TR module.	This signal is applied through diode D11 to the emitter of Q1 and through diode D33 to the emitter of Q4. NOTE: Transistors Q1 and Q4 are reverse biased by the low voltage signal applied to the base and the high current signal applied to the emitter. As track speed increases, the voltage signal increases and the current signal decreases. This results in a decrease of reverse bias. A further increase in speed results in forward bias on Q4.
8	Increase in track speed results in forward bias on Q4.	Q4 turns on allowing current flow through secondary No. 1 of T3 and through the primary of T5. This results in a voltage being induced into secondary of T5. Output of T5 is rectified and filtered then applied to the base of Q6. This results in forward bias on Q6.
9	Forward bias on Q6.	BTR ↑.
10	BTR ↑.	Recalibrates the voltage divider that provides forward bias for Q4. This ensures against dropout of BTR until track speed decreases to a low value. Sets up circuit to FTX.
11	A further increase in track speed results in forward bias on Q1.	Q1 turn on allows current to flow through secondary No. 2 of T3 and through the primary of T4. This results in a voltage being induced into the secondary of T4. The output of T4 is rectified and filtered, then applied to the base of Q5. This forward bias results in turn on of Q5.

Fig. TR-4 – Sequence Of Events During Acceleration, Forward Transition, Wheel Overspeed, And Backward Transition (Sheet 2 of 9)

Step	Procedure Or Condition	Result Of Procedure Or Condition
12	Forward bias on Q5.	FTR ↑.
13	FTR ↑.	FTX ↑.
		Recalibrates the voltage divider that provides forward bias for Q1. This prevents cycling of FTR by reducing the dropout level of FTR.
14	FTX ↑.	PR ↑.
		Provides holding feed to S14.
		Drops one feed to EQP so that EQP will drop out when PRA picks up.
		Sets up simultaneous wheel overspeed circuit to the WS module. This provides wheel overspeed protection after transition to parallel motor connections.
15	PR ↑.	Provides feed to the U relay on the WS module. This increases response of wheel slip correction circuit at the higher track speeds.
		Provides holding feed to PR until drop out of BTR.
		Opens main feed to S14, but S14 is held in by FTX contacts.
		Sets up circuit for pick up of GFC and PRA after forward transition has been made.
		Drops the feed to the generator field contactor GFC.
		Sets up circuit to provide feed to the base of Q7 and for pickup of TDR when PR drops out during backward transition.
		Disables wheel slip correction circuit during forward transition. This prevents operation of the WS module due to a false differential wheel slip signal during transition.
16	GFC ↓.	Disconnects D14 alternator from main generator field. Main generator output decreases.
		GFX ↓.
		Energizes ORS causing load regulator to move toward minimum field position during transition. This provides for smooth reapplication of power after completion of transition.
		NOTE: On some units ORS is not energized until dropout of FTX (Step 21). Delaying the pickup signal to ORS decreases the time required for the transition process.

Fig. TR-4 – Sequence Of Events During Acceleration, Forward Transition, Wheel Overspeed, And Backward Transition (Sheet 3 of 9)

Step	Procedure Or Condition	Result Of Procedure Or Condition
17	GFX ↓.	Disconnects RC module from TH module. This removes the throttle signal from the RC module.
18	Main generator output decreases (Step 16).	Reverse bias is applied to Q1 when voltage on base of Q1 decreases to a low value.
19	Reverse bias on Q1.	Opens the primary circuit of T4 which removes forward bias from Q5, and results in drop out of FTR.
20	FTR ↓.	FTX ↓. Increases reverse bias on Q1 by recalibrating the voltage divider circuit at the base of Q1. This prevents pickup of FTR until after completion of forward transition.
21	FTX ↓.	TDR ↑. S14 ↓. Provides forward bias to Q7 and Q6. This ensures against drop out of BTR during forward transition. NOTE: ORS may be energized by dropout of FTX. Refer to NOTE in Step 16.
22	TDR ↑.	Provides feed to TDR relay on TR module. Pickup of TDR on TR module recalibrates voltage divider that provides voltage feedback signal to the base of Q1 and Q4. This increases pickup level of FTR and decreases dropout level of BTR. This ensures against drop out of BTR on low voltage transients during forward transition.
23	S14 ↓ (Step 21).	P1 ↑ and P4 ↑. Disconnects traction motors 1 and 4 from main generator.
24	P1 ↑.	Connects traction motor 1 across main generator output. S25 ↓. Sets up circuit to P2 and P5. Ensures against pickup of S14 and S25 when P1 is picked up. Sets up circuit to GFC.
25	P4 ↑ (Step 23).	Connects traction motor 4 across main generator output.

Fig. TR-4 – Sequence Of Events During Acceleration, Forward Transition, Wheel Overspeed, And Backward Transition (Sheet 4 of 9)

Step	Procedure Or Condition	Result Of Procedure Or Condition
26	S25 ↓ (Step 24).	Opens feed to wheel slip bridge circuit.
		Ensures against pickup of B contactor when motors are connected in parallel.
		P2 ↑ and P5 ↑ .
27	P2 ↑ .	Connects traction motor 2 across main generator output.
		Ensures against pickup of S25 when P2 is picked up.
		Sets up circuit to P3 and P6.
		Sets up circuit to GFC.
28	P5 ↑ (Step 26).	Connects traction motor 5 across main generator output.
		Provides holding feed to P2 and P5.
		Drops feed to S36.
29	S36 ↓ .	Provides feed to P3 and P6.
30	P3 ↑ .	Connects traction motor 3 across main generator output.
		Ensures against pickup of S36 while P3 is picked up.
		Enables wheel slip control circuit.
		GFC ↑ .
		PRA ↑ .
31	PRA ↑ .	Recalibrates feed to base of Q1 to increase pickup level of FTR for simultaneous wheel overspeed correction.
		Opens main feed to EQP, but EQP is held in by closed FTX contacts. However, in case of wheel overspeed during parallel operation FTX picks up to remove excitation from the main generator.

Fig. TR-4 – Sequence Of Events During Acceleration, Forward Transition, Wheel Overspeed, And Backward Transition (Sheet 5 of 9)

Step	Procedure Or Condition	Result Of Procedure Or Condition
32	P6 ↑ (Step 29).	Connects traction motor 6 across main generator output. Provides holding feed to P3 and P6. Drops feed to TDR and removes forward bias from Q7 and Q6.
33	GFC ↑ (Step 30).	GFX ↑. Drops feed to ORS to allow load regulator to move toward maximum field position. Reconnects D14 alternator to main generator field.
34	GFX ↑.	Reconnects RC module to TH module allowing excitation to be reapplied to the main generator field. NOTE: Traction motors are now connected in parallel across main generator output and excitation is applied to the main generator field.
35	TDR ↓ (Step 32).	Drops feed to the TDR relay on the TR module, after a short time delay.
36	TR module TDR ↓.	Recalibrates voltage dividers that are connected to the base of Q1 and Q4. This permits BTR to dropout to initiate backward transition in case track speed decreases to a low value and also permits FTR to pick up in case a wheel overspeed condition is detected.
	SIMULTANEOUS WHEEL OVERSPEED	
37	A simultaneous wheel overspeed condition resulting from excessive track speed or from a simultaneous wheel slip provides forward bias to Q1.	Q1 turn on allows current to flow through secondary No. 2 of T3 and through the primary of T4. This results in a voltage being induced into the secondary to T4. The output of T4 is rectified and filtered, then applied to the base of Q5. This forward bias results in turn on of Q5.
38	Forward bias on Q5.	FTR ↑.
39	FTR ↑.	FTX ↑.
40	FTX ↑.	Drops the feed to EQP. Provides a feed to the WL relay and to terminal 18 of the WS module.

Fig. TR-4 -- Sequence Of Events During Acceleration, Forward Transition, Wheel Overspeed, And Backward Transition (Sheet 6 of 9)

Step	Procedure Or Condition	Result Of Procedure Or Condition
41	EQP $\downarrow$.	Provides a discharge path for the RC capacitors on the RC module and drops the feed to GFC.
42	GFC $\downarrow$.	Disconnects the D14 alternator from the main generator field.
43	Feed provided to terminal 18 of the WS module.	The WS module initiates wheel slip correction and provides a sanding signal to the SA module. The WS module also provides a feed to the ORS to drive the load regulator toward minimum field position. This provides for smooth reapplication of power when operation is restored. NOTE: Reduced excitation and sanding corrects for the wheel overspeed condition. When the overspeed condition is corrected, FTR drops out, FTX drops out, EQP picks up and power is restored. Cycling will continue if the wheel overspeed condition reoccurs. Operation may continue, but regulation will be very coarse. Cause of the wheel overspeed condition should be determined and corrected if it reoccurs.
	BACKWARD TRANSITION	
44	Assume that traction motors are connected in parallel across main generator output and track speed decreases to a low value.	Main generator voltage decreases and current increases. This provides reverse bias for Q4.
45	Reverse bias on Q4.	Removes forward bias from Q6 by opening the primary of T5.
46	Forward bias removed from Q6.	BTR $\downarrow$.
47	BTR $\downarrow$.	PR $\downarrow$. Recalibrates voltage divider connected to base of Q4.
48	PR $\downarrow$.	TDR $\uparrow$, PRA $\downarrow$, GFC $\downarrow$, P1 $\downarrow$, P4 $\downarrow$. Drops feed to U relay on WS module. Sets up circuit to S14. Drops holding feed to PR. Provides forward bias for Q7 and Q6.

Fig. TR-4 – Sequence Of Events During Acceleration, Forward Transition, Wheel Overspeed, And Backward Transition (Sheet 7 of 9)

Step	Procedure Or Condition	Result Of Procedure Or Condition
49	TDR ↑.	Provides feed to TDR relay on TR module. This recalibrates the biasing circuit to Q4 and Q1.
50	PRA ↓ (Step 48).	Removes feed from PRA relay on TR module. This recalibrates the biasing circuit to Q1 to prevent pickup of FTR during backward transition.
51	GFC ↓ (Step 48).	Provides feed to ORS to drive the load regulator toward minimum field. This provides for smooth reapplication of power after backward transition.
		Disconnects D14 alternator from main generator field.
		GFX ↓.
52	GFX ↓.	Disconnects RC module from TH module. This removes throttle signal from the TH module.
53	Forward bias on Q7 and Q6.	BTR ↑.
54	P1 ↓ (Step 48).	Disconnects motor 1 from main generator.
		S14 ↑.
55	P4 ↓ (Step 48).	Disconnects motor 4 from main generator.
56	S14 ↑.	Connects motors 1 and 4 in series across main generator.
		Drops feed to P2 and P5.
		Sets up circuit to GFC.
57	P2 ↓.	Disconnects motor 2 from main generator.
		S25 ↑.
58	P5 ↓ (Step 56).	Disconnects motor 5 from main generator.
		Sets up circuit to S36.
59	S25 ↑ (Step 57).	Connects motors 2 and 5 in series across main generator.
		Sets up circuit to B contactor.
		Drops feed to P3 and P6.

Fig. TR-4 -- Sequence Of Events During Acceleration, Forward Transition, Wheel Overspeed, And Backward Transition (Sheet 8 of 9)

Step	Procedure Or Condition	Result Of Procedure Or Condition
60	P3↓.	Disconnects motor 3 from main generator. S36↑.
61	P6↓ (Step 59).	Disconnects motor 6 from main generator. TDR↑. Removes forward bias from Q7 and Q6 on TR module.
62	S36↑.	Connects motors 3 and 6 in series across main generator. Provides feed to GFC.
63	TDR↑ (Step 61).	Recalibrates Bias circuit to Q1 and Q4.
64	GFC↑.	Connects output of D14 alternator to main generator field. Opens feed to ORS allowing load regulator to move toward maximum field position. GFX↑.
65	GFX↑.	Connects RC module to TH module so that throttle signal is applied to the RC module. NOTE: Locomotive is now operating with series-parallel motor connections.

Fig. TR-4 -- Sequence Of Events During Acceleration, Forward Transition, Wheel Overspeed, And Backward Transition (Sheet 9 of 9)

WHEEL SLIP SYSTEM

INTRODUCTION

The wheel slip system helps to maintain wheel traction under adverse operating conditions and provides protection for the traction motors by detecting and correcting wheel slip conditions before the slip is severe enough to damage the traction motors.

Two types of wheel slip conditions that may be encountered are simultaneous wheel slip and differential wheel slip. Simultaneous wheel slip is a condition where wheel slip occurs at the same rate on all wheels of the locomotive. Differential wheel slip is a condition where one pair of wheels slip at a different rate than the other wheels on the locomotive.

The primary wheel slip detection device for a differential wheel slip condition is the wheel slip transductor WST. Six axle locomotives are equipped with three wheel slip transductors, and four axle locomotives are equipped with four. During normal operation the armature current is approximately equal for all traction motors and a balanced condition exists. However, during a differential wheel slip condition armature current through the motors is unequal and an unbalanced condition exists. The WST's are connected so that any unbalance in traction motor armature current is detected. This unbalanced condition causes the WST's to develop a differential wheel slip signal. This signal is applied to the wheel slip module WS. The WS module initiates corrective action for the wheel slip condition. The wheel slip transductors operate during power application and during dynamic braking. A detailed description of the wheel slip transductors is provided later in this section.

The wheel slip transductors operate during dynamic braking and during operation under power. However, they cannot detect a wheel slip condition where all wheels on the same truck slip at the same rate. Therefore, a wheel slip bridge circuit is provided for detecting wheel slip conditions of this nature. The wheel slip bridge circuit on SD model locomotives operates during dynamic braking and during operation under power when the traction motors are connected in series-parallel. The wheel slip bridge circuit on GP model locomotives operates only during dynamic braking.

The output from the wheel slip bridge circuit is applied to the WSR relay on the WS module. The WSR relay initiates corrective action for the wheel slip condition. A detailed description of the wheel slip bridge circuit is provided later in this section.

The transition module TR detects and initiates corrective action for wheel overspeed conditions. The TR module also provides wheel overspeed information to the WS module. Wheel overspeed conditions may result from simultaneous wheel slip or from excessively high track speed. In either case the main generator voltage increases and main generator current decreases. The TR module detects an overspeed condition by comparing main generator voltage with main generator current. The overspeed condition is corrected by reducing excitation to the main generator field and applying sand to the rails. A detailed description of the TR module is provided in Section 7 Part B.

The wheel slip module WS initiates corrective action for a wheel slip condition upon receiving a wheel slip signal from the wheel slip transductors, the wheel slip bridge circuit, or from the TR module. A detailed description of the WS module is provided later in this section.

The sanding module SA, upon receiving a signal from the WS module, initiates application of sand to the rails to assist in correcting a wheel slip condition. A detailed description of the SA module is provided later in this section.

CONTENTS

The contents of Section 7 Part C are presented in the following order.

1. Sanding Module

2. Wheel Slip Bridge Circuit

3. Wheel Slip Module

4. Wheel Slip Transductor

SANDING MODULE, SA10

INTRODUCTION

The sanding module SA10 controls the application of sand to the rails whenever a sanding signal is applied to the SA module. The sanding signal may be applied to the SA module by manually operating the MANUAL SAND lever or automatically from the emergency sanding switch or from the WS module. Sand may be applied to the No. 1 truck by manually closing the LEAD TRUCK SAND switch. In this case, the sanding signal is applied directly to the MV1 SF magnet valve without passing through the SA module.

A simplified schematic diagram of a typical SA module is provided in Fig. SA-1 for convenient reference. The applicable locomotive wiring diagram should be used when performing troubleshooting or maintenance.

AUTOMATIC SANDING

The RA relay on the wheel slip module WS picks up during the second and third stages of wheel slip correction and whenever a wheel slip is detected by the wheel slip bridge circuit. The RA relay also picks up whenever a simultaneous wheel overspeed condition is detected. Pickup of RA applies a signal to terminal 19 of the WS module and this terminal is connected to terminal 2 of the SA module. Therefore, pickup of RA provides an automatic sanding signal to terminal 2 of the SA module.

The signal from terminal 2 of the SA module is applied through diode D4 and resistor R11 to the base of Q6. This provides forward bias for Q6. Turn on of Q6 provides forward bias, through R9, to the base of Q3 causing Q3 to turn on. The signal from terminal 2 is also applied, through diode D2 and resistor R7, to the cathode gate G_C of silicon controlled rectifier SCR1. This signal to G_C causes SCR1 to conduct from terminal 1 of SA, through R1, R4, SCR1, R5, and Q3 to negative at terminal 14 of the SA module.

Current flow through R4 results in a potential of approximately 35 volts at the junction of R3 and R6. This places forward bias on Q2 and Q4. Turn on of Q4 results in current flow through R12 and zener diode Z5. Reverse conduction of Z5 provides a positive potential of 15 volts at base 2 of unijunction transistor Q5. Turn on of Q4 also results in current flow through rheostat RH1, resistor R15, collector to emitter of Q6, resistor R9, and base to emitter of Q3. Since Q6 is turned on, the charge on capacitor C2 is held to a very low specific voltage. This low voltage is not sufficient to turn on unijunction transistor Q5.

Turn on of Q2 results in current flow from terminal 1 of SA, through resistor R1, diode D7, emitter to collector of Q2, diode D1, and resistor R14 to negative. The voltage developed across R14 places forward bias on Q1. Turn on of Q1 results in current flow from collector to emitter of Q1, then through diode D6 and resistor R8 to the base of Q3 and from base to emitter of Q3 to negative. Turn on of Q1 also results in providing a signal to D12. This signal passes through D12 to terminal C2 of DSR.

If the reverser lever is in forward position, the signal passes from C2 to NC2 of DSR then to terminals 8 and 10 and magnet sanding valves MV1-SF and MV2-SF to negative. If the reverser is in reverse position, the signal passes from C2 to NO2 of DSR then to terminals 9 and 11 and magnet sanding valves MV1-SR and MV2-SR to negative. This signal to the magnet sanding valves will be maintained for 3 to 5 seconds after the signal is removed from terminal 2 of the SA module.

When the signal is removed from terminal 2, bias is removed from Q6 and from the cathode gate G_C of SCR1. Removing forward bias from Q6 results in turn off of Q6, but SCR1 will continue to conduct as long as a path for conduction is maintained. The path for conduction is maintained until Q3 is turned off. Q6 turn off allows capacitor C2 to charge through R1, Q4, RH1, R15, R10, R9, and Q3. Unijunction transistor Q5 conducts when the charge on C2 increases to approximately 6 volts. C2 will be charged to approximately 6 volts within 3 to 5 seconds after the signal is removed from terminal 2 of SA. Turn on of Q5 allows C2 to discharge through Q5, D5, R9, and R10. Discharging of C2 places reverse bias on Q3 causing Q3 to turn off. Q3 turn off opens the cathode circuit of SCR1 and stops current flow through SCR1. This places reverse bias on Q4 and Q2. Q2 turn off places reverse bias on Q1. Q1 turn off removes the signal from the magnet sanding valves.

MANUAL SANDING

When the MANUAL SAND lever is operated, the sanding signal will be applied through terminal 3 and diode D9 of the SA module. From D9 the signal is applied to terminal C2 of the directional sanding relay DSR and from D9 through D10 to terminal C1 of DSR. If the reverser lever is set to forward position, RV contacts G-H are open and DSR will not be energized and the sanding signal will be applied from C1 to NC1 of DSR then to terminal 8 and magnet sanding valve MV1-SF. The signal will also be applied from C2 to NC2 of DSR then to terminal 10 and magnet sanding valve MV2-SF and from NC2 through D14 to terminal 8 and magnet sanding valve MV1-SF. Sanding will continue until the MANUAL SAND lever is released. If the reverser lever is set to reverse position, contacts G-H of RV are closed and DSR will be picked up and the sanding signal will be applied from C1 to NO1 of DSR, then to terminal 9 and MV1-SR. The signal will also be applied from C2 to NO2 of DSR, then to terminal 11 and MV2-SR and from NO2 to terminal 9 and magnet sanding valve MV1-SR. Energizing MV1-SF and MV2-SF when the reverser lever is in forward position, or energizing MV1-SR and MV2-SR when the reverser lever is in reverse position results in application of sand in front of the lead axle on each truck of the locomotive. The signal from terminal 3 will be applied to terminal 7 through diode D19. The signal from terminal 7 may be applied to a MANUAL SAND indicating light. The signal applied to terminal 3 of the SA module may be trainlined so that the sanding signal will be applied to terminal 3 of SA modules in all other locomotives in the consist.

TEST CIRCUIT

A test switch is provided for performing a check on the SA module and also on the magnet sanding valves. Closing the TEST SWITCH provides an input to terminal 2 of the SA module. This input performs the same function as the input from terminal 19 of the WS module.

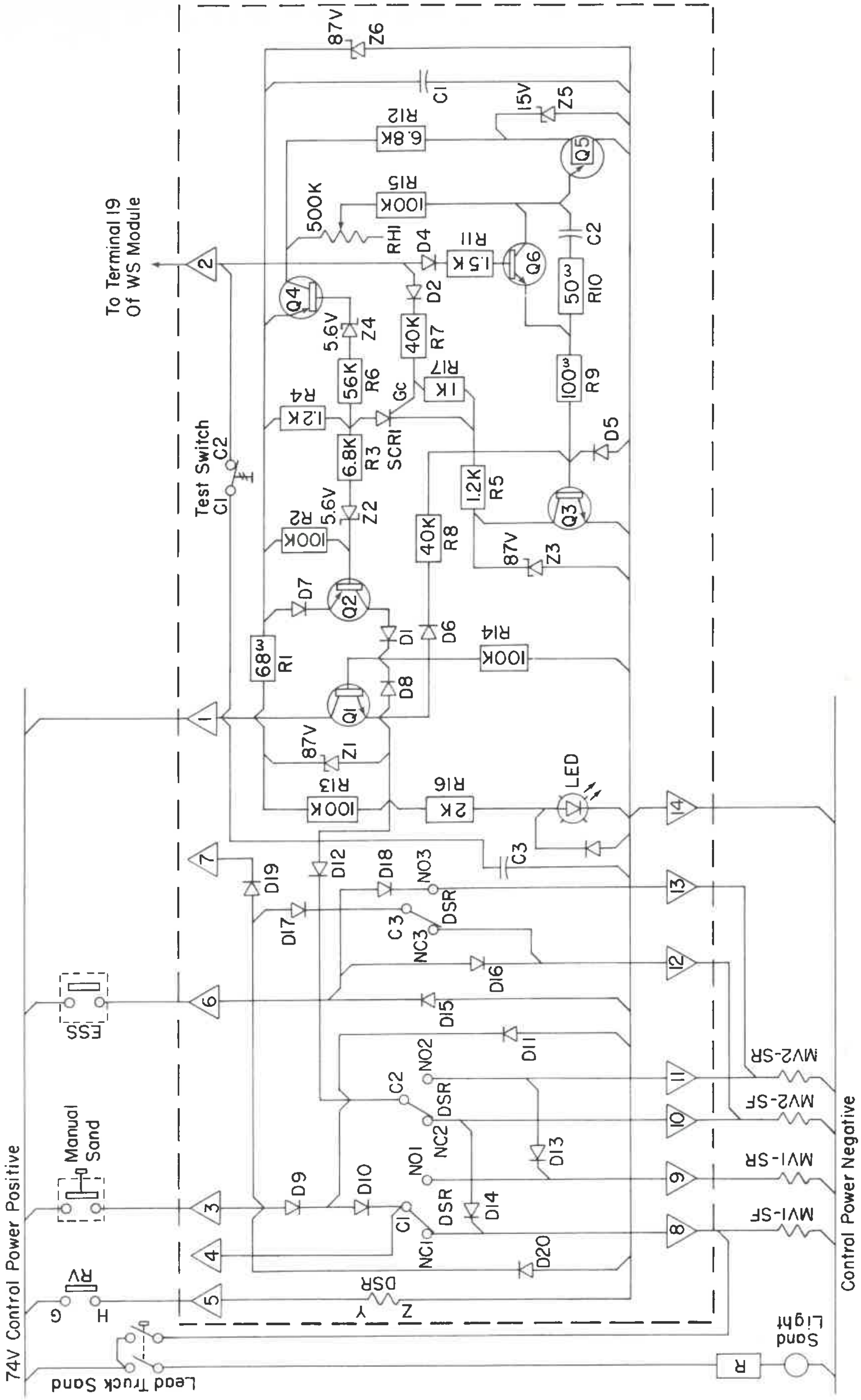


Fig. SA-1 -- SA Module, Simplified Schematic Diagram

WHEEL SLIP MODULE, WS10

INTRODUCTION

The wheel slip module WS10 is designed to provide wheel slip correction when a wheel slip is detected by the wheel slip transductors or by the wheel slip bridge circuit. The WS module also responds to a wheel overspeed signal when applied to terminal 18. A wheel overspeed signal may result from excessive track speed or from a simultaneous wheel slip. At higher track speeds a recalibration signal is applied to terminal 15 of WS module. This recalibration provides for faster discharge of the RC capacitors when a wheel slip is detected during higher track speed operation. Three stages of wheel slip correction are provided when a wheel slip is detected by the wheel slip transductors. Only one stage of correction is provided when a signal is received from the wheel slip bridge circuit. A wheel overspeed signal results in discharging the rate control capacitors on the RC module through the WS module. The WS module is equipped with a test circuit which may be used to qualify operation of the WS module.

A simplified schematic diagram of the WS module is provided in Fig. WS-1 for convenient reference. The applicable locomotive wiring diagram should be used when performing troubleshooting or maintenance.

The high sensitivity of the wheel slip transductors and the instantaneous response of the WS module reduces the chances of simultaneous wheel slip by correcting the slip before severe loss of adhesion occurs. Therefore, the WS module maintains locomotive power at the optimum level under conditions of heavy drag and poor adhesion where repetitive slips are encountered. Train handling is smooth and power reduction by the operator is not required.

Transistor Q1 is connected across a power supply consisting of resistor R6, isolation transformer T2, a bridge rectifier, zener diode Z1, and capacitor C4. Transformer T2 in series with resistor R6 is connected across one phase of the D14 alternator. The output of T2 is rectified by diodes D5 through D8. Zener diode Z1 regulates the DC voltage at 50 volts.

Minor differences in wheel diameter cause the wheel slip transductors to provide a small and essentially steady signal to the WS module during normal operation. This signal is applied to transformer T1, then rectified and filtered and applied across rheostat RH1. The wiper arm of RH1 is set at the factory to provide the desired response of the WS module. The signal is available at the wiper arm of RH1 is applied through capacitor C3 to diodes CR7 and CR8. This small steady state signal is not sufficient to cause conduction of CR7 and CR8, therefore, transistor Q1 is turned off during normal operation.

Description of the different stages of wheel slip correction is provided in the following paragraphs. The first and second stages of wheel slip correction operate on the rate of change in wheel slip instead of on the magnitude of wheel slip. The third stage of wheel slip correction operates on the magnitude or level of wheel slip. The correction brought about by a signal from the wheel slip bridge circuit also operates on the magnitude or level of wheel slip.

FIRST STAGE CORRECTION

The first stage of wheel slip correction is designed to correct minor wheel slip conditions. This is accomplished by producing a sharp reduction in the reference signal applied to the base of transistor Q1 on the sensor bypass module SB. This reduction is made without discharging the rate control capacitors in the RC module, or changing position of the load regulator wiper arm. Reducing this signal results in an immediate decrease in excitation to the main generator field and a corresponding decrease in output of the main generator. Unnecessary power reduction is prevented by reducing the reference signal to the base of Q1 on the SB module in direct proportion to the acceleration of the slipping wheels and immediate reapplication of normal power after a minor wheel slip is corrected.

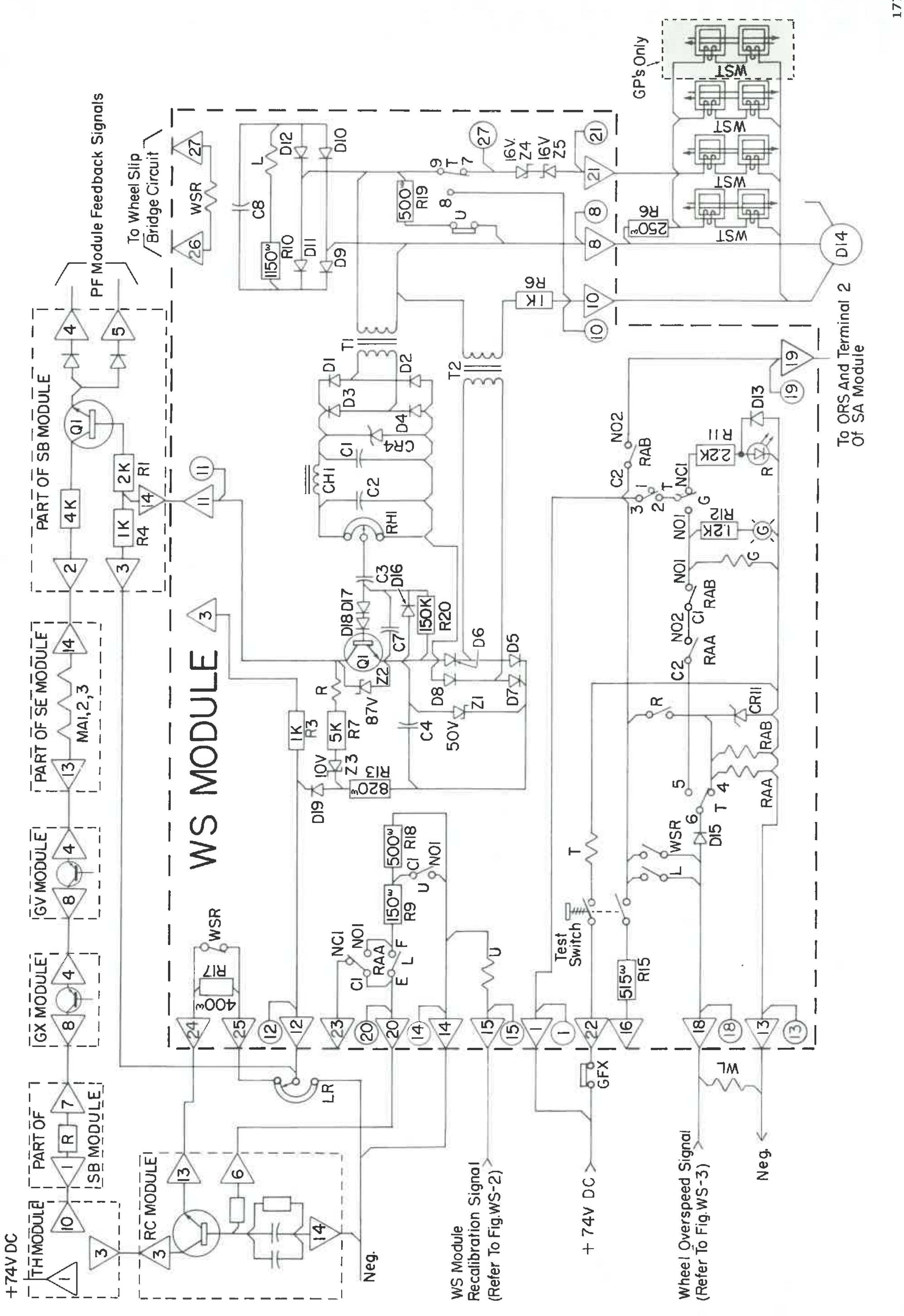


Fig. WS-1 -- Wheel Slip Module, Simplified Schematic Diagram

When a wheel slip occurs, the voltage applied to transformer T1 increases at a rate which is directly proportional to the acceleration of the slipping wheels. The signal is rectified and applied to the upper portion of RH1 and to the lower portion of RH1 in parallel with C3 and C7. The voltage across capacitors C3 and C7 increases at a rate determined by the acceleration of the slipping wheels and the RC circuit consisting of RH1, C3, and C7.

The increase in voltage across C7 places forward bias on transistor Q1. Forward bias on Q1 results in current flow through resistor R13, diode CR9, to terminal 12 on the WS module, to terminal 3 on the SB module, through R4 on the SB module, to terminal 14 on the SB module, to terminal 11 on the WS module, then from collector to emitter of Q1 on the WS module. This current flow through R4 on the SB module causes an increase in the voltage developed across R4 and results in decreasing the voltage applied to the base of Q1 on the SB module. This decrease in forward bias on transistor Q1 of the SB module results in a decrease in excitation to the main generator field.

The decrease in excitation to the main generator field causes a decrease in power output from the main generator and improves traction sufficiently to correct for a minor wheel slip condition.

After the wheel slip is corrected, C3 and C7 discharge through the lower portion of RH1, to the small steady state value. Discharging of C7 removes forward bias from Q1 which stops the current flow and allows the voltage applied to the base of Q1 on the SB module to return to its normal value.

SECOND STAGE CORRECTION

A second stage of wheel slip correction occurs if the wheel slip signal from the wheel slip transductors exceeds a predetermined value. During the second stage of wheel slip correction sand is applied to the rails and the rate control capacitors on the RC module are discharged at a controlled high rate.

The wheel slip signal that brings about the second stage of correction causes a large forward bias to be applied to transistor Q1. This large forward bias results in an increase of current flow through resistor R4 on the SB module. Reverse current will flow through zener diode Z3 when the voltage across R4 rises above 10 volts. The current through Z3 causes the R relay to pick up.

Pickup of the R relay provides a feed to the RAA and RAB relays. Pickup of RAA provides a fast discharge path for the rate control capacitors through R9 and R18 to negative. Pickup of RAB provides a signal to terminal 19 of the WS module. The signal from terminal 19 is applied to the SA module and results in application of sand to the rails.

Discharging the rate control capacitors reduces generator excitation which results in a decrease of output power from the main generator. The decreased power and sanded rails improves traction which causes a reduction in forward bias on Q1. The reduced forward bias results in less current flow through R4 on the SB module. When the voltage across R4 drops below 10 volts, Z3 blocks current flow through the R relay causing the R relay to drop out. Dropout of the R relay removes the feed to RAA and RAB. Dropout of RAA removes the discharge path for the rate control capacitors and allows the capacitors to charge at their normal rate for smooth reapplication of power. Dropout of RAB removes the sanding signal from the SA module. Sanding continues for a timed interval after the sanding signal is removed.

THIRD STAGE CORRECTION

The output of the wheel slip detectors is applied to the wheel slip level detector circuit consisting of diodes D9 through D12, R10, C8, and the L relay. The L relay picks up when the magnitude or level of the wheel slip signal increases above a predetermined level instead of picking up on the rate of increase of the wheel slip signal.

Pickup of the L relay provides a feed to the WL relay, the RAA relay, and the RAB relay. Pickup of the WL relay provides a feed to the wheel slip light WS. Pickup of the RAA and RAB relays provide the same corrective action that takes place during the second stage of wheel slip correction. The L relay remains picked up until the wheel slip is corrected or until power reduction causes a decrease in the current differential at the transductors to a level that permits dropout of the L relay.

Dropout of the L relay removes the feed to WL, RAA, and RAB. Dropout of WL removes the feed to the WS light. Dropout of RAA removes the discharge path for the rate control capacitors and allows the capacitors to charge at their normal rate for smooth reapplication of power. Dropout of RAB removes the sanding signal from the SA module. Sanding continues for a timed interval after the sanding signal is removed.

If the slip persists, the three stages of correction are repeated. The wheel slip light will blink on and off as the cycle repeats or it will burn continuously if the throttle is advanced far enough to hold the L relay picked up.

WHEEL SLIP CORRECTION BY WSR

When operating under power, a separate path for current flow is provided for each traction motor on GP locomotives. A separate path for current flow is also provided for each traction motor on SD locomotives when operating under power with parallel motor connections. However, two motors are connected in series on the SD locomotive when operating under power with series-parallel motor connections and on all locomotives during dynamic braking.

When two motors are connected in series, the wheel slip transductors are not unbalanced during simultaneous wheel slip of all wheels on one truck. Therefore, the wheel slip bridge circuit is designed to detect wheel slip conditions of this nature.

The wheel slip bridge circuit consists of two resistors and two traction motors with the wheel slip relay WSR connected across the bridge. The WSR relay is located on the WS module. The bridge circuit becomes unbalanced, causing pick-up of the WSR relay during simultaneous wheel slip of all wheels on the front truck or on the rear truck of GP and SD locomotives.

Pickup of WSR provides immediate power reduction by inserting a resistor in series with the load regulator to reduce excitation. Pickup of WSR also provides a feed to the WL relay, the RAA relay, and the RAB relay. Pickup of WL provides a feed to the WS light. Pickup of RAA provides a fast discharge path for the rate control capacitors. Pickup of RAB provides a sanding signal to the SA module.

When the wheel slip is corrected, WSR drops out, which immediately removes the resistance in series with the load regulator. The rate control capacitors are charged at the normal rate. Braking effort or power is smoothly restored, and sanding continues for a timed interval after dropout of RAB.

WS MODULE RECALIBRATION

The WS module is recalibrated at intermediate and higher track speeds by applying a recalibration signal to terminal 15 of the WS module to pick up the U relay. Pickup of the U relay increases the discharge rate of the rate control capacitors on the RC module when a wheel slip is detected. This increased discharge rate provides for faster correction of wheel slips at intermediate and higher track speeds.

On SD model locomotives, the recalibration signal is provided by pick up of the PR or FSR relays. On GP locomotives, the recalibration signal is provided by pickup of the RB relay on the WO module. Refer to Fig. WS-2.

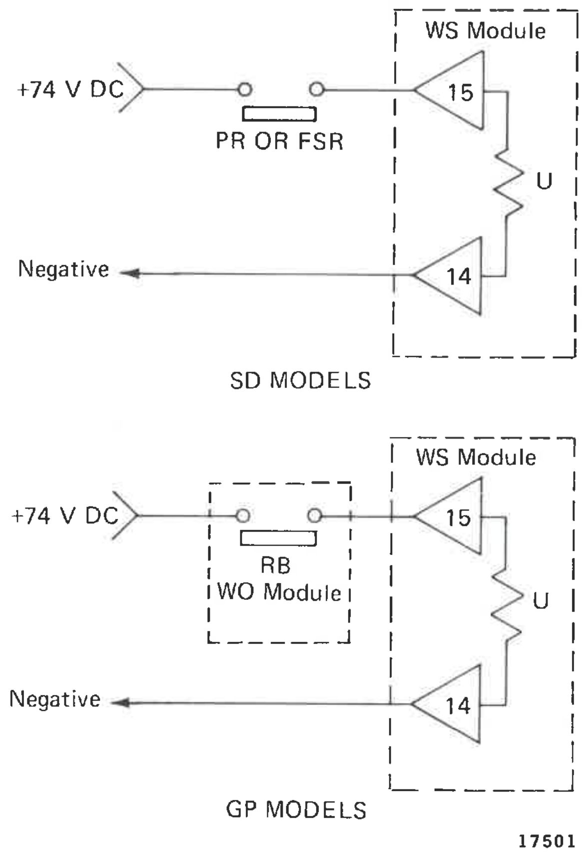


Fig. WS-2 -- Application Of Recalibration Signal To WS Module

SIMULTANEOUS WHEEL OVERSPEED CORRECTION

A signal is applied to terminal 18 of the WS module in case a wheel overspeed condition occurs. Wheel overspeed may result from excessive track speed or from a simultaneous wheel slip condition.

Wheel overspeed is detected by the wheel overspeed module WO on locomotives that are not equipped for transition from series-parallel to parallel motor connections. The RA relay in the

WO module picks up when a wheel overspeed is detected by the WO module. Pickup of RA provides a feed to the WL relay and to terminal 18 of the WS module. Pickup of RA also drops the feed to the equipment protection relay EQP.

Wheel overspeed is detected by the transition module TR on locomotives equipped for transition from series-parallel to parallel motor connections. The PRA relay picks up during transition to parallel motor connections. PRA remains picked up until track speed decreases and backward transition occurs. If an overspeed condition occurs, the TR module provides a feed to the FTX relay. Pickup of FTX provides a feed to the WL relay and to terminal 18 of the WS module. Pickup of FTX also drops the feed to EQP.

Pickup of WL provides a feed to the wheel slip light WS. The feed to terminal 18 results in pickup of RAA and RAB. Pickup of RAA provides a fast discharge path for the RC capacitors on the RC module. Pickup of RAB provides a sanding signal to the SA module. Dropout of EQP removes the feed from the generator field contactor GFC which results in disconnecting the D14 alternator from the main generator field. Therefore, the overspeed condition is corrected by removing excitation from the main generator field. The RC capacitors are discharged to provide for smooth reapplication of power when the overspeed condition is corrected and power is reapplied. Refer to Fig. WS-3.

TEST CIRCUIT OPERATION

With the isolation switch in RUN position and the throttle opened, the GFX relay picks up. Pickup of GFX prevents pickup of the test relay T in case the test switch is closed when operating under power. This prevents the application of high (Run 8) voltage from the D14 alternator to transformer T1.

When the locomotive is isolated or the throttle is placed in IDLE position, the GFX relay drops out to allow application of 74 volts DC control current to the T relay when the test switch is closed. Pickup of the T relay also connects one phase from the D14 alternator to transformer T1 and to the wheel slip level detector circuit. The output of the D14 alternator is approximately 75 volts when the throttle is in IDLE or the isolation switch is placed in the isolated position.

The output from the secondary of T1 provides a signal to RH1. This signal places a large forward bias on Q1 which causes the R relay to pick up. Pickup of the R relay provides a feed to the RAA and RAB relays. Pickup of RAB provides a sanding signal to the SA module. Pickup of RAA provides a discharge path for the rate control capacitors, however, the charge on the capacitors is very small since the throttle is in IDLE position.

Pickup of the L relay provides a feed to the WL relay causing the WS light on the locomotive control stand to go on. Pickup of the L relay also provides a feed to the G relay and the green test light, through the No. 2 contacts of the T relay, the No. 2 contacts of RAA, and the No. 1 contacts of RAB. Pickup of the G relay drops the feed to the red test light and provides a holding circuit for the G relay and also provides a feed to the green test light.

The R relay drops out when capacitor C3 is fully charged and Q1 turns off, but the green light and G relay remain energized through the holding circuit. Dropout of the R relay drops the feed to RAA and RAB which removes the sanding signal from the SA module. The green test light will remain on as long as the test switch is held in the closed position. The circuits of the WS module return to normal when the test switch is released.

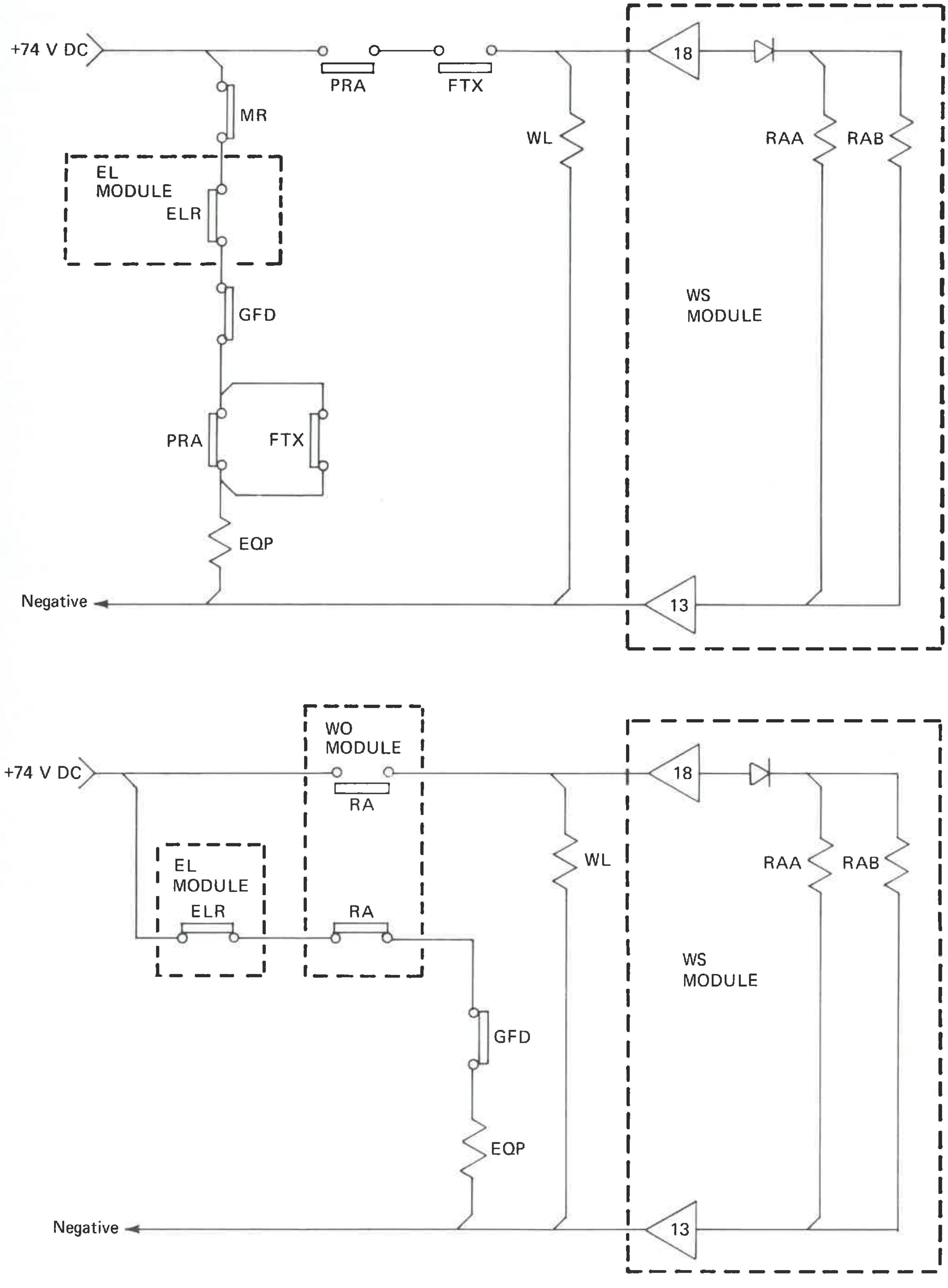


Fig. WS-3 – Application Of Wheel Overspeed Signal To WS Module

12S172

WHEEL SLIP BRIDGE CIRCUIT

The wheel slip bridge circuit is designed to detect a simultaneous wheel slip of all wheels on one truck during slow speed operation and during dynamic brake operation. The bridge circuit consists of two traction motors and two 2K resistors. The wheel slip relay WSR on the WS module is connected across the bridge circuit. Refer to Fig. WSBC-1.

The bridge circuit is balanced during normal operation. However, the bridge circuit will become unbalanced if all wheels on one truck develop a simultaneous slip. This unbalanced condition is detected by the WSR relay. Pickup of WSR results in reduced excitation and application of sand to the rails. Refer to the description of the WS module for explanation of this corrective action.

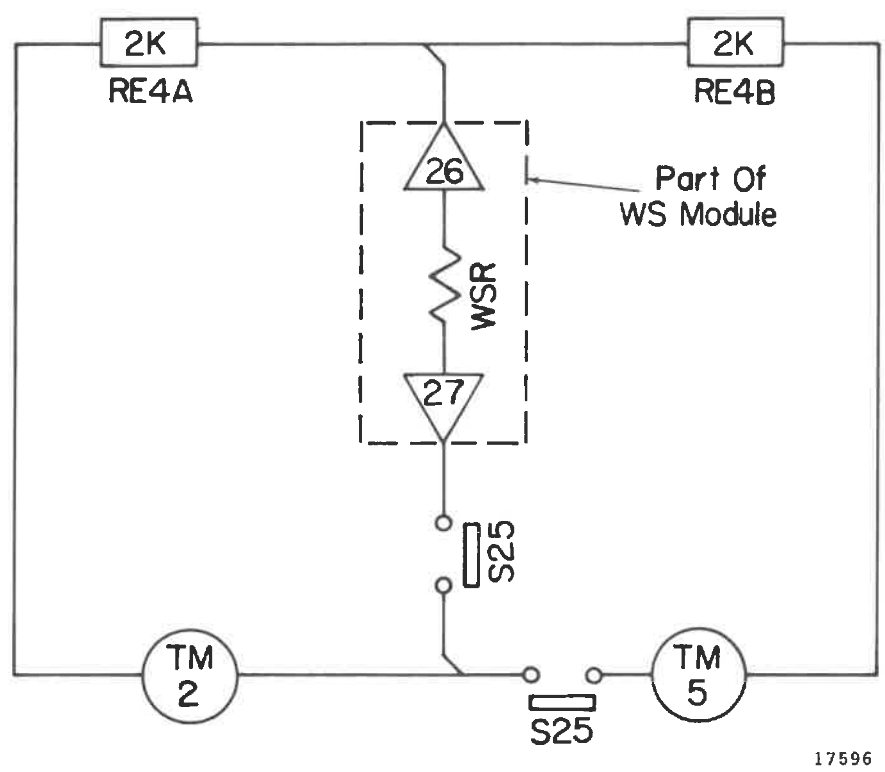


Fig. WSBC-1 -- Wheel Slip Bridge Circuit, Simplified Schematic Diagram

WHEEL SLIP TRANSDUCTOR, WST

The wheel slip transductor consists of two laminated iron cores, two AC windings, and two single conductor motor current bias windings. The two cores are magnetically isolated from each other by an air gap and each core contains an AC winding. The two motor current bias windings are common to both cores. A simplified schematic diagram of a wheel slip transductor is provided in Fig. WST-1.

One of the motor current bias windings carries current to a traction motor that drives one pair of wheels. The other motor current bias winding carries current to a traction motor that drives a different pair of wheels. The current through the two motor current bias windings is approximately equal when the motors are operating at the same speed. Therefore, the flux lines set up by the two motor current bias windings are approximately equal. The two motor current bias windings are connected so that their flux lines are opposite causing the resultant flux lines to be near zero during normal operation.

The two AC windings are connected series opposing so that the magnetic lines of force in the two cores travel in opposite directions. The AC windings, in series with resistor RE6, are energized by current flow from the D14 alternator. The reactance of the AC windings is much larger than the resistance of RE6. Therefore, during normal operation, practically all of the input AC voltage is developed across the AC windings and very little voltage appears across RE6. The voltage across RE6 is applied to the WS module. Therefore, the input signal to the WS

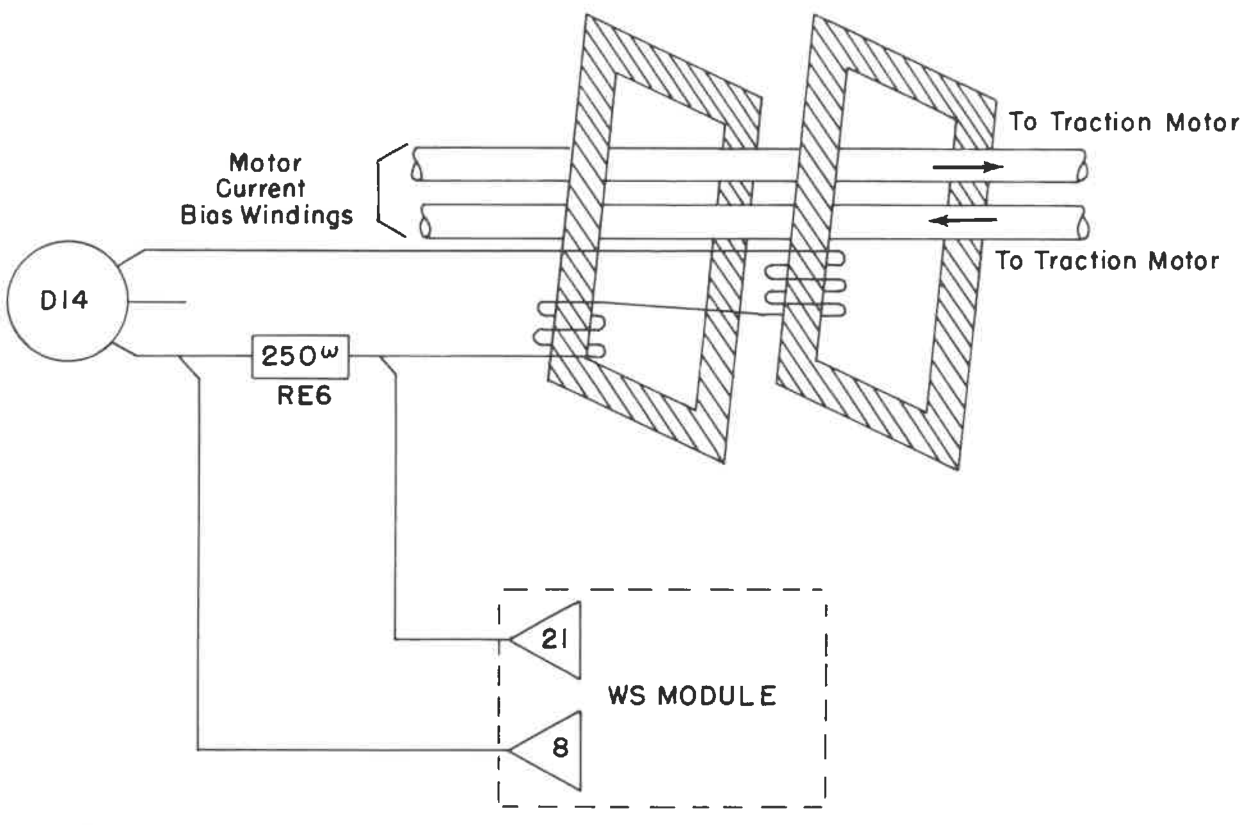


Fig. WST-1 – Typical Wheel Slip Transductor, Simplified Schematic Diagram module is very small and essentially constant during normal operation.

When a differential wheel slip occurs, the current flow in the two motor current bias windings becomes unbalanced. This current unbalance results in an unbalance in the flux lines from the bias windings.

During any unbalance in bias, the resultant flux lines set up by the bias winding aids the flux lines set up by the AC winding in one core and opposes the flux lines set up by the AC winding in the other core. The core in which the flux lines aid moves toward magnetic saturation causing the reactance of the AC winding on this core to decrease. The core in which the flux lines oppose moves away from saturation, but the reactance of the winding on this core is affected by only a very small amount. Therefore, the total resultant reactance of the two AC windings decreases whenever an unbalance occurs in the current flow through the two motor current bias windings. The decrease in reactance is proportional to the amount of unbalance in current flow through the motor current bias windings.

A decrease in reactance of the AC windings results in an increase in current flow through RE6 and an increase in the signal developed across RE6. Therefore, the signal applied to the WS module from RE6 is proportional to the unbalance in current flow through the motor current bias windings.

A simultaneous wheel slip, where all wheels slip at the same rate, will not cause a current unbalance in the motor current bias windings. Therefore, the wheel slip transductors cannot detect a simultaneous wheel slip. However, the wheels would tend to overspeed and this condition would be detected by the WO module on GP model locomotives and by the TR module on SD locomotives.

Refer to description of the WS module for further details on wheel slip detection and correction.

DYNAMIC BRAKING SYSTEM EXCITATION AND CONTROL

INTRODUCTION

This section provides a general description of the dynamic braking system excitation and control. Description of the system is followed by a detailed description of typical modules and components used in the system. Simplified schematic diagrams of the system modules and components are provided in this section for convenient reference. The locomotive wiring diagram should be used when performing troubleshooting or maintenance on the dynamic braking system.

GENERAL DESCRIPTION

Locomotive dynamic braking is a system which is used to retard locomotive speed through the conversion of kinetic energy to electrical energy. This energy conversion is accomplished by connecting the traction motors as separately excited generators with field current being provided by the main generator. The motor armatures are geared to the axles and rotate whenever the locomotive is moving. Loading is provided by connecting the traction motor armature circuits to the dynamic braking grids. Armature current (grid current) is determined by the speed at which the armatures rotate (track speed) and by the amount of excitation applied to the motor fields. The motor field connections during dynamic braking are shown in Fig. 7D-1 and the motor armature connections are shown in Fig. 7D-2.

The graph in Fig. 7D-3 illustrates the increase in braking effort as track speed increases. With maximum field excitation (approximately 975 amperes with braking lever in position 8) braking effort increases from minimum at zero miles per hour to maximum at approximately 24 miles per hour. Maximum braking effort for the lower braking lever positions is progressively lower and is attained at progressively higher track speeds as the braking lever position is decreased. After maximum braking effort is attained, an increase in track speed results in a decrease in braking effort. High braking effort is maintained at low track speeds on locomotives equipped with extended range dynamic brakes. Refer to description of the extended range dynamic brake module DE for description of the extended range dynamic brakes.

The amount of kinetic energy that is converted into electrical energy is proportional to I^2R where I is braking grid current and R is the effective resistance of the braking grids. The increase in braking effort from zero to maximum results from increased motor armature grid current as track speed increases. This results in an increase of I^2R and consequently an increase in braking horsepower since horsepower is equal to I^2R divided by 746. The armature or grid current increases to its maximum value at the speed where maximum braking effort is attained and remains at the maximum value at all higher speeds.

The reason for a decrease in braking effort at higher track speeds may be explained as follows. It is important to remember that braking horsepower remains constant at the higher track speeds. Braking effort may be defined as the amount of retarding force in pounds that is applied to decrease the track speed. The horsepower formula often used in railroad work is given as follows:

Horsepower = weight in pounds x speed in miles per hour divided by 375.

Retarding force in pounds (braking effort in pounds) may be substituted for weight in the above formula, then:

Horsepower = braking effort in pounds x speed in miles per hour divided by 375.

Braking horsepower remains constant, therefore, the product of (braking effort in pounds) and (speed in miles per hour) must remain constant. If speed increases, the retarding force or braking effort must decrease in order for braking horsepower to remain constant.

Excitation current to the motor fields is controlled by the braking lever (throttle) position and by the dynamic braking regulator module DR. The DR module senses a voltage across a portion of one braking grid, which is proportional to braking grid current. The DR module operates to limit the excitation current to a value that prevents armature or grid current from increasing above the maximum safe current carrying capacity of the braking grids. Refer to description of the DR module for a detailed description of this regulating action.

The braking grids are cooled by an exhaust blower to prevent overheating. The blower motor is connected across a portion of one braking grid. The blower, located above the grids, draws outside air through a grill, circulates it around the grids, and exhausts to atmosphere. The DG module provides protection by dropping the feed to the brake relay B in case the blower motor fails to operate. Refer to description of the DG module for description of this protective action.

The DP module contains a motor field protection circuit MFP and a brake warning circuit BWR. The motor field protection circuit operates to protect the motor fields, if a fault in the excitation circuit permits motor field excitation current to rise above a safe value. The brake warning circuit is provided for backup protection of the braking grids. If a fault develops in the DR module, grid current may tend to rise and cause failure of the grids. If grid current increases above a safe value, the BWR circuit operates to decrease excitation which results in a decrease in grid current. Refer to description of the DP module for description of this protective action.

If a braking grid opens, the open circuit protection relay OCP detects an unbalance and operates to drop the feed to brake relay B. Dropping this feed disables the dynamic braking system. This prevents opening of the grid shorting contactors while carrying high current and it also protects the traction motors from excessively high voltages. After pickup, the OCP relay mechanically latches in and should not be reset until the braking grid circuit has been repaired.

The brake current transductor BCT is used on locomotives equipped with extended range dynamic brakes. BCT provides a signal, to transformer T4, which is proportional to braking grid current. The output of T4 is used as an input to the DE module where it is compared with the field current signal. If the grid current signal is smaller than the field current signal, the DE module initiates pickup of a grid shorting contactor. If the grid current signal is larger than the field current signal, the DE module initiates dropout of a grid shorting contactor. Refer to description of the DE module for further details.

The brake current transductor BCT is also used on locomotives equipped with (special order) grid current control. On these special order locomotives, output of the BCT is applied to the DR module. The DR module compares the BCT signal with the braking lever signai. This comparison results in limiting grid current to a value proportional to braking lever position. Refer to description of the DR module for a detailed description of this regulating action.

DYNAMIC BRAKING FOR LOCOMOTIVES EQUIPPED WITH TRAINLINE GRID CURRENT CONTROL

On locomotives equipped with trainline grid current control, maximum grid current is limited to a value proportional to braking lever position. The grid current values and braking effort for braking lever positions 3 through 8 are provided in Fig. 7D-4. Refer to description of the DR module for description of trainline grid current control.

CONTENTS

The contents of Section 7 Part D are arranged in the following order.

DE - Extended Range Dymamic Brake Module.

DG - Dynamic Brake Grid Protection System.

DP - Dynamic Brake Protection Module.

DR - Dynamic Brake Regulator Module.

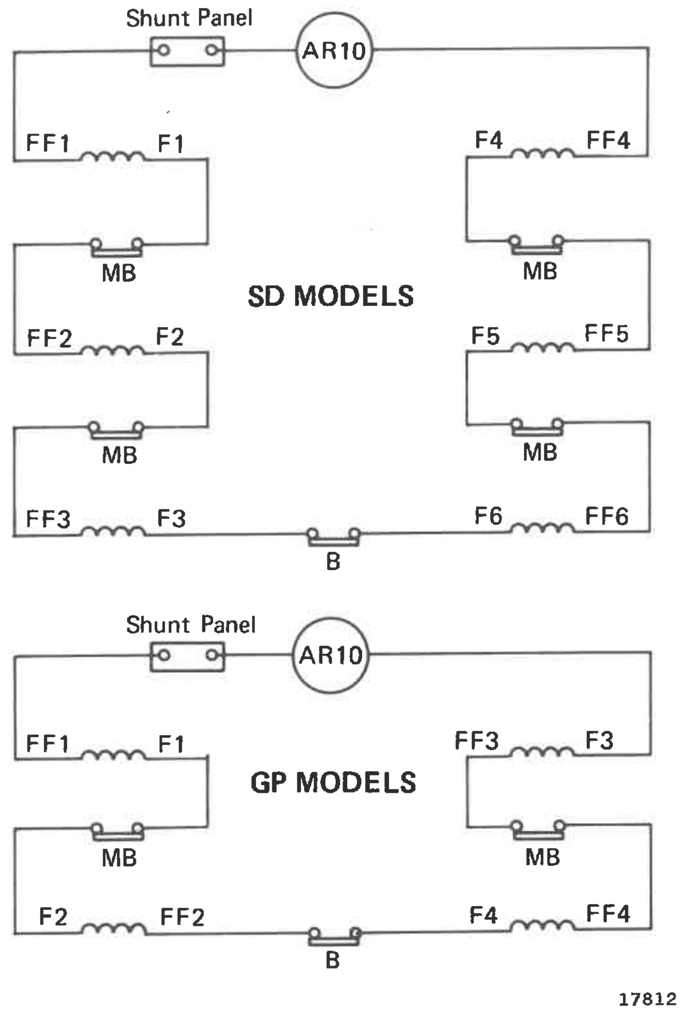
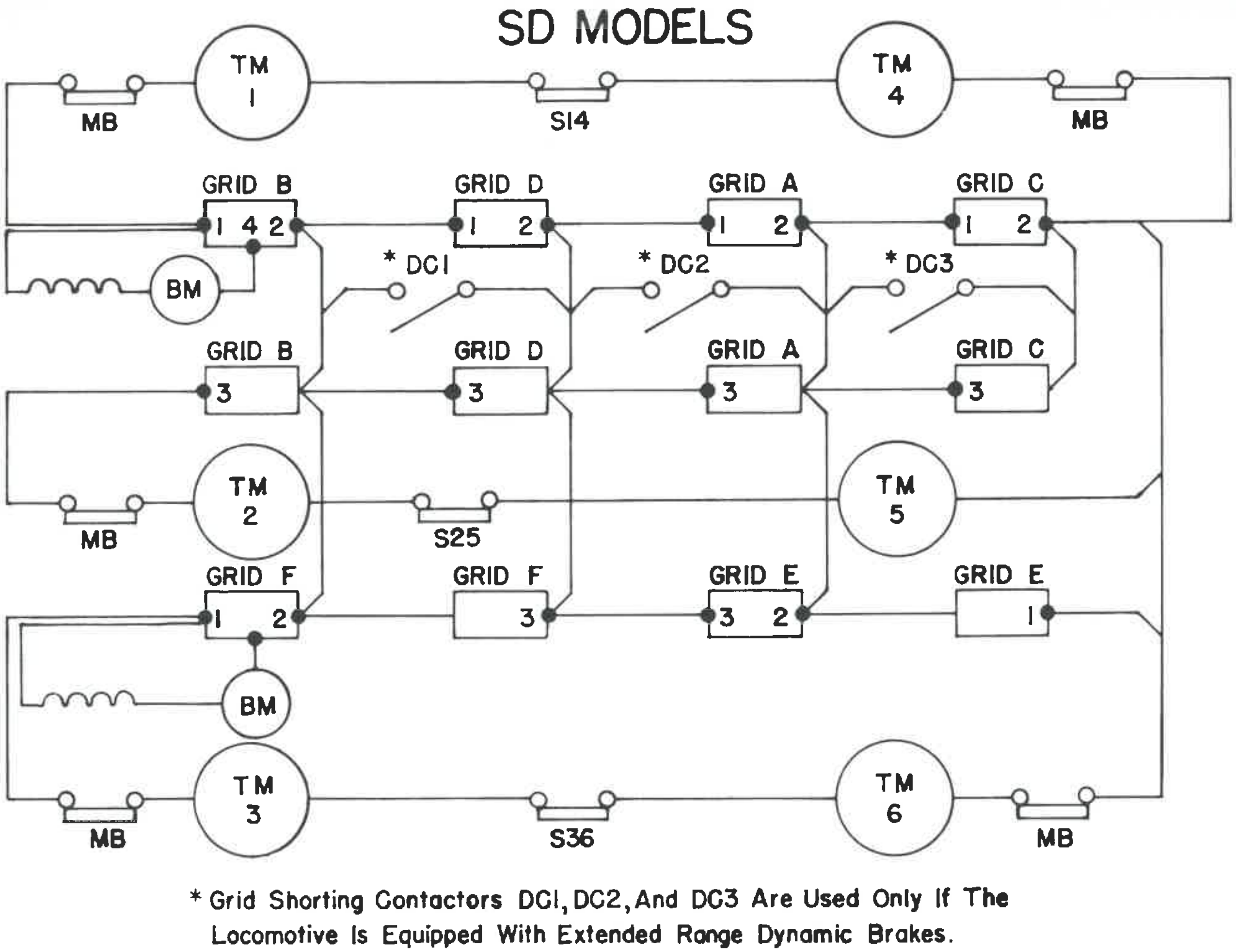


Fig. 7D-1 – Motor Field Connections During Dynamic Braking
Simplified Schematic Diagram



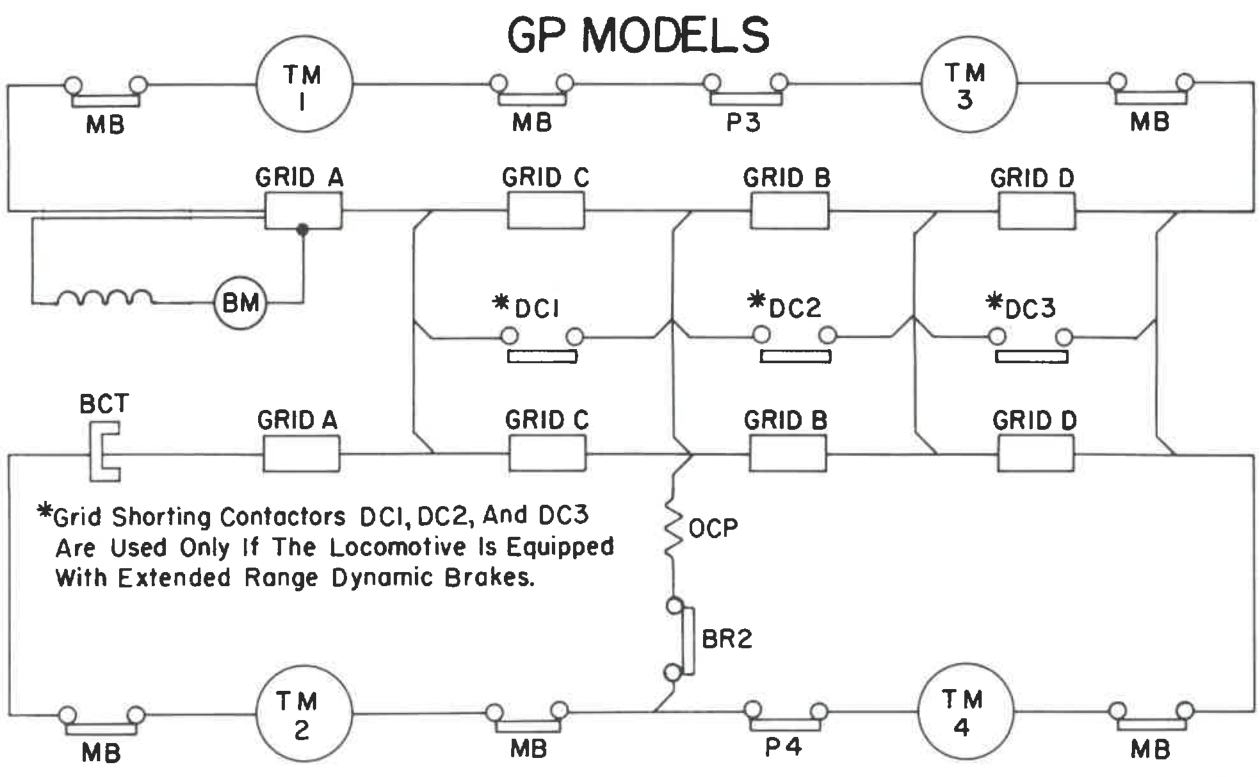


Fig. 7D-2 – Motor Armature Connections During Dynamic Braking Simplified Schematic Diagram

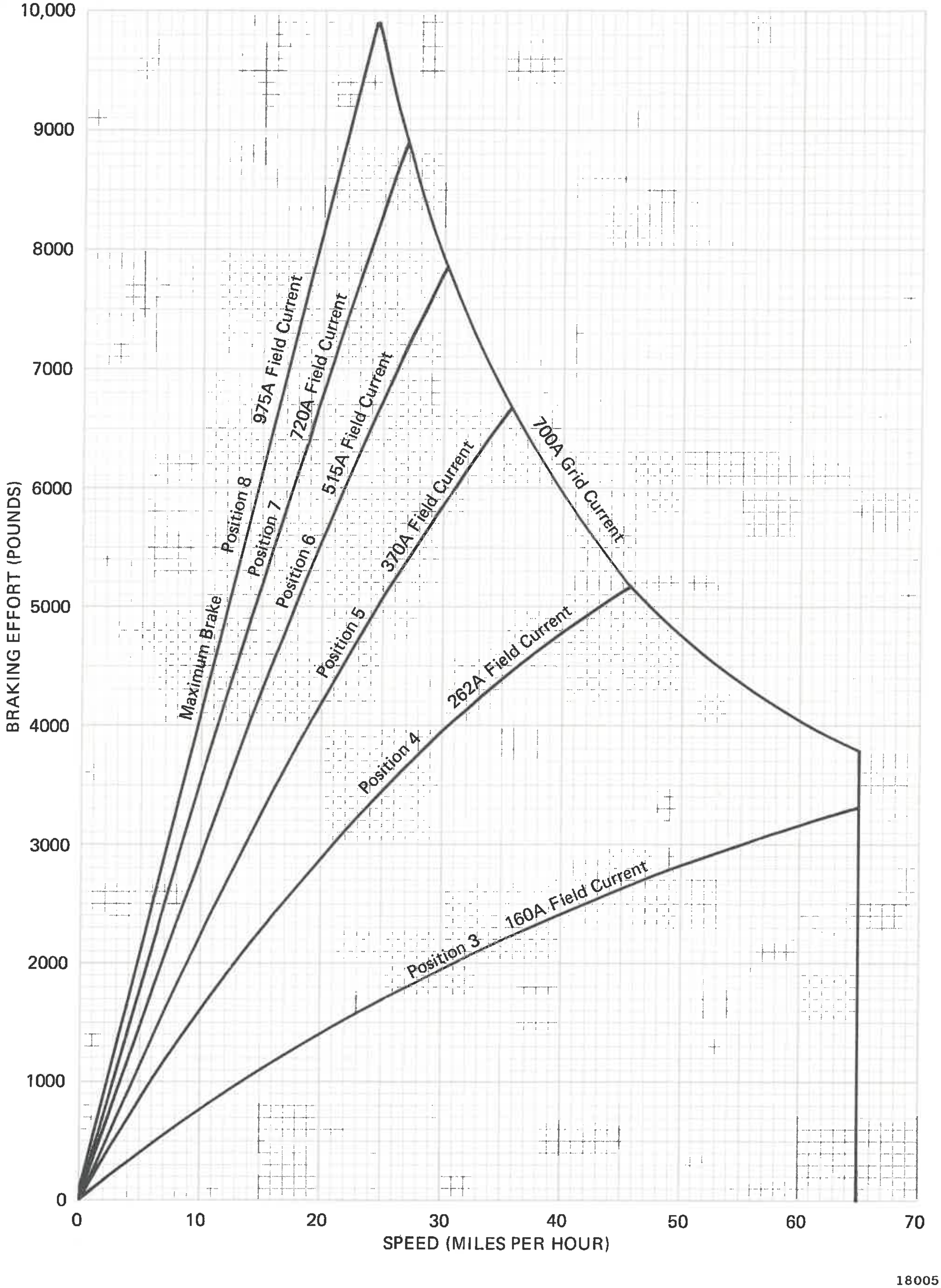


Fig. 7D-3 -- Braking Effort Curves With Basic Dynamic Brakes

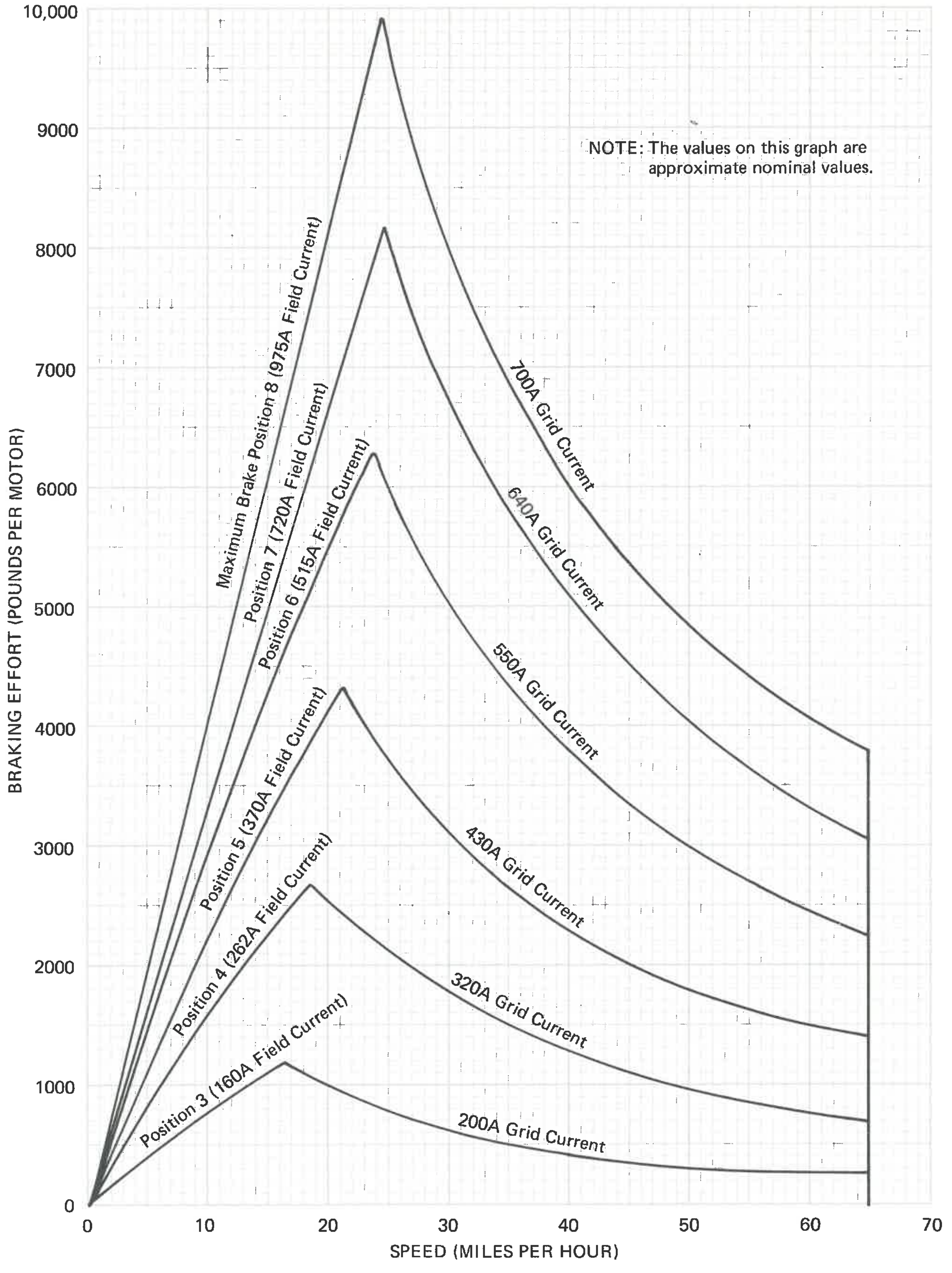


Fig. 7D-4 – Breaking Effort Curves When Equipped With Trainline Grid Current Control (Special)

EXTENDED RANGE DYNAMIC BRAKE MODULE, DE (SPECIAL ORDER)

INTRODUCTION

On locomotives equipped with basic dynamic brakes, maximum braking effort normally drops off rapidly at track speed below approximately 24 miles per hour on locomotives equipped with 0.86 ohm dynamic braking grids. On locomotives equipped with 0.66 ohm dynamic braking grids, maximum braking effort drops off rapidly at track speeds below approximately 19 miles per hour. However, on locomotives equipped with extended range dynamic brakes, the braking effort remains high until track speed decreases to approximately 5 to 7 miles per hour. High braking effort is maintained by shorting out a portion of the dynamic braking grids as track speed decreases.

The extended range dynamic brake module DE consists of comparison circuits and control circuits as necessary to short out the braking grids at the proper time to maintain high grid current and high braking effort. The DE module also contains a comparison circuit that operates to limit braking grid current to a value that is proportional to braking lever position.

GENERAL DESCRIPTION

GRID CURRENT CONTROL

An input signal proportional to braking grid current is applied between terminals 7 and 11 of the DE module. This signal is rectified and applied to a voltage divider consisting of resistors R5 through R11. The voltage developed across R8 through R11 is applied to the base of Q1, through diode D2. Therefore, a signal proportional to braking grid current is applied to the base of Q1.

An input signal proportional to braking lever position is applied to terminal 2 of the DE module. This signal is applied to the emitter of Q1, through resistor R3. Forward bias is applied to Q1 when the grid current signal rises above the braking lever signal. Turn on of Q1 connects terminal 4 to terminal 5 on the DE module.

Terminal 5 on the DE module is connected to terminal 5 on the DR module. Terminal 4 on the DE module is connected to terminal 4 on the DR module when the DP1A contacts at terminal 4 are closed. The DP1A contacts are closed during extended range dynamic brake operation. Therefore, during extended range dynamic brake operation, terminals 4 and 5 on the DE module are connected to terminals 4 and 5 on the DR module when Q1 on the DE module is turned on.

Connecting terminals 4 and 5 of the DE module to terminals 4 and 5 on the DR module results in forward bias to Q3 on the DR module. Turn on of Q3 discharges the rate control capacitors on the RC module. Refer to description of the DR module for a more detailed description of grid current regulation. Discharging the capacitors reduces excitation to the main generator field and results in less grid current. The grid current decreases until the grid current signal applied to the base of Q1 on the DE module is equal to or less than the braking lever signal applied to the emitter of Q1. Regulation of grid current to a value proportional to braking lever position is available during basic dynamic brake operation as well as during extended range dynamic brake operation by shorting out the DP1A contacts to provide a direct connection from terminal 4 on the DE module to terminal 4 on the DR module.

700 AMPERE – 0.86 OHM EXTENDED RANGE DYNAMIC BRAKES

The following general description applies to extended range dynamic brake operation for locomotives equipped with 0.86 ohm dynamic braking grids and braking lever in maximum brake position. The same general description is applicable when the braking lever is moved away from maximum brake position. However, braking effort, grid current, and field current decrease as the braking lever is moved away from maximum brake position. The braking grids are shorted out at a different track speed for each braking lever position. Refer to braking effort, grid current, and field current curves, Fig. DE-1. This general description also applies to locomotives equipped with 0.66 ohm dynamic braking grids. However, maximum braking effort and shorting out of dynamic braking grids occur at different track speeds for different values of braking grid resistance. Braking effort, grid current, and field current curves for 0.66 ohm braking grids are provided in Fig. DE-2.

At track speeds above approximately 24 miles per hour, the field current is regulated by the dynamic brake regulator module DR as necessary to limit braking grid current to a maximum of 700 amperes. Refer to description of the DR module for description of this regulating action. Braking grid current is limited to a maximum of 700 amperes to prevent overheating of the braking grids. Regulation of grid current to a value proportional to braking lever position is available by special order from the customer. Approximately 500 amperes of field current is required to produce 700 amperes of grid current at 30 miles per hour. An increase in field current from 500 amperes to 975 amperes is required to maintain a grid current of 700 amperes as track speed decreases from 30 miles per hour to approximately 24 miles per hour. This relationship is shown between points A and B of Fig. DE-1.

Field current is limited to a maximum of 975 amperes, therefore, a decrease in track speed below 24 miles per hour results in a decrease in grid current and a decrease in braking effort. This decrease is shown between point B and area C of Fig. DE-1. With basic dynamic brakes, braking effort would decrease rapidly along a line from point B to O on the braking effort curve as track speed decreases from 24 miles per hour to standstill. However, with extended range dynamic brakes a high level of grid current and braking effort is maintained until track speed decreases to approximately 7 miles per hour. This improved braking effort with extended range dynamic brakes is obtained by shorting out a portion of the dynamic braking grids as track speed decreases. Shorting out a portion of the braking grids results in maintaining braking grid current near 700 amperes. Otherwise, braking grid current would decrease rapidly from point B to O as track speed decreases from 24 miles per hour to standstill. Shorting out of the braking grids is controlled by the DE module.

The DE module consists of the necessary comparison circuits and control circuits to short out the braking grids at the proper time to maintain high grid current. A step by step operational description of the DE module is provided in Fig. DE-3. A simplified schematic diagram of the DE module, Fig. DE-4, is included for reference only. The applicable locomotive wiring diagrams should be used when performing troubleshooting or maintenance of the extended range dynamic braking system.

The grid current decreases from 700 amperes at 24 miles per hour to approximately 600 amperes at 21 miles per hour. This grid current decrease is shown by the line from point B to area C on the grid current curve of Fig. DE-1. The DE module senses this decrease in grid current and initiates pickup of grid shorting contactor DC1 and also places a fast discharge path across the rate control capacitors located on the rate control module RC. This permits partial discharge of the RC capacitors and results in a reduction of excitation to the main generator field. The reduced excitation results in fast reduction of field current as shown at area C of the field current curve in Fig. DE-1. This reduction in field current prevents excessive grid current when a portion of the braking grids are shorted out.

Pickup of DC1 shorts out a portion of the braking grids. Pickup of DC1 also removes the fast discharge path from the rate control capacitors. Removing the fast discharge path allows field current to increase to a maximum of 975 amperes as necessary to maintain a grid current of 700 amperes. This increase in field current is shown between area C and point D of the field current curve in Fig. DE-1.

Shorting out a portion the braking grid reduces the total braking grid resistance by 25%. This results in a fast increase of grid current to 700 amperes, as shown at area C of the grid current curve in Fig. DE-1. The braking effort increases as track speed decreases from approximately 21 miles per hour at area C to approximately 18 miles per hour at point D, as shown by the braking effort curve in Fig. DE-1. This increase in braking effort is the result of maintaining constant horsepower ($I^2 R$ divided by 746) and a decrease in track speed. When horsepower is constant, the retarding force or braking effort increases as track speed decreases. This is indicated by the following horsepower formula:

Horsepower is equal to retarding force times miles per hour divided by 375.

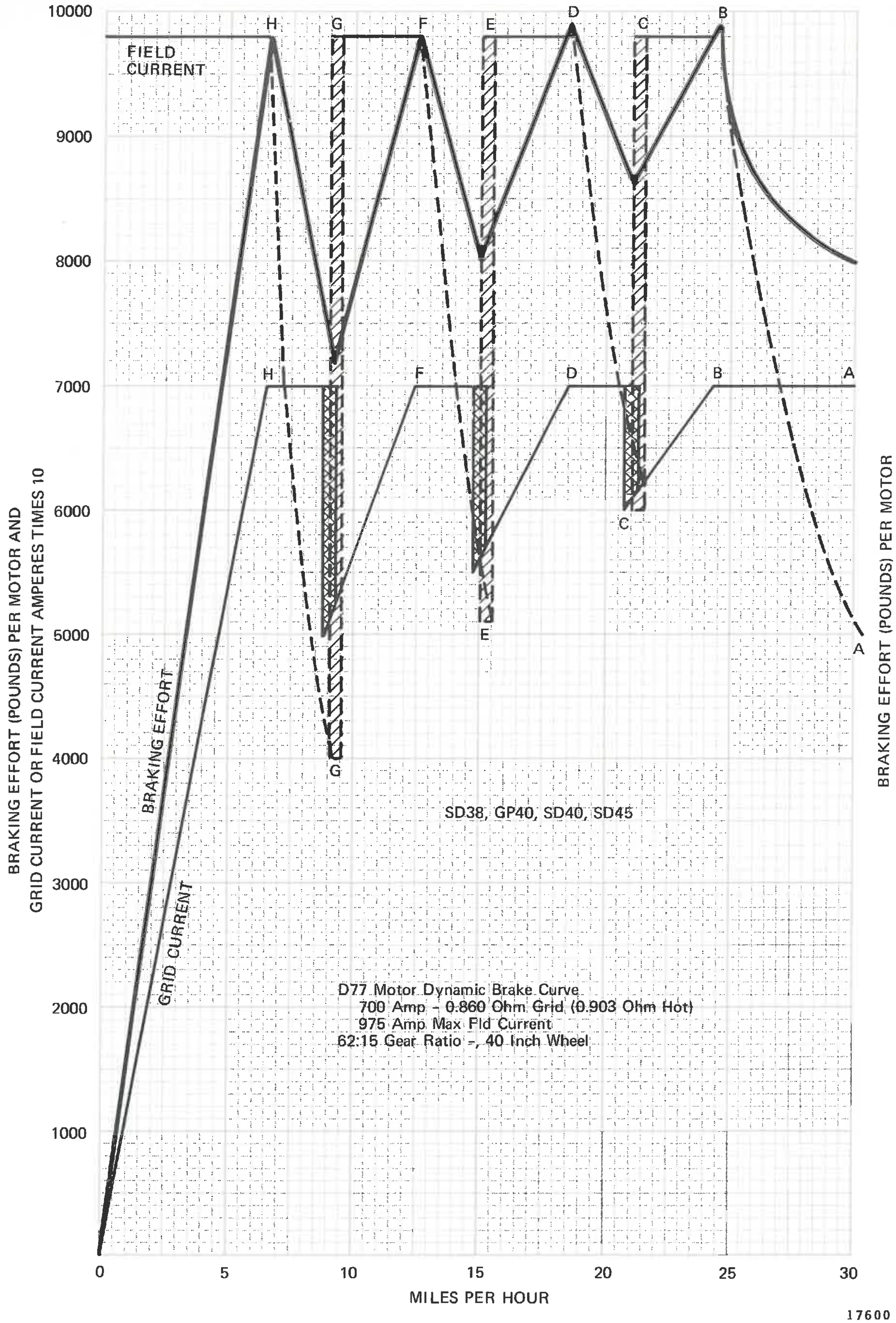


Fig. DE-1 -- Braking Effort, Grid Current And Field Current Curves For Extended Range Dynamic Brakes With 0.86 Ohm Grids

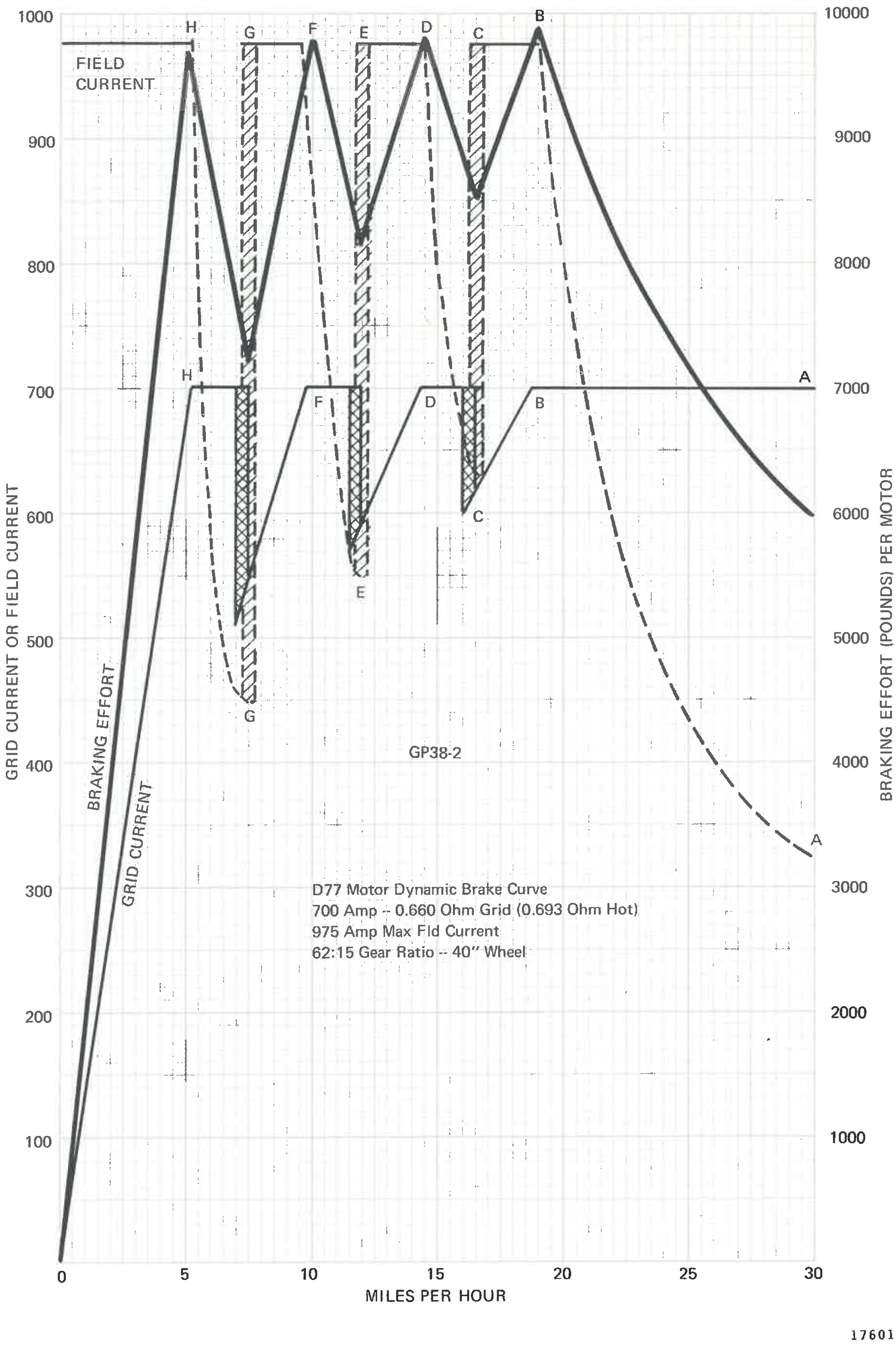


Fig. DE-2 – Braking Effort, Grid Current And Field Current Curves For Extended Range Dynamic Brakes With 0.66 Ohm Grids

Field current and braking effort reach their maximum value at approximately 18 miles per hour as shown at point D on the field current and braking effort curves in Fig. DE-1. A further decrease in track speed from approximately 18 miles per hour at point D to approximately 15 miles per hour at area E results in a decrease in grid current and braking effort. At area E the grid current has decreased to approximately 560 amperes. The DE module senses the decrease in current and initiates pickup of grid shorting contactor DC2 and also places a fast discharge path across the rate control capacitors. This results in partial discharge of the capacitors and reduces excitation to the main generator. The reduced excitation results in a fast reduction in field current as shown at area E of the field current curve in Fig. DE-1. The reduction in field current prevents excessive grid current when DC2 picks up.

Pickup of DC2 shorts out a second portion of the braking grid and also removes the fast discharge path from the rate control capacitors. Removing the fast discharge path allows field current to increase to a maximum of 975 amperes as necessary to maintain a grid current of 700 amperes. This increase in field current is shown between area E and point F of the field current curve in Fig. DE-1.

Shorting out the second portion of the braking grid reduces the remaining braking grid resistance by approximately 33%. This results in a fast increase of grid current to 700 amperes as shown at area E of the grid current curve in Fig. DE-1. The braking effort increases as track speed decreases from approximately 15 miles per hour at area E to approximately 13 miles per hour at point F as shown by the braking effort curve in Fig. DE-1. This increase in braking effort is the result of constant horsepower and a decrease in track speed.

Field current and braking effort again reach their maximum value at approximately 13 miles per hour as shown at point F on the field current and the braking effort curves in Fig. DE-1. A further decrease in track speed from approximately 13 miles per hour at point F to approximately 9 miles per hour at area G results in a decrease in grid current and in braking effort. At area G the grid current has decreased to approximately 500 amperes. The DE module senses the decrease in current and initiates pickup of grid shorting contactor DC3 and also places a fast discharge path across the rate control capacitors which permits partial discharge of the capacitors and reduces excitation to the main generator field. The reduced excitation results in a fast reduction in field current as shown at area G of the field current curve in Fig. DE-1. The reduction in field current prevents excessive grid current when DC3 picks up.

Pickup of DC3 shorts out a third portion of the braking grid and also removes the fast discharge path from the rate control capacitors. Removing the fast discharge path allows field current to again increase to a maximum of 975 amperes as necessary to maintain a grid current of 700 amperes. This increase in field current is shown between area G and point H on the field current curve in Fig. DE-1.

Shorting out the third portion of the braking grid reduces the remaining braking grid resistance by approximately 50% which results in a fast increase of grid current to 700 amperes as shown at area G of the grid current curve in Fig. DE-1. The braking effort increases as track speed decreases from approximately 9 miles per hour at area G to approximately 7 miles per hour at point H as shown by the braking effort curve in Fig. DE-1. This increase in braking effort is the result of maintaining constant horsepower as track speed decreases.

The field current and braking effort again reach their maximum value at approximately 7 miles per hour as shown at point H on the field current and braking effort curves in Fig. DE-1. A further decrease in track speed below 7 miles per hour results in a decrease in grid current and in braking effort as shown between points H and O on the grid current and braking effort curves in Fig. DE-1.

700 AMPERE – 0.66 OHM BRAKING GRIDS

The general description of extended range dynamic brake operation for locomotives equipped with 0.66 ohm braking grids is the same as for locomotives equipped with 0.86 ohm braking grids. However, maximum braking effort and shorting out of dynamic braking grids occur at different track speeds for different values of braking grid resistance. Refer to Fig. DE-2 for braking effort, grid current, and field current curves applicable to 0.66 ohm braking grids.

OPERATION OF THE DE MODULE

An input signal, from transformer T4, which is proportional to braking grid current is applied between terminals 7 and 11 of the DE module. This signal is rectified and applied to a voltage divider consisting of resistors R5, R6, R7, R8, R9, R10, and R11. A portion of the grid current signal from the voltage divider is applied to the emitter of solid state switch Q3. A smaller portion of the grid current signal is applied to the base of solid state switch Q2.

A feedback signal, from the performance control module, which is proportional to traction motor field current is applied between terminals 6 and 14 of the DE module. The traction motor field current signal is applied to the base of Q3 and to the emitter of Q2. Therefore, the grid current signal is compared with the traction motor field current signal by solid state switches Q3 and Q2.

The power supply for solid state switches Q3 and Q2 is provided by transformer T1. The D14 alternator input to transformer T1 is applied between terminals 8 and 10 of the DE module. Transformer T1 contains two secondary windings, one for each solid state switch. The voltage applied to the primary of T1 is limited to 10 volts by zener diodes Z1 and Z2 along with resistors R1 and R2.

The traction motor field current signal is contant at all speeds for a given braking lever position. The signal increases as the braking lever is advanced. The grid current signal increases with speed, until the maximum value of grid current allowed by the DR module is attained. Assume that the braking lever is in maximum brake position and track speed is above 25 miles per hour. Under these conditions, the grid current signal applied to the emitter of Q3 is larger than the field current signal applied to the base of Q3. This keeps Q3 cut off and no current flows through T1A secondary or T3 primary.

The sequence of events that occur during extended range dynamic brake operation for locomotives equipped with 0.86 ohm braking grids is given in Fig. DE-3. The general information provided in Fig. DE-3 is applicable to locomotives equipped with 0.66 ohm braking grids. However, shorting out the different braking grid sections occurs at different track speeds for different braking grid resistance values. A simplified schematic diagram of the DE module, Fig. DE-4, is provided for reference only. The applicable locomotive wiring diagrams should be used when performing troubleshooting or maintenance on the extended range dynamic braking system.

Step	Procedure Or Condition	Result Of Procedure Or Condition
	OPERATION OF DE MODULE DURING DECREASING TRACK SPEED	
1	Assume that braking lever is in maximum brake position and track speed is above 24 miles per hour.	The grid current signal at emitter of Q3 is larger than the field current signal at the base of Q3. Q3 is reverse biased.
2	Assume that track speed decreases to 22 miles per hour.	The grid current signal decreases while field current signal remains the same. Q3 is forward biased.
3	Q3 forward biased.	Current flows through T1A secondary and primary of T3.
4	T3 energized.	Q4 is forward biased by rectified output of T3. Refer to sheet 2 of 2, Fig. DE-4.
5	Forward bias on Q4.	Current flows from terminal 1 of DE module, through Q4, D9, and R32 to negative. C3 charges through R33 until voltage across C3 is sufficient to cause reverse conduction through zener diode Z6. Breakdown voltage of Z6 is 47 volts.

Fig. DE-3 -- Operation Of The DE Module (Sheet 1 Of 6)

Step	Procedure Or Condition	Result Of Procedure Or Condition
6	Charge on C3 causes Z6 to conduct.	Forward bias applied to Q11. Q12 is forward biased through R37.
7	Q11 and Q12 turned on.	Forward bias applied to Q8 by connecting base of Q8 to negative through D8, R36, Q11, and Q12.
8	Forward bias on Q8.	Current flows from terminal 1 of DE, through Q4, Z4, Q8, D14, and coil of relay DP1. DP1 picks up. NOTE: Charging of C3 in Step 5 provides a short time delay which prevents pickup of DP1 from transient voltages in T3.
9	DP1 picked up.	Provides holding feed to DP1 (1NC - 1NO) through forward biased Q10. Places forward bias on Q13 and provides charging path for C4 and C5 (3C - 3NO) through A-B of DC1. Provides feed to DP1A (3C - 3NO). Provides feed to DC1 (2C - 2NO). DC1 picks up after a short inherent time delay.
10	Forward bias on Q13.	Provides fast discharge path for rate control capacitors (on RC module) to prevent excessive spikes in grid current when DC1 picks up to short out one braking grid.
11	Charge placed on C4 and C5 (Step 9).	Places forward bias on Q6 when charge on C4 and C5 rises above breakdown value of zener diode Z8.
12	Forward bias on Q6.	Provides feed to TD relay and places reverse bias on Q12.
13	DC1 picked up (Step 9).	Removes forward bias from Q13 which opens fast discharge path for RC capacitors on the RC module (A-R). These contacts also remove charging current from C4 and C5. Shorts out one dynamic braking grid (main contacts). Provides feed to DC1A and DC1B (E-F). These contacts also provide a feed to LED1 on the DE module.

Fig. DE-3 -- Operation Of The DE Module (Sheet 2 Of 6)

Step	Procedure Or Condition	Result Of Procedure Or Condition
14	TD relay energized (Step 12).	Disables grid overcurrent detector circuit on DP module to prevent operation of BWR due to grid current spikes when braking grid is shorted out by pickup of DC1 (2). Provides a fast charging path for the RC capacitors on the RC module for fast recovery of grid current (1).
15	Reverse bias on Q12.	Provides open circuit to base of Q8. This prevents a feed to DP2 when DC1B picks up. This forces a short time delay between pickup of DC1 and DC2.
16	Open circuit to base of Q8.	Drops main feed to DP1. DP1 remains picked up by holding feed.
17	Dynamic braking grid shorted out (Step 13).	Grid current increases due to reduced resistance in braking grid circuit. Grid current increase results in maintaining high braking effort.
18	DC1A picked up (Step 13).	Recalibrates the grid current signal applied to emitter of Q3. This provides reverse bias to Q3.
19	Reverse bias on Q3.	Blocks current flow through T1A secondary and T3 primary. This results in turn off of Q4.
20	DC1B picked up (Step 13).	Sets up circuit to DP2 in preparation for shorting out a second braking grid in case track speed decreases.
21	Assume that track speed decreases to approximately 18 miles per hour.	Grid current signal decreases while the field current signal remains the same. This places forward bias on Q3.
22	Procedures and conditions of Steps 3 through 17 are repeated except: a. Substitute DP2 for DP1; b. Substitute DC2 for DC1; c. Substitute DC2A for DC1A; d. Substitute DC2B for DC1B; e. Substitute LED2 for LED1.	
23	DC2A picked up.	Q3 turned off by recalibrating grid current signal applied to emitter of Q3. Recalibrates grid current signal to base of Q2. This prevents turn on of Q2 until track speed increases.

Fig. DE-3 -- Operation Of The DE Module (Sheet 3 Of 6)

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Step	Procedure Or Condition	Result Of Procedure Or Condition
24	DC2B picked up.	Sets up circuit to DP3 and provides a holding circuit to DP1 to ensure that DP1 remains picked up until DC2B drops out.
25	Assume that track speed decreases to approximately 12 miles per hour.	Grid current signal decreases while the field current signal remains the same. This places forward bias on Q3.
26	Procedures and conditions of Steps 3 through 17 are repeated except: a. Substitute DP3 for DP1; b. Substitute DC3 for DC1; c. Substitute DC3A for DC1A; d. Substitute LED3 for LED1.	
27	DC3A picked up.	Recalibrates grid current to base of Q2. This prevents turn on of Q2 until track speed increases. Provides holding circuit for DP2 to ensure that DP2 remains picked up until DC3A drops out.
	OPERATION OF DE MODULE DURING INCREASING TRACK SPEED	
1	Assume that braking lever is in position 8 and track speed is below 7 miles per hour.	All DP and DC relays and contactors are picked up.
2	Assume that track speed increases to approximately 9 miles per hour.	Grid current increases to 700 amperes at about 7 miles per hour. The DR module limits grid current to 700 amperes by decreasing excitation. The increase in grid current and decrease in field current places forward bias on Q2 and reverse bias on Q3.
3	Forward bias on Q2.	Current flows through T1B secondary and T2 primary.
4	T2 energized.	Q5 is forward biased by rectified output of T2.
5	Forward bias on Q5.	Current flows from terminal 1 of DE module, through Q5, D11 and R32 to negative and capacitor C3 is charged through R33 until voltage across C3 is sufficient to cause reverse conduction through zener diode Z6. Breakdown voltage of Z6 is 47 volts.
6	Reverse conduction through Z6.	Forward bias is placed on Q11. Q12 is normally forward biased through R37.

Fig. DE-3 – Operation Of The DE Module (Sheet 4 Of 6)

Step	Procedure Or Condition	Result Of Procedure Or Condition
7	Forward bias on Q11.	Places forward bias on Q9.
8	Forward bias on Q9.	Current flows from terminal 1 of DE, through Q5, Q9, and R30. This places reverse bias on Q10 which is normally forward biased.
9	Reverse bias on Q10.	Drops feed to DP3. Feed to DP1 and DP2 is maintained by DC2B and DC3A.
10	DP3 drops out.	C4 and C5 charge through R40. This places forward bias on Q6 when the charge rises above 36 volts. DC3 drops out after a short inherent time delay.
11	Forward bias on Q6.	Places reverse bias on Q12 which removes forward bias from Q9. Cut off of Q9 places forward bias on Q10. TD relay picks up which prevents operation of BWR in the DP module and also provides a fast charging path for the RC capacitors in the RC module. This fast rate of charge provides for fast increase in excitation. TD contacts remain picked up for a short time after C4 and C5 discharge to cut off Q6.
12	Forward bias on Q10.	Provides holding circuit for DP2.
13	DC3 drops out after a short inherent time delay (Step 10).	Removes short circuit from one braking grid which increases effective braking grid resistance and decreases grid current. Removes charging current from C4 and C5 causing Q6 to cut off when charge on C4 and C5 falls below 36 volts. Removes feed from DC3A causing DC3A to drop out. LED3 light on DE module goes out.
14	Q6 cuts off.	TD drops out. Dropout of TD enables BWR to operate in a normal manner and also removes fast charging path for RC capacitors on the RC module.
15	DC3A drops out (Step 13).	Recalibrates grid current signal to base of Q2 which places reverse bias on Q2 until grid current signal increases. Drops DP2 holding feed from terminal 1 of DE. Holding feed for DP2 is maintained through Q10.

Fig. DE-3 -- Operation Of The DE Module (Sheet 5 Of 6)

Step	Procedure Or Condition	Result Of Procedure Or Condition
16	Assume that track speed increases to approximately 15 miles per hour.	Grid current increases to 700 amperes at about 13 miles per hour. The DR module limits grid current to 700 amperes by decreasing excitation as speed increases. The decrease in field current and increase in grid current places forward bias on Q2.
17	Procedures and conditions of Steps 3 through 14 are repeated except: a. Substitute DP2 for DP3; b. Substitute DC2 for DC3; c. In Step 9 feed is not maintained to DP2; d. Substitute DC2A and DC2B for DC3A.	
18	DC2A Drops out.	Recalibrates grid current signal applied to Q2 and Q3. This places reverse bias on Q2 until grid current signal increases.
19	DC2B drops out.	Drops DP1 holding feed from terminal 1 of DE. Holding feed for DP1 is maintained by Q10.
20	Assume that track speed increases to approximately 21 miles per hour.	Grid current increases to 700 amperes at about 18 miles per hour. The DR module limits grid current to 700 amperes by decreasing excitation as speed increases. The decrease in field current signal places forward bias on Q2.
21	Procedures and conditions of Steps 3 through 14 are repeated except: a. Substitute DP1 for DP3; b. Substitute DC1 for DC3; c. In Step 9, feed is not maintained to DP1 and DP2; d. In Step 12, feed is not provided to DP2; e. Substitute DC1A and DC1B for DC3A.	
22	DC1A drops out.	Recalibrates grid current signal applied to Q3.
23	DC1B drops out.	This prevents pickup of DP2 relay until DC1 again picks up.

Fig. DE-3 – Operation Of The DE Module (Sheet 6 Of 6)

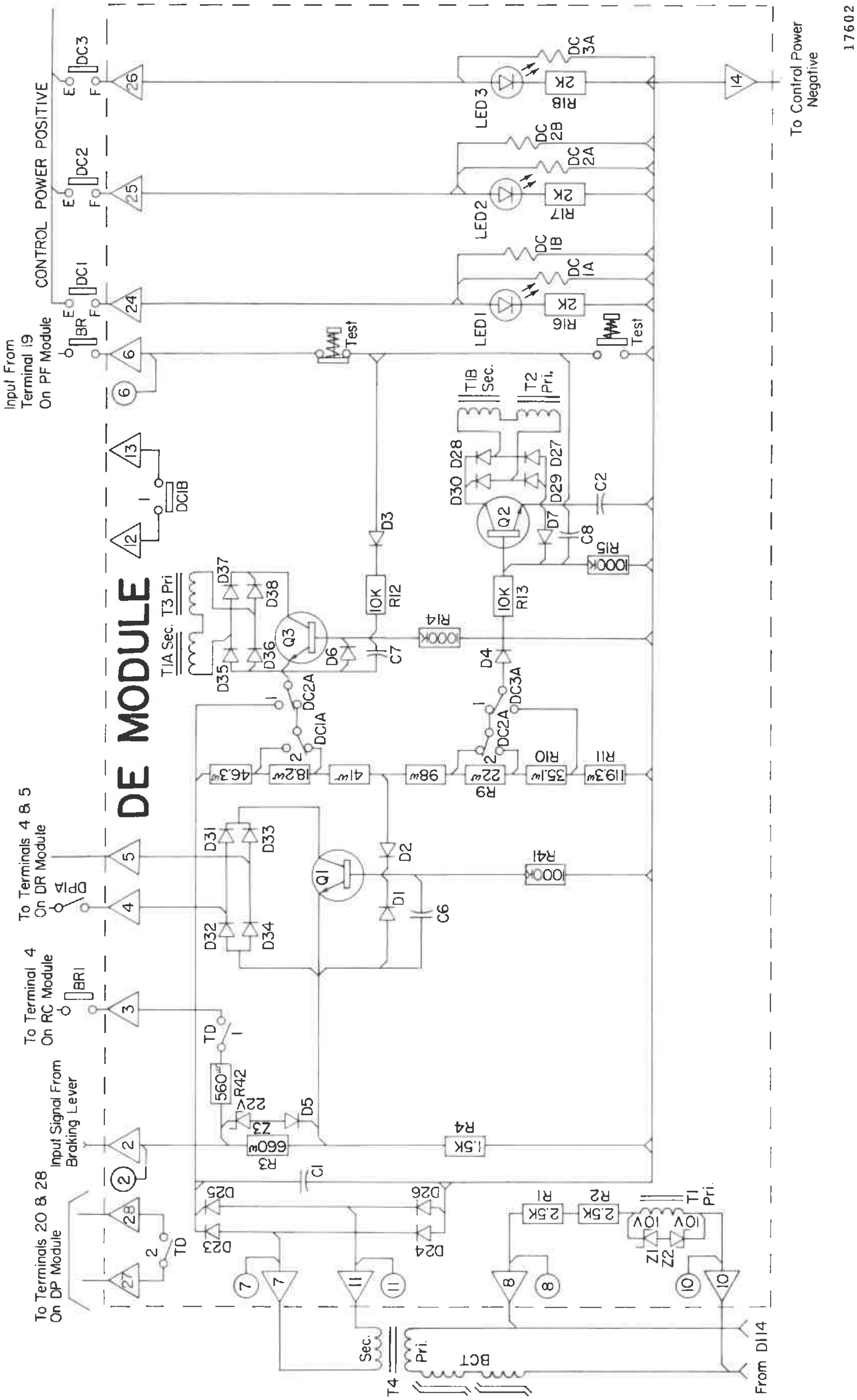


Fig. DE-4 -- Extended Range Dynamic Brake Module DE, Simplified Schematic Diagram (Sheet 1 of 2)

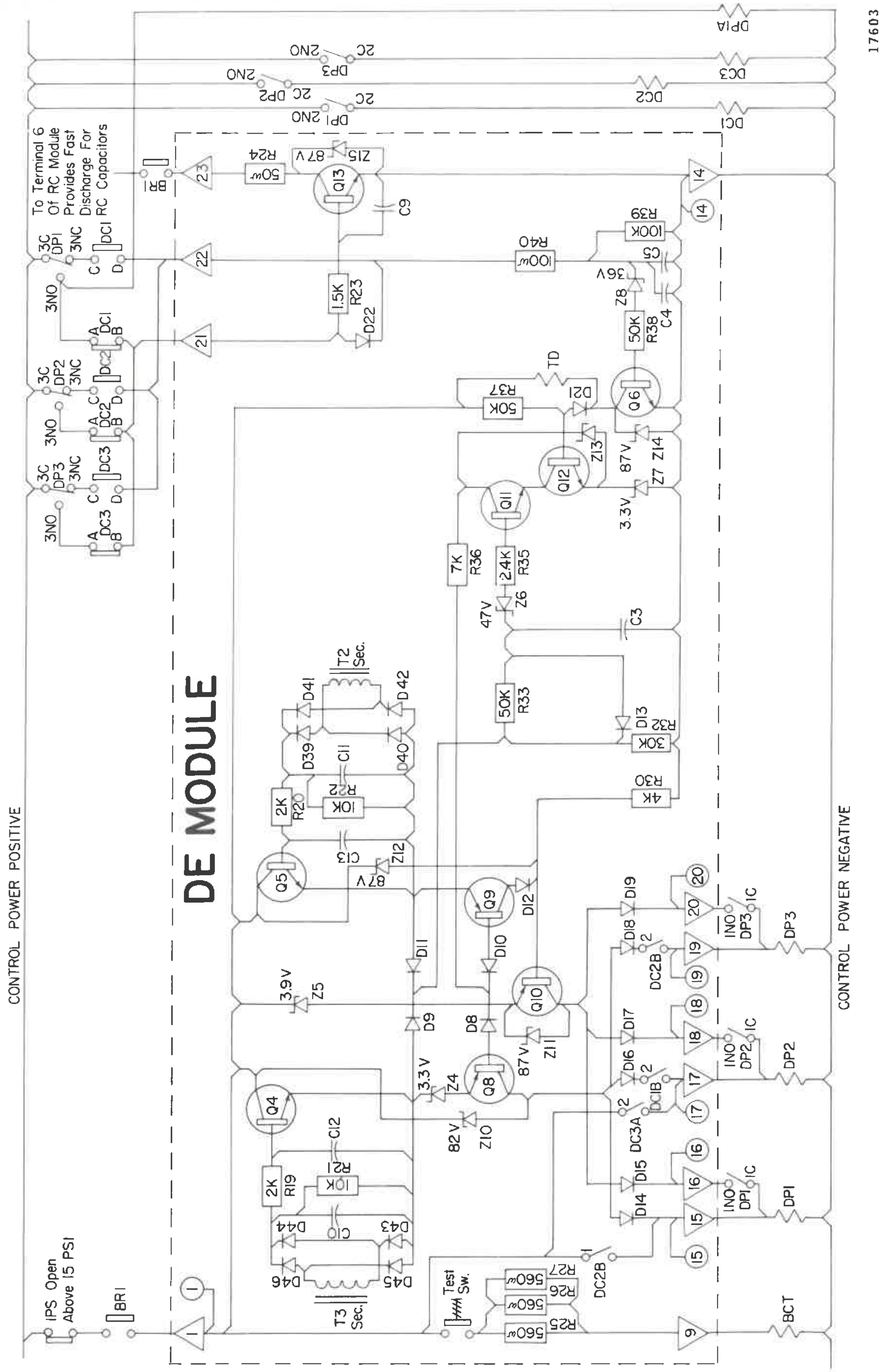


Fig. DE-4 -- Extended Range Dynamic Brake Module DE, Simplified Schematic Diagram (Sheet 2 of 2)

DYNAMIC BRAKING GRID PROTECTION SYSTEM (SPECIAL ORDER)

INTRODUCTION

The purpose of this section is to describe the operation of the special order dynamic braking grid protection system consisting of the dynamic braking grid protection module DG10 and the dynamic braking grid transductor DGT.

The dynamic braking grid protection module DG10 provides protection for the dynamic braking grids by dropping the feed to the generator field contactor GFC, in case of failure in the grid blower motor circuit, during dynamic brake operation or when performing self load test on the dynamic braking grids. Simplified schematic diagrams of the protection system are provided for convenient reference only. The applicable locomotive wiring diagram should be used when performing troubleshooting or maintenance on the system.

DYNAMIC BRAKING GRID TRANSDUCTOR, DGT

The dynamic braking grid transductor DGT consists of two laminated iron cores, two AC windings, a test winding, and two bias windings. On GP model locomotives, the two bias windings consist of one grid current bias winding and one grid blower bias winding. On SD locomotives, the two bias windings consist of two grid blower bias windings. The two cores are magnetically isolated from each other by an air gap and each core contains an AC winding. The test winding and both bias windings are common to both cores. A simplified schematic diagram of the DGT is provided in Fig. DG-1.

The two AC windings are connected series opposing so that the magnetic lines of force in the two cores travel in opposite directions. The AC windings, in series with the primary of transformer T1 on the DG module, are energized by current from the D14 alternator.

The reactance of the AC windings is much larger than the reactance of T1. Therefore, during normal operation, practically all of the input AC voltage is developed across the AC windings and very little voltage appears across T1. Transformer T1 provides an input signal to the DG module. Consequently, the input signal to the DG module is very small during normal operation.

SD MODEL LOCOMOTIVES

Each of the blower motor bias windings, on SD locomotives, consists of five turns wound about both cores. Each of the five turn bias windings is connected in series with a separate blower motor. During normal operation, the flux lines set up by the two blower motor bias windings are equal and opposite in both cores so that the resultant flux lines set up by the two windings is near zero.

An increase in current through one blower motor without a corresponding increase in current through the other blower motor would result in an unbalance in the flux lines set up by the two blower motor bias windings. This condition could result from a frozen bearing or locked fan blades in one of the blower motors. Either of these conditions would probably result in burning out the blower motor windings. An open in one of the blower motor windings would also result in an unbalance of flux lines.

GP MODEL LOCOMOTIVES

The blower motor bias winding consists of five turns connected in series with the blower motor on GP38 model locomotives and seven turns connected in series with the blower motor on GP40 model locomotives. The grid current bias winding is a single conductor passing through both cores and connected in series with the braking grids.

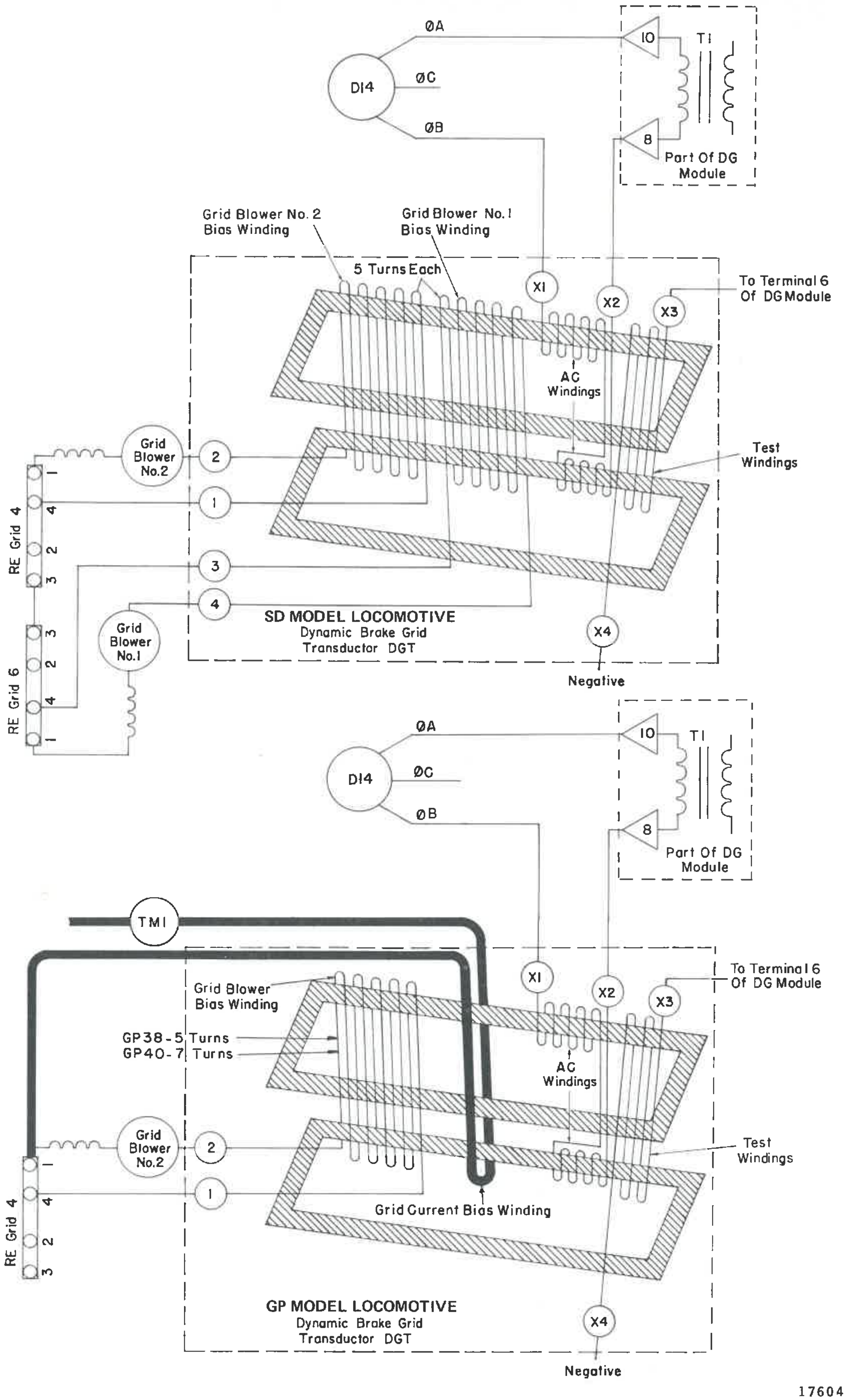


Fig. DG-1 – Dynamic Braking Grid Transductor, Simplified Schematic Diagram

During normal operation, the flux lines set up by the blower motor bias winding and the grid current bias winding are equal and opposite in both cores, so that the resultant flux lines set up by the two bias windings is near zero. However, if an open circuit develops in the blower motor windings, no current would flow through the blower motor bias winding and the flux lines set up by the two bias windings would be unbalanced.

An increase in blower motor current without a corresponding increase in grid current would result in an unbalance in flux lines set up by the two bias windings. This condition could result from a frozen bearing or from locked fan blades in the blower motor. Either of these conditions would probably result in burning out the blower motor windings.

OPERATION

During any unbalance in bias, the resultant flux lines would aid the flux lines from the AC winding in one core and oppose the flux lines from the AC windings in the other core. The core in which the flux lines aid would move toward magnetic saturation which would reduce the reactance of the AC winding on this core to near zero. The core in which the flux lines oppose would move away from saturation, but the reactance of the winding on this core would be affected by only a very small amount. The resultant reactance of the two AC windings would be only about one-half of the reactance that exists during normal operation. This causes a large increase in current through the two AC windings and through the primary of transformer T1 on the DG module. The increase in current through T1 provides a signal to the DG module which results in dropping the brake contactor B. Dropout of the B contactor removes braking current from the braking grids.

The test winding on DGT is provided for testing the dynamic braking grid protection system. Closing the test switch on the DG module allows current to flow through the test windings. Current flow through the test winding causes an unbalance of flux lines in the two cores and a signal to T1 results.

DYNAMIC BRAKING GRID PROTECTION MODULE DG 10

A simplified schematic diagram of the DG module is provided in Fig. DG-2 for convenient reference only. The applicable locomotive wiring diagram should be used when performing trouble-shooting or maintenance on the system.

The output voltage of transformer T1, which is proportional to the amount of unbalance between the bias windings on DGT, is rectified and applied to rheostat RH1. Capacitor C2 suppresses transient surges in the output of T1. The voltage at the wiper arm of RH1 is applied to the series combination of resistor R4B, R4A, and capacitor C1. The junction of R4A and C1 is connected to the base of transistor Q1 so that the voltage across C1 is applied to the base of Q1.

Forward bias is applied to transistor Q1 when the charge on C1 exceeds 6.2 volts. The RC circuit consisting of R4B, R4A, and C1 provides a time delay in applying forward bias to Q1. This time delay prevents turn on of Q1 from transient bias unbalance of DGT.

Turn on of Q1 provides a path for current flow from terminal 1 of the DG module through R7, R10, D7, from collector to emitter of Q1, then through zener diode Z1 to negative. The voltage developed across R7 provides forward bias for Q2. Turn on of Q2 provides a path for current flow from terminal 1 of the DG module through R9, from collector to emitter of Q2, then through the DGR relay to negative. Pick up of DGR provides a holding feed through the reset switch and DGR-2 contacts. Pick up of DGR also opens DGR-1 contacts between terminals 5 and 4 of the DG module and closes DGR-1 contacts between terminals 5 and 3 on the DG module. Closing DGR-2 contacts between terminals 5 and 3 provides a feed to the annunciator module.

LOCOMOTIVES EQUIPPED FOR SELF LOAD TEST

Opening DGR-1 contacts between terminals 5 and 4 on the DG module drops the feed to the DGX relay during dynamic brake operation or when performing self load test on the dynamic braking grids. Dropout of DGX drops the feed to the B contactor and to the generator field contactor

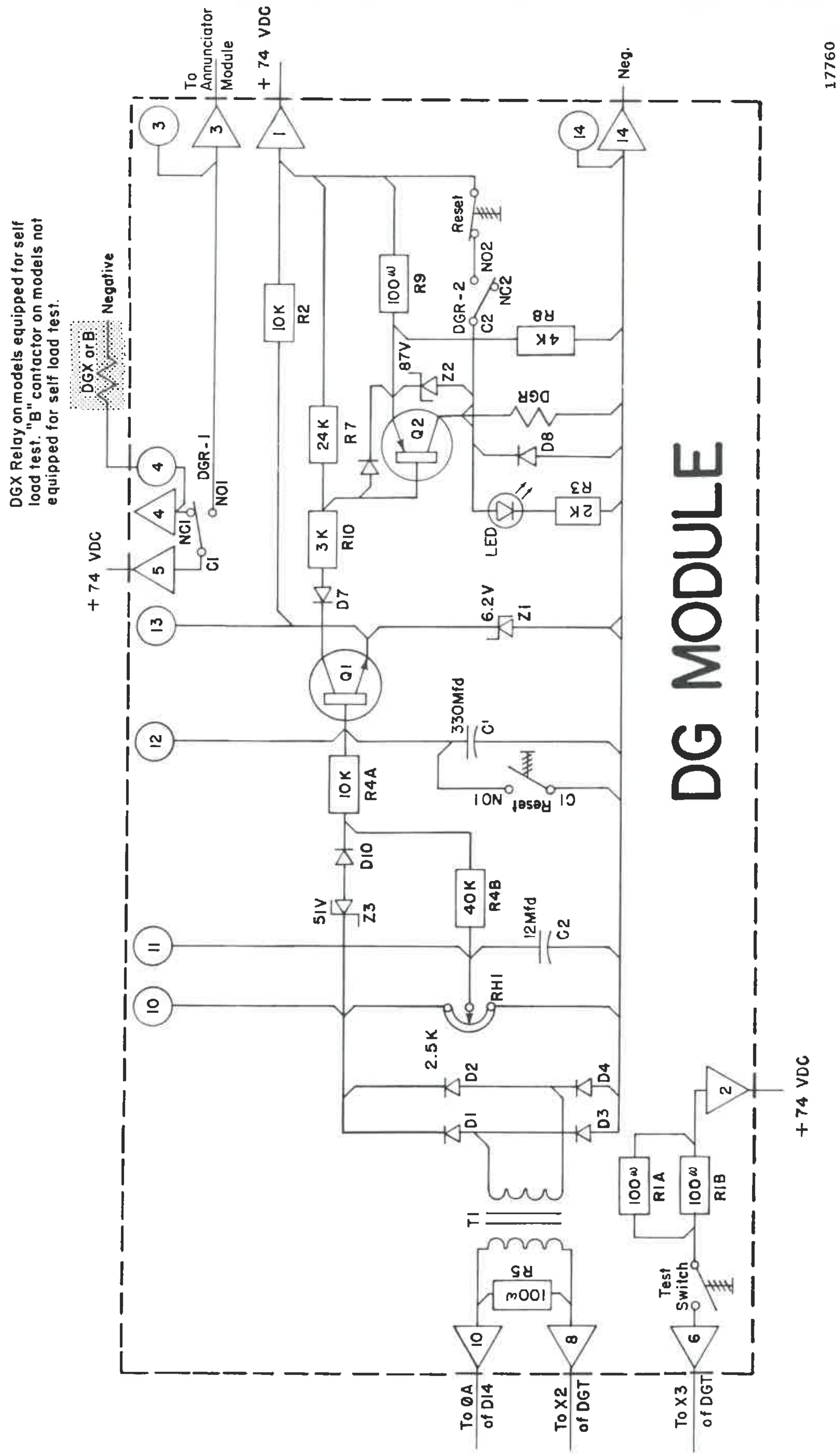


Fig. DG-2 -- Dynamic Braking Grid Module DG, Simplified Schematic Diagram

GFC. Dropout of GFC removes excitation from the main generator field. Dropout of the B contactor opens the circuit to the motor fields.

LOCOMOTIVES NOT EQUIPPED FOR SELF LOAD TEST

Opening DGR-1 contacts between terminals 5 and 4 on the DG module drops the feed to the B contactor during dynamic brake operation. Drop-out of the B contactor opens the circuit to the motor fields and drops the feed to the generator field contactor GFC. Dropout of GFC removes excitation from the main generator field.

TEST CIRCUIT

A test switch and a reset switch are provided on the DG module. The test switch, when pressed energizes the test winding on the DGT which unbalances the flux lines in the two cores of DGT. This provides an input to transformer T1 and causes DGR to pick up. This provides a means of performing a functional test of the DG module and also of DGT. The reset switch provides a means of resetting the DGR relay after a test or after pickup of DGR due to a blower motor fault. However, the reset switch should not be operated, after pickup of DGR due to a fault, until the dynamic braking system has been checked and repaired as necessary.

DYNAMIC BRAKE PROTECTION MODULE, DP

INTRODUCTION

The dynamic brake protection module DP12 provides backup protection for the traction motor fields and the dynamic braking resistor grids in case a fault develops in the dynamic braking regulator module DR. The DP12 module operates to remove excitation from the main generator field in case motor field excitation or the dynamic braking grid current rises above a safe value.

A simplified schematic diagram of the dynamic brake protection module is provided in Fig. DP-1 for convenient reference only. The applicable locomotive wiring diagram should be used when performing troubleshooting or maintenance.

MOTOR FIELD PROTECTION CIRCUIT

The motor field protection circuit, Fig. DP-1, is connected across the main generator in parallel with the traction motor fields during dynamic braking. Main generator output is applied between terminals 2 and 12 on GP model locomotives and between terminals 3 and 12 on SD model locomotives. Therefore, the motor field protection circuit detects any change in excitation voltage applied to the traction motor fields.

The voltage applied between terminals 2 and 12 or 3 and 12 provides a current flow through the voltage divider consisting of resistors R16, R17, R18, and rheostat RH2. The base of transistor Q5 is connected to the wiper arm of RH2 so that the voltage applied to the base of Q5 is directly proportional to the excitation voltage applied to the traction motor fields. Zener diode Z8 maintains 6.2 volts on the emitter of Q5.

During normal operation reverse bias is applied to Q5 by Z8 and the wiper arm of RH2. However, if a fault develops in the dynamic braking regulator module DR, the excitation voltage applied to the traction motor fields may tend to rise above a safe value. Any increase in excitation voltage results in an increase in voltage at the wiper arm of RH2. Forward bias will be applied to Q5 if excitation voltage tends to rise above a safe value.

With forward bias on Q5, current flows through the motor field protection relay MFP. Pickup of MFP drops the feed to the equipment protection relay EQP and recalibrates the motor field protection circuit by shorting out resistor R16. Pickup of MFP also provides a positive feed to the motor field annunciator relay MFA and to resistor R21.

Drop out of EQP drops the feed to the generator field contactor GFC which removes excitation voltage from the main generator field and this decreases the main generator output voltage. The inductance of the main generator field windings prevents an immediate collapse of current through the field. The decrease in main generator output voltage results in a reduction in the voltage applied to the base of Q5. This reduction in voltage causes Q5 to become reverse biased. Reverse bias on Q5 blocks the current flow through MFP causing MFP to drop out. Dropout of MFP re-establishes the feed to EQP and results in the reapplication of excitation voltage to the main generator field. If the fault persists and excitation voltage to the traction motor fields rises above a safe value, Q5 will again be forward biased causing pickup of MFP. This results in removing excitation voltage from the main generator field causing a reduction in the excitation voltage to the traction motor fields. This pickup and dropout of MFP continues as long as the fault persists with dynamic brakes applied. Operation of the dynamic brakes may be continued, but the regulation will be very coarse. For this reason the fault should be corrected as soon as practical.

Recalibrating the motor field protection circuit, by shorting out R16, applies a larger forward bias to Q5 so that MFP will remain picked up until the excitation voltage to the traction motor fields drops several volts below the safe value. Therefore, the recalibration prevents rapid cycling of the MFP relay, the EQP relay, and the GFC contactor.

The positive feed applied to R21 provides forward bias for Q2. Turn on of Q2 results in pickup of MFA. Pickup MFA provides a feed to the annunciator module.

GRID OVERCURRENT PROTECTION CIRCUIT

The grid overcurrent protection circuit, Fig. DP-1, consists of a detector circuit and a trigger circuit. The detector circuit is connected to the dynamic braking grids. On GP model locomotives, the grids are connected between terminals 22, 24, and 28. On SD model locomotives, the grids are connected between terminals 22, 24, 26, and 28. The trigger circuit turns on if a grid overcurrent condition is detected and then operates to remove excitation from the main generator field.

The input voltage, from the dynamic braking resistor grids, to the detector circuit is applied through blocking rectifiers to two voltage divider circuits. One of the voltage dividers consists of resistors R11, R12, R13, R14, and rheostat RH1. The other voltage divider consists of resistor R8 and zener diode Z6. The blocking rectifiers prevent interchange of current between the braking resistor grids in case the voltage across one grid rises above that of the other grids.

The voltage applied to the emitter of transistor Q4 is limited to 49.6 volts by zener diode Z6. The base of Q4 is connected to the wiper arm of RH1 so that the voltage applied to the base of Q4 is directly proportional to the voltage developed across the dynamic braking resistor grids. During normal operation, the voltage applied to the base of Q4 is less than 49.6 volts and results in reverse bias to Q4. However, if the braking resistor grid current tends to rise above a safe value, the voltage applied to the base of Q4 increases above 49.6 volts and forward bias is applied to Q4.

Turn on of Q4 provides a path for current flow through the secondary of transformer T1 in series with the primary of transformer T2. The rectified output of T2 applies forward bias, through resistor R1, to transistor Q1. With forward bias on Q1, current flows from terminal 1 of the DP module to the collector of Q1, from collector to emitter of Q1, then through the BWR relay to negative. Current also flows through diode D1 and resistor R2 to charge capacitor C2. Forward bias is applied to the base of transistor Q3 when the charge on C2 is sufficient to cause reverse conduction through zener diode Z2.

Forward bias on Q4 results in forward bias on Q1 and immediate pickup of BWR, but the time delay provided by R2 and C2 is sufficient to prevent turn on of Q3 by a single short-time duration spike in the grid current. However, three or more short-time duration spikes that are closely spaced will result in turn on of Q3. Any grid overcurrent condition lasting longer than approximately one or two seconds will result in turn on of Q3.

Pickup of BWR drops the feed to the EQP relay. Dropout of EQP drops the feed to the generator field contactor GFC which removes excitation voltage from the main generator field. The inductance of the main generator field windings prevents an immediate collapse of current through the field. Removing excitation voltage from the main generator field results in a decrease of braking grid current. The decrease in braking grid current tends to apply reverse bias on Q4 as the current decreases below the maximum safe value. However, pickup of BWR recalibrates the detector circuit by removing the short circuit from R14 so that forward bias on Q4 is maintained until the braking grid current decreases to several amperes below the maximum safe value. This recalibration prevents rapid cycling of the detector circuit, BWR, EQP, and the GFC contactor.

Pickup of BWR and forward bias on Q3 allows current flow from terminal 1 of the DP module, through the BWA relay coil, from collector to emitter of Q3, then to negative at terminal 14. Pickup of BWA provides a feed to the brake warning light at terminal 19 and to the annunciator module from terminal 17.

LOCOMOTIVES EQUIPPED FOR EXTENDED RANGE DYNAMIC BRAKES

Voltage spikes occur in the braking grids when shorting contactors close during extended range dynamic brake operation. Pickup of time delay relay TD on the DE module recalibrates the DP module, by connecting terminal 20 to terminal 28 on the DP module. This recalibration disables the grid current protection circuit, to prevent turn on of Q4 by transient voltage spikes during pickup and for a short time after pickup of the grid shorting contactors. This time delay provides time for grid voltage spikes to dissipate. For further details refer to description of the DE module.

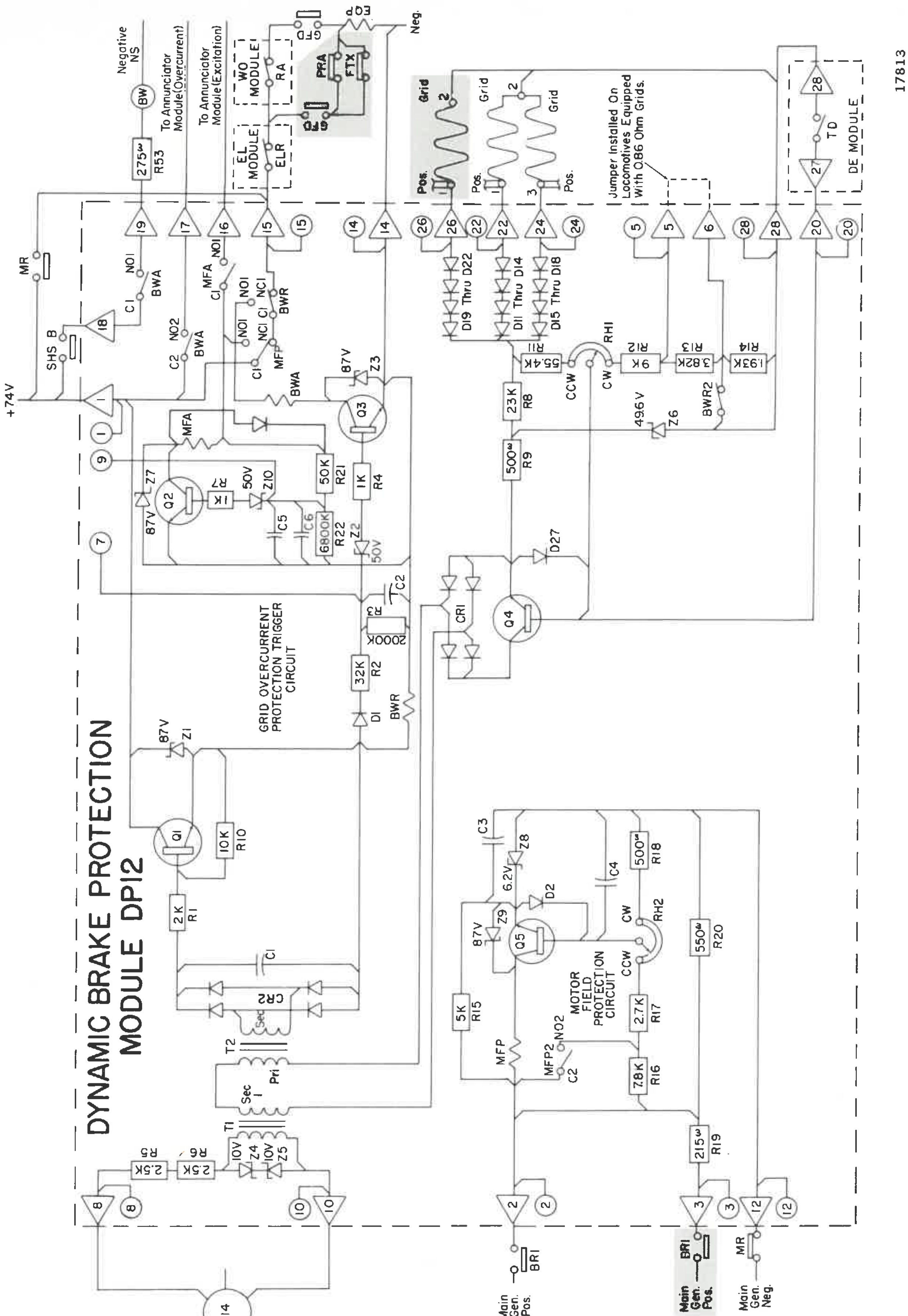


Fig. DP-1 -- Dynamic Brake Regulator Module DP, Simplified Schematic Diagram

DYNAMIC BRAKE REGULATOR MODULE, DR

INTRODUCTION

The dynamic braking grids are designed to carry braking current of 700 amperes. Dynamic brake regulator modules DR10 and DR13 are designed to limit braking grid current to this maximum value of 700 amperes regardless of braking lever position. Braking grid current is limited to 700 amperes by reducing excitation to the main generator field. Excitation to the main generator field is reduced as necessary to limit braking grid current to 700 amperes by discharging the rate control capacitors on the RC module, through transistor Q3 on the DR module.

The DR module is connected as shown in Fig. DR-1 when the locomotive is equipped with basic dynamic brakes. This connection may be used on SD or GP type locomotives. When using this connection, a voltage signal proportional to braking grid current is provided through diodes CR26, CR27, CR28, and CR29 to terminals 13 and 2 or to 13 and 1 of the DR module. This voltage signal is obtained across a portion of one braking grid. Resistors R36 and R37 are connected between the braking grids and terminals 13 and 2 or terminals 13 and 1. These resistors are used to ensure a voltage signal to the DR module in case of an open braking grid.

The voltage signal provided to the DR module by CR26 through CR29 results in limiting the grid current to 700 amperes in the grid connected between terminals 13 and 2 or between 13 and 1. The current through all braking grids is equal during normal operation. However, the current becomes unequal if an open circuit develops in one or more of the grids. In this case a signal is provided through R36 and R37 to the DR module. This signal protects the traction motors by limiting the voltage across the motors to a safe value. This signal provides some protection against burn out of successive braking grids by limiting braking grid current. However, full protection against burn out of successive braking grids is not provided by this connection.

The DR module is connected as shown in Fig. DR-2 when the locomotive is equipped with extended range dynamic brakes. This connection may be used on SD or GP type locomotives. When using this connection, a voltage signal proportional to braking grid current is provided to terminals 13 and 2 or to terminals 13 and 1 of the DR module. This voltage is obtained across a portion of one braking grid. This voltage signal results in limiting grid current to 700 amperes in the braking grid used for monitoring the grid current. The current through all braking grids is equal during normal operation. An open circuit protection relay OCP is used to provide some protection against burn out of successive braking grids when the locomotive is equipped with extended range dynamic brakes.

A voltage signal across a portion of one braking grid is compared to a reference signal by transistors Q1 and Q2. The braking grid signal is proportional to braking grid current. If braking grid current rises above 700 amperes, the braking grid signal becomes larger than the reference signal and results in turn on of Q1 and Q2. Turn on of Q1 and Q2 provides excitation to transformer T2-A primary which results in turn on of Q3. Turn on of Q3 discharges the rate control capacitors which decreases excitation to the main generator field. This feature of the DR module will be referred to as grid current limiting. Grid current limiting is provided by DR10 or DR13 during basic dynamic brake operation. Grid current limiting provides back up protection during extended range dynamic brake operation.

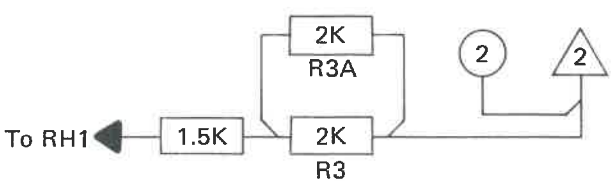
During extended range dynamic brake operation, the DR10 or DR13 module in conjunction with the DE module regulates braking grid current to a value that is proportional to braking lever position. The DE module compares the braking grid signal with the braking lever signal. The braking grid signal is proportional to braking grid current and the braking lever signal is proportional to braking lever position. Advancing the braking lever increases the braking lever signal.

If the braking signal becomes larger than the braking lever signal, a solid state switch on the DE module operates to connect terminal 4 to terminal 5. This results in excitation to transformer T2-B primary on the DR module. The output of T2-B results in turn on of Q3 on the DR module. Turn on of Q3 discharges the rate control capacitors which decreases excitation to the main generator field as necessary to reduce the braking grid signal to a value equal to the braking lever signal. This feature of the DR module will be referred to as extended range dynamic brake grid current regulation.

The above description of the DR module applies to the DR10 and DR13 modules. However, some major differences exist between the two modules. Refer to Fig. DR-1, Fig. DR-2, and the following points of difference.

1. The DR13 module may be used with 0.66 ohm or 0.86 ohm braking grids. The DR10 module may be used with the 0.86 ohm braking grids, but cannot be used with the 0.66 ohm braking grids. This is due to the design of the module in the R2, R3, and R4 area of Fig. DR-1 and Fig. DR-2. In this area the DR13 module is designed as shown in Figs. DR-1 and DR-2. Terminal 1 is provided for use when 0.66 ohm braking grids are employed. Terminal 2 is provided for use when 0.86 ohm braking grids are employed.

2. The DR10 module does not use terminal 1 and the R2, R3, and R4 area of Figs. DR-1 and DR-2 is designed as follows for the DR10 module. Note that the resistance between terminal 2 and RH1 is approximately the same for both modules. This resistance is for use with the 0.86 ohm braking grids. Note that there is no connection to terminal 1 on the DR10 module. Therefore, DR10 cannot be used with 0.66 ohm braking grids.



3. The circuit in the shaded area of Fig. DR-1 and Fig. DR-2, is provided in the DR13 module, but is not provided on the DR10 module. This circuit provides for braking grid current regulation on locomotives equipped with basic dynamic brakes, whenever this feature is requested by the customer.

When this feature is used, a braking lever signal which is proportional to braking lever position is applied to terminal 7 of the DR module and a signal proportional to braking grid current is applied between terminals 9 and 11. These signals are applied, through voltage dividers, to transistor Q4. Transistor Q4 turns on when the braking grid signal is larger than the braking lever signal. Turn on of Q4 provides excitation to transformer T2-B primary. The output of T2-B results in turn on of Q3. Turn on of Q3 reduces excitation to the main generator field by discharging the rate control capacitors on the RC module, through Q3 on the DR module. Excitation is reduced until the braking grid signal is reduced to a value no larger than the braking lever signal. Therefore, the circuit in the shaded area regulates braking grid current to a value proportional to braking lever position when operating with basic dynamic brakes.

The shaded area of Fig. DR-2 is used on locomotives equipped with basic dynamic brakes if dynamic brake grid regulation is desired. On locomotives equipped with extended range dynamic brakes, grid current regulation is obtained by connecting terminals 4 and 5 to the DE module and the shaded area is not used.

OPERATION OF DR MODULE DURING GRID CURRENT LIMITING AND DURING GRID CURRENT REGULATION

Grid current limiting is that action by the DR module that limits the maximum braking grid current to 700 amperes regardless of braking lever position.

Grid current regulation is that action by the DR module that regulates braking grid current to a value that is proportional to the braking lever position.

Operation of the DR module during grid current limiting action and during grid current regulating action is provided in the following paragraphs.

GRID CURRENT LIMITING

The voltage developed across a portion of one braking grid is applied to a voltage divider consisting of rheostat RH1 and resistors R1, R2, R3, and R4. This same voltage is also applied to resistor R7 in series with zener diodes Z1 through

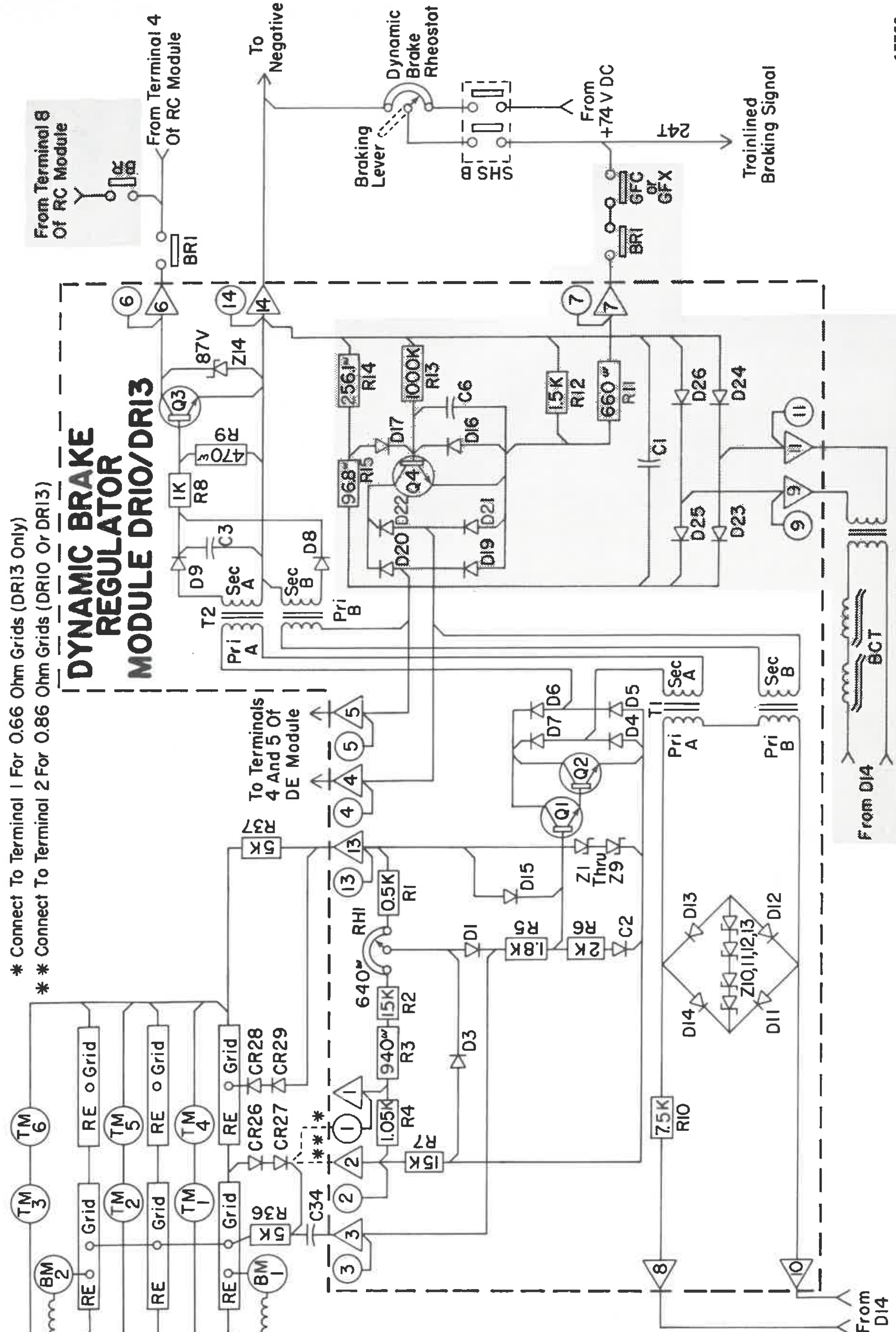


Fig. DR-1 -- Dynamic Brake Regulator Module DR Simplified Schematic Diagram (Basic Dynamic Brakes)

Z9. The zener diodes provide a constant reference signal to the emitter of transistor Q2.

A signal proportional to braking grid current is applied to the base of transistor Q1 by a voltage divider consisting of R5 and R6 connected between the wiper arm of RH1 and the emitter of Q2. When braking grid current is less than 700 amperes, the voltage at the wiper arm of RH1 is less than the reference signal applied to the emitter of Q2. This places reverse bias on transistors Q1 and Q2.

When braking grid current rises above 700 amperes, the voltage at the wiper arm of RH1 is larger than the reference signal applied to the emitter of Q2. This causes current flow from the wiper arm of RH1 to the zener diodes. This current flow results in placing forward bias on Q1 and Q2.

Output voltage of the D14 alternator is connected to terminals 8 and 10 of the DR module. The voltage applied to the primary of transformer T1 from terminals 8 and 10 is limited to 10 volts by zener diodes Z10, Z11, Z12, and Z13 in conjunction with resistor R10 and diodes D11, D12, D13, and D14. Secondary T1-A is open until transistors Q1 and Q2 turns on.

With forward bias on Q1 and Q2, current flows through the secondary winding of transformer T1-A and through the primary winding of transformer T2-A, then from collector to emitter of Q1 and Q2. The current flow through the primary T2-A induces a voltage into secondary T2-A. This voltage is rectified and applied to a voltage divider consisting of R8 and R9. Transistor Q3 is forward biased by the voltage developed across R9.

With forward bias on Q3, the braking lever signal is removed from the rate control capacitors in the RC module. The signal passes through a resistance, in the RC module, to terminal 4 of the RC module, through BR1 contacts to terminal 6 of the DR module, from collector to emitter of Q3 on the DR module, then to negative at terminal 14 of the DR module. The rate control capacitors in the RC module discharge through a resistor in the RC module to negative at terminal 14 of the RC module. Excitation to main generator field decreases as the rate control capacitors discharge. This reduced excitation results in a decrease in braking grid current.

When braking grid current decreases below 700 amperes, the signal at the wiper arm of RH1 decreases and places a reverse bias on Q1 and Q2. Reverse bias on Q1 and Q2 stops the current flow through T1-A secondary and T2-A primary which removes forward bias from Q3. With Q3 turned off, the braking lever signal is again applied to the rate control capacitors and allows an increase in excitation to the main generator field. This regulating action limits braking grid current to a maximum of approximately 700 amperes regardless of braking lever position.

DR10/DR13 GRID CURRENT REGULATION DURING EXTENDED RANGE DYNAMIC BRAKE OPERATION

The following description is applicable to locomotives equipped with extended range dynamic brakes and the DR10 or DR13 module.

The DR module limits maximum braking grid current to 700 amperes regardless of braking lever position. However, when operating with extended range dynamic brakes, the DR module in conjunction with the DE module regulates the braking grid current to a value that is proportional to the braking lever position.

A signal proportional to braking grid current is applied to the DE module. Another signal, proportional to braking lever position is also applied to the DE module. A comparison circuit on the DE module compares the braking grid current signal with the braking lever signal. A solid state switch on the DE module turns on if the braking grid current signal is larger than the braking lever signal. Turn on of the solid state switch provides a path for current flow between terminals 4 and 5 on the DE module and on the DR module. This permits current flow through transformer T1-B secondary and T2-B primary on the DR module.

The current flow through T2-B primary induces a voltage into T2-B secondary. The output of T2-B is rectified and applied to a voltage divider consisting of R8 and R9. The voltage developed across R9 provides forward bias for Q3. Forward bias on Q3 results in discharge of the rate control

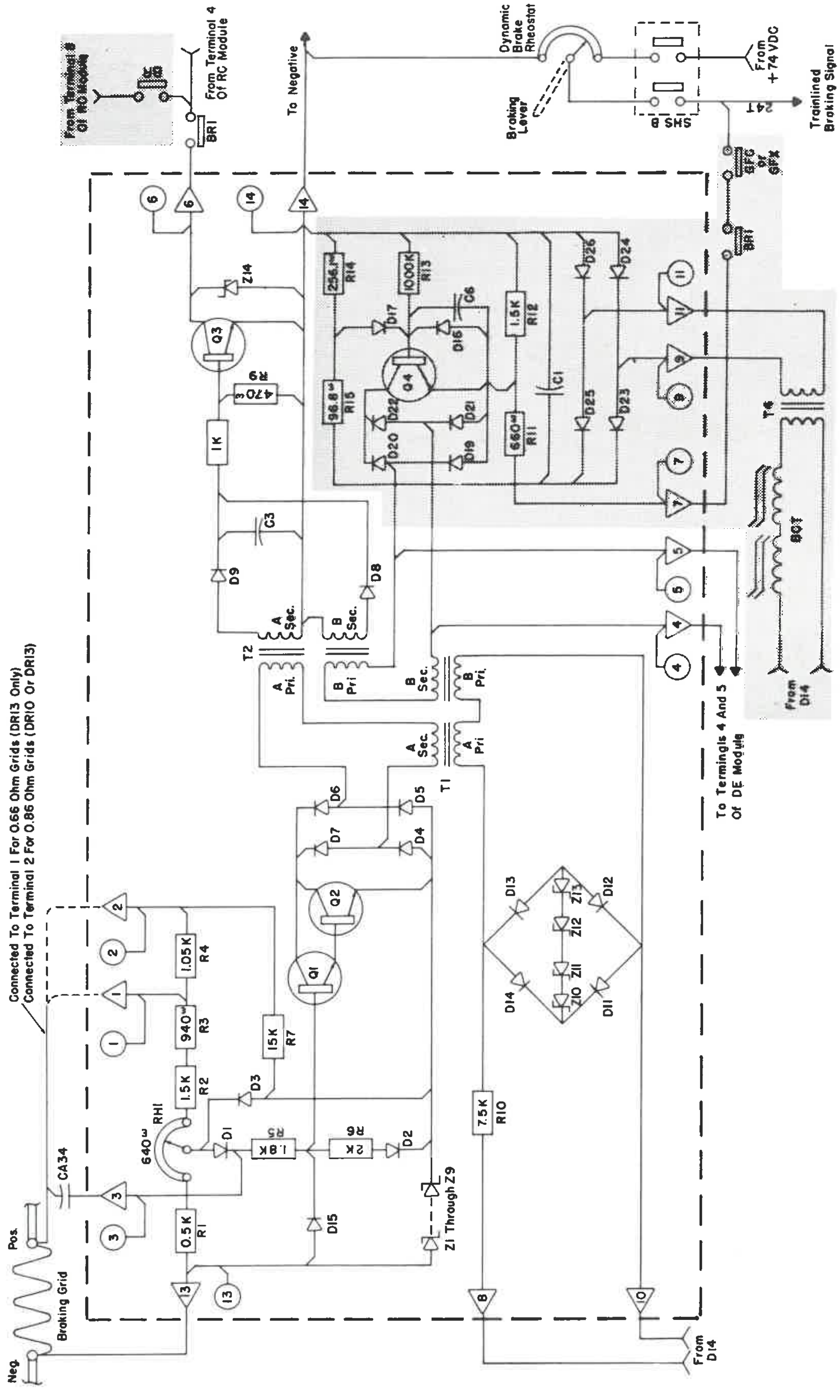


Fig. DR-2 – Dynamic Brake Regulator Module DR Simplified Schematic Diagram
(Extended Range Dynamic Brakes)

capacitors on the RC module. Excitation to the main generator field decreases as the rate control capacitors discharge. This reduced excitation results in a decrease in braking grid current until the braking grid signal decreases to a value equal to or less than the braking lever signal. The approximate maximum value of braking grid current for each position of the braking lever is given below.

Braking Lever Position	Maximum Braking Grid Current
1	–
2	90 amperes
3	200 amperes
4	320 amperes
5	430 amperes
6	550 amperes
7	640 amperes
8	700 amperes

DR13 GRID CURRENT REGULATION DURING BASIC DYNAMIC BRAKE OPERATION

The following description is applicable to locomotives equipped with the DR13 module when grid current regulation is provided during basic dynamic brake operation.

Output voltage of the D14 alternator is applied to the primary of transformer T4 in series with brake current transductor BCT. Brake current transductor BCT is a saturable reactor that is biased by braking grid current. When braking grid current is low, the reactance of BCT is high and the voltage applied to the primary of T4 is low. As braking grid current increases, the reactance of BCT decreases and the voltage applied to the primary of T4 increases. Therefore, the voltage applied to the primary of T4 is directly proportional to braking grid current.

The output voltage of T4 is applied between terminals 9 and 11 of the DR module. This voltage is rectified by diodes D23, D24, D25, and D26 and filtered by capacitor C1. This rectified and filtered signal is applied to a voltage divider consisting of R14 and R15. The junction of R14 and R15 is connected to the base of transistor Q4, through diode D17. Therefore, the signal applied to the base of Q4 is directly proportional to braking grid current.

A voltage which is proportional to the braking lever signal, as determined by the braking lever position, is applied to terminal 7 of the DR module. This voltage is applied to a voltage divider consisting of R11 and R12. The junction of R11 and R12 is connected to the emitter of Q4. Therefore, the signal applied to the emitter of Q4 is directly proportional to the braking lever signal.

Transistor Q4 compares the braking lever signal with the braking grid current signal. Q4 is forward biased if braking grid current increases so that the braking grid current signal applied to the base of Q4 is larger than the braking lever signal applied to the emitter of Q4. Turn on of Q4 provides a path for current flow through transformer T1-B secondary and T2-B primary. The current flow through T2-B primary induces a voltage into T2-B secondary. The output of T2-B is rectified and applied to a voltage divider consisting of R8 and R9. The voltage developed across R9 provides forward bias for Q3.

Forward bias on Q3 results in discharge of the rate control capacitors on the RC module. Excitation to the main generator field decreases as the rate control capacitors discharge. This reduced excitation results in a decrease in braking grid current until the braking grid signal applied to the base of Q4 decreases to a value equal to or less than the braking lever signal applied to the emitter of Q4. This regulating action regulates the braking grid current to a value that is proportional to the braking lever signal. The approximate maximum value of braking grid current for each position of the braking lever is the same as in the previous table.

INDICATING LIGHTS AND DEVICES

INTRODUCTION

Various indicating lights and devices are located on the engine control panel and on the locomotive control stand to provide information to the operator. A description of these indicating lights and devices will be found in the Operator's Manual and in Section 6 of the Locomotive Service Manual.

The annunciator module, located in the module compartment, contains indicating lights to provide information for maintenance personnel. A description of the annunciator module is provided in the following paragraphs.

ANNUNCIATOR MODULE

The following description applies to the AN10, AN11, and AN12 annunciator modules. Each annunciator module contains a TEST/RESET switch and four or more identical annunciator circuits. The AN module is equipped with one positive and one negative input terminal. A fault signal input terminal is provided for each annunciator circuit on the module. A simplified schematic diagram showing one annunciator circuit is provided in Fig. AN-1.

The following table identifies the fault signals that may be applied to AN10, AN11, and AN12 modules. The table also identifies the input terminal for each fault. When one of the faults listed in the table is detected, a signal is applied to the applicable input terminal. This signal is applied to the applicable magnetic latching annunciator relay ANR. Pickup of ANR provides a feed to the applicable light emitting diode LED. The light emitted by LED provides a visual indication of the fault. The specific fault is identified on the face plate of the AN module. After pickup, ANR remains in the latched position until the fault signal is removed and the TEST/RESET switch is moved to the RESET position.

Input Term.	Fault Signal	Applicable Module		
2	Hot Engine	AN10	AN11	AN12
3	Engine Air Filter	AN10	AN11	AN12
4	Ground Relay	AN10	AN11	AN12
5	Excitation Limit	AN10	AN11	AN12
6	Grid Overcurrent		AN11	AN12
7	Motor Excitation		AN11	AN12
8	Grid Open Circuit		AN11	AN12
9	Grid Blower Failure			AN12

HOT ENGINE

The engine temperature switch ETS closes to provide a feed to the THL relay when a hot engine fault is detected. Pickup of THL provides a positive feed to terminal 2 on the AN module.

ENGINE AIR FILTER

The filter vacuum switch FVS closes to provide a feed to input terminal 3 when the engine air filter becomes plugged.

GROUND RELAY

The ground relay picks up to provide a feed to input terminal 4 when a high voltage ground fault is detected, and when a group of 5 main generator diodes have failed.

EXCITATION LIMIT

Excitation current to the main generator field is monitored by the excitation limit module EL. The EL module provides a signal to terminal 5 if excitation current rises above a safe value.

GRID OVERCURRENT

Dynamic brake grid current is monitored by the dynamic brake protection module DP. The DP module provides a signal to terminal 6 if braking grid current rises above a safe value.

MOTOR EXCITATION

Traction motor field excitation voltage is monitored by the dynamic brake protection module DP during dynamic brake operation. The DP module provides a signal to terminal 7 if traction motor field excitation voltage rises above a safe value.

GRID OPEN CIRCUIT

On locomotives equipped with extended range dynamic brakes, the grid open circuit protection relay OCP picks up if an open circuit develops in a braking grid. Pickup of OCP provides a signal to terminal 8.

Locomotives equipped with basic dynamic brakes are not equipped with an OCP relay. Therefore, an open grid does not provide an indication on the annunciator module on these locomotives.

TEST/RESET SWITCH

Placing the TEST/RESET switch to TEST position places positive potential on the TEST LINE. This allows current flow from the marked terminal to the unmarked terminal of all ANR relays on the AN module. Current in this direction causes the ANR relay contacts to close and provides a feed to all lights on the AN module. This performs a functional check of all lights and relays on the AN module. The lights will remain on until the TEST/RESET switch is moved to RESET position.

Placing the TEST/RESET switch to RESET position places positive potential on the RESET LINE. This allows current flow from the unmarked terminal to the marked terminal of all ANR relays on the AN module. Current in this direction causes the ANR relay contacts to open and all lights on the AN module will go out.

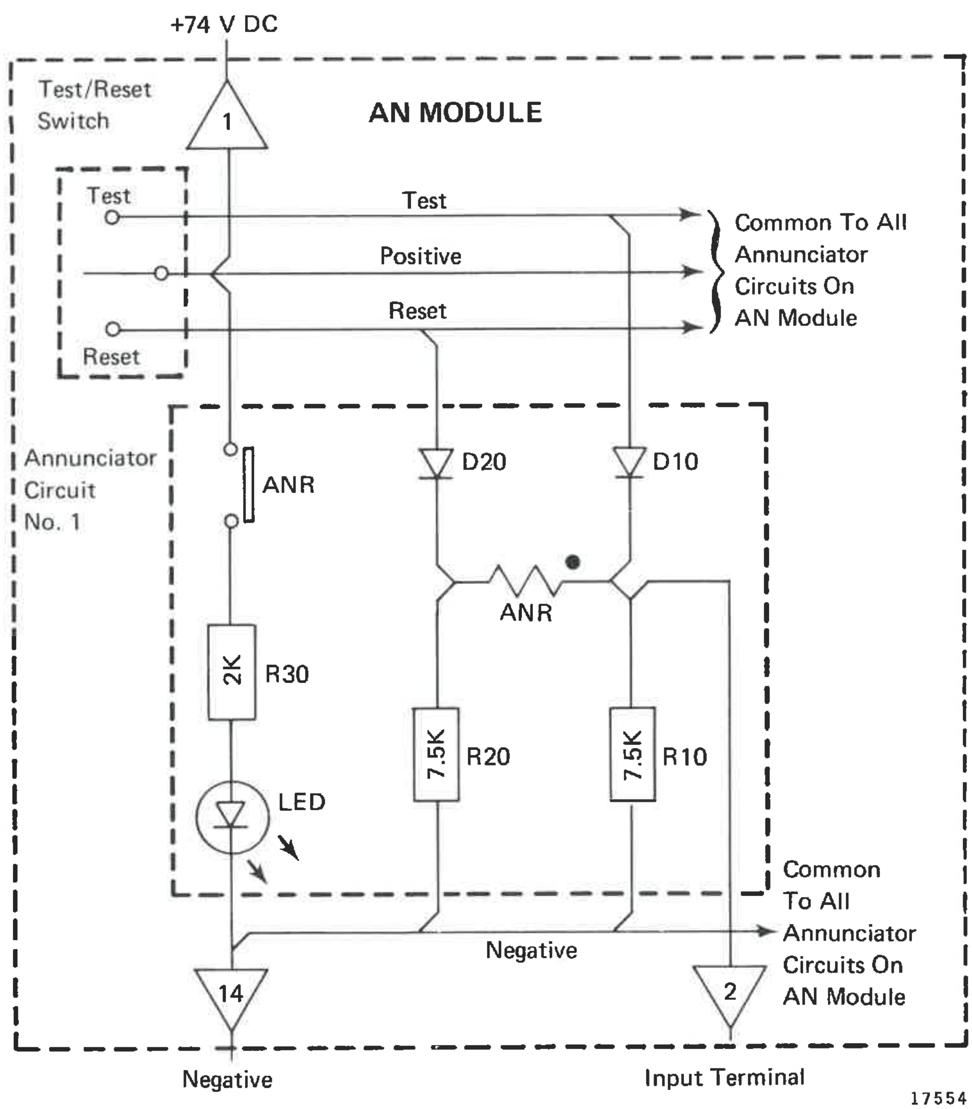


Fig. AN-1 -- Annunciator Module, Simplified Schematic Diagram

INSPECTION AND REPLACEMENT OF CONTACT TIPS FOR CONTACTORS AND MOTOR OPERATED TRANSFER SWITCH

MAINTENANCE OF CONTACT TIPS – GENERAL

Only skilled personnel familiar with electrical equipment and the hazards involved should be permitted to service contactors or motor operated transfer switches. All safety precautions must be observed.

Minimum maintenance is required to keep the switchgear in serviceable condition. Moving mechanical parts should be free from excess friction. Parts should also be checked for excessive wear. The bearing surfaces are designed to operate without lubrication. Do not oil or grease at any time.

Main contact and arc chute parts are normally oxidized and smoked from regular service. Other parts should not show visable damage from high temperatures.

Contact tips used on all EMD switchgear are made of alloy material. The contacting surfaces of these alloy tips take on irregularities during the first few operating cycles. It is during this initial operation that the majority of contact wear occurs. The discoloration on the surfaces of the contact tips, which results from repeated cycling, does not affect contact operation.

ALLOY CONTACTS WILL OPERATE SATISFACTORILY EVEN THOUGH BLACKENED, PITTED, AND ERODED. DO NOT CLEAN, DRESS, OR FILE CONTACT SURFACES. REPLACE CONTACTS WHEN ANY PORTION OF THE ALLOY MATERIAL IS WORN TO THE BASE METAL.

The contactor must be kept clean, connections must be tight, and should be inspected and serviced at intervals as specified in the Scheduled Maintenance Program.

SAFETY PRECAUTIONS

The following safety considerations should always be carefully observed in the application, operation, or servicing of the equipment.

1. ELECTRICAL RATINGS of the equipment are values that should be considered to be EXTREMELY DANGEROUS to personnel.

2. EQUIPMENT SHOULD ALWAYS BE COMPLETELY DE-ENERGIZED BEFORE HANDLING OR PERFORMING ANY SERVICE OPERATIONS. De-energizing the operating coil is not sufficient to render the equipment safe, the power lines must also be disconnected or otherwise de-energized. If power lines are not de-energized, all parts of the device should be considered to be at the maximum system voltage.

3. IF INSPECTION OF ENERGIZED EQUIPMENT IS NECESSARY, DO NOT TOUCH OR HANDLE ANY PARTS. DO NOT STAND IN FRONT OF THE EQUIPMENT OR AT CLOSE RANGE TO PERFORM VISUAL INSPECTIONS. The discharge of hot gases and particles is always likely when the contactor is operated in an energized circuit.

4. NEVER ATTEMPT TO OPERATE THE POWER CONTACTOR WITHOUT HAVING THE ARC CHUTE PROPERLY IN PLACE. A mechanical interlock is provided in the design to prevent the closing of main contacts until the arc chute is in position. TO AVOID EQUIPMENT DAMAGE OR DANGER TO PERSONNEL, DO NOT APPLY BY PASS DEVICES OR OTHERWISE ATTEMPT TO DEFEAT THE ACTION OF THIS INTERLOCK.

5. Operating temperatures for the contactors and switches are high. Some parts of these devices may normally reach temperatures considerably higher than the temperature of boiling water. SERIOUS BURNS CAN RESULT FROM HANDLING THE EQUIPMENT AFTER IT HAS BEEN IN SERVICE AND BEFORE IT HAS BEEN ALLOWED TO COOL.

INSPECTION OR REPLACEMENT OF POWER CONTACTOR CONTACT ASSEMBLIES

INSPECTION OF MAIN CONTACTS

1. Press arc chute latch spring, Fig. 8-1, and remove arc chute assembly by pulling forward.

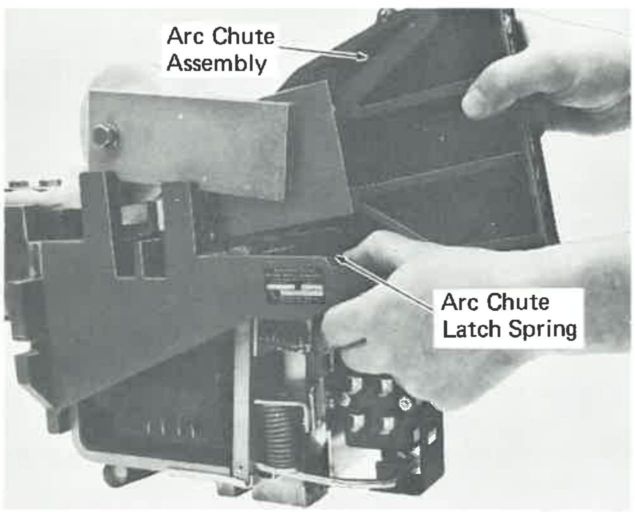


Fig. 8-1 – Removing Arc Chute

2. Inspect the three pivot contact tips and the movable main contact. The contacts will operate satisfactorily even though blackened, pitted, or eroded as shown in Fig. 8-2. If any tip is eroded beyond wear limits of Fig. 8-3, replace all three pivot contacts and the main movable contact.

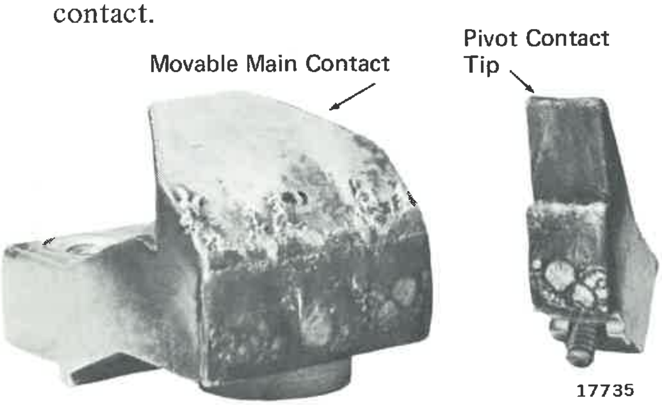


Fig. 8-2 – Usable Blackened And Pitted Main Contacts

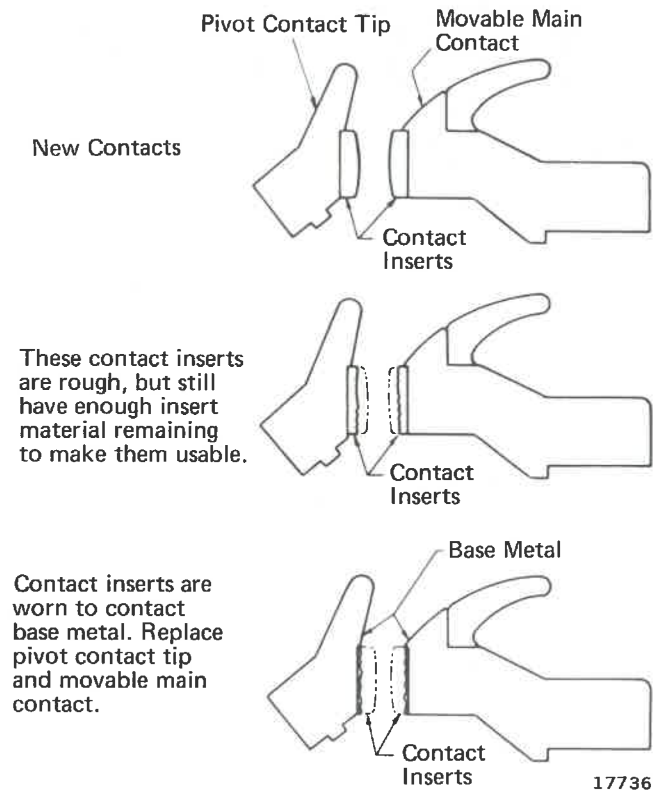
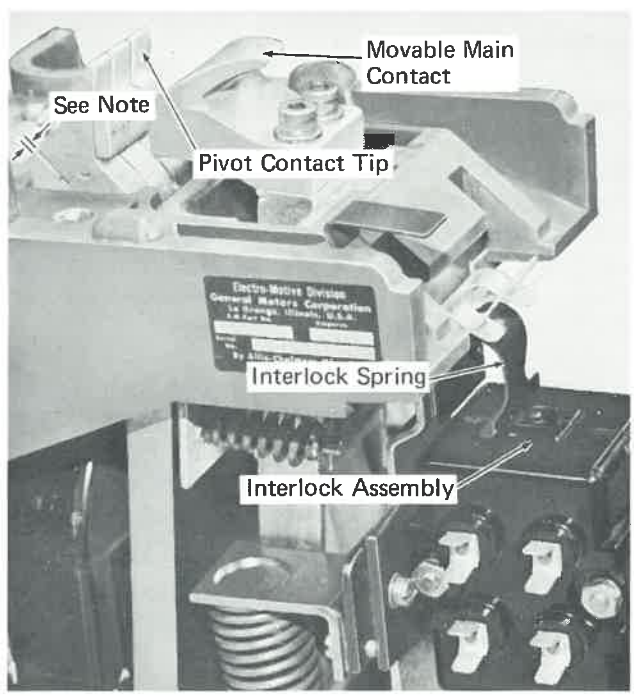


Fig. 8-3 – Main Contacts Wear Limits

NOTE: When arc chute assembly is removed or not fully engaged, an interlock spring, Fig. 8-4, interferes with motion of the interlock to prevent closing of the contactor.



NOTE: Contact motion .030-.045" measured at top of gap.

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Fig. 8-4 – Contactor With Arc Chute Removed

REPLACEMENT OF MAIN CONTACTS

1. Remove three screws and carfully remove pivot contact tips as shown in Fig. 8-5.
2. Align new pivot contacts at tongue and groove interface with pivot support half, Fig. 8-5, and secure with screws and lockwashers.

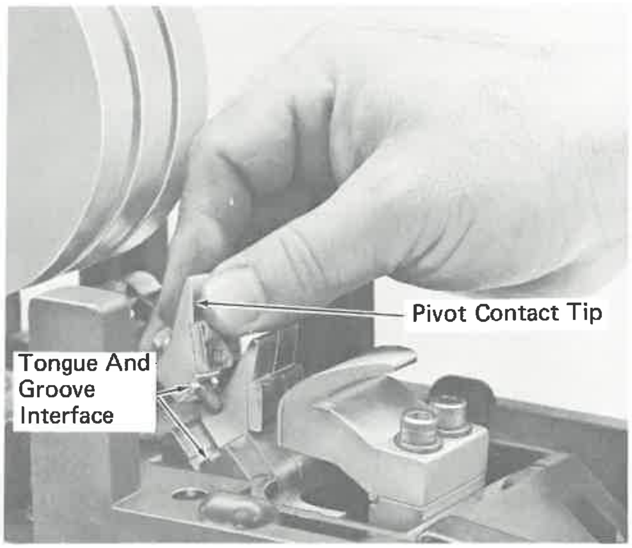


Fig. 8-5 – Pivot Contact Tip Replacement

3. Replace movable main contact by removing two screws as shown in Fig. 8-6. New contact is self-aligning. Secure with screws.

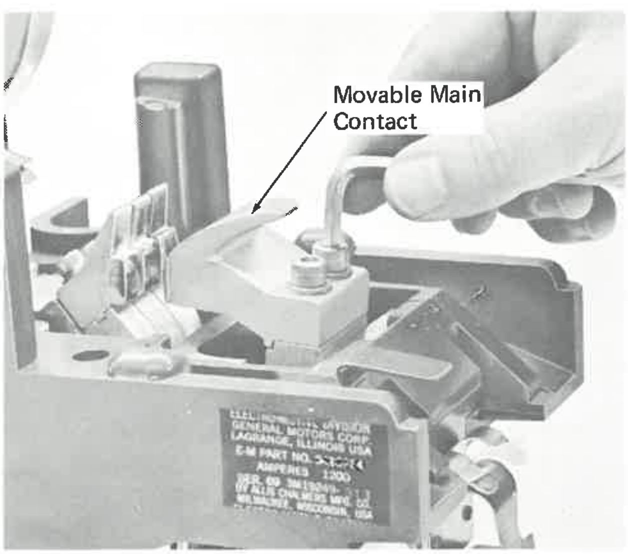
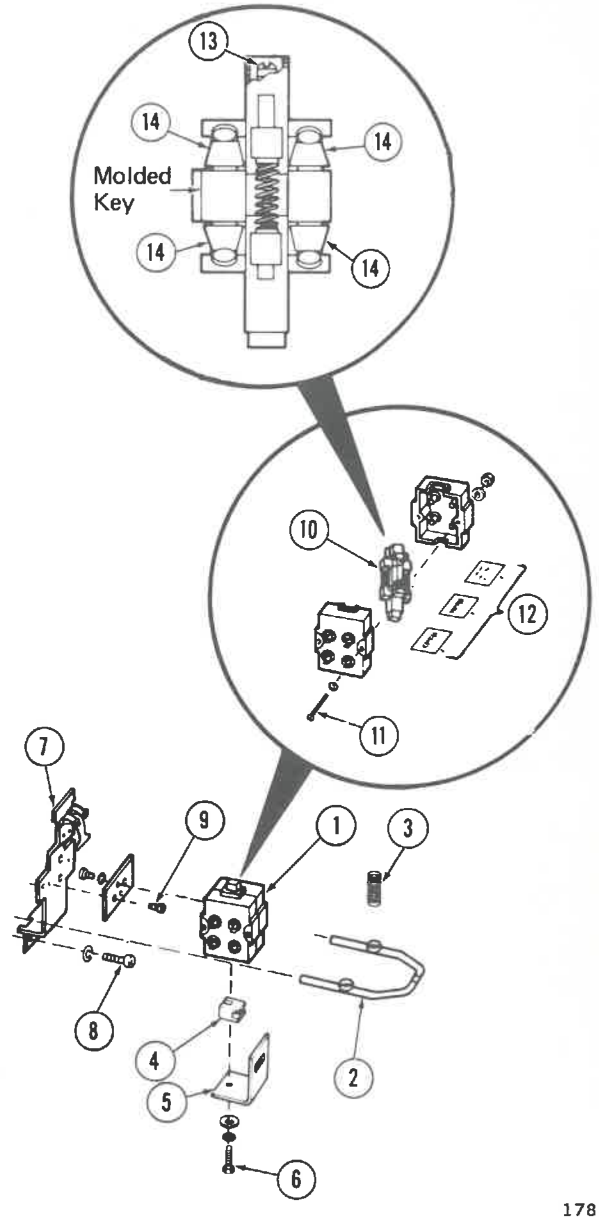


Fig. 8-6 -- Movable Main Contact Tip Replacement

INSPECTION OF INTERLOCK CONTACTS

1. Remove screw (6, Fig. 8-7) and washer from bottom of movable contact carrier (10), and remove slider (5) and interlock operator (4).



1. Interlock Assembly	8. Screw
2. Operating Lever	9. Screw
3. Return Spring	10. Contact Carrier Assembly
4. Interlock Operator	11. Screw
5. Slider	12. Labels
6. Screw	13. Screw
7. Support Bracket	14. Movable Contact Bridge

Fig. 8-7 -- Interlock Assembly, Exploded View

2. Slit labels (12) along parting line between the two interlock covers.

3. Remove two screws (11) from interlock covers and carefully remove the left-hand interlock cover, exposing interlock contacts. Interlock contacts do not require replacement until they are worn 0.060" per mating pair, when compared to new contact dimensions. Refer to Fig. 8-8 to determine if contacts are usable or require replacement.

NOTE: If the contacts in the movable contact carrier are worn beyond the tolerances in Fig. 8-8, the contact bridges should be replaced. If the stationary contacts located within the interlock covers are defective or loose, the interlock assembly should be replaced.

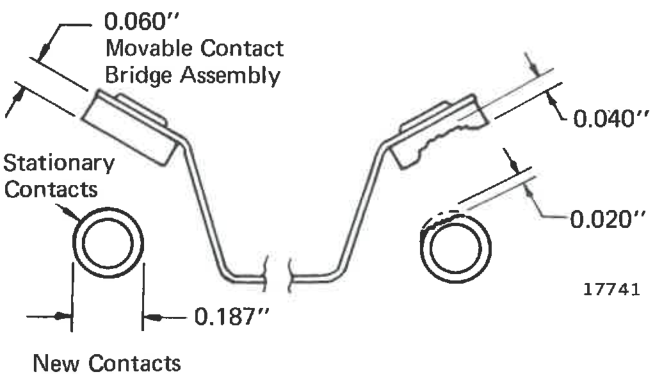


Fig. 8-8 – Interlock Contacts Wear Limits

REPLACEMENT OF INTERLOCK ASSEMBLY

If determined from inspection procedure that interlock assembly should be replaced, proceed as follows:

1. Remove return springs (3, Fig. 8-7) with screw driver.
2. Remove two screws (8) from bottom terminal assembly and swing the support bracket (7), with interlock assembly attached, forward until disengaged from top terminal molding, Fig. 8-9.

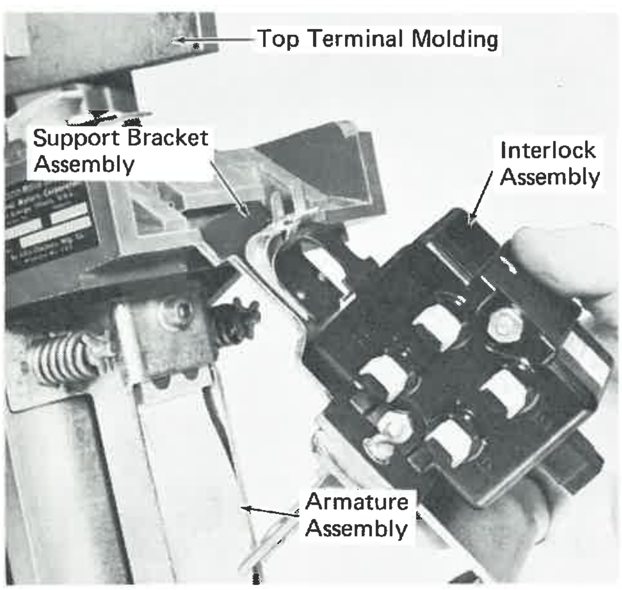


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Fig. 8-9 – Removing Support Bracket And Interlock Assembly

3. Remove two screws (9, Fig. 8-7) and remove interlock assembly from support bracket.
4. Mount new interlock assembly to support bracket with screws.
5. Position top end of interlock support bracket under front end of top terminal molding.
6. Attach interlock support bracket to bottom terminal assembly with two screws and lockwashers. Center contact assembly in the opening of top terminal molding and tighten screws.
7. Insert both return springs between cups on operating lever (2) and spring location buttons on return spring bracket. Springs must be fully seated in cups.
8. Attach interlock operator and slider to bottom of contact carrier assembly (10) with screw, Belleville washer, and lockwasher. Flattened portion of operating lever must be nested inside recess in interlock operator.

NOTE: Ensure slider (5) does not interfere with motion of interlock movable contact carrier.

REPLACEMENT OF INTERLOCK CONTACTS

If determined from inspection procedure that interlock contacts must be replaced, proceed as follows:

1. Remove movable contact carrier (10, Fig. 8-7) from interlock assembly cover.

NOTE: Work on movable contact carrier in an area where small parts will not be lost if accidentally dropped.

2. Hold movable contact carrier in palm of hand and loosen screw (13) so that the top, center, and bottom elements of the contact carrier can be separated sufficiently to remove an upper and lower set of contact bridges (14). Insert two new contact bridges.

CAUTION: Ensure that each contact bridge is positioned properly and not inverted since this could cause malfunction of the contactor. See inset in Fig. 8-7 for correct position of contact bridges.

3. Turn over movable contact carrier in palm of hand and repeat Step 2 for remaining two

contact bridges and tighten screw (13). Ensure brass sleeves on all four contact bridge assemblies are free after screw is tightened.

4. Place the movable contact carrier (10) into the interlock cover remaining on the contactor. Ensure the screw (13) in the movable contact carrier is at the end of the interlock cover stamped C-D and the molded key is outside the cover. Move movable contact carrier from end to end to ascertain that the contact bridge assemblies are correctly related to the stationary contacts inside the interlock cover. Align bottom and top elements of the movable contact carrier rotationally, if required, so they do not bind in the square bearing hole of the interlock cover.

5. Mate cover to the interlock assembly and secure with two screws (11), lockwashers, and nuts. Lockwashers are to be used under screw heads and under nuts.

INSPECTION OR REPLACEMENT OF BRAKING CONTACTOR CONTACT ASSEMBLIES

INSPECTION OF MAIN CONTACTS

1. Pull arc chute assembly latch spring, Fig. 8-10, forward and remove arc chute assembly by lifting front end of arc chute away from main body of contactor.

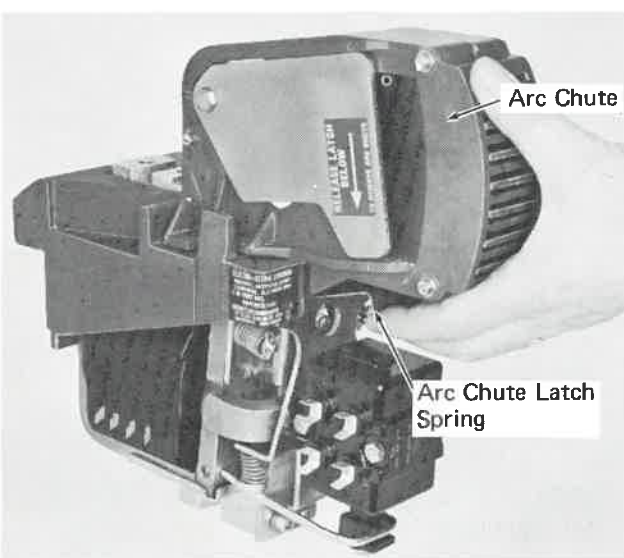

Fig. 8-10 – Braking Contactor

2. Inspect the two flexible stationary contact tips and the movable main contact tip. Refer to Fig. 8-11 to determine if contacts are usable or require replacement. If one is eroded beyond wear limits of Fig. 8-11, replace flexible stationary contact tips and movable main contact tip.

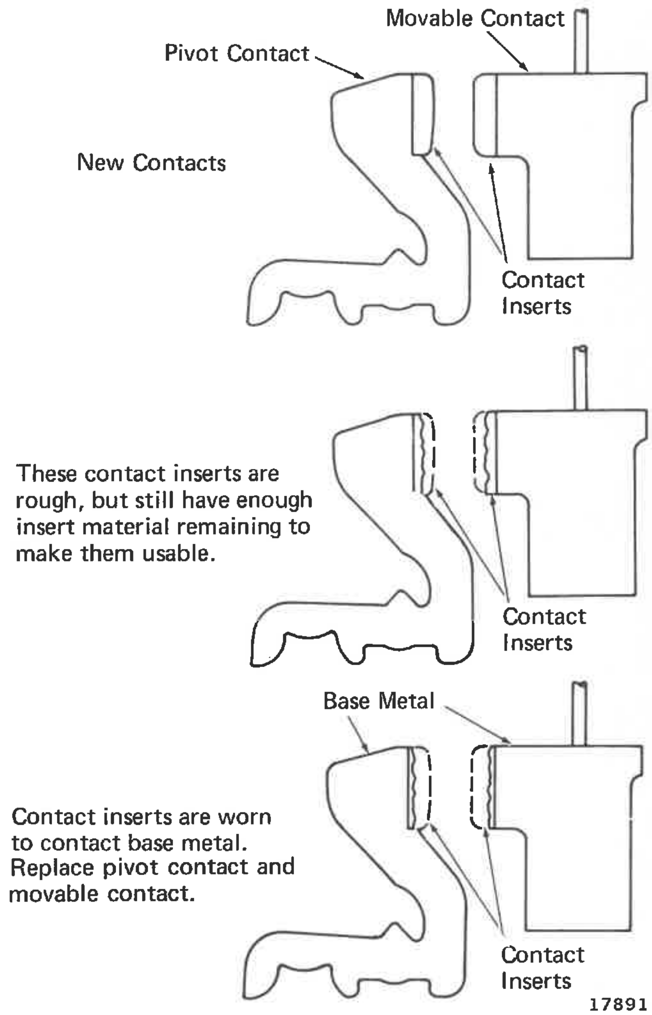

Fig. 8-11 – Main Contacts Wear Limits

REMOVAL OF MOVABLE ARC TIP ASSEMBLY

NOTE: If arc chute assembly has not been removed for inspection, remove per Step 1 of Inspection Of Main Contacts paragraph.

1. Remove screw and lockwasher, Fig. 8-12, holding the movable arc tip assembly to the movable main contact assembly.

2. Remove arc tip assembly from slot between movable main contact support and the hold-on magnet bracket by pulling up on the movable arc tip, while moving the movable arc tip slightly from side to side.

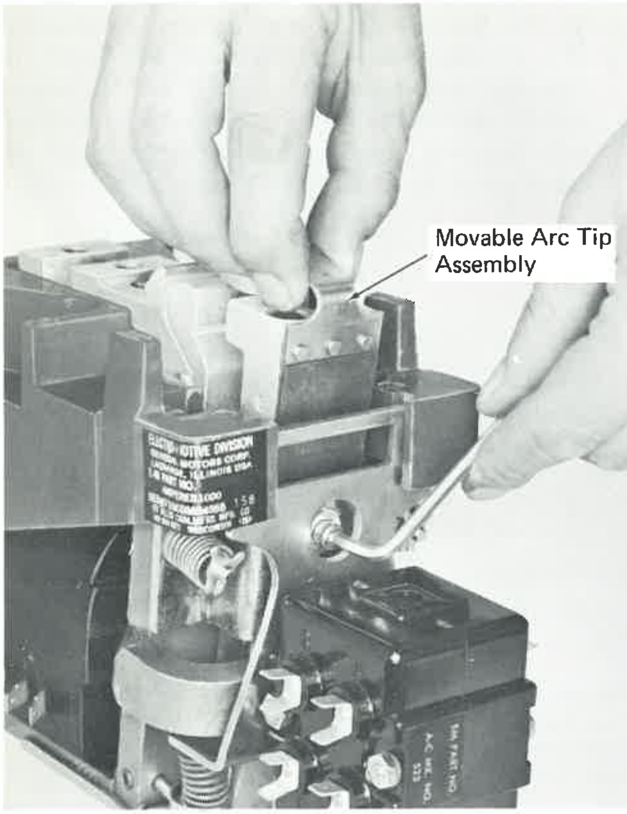

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Fig. 8-12 -- Removal Of Movable Arc Tip Assembly

REMOVAL AND REPLACEMENT OF MOVABLE MAIN CONTACT ASSEMBLY

1. Remove two screws and lockwashers, Fig. 8-13, holding movable main contact assembly in place. Remove movable main contact assembly and replace with a new contact assembly.

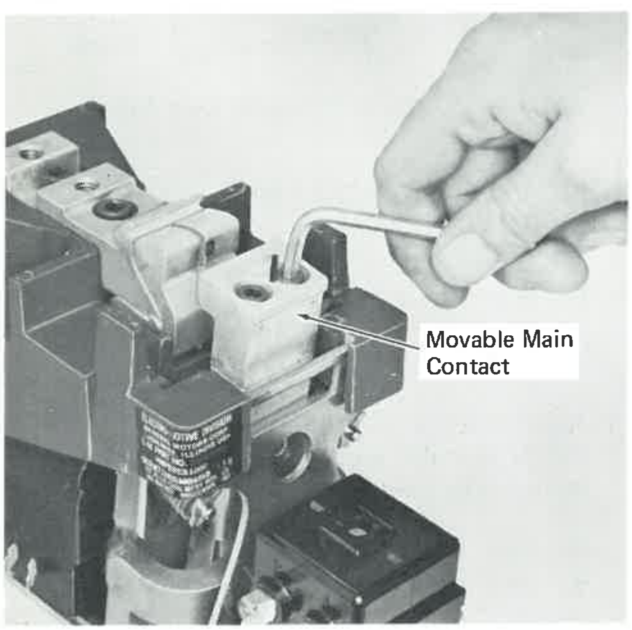

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Fig. 8-13 -- Removing Movable Main Contact

Secure new contact assembly with screws and lockwashers, but do not tighten screws at this time.

2. Ensure that the movable main contact assembly is properly seated, then tighten screws. Recheck seating of the contact after screws are tightened.

REPLACEMENT OF MOVABLE ARC TIP ASSEMBLY

1. Insert new movable arc tip assembly into slot between movable main contact support and the hold-on magnet bracket, Fig. 8-14.

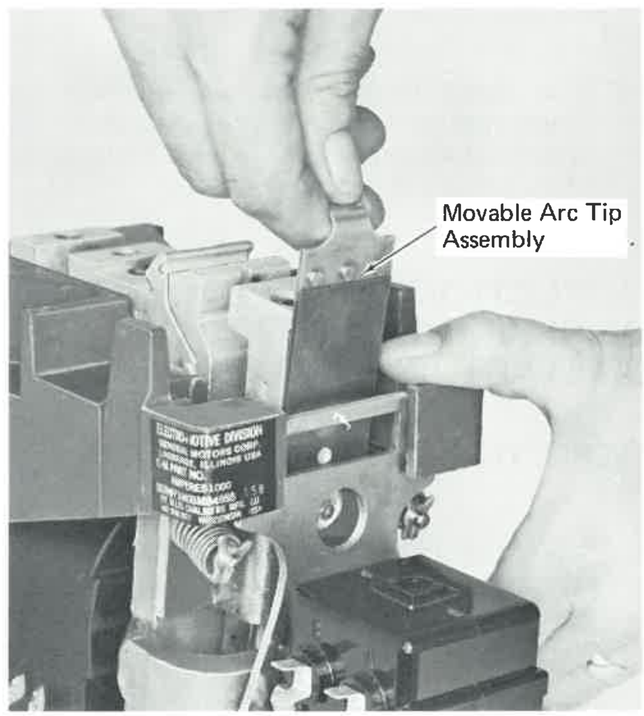

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Fig. 8-14 – Insertion Of Movable Arc Tip Assembly

CAUTION: Arc tip assembly must be inserted between the hold-on magnet bracket and the movable main contact support, not in front of the hold-on magnet bracket.

2. Align the hole in the movable arc tip assembly and the hole in the movable main contact support with the hole in the hold-on magnet bracket. Insert screw and tighten securely.

REMOVAL AND REPLACEMENT OF STATIONARY ARC TIP ASSEMBLY

The stationary arc tip assembly is located in the arc chute assembly.

1. Remove two screws and lockwashers holding the stationary arc tip assembly to the arc chute, Fig. 8-15.

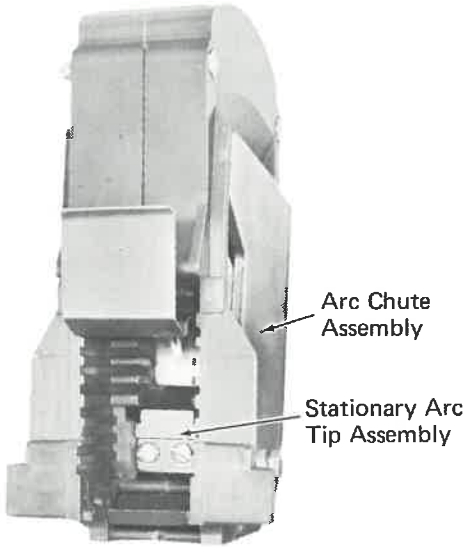


Fig. 8-15 – Replacement Of Stationary Arc Tip Assembly

2. Lift out stationary arc tip assembly.

3. Place new stationary arc tip in proper position and install two screws and lockwashers. Tighten screws securely.

REMOVAL AND REPLACEMENT OF FLEXIBLE STATIONARY CONTACT ASSEMBLIES

1. Remove the top stationary contact assembly and two flexible stationary contacts and spacer by removing two screws and lockwashers, Fig. 8-16.

2. Position spacer on the top terminal molding, with the short leg of the "L" down between the pivot springs and the long leg extending back between the wipe springs.

3. Place new flexible stationary contacts over wipe springs and pivot springs. Be certain that the spring caps are firmly seated on pivot springs.

4. Insert pointed nose of the top stationary contact assembly into the cavity in back of the flexible stationary contact, engaging the mating pivots.

5. With pivots engaged and the top stationary contact assembly held back against the stop in the top terminal molding, secure with two screws and lockwashers.

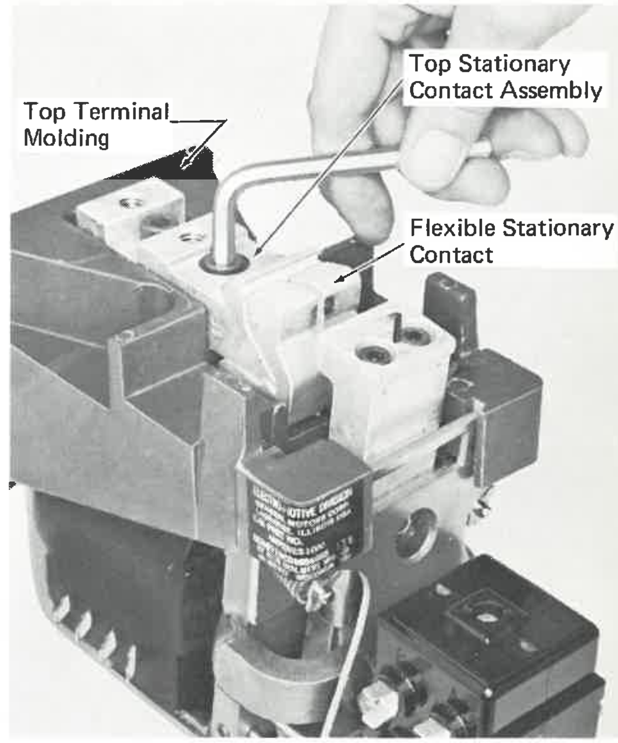


Fig. 8-16 – Removing Stationary Contact Assemblies

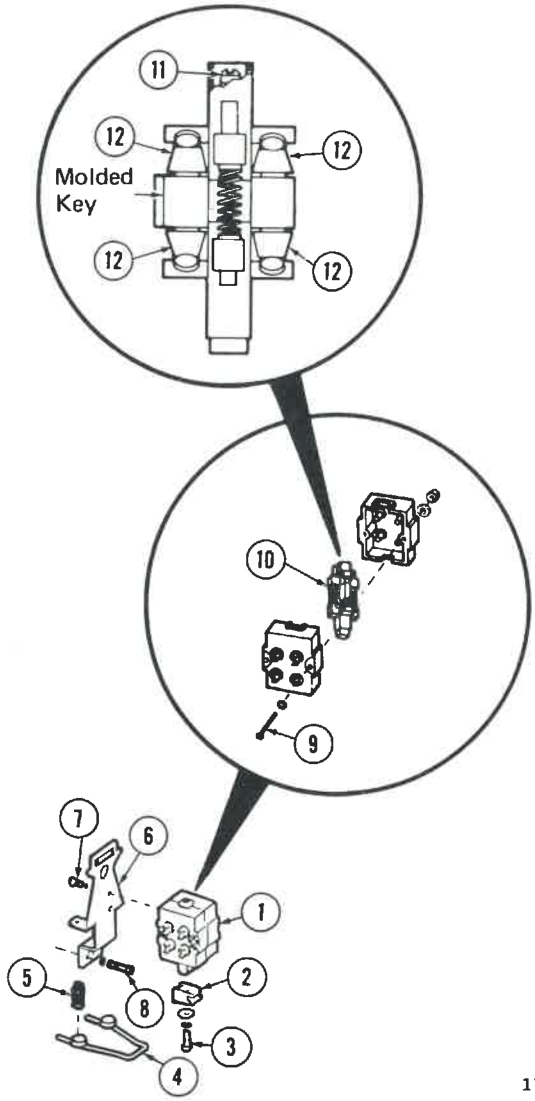
6. Check for freedom of movement of both stationary contact assemblies. Refer to Service Data for contact gap.

INSPECTION OF INTERLOCK CONTACTS

1. Remove screw (3, Fig. 8-17), lockwasher, and washer from bottom of movable contact carrier (10), and remove interlock operator (2).

2. Remove two screws (9) from interlock assembly and carefully remove the left-hand cover exposing interlock contacts. Interlock contacts do not require replacement until they are worn 0.060" per mating pair, when compared to new contact dimensions. Refer to Fig. 8-18 to determine if contacts are usable or require replacement.

NOTE: If the contacts in the movable contact carrier are worn beyond the tolerances in Fig. 8-18, the contact bridges should be replaced. If the stationary contacts located within the interlock covers are defective or loose, the interlock assembly should be replaced.



1. Interlock Assembly
2. Interlock Operator
3. Screw
4. Operator Lever
5. Return Spring
6. Support Bracket
7. Screw
8. Screw
9. Screw
10. Contact Carrier Assembly
11. Screw
12. Movable Contact Bridge

Fig. 8-17 – Interlock Assembly, Exploded View

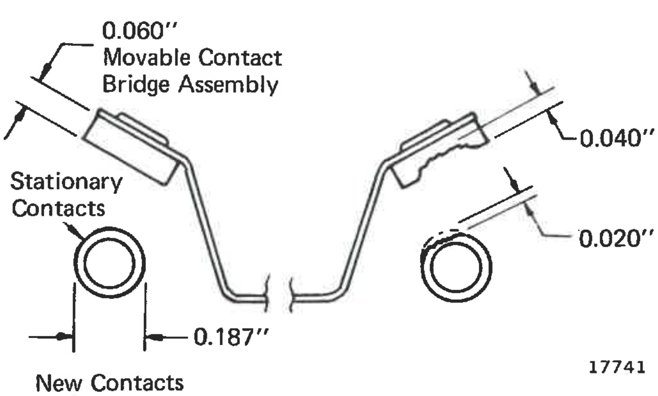


Fig. 8-18 -- Interlock Contacts Wear Limits

REPLACEMENT OF INTERLOCK ASSEMBLY

If determined from inspection procedure that interlock assembly should be replaced, proceed as follows:

1. Remove return springs (5, Fig. 8-17), with screw driver.

2. Remove two screws (8) from bottom terminal assembly and swing the interlock support bracket (6), with interlock assembly attached, forward until disengaged from top terminal molding.

3. Remove two screws (7) and remove interlock assembly from support bracket.

4. Mount new interlock assembly to support bracket with screws.

5. Position top end of interlock support bracket under front end of top terminal molding.

6. Attach interlock support bracket to bottom terminal assembly with two screws and lockwashers. Center contact assembly in the opening of top terminal molding and then tighten screws.

7. Insert both return springs between cups on operating lever (4) and spring location buttons on return spring bracket. Springs must be fully seated in cups.

8. Attach interlock operator to bottom of movable contact carrier (10) with screw, Belleville washer, and lockwasher.

REPLACEMENT OF INTERLOCK CONTACTS

If determined from inspection procedure that the interlock contacts must be replaced, proceed as follows:

1. Remove movable contact carrier (10, Fig. 8-17) from interlock assembly cover.

NOTE: Work on movable contact carrier in an area where small parts will not be lost if accidentally dropped.

2. Hold movable contact carrier in palm of hand and loosen screw (11) so that the top, center, and bottom elements of the contact carrier can be separated sufficiently to remove an upper and lower set of contact bridges (12).

CAUTION: Each contact bridge must be positioned properly and not inverted since this could cause malfunction of the contactor. See inset in Fig. 8-17 for correct position of contact bridges.

3. Turn over movable contact carrier in palm of hand and repeat Step 2 for remaining two contact bridges and tighten screw (11). Brass sleeves on all four contact bridge assemblies should be free after screw is tightened.

4. Place movable contact carrier (10) into the interlock cover remaining on the contactor. Ensure the screw (11) in the movable contact carrier is at the end of the interlock cover stamped C-D and the molded key is outside the cover. Move movable contact carrier from end to end to ascertain that the contact bridge assemblies are correctly related to the stationary contacts within the covers.

5. Mate cover to the interlock assembly.

INSPECTION OR REPLACEMENT OF DYNAMIC BRAKE GRID SHORTING CONTACTOR CONTACT ASSEMBLIES

INSPECTION OF MAIN CONTACTS

Under normal circumstances, main contacts should not need replacement. If the following inspection procedure does determine main contacts require replacement, replace the dynamic brake grid shorting contactor with a new contactor. Replacement of main contacts is a bench type operation since disassembly of the contactor is not possible on the locomotive.

1. Rotate spring-loaded latch on the left side, upper rear of the arc chute, Fig. 8-19, out of the way of the arc chute latch post, and lift arc chute vertically.

2. With the operating coil of the contactor energized, push the top and bottom contact retaining screws in with one hand, so that the movable main contact is firmly held against the stationary main contact, Fig. 8-20. With the other hand, check the gap between the rear of locknut and the front of the spacer. Main contacts must be replaced if the original gap of 0.035" (wear allowance) has been reduced to 0.010". Do not disturb original adjustment.

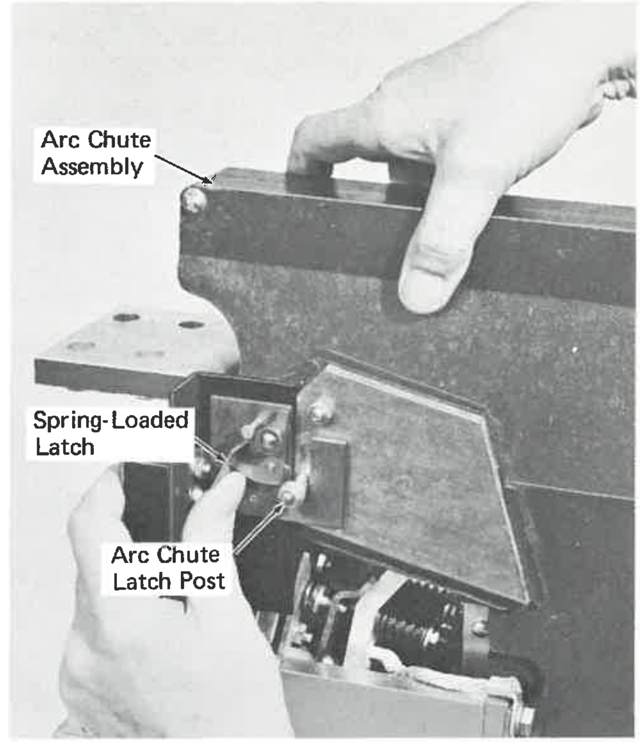


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Fig. 8-19 – Removing Arc Chute

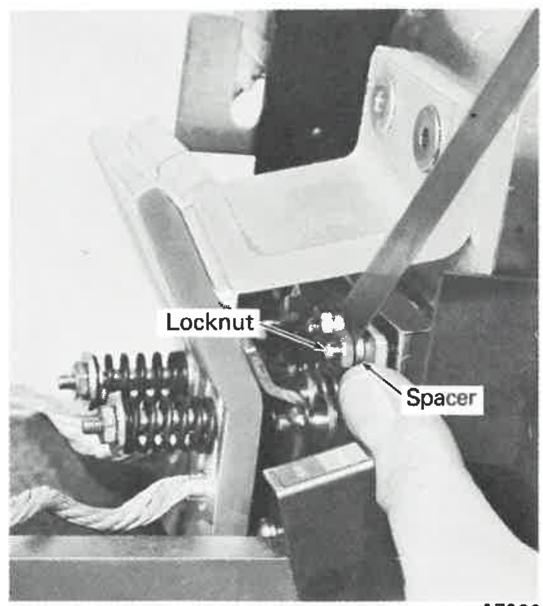

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Fig. 8-20 – Checking Main Contacts Wear Allowance

NOTE: When main contacts are being measured to determine if they need replacement, the arcing contacts and other parts need not be removed. Two of the eight measuring points will be hidden, but need not be checked.

INSPECTION OF ARCING CONTACTS

Replacement of arcing contacts is required when the silver contact insert in the stationary arcing contact is eroded to the copper base at the lower edge of the insert. Replace both movable and stationary arcing contacts as a set.

REPLACEMENT OF MOVABLE AND STATIONARY ARCING CONTACTS

NOTE: If arc chute is not removed, remove per Step 1 of Inspection Of Main Contacts.

1. Remove two bolts holding the two flexible wires to the movable contacts, Fig. 8-21.

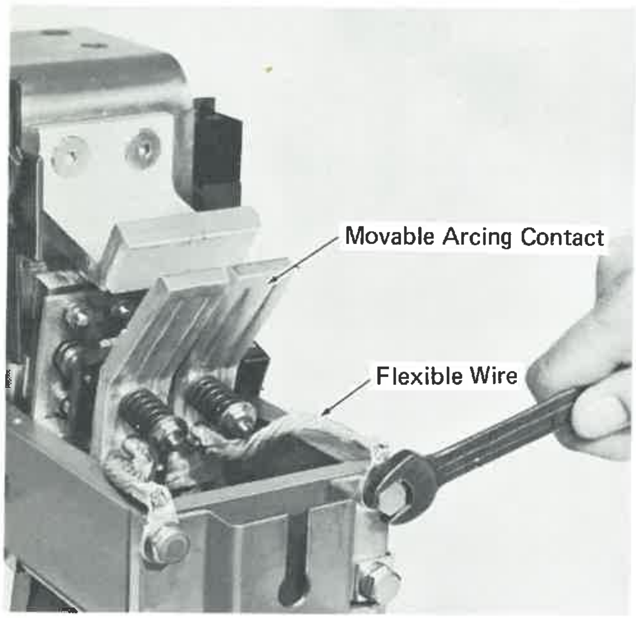

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Fig. 8-21 – Removing Flexible Wires To Movable Arcing Contacts

2. Remove the two locknuts and spring glands, holding the pressure springs and the movable arcing contacts to the armature, Fig. 8-22, and remove the movable arcing contacts.

3. Remove two flathead hex socket screws from the stationary arcing contacts, Fig. 8-23, and remove stationary arcing contacts.

4. Install two new stationary arcing contacts with new lockwashers and screws.

5. Install two new movable arcing contacts, two pressure springs with spring glands, and two locknuts.

6. Tighten the two arcing contact locknuts so that the nut is advanced until a flat area filed on the threads of the screw is just fully visable.

7. Replace the two bolts holding the flexible wires.

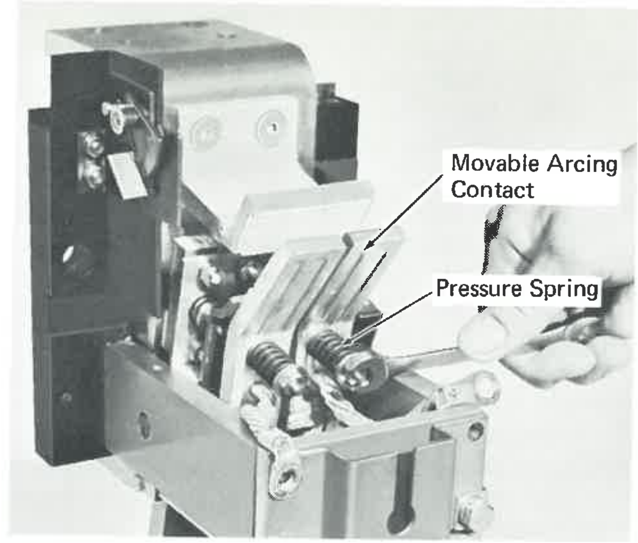

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Fig. 8-22 -- Removing Movable Arcing Contacts

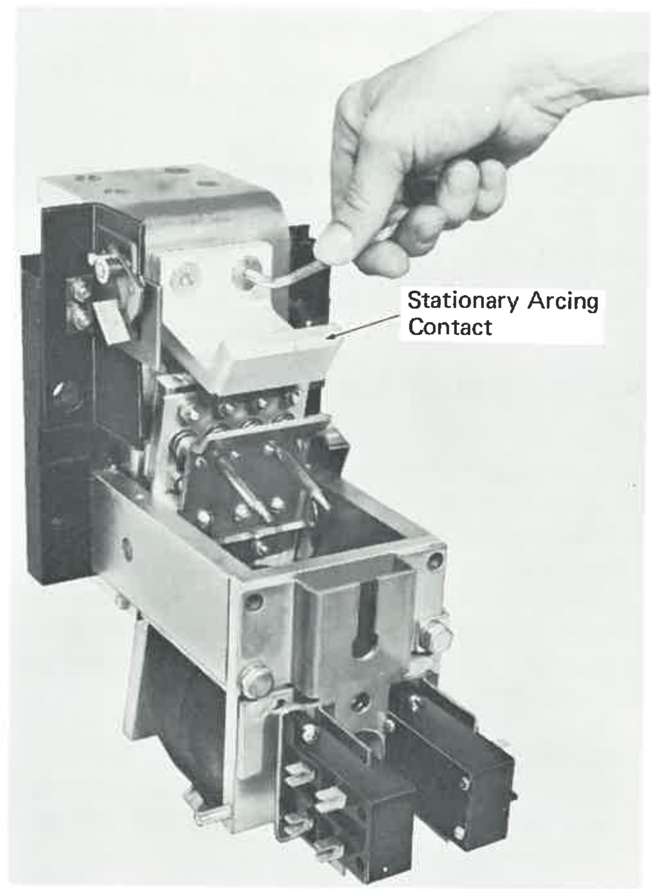

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Fig. 8-23 -- Removing Stationary Arcing Contact

REPLACEMENT OF CONTACT ASSEMBLIES AND ADJUSTMENTS OF MOTOR OPERATED SWITCHES

The motor operated switch is a composite of one motor module driving a maximum of six switch modules through a segmented shaft.

MOTOR MODULE

AUXILIARY INTERLOCK CONTACT ADJUSTMENT

1. Disconnect all wires from interlock terminals.

2. Remove retaining ring and link pin from link assembly, Fig. 8-24.

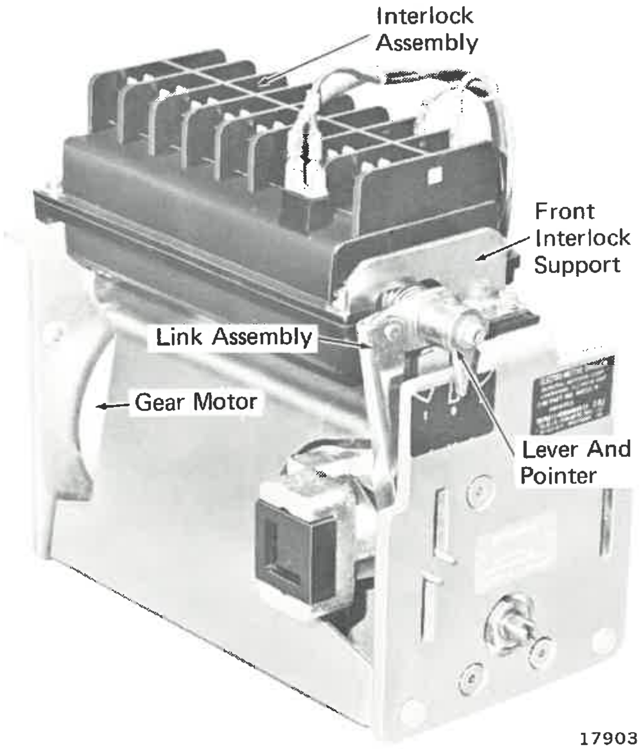


Fig. 8-24 -- Motor Module

3. Remove three screws and remove the front interlock support.

4. Separate interlock assembly from gear motor by lifting front end of interlock assembly and sliding forward out of rear interlock support.

5. Remove three screws from interlock cover and open interlock assembly.

6. Place interlock cover in the inverted position. Place the cam shaft with bearing liners and wrap-around bearings into bearing sockets of the cover.

7. With drilled lever pointing up, check contact gaps on the front two circuits, V-Y and X-W, as shown in Fig. 8-25. Gaps must be between 0.172" and 0.187". If required, adjust by bending stationary contact finger between the second bend and point of contact with cover molding, Fig. 8-26.

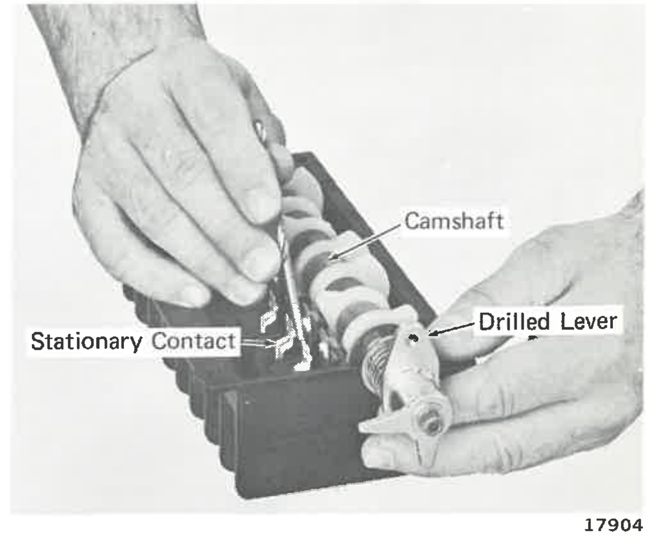


Fig. 8-25 -- Auxiliary Interlock Adjustment

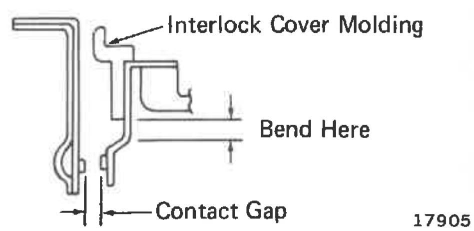


Fig. 8-26 -- Interlock Contact Adjustment

8. Rotate camshaft clockwise until drilled lever points to the right. Contact gaps on the six rear circuits must be between 0.172" and 0.187". If required, adjust by bending as described in Step 7.

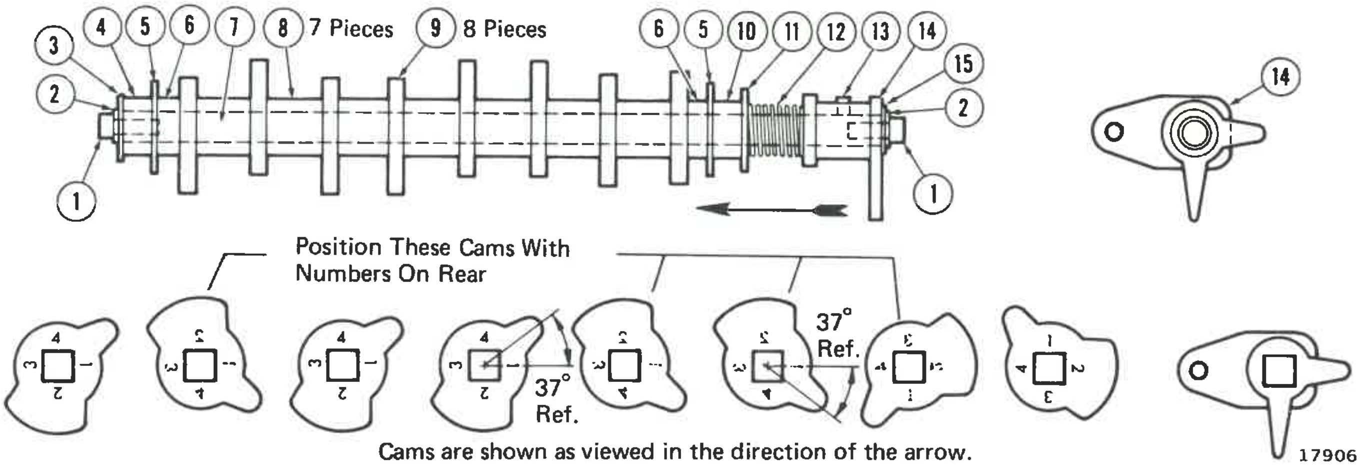
9. Place base assembly over the cover and cam assembly. Invert and secure with three screws and washers.

10. Slide the interlock assembly into the rear interlock support, over the gear motor assembly, with the cam shaft pointer in front. Position the front interlock support and secure with three screws and lockwashers.

GEAR MOTOR MAINTENANCE

The gear motor assembly, Fig. 8-24, is lubricated for the life of the gear motor.

The brushes should be replaced in the conventional manner when worn down to 1/4" length.



1. Cap Screw
2. Lockwasher
3. Plain Washer, 0.75" O.D.
4. Interlock Bearing, 13/32" lg.
5. Creepage Washer
6. Spacer Tube, 15/64" lg.
7. Camshaft
8. Spacer Tube, 21/32" lg.
9. Cam
10. Interlock Bearing, 21/64" lg.
11. Washer
12. Spring
13. Set Screw
14. Lever And Pointer
15. Plain Washer, 0.219" O.D.

Fig. 8-27 – Camshaft Assembly

CAMSHAFT ASSEMBLY

If it becomes necessary to rebuild the camshaft interlock assembly, refer to Fig. 8-27 for sequence of parts and the proper orientation of the cams.

SWITCH MODULE

REMOVING AND REPLACING MOVABLE CONTACT ASSEMBLY

1. Remove operating head, Fig. 8-28, by removing screws.

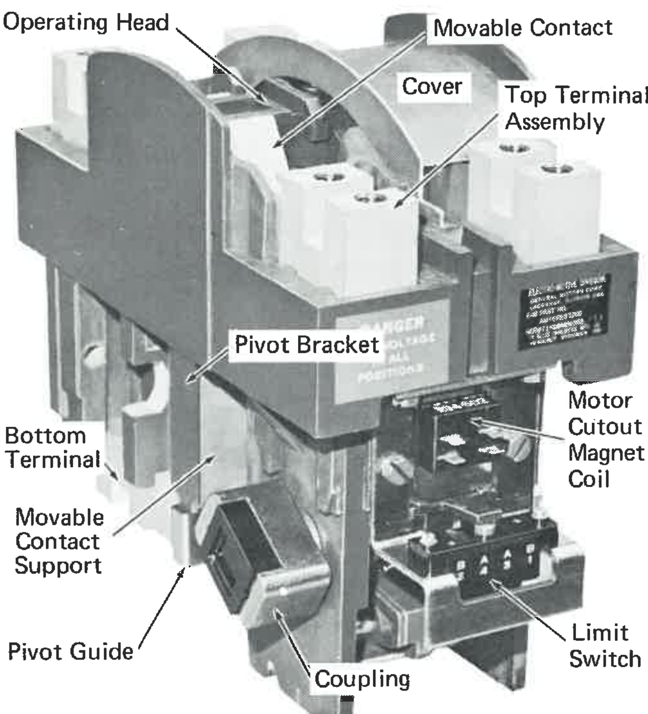
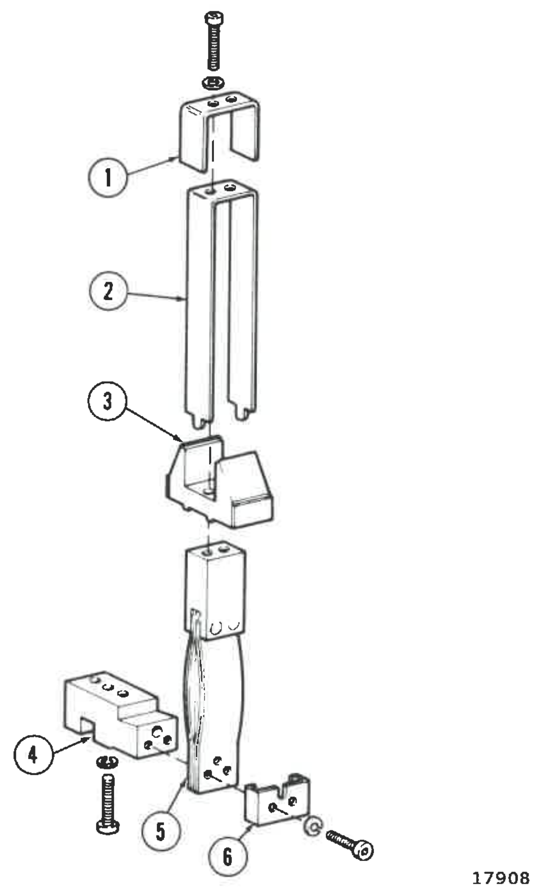


Fig. 8-28 -- Switch Module

2. Remove two screws, hold-on iron (1, Fig. 8-29), pivot bracket (2), and movable contact (3).

3. Remove two screws, hold-on iron, pivot bracket, and movable contact from the other side.



1. Hold-On Iron
2. Pivot Bracket
3. Movable Contact
4. Bottom Terminal
5. Movable Contact Support
6. Pivot Guide

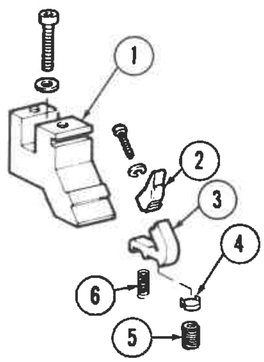
Fig. 8-29 -- Movable Contact Assembly, Exploded View

4. Place two new movable contacts on movable contact supports, reassemble pivot bracket and hold-on iron and secure with two screws.

REMOVING AND REPLACING STATIONARY PIVOT CONTACT ASSEMBLIES

If inspection has determined that any one of the three stationary pivot contacts requires replacement, replace all three to maintain proper contact pressure distribution.

1. Remove screw, releasing top terminal assembly (1, Fig. 8-30) with the three pivot contact assemblies (2 and 3).



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1. Top Terminal Assembly
2. Pivot Contact Tip
3. Pivot Contact Support
4. Pivot Spring Cap
5. Pivot Spring
6. Wipe Spring

Fig. 8-30 – Stationary Contact Assembly, Exploded View

2. Remove three wipe springs (6) and three pivot springs (5) with spring caps (4) from the base molding.

3. Repeat Steps 1 and 2 to remove the stationary contact assemblies in the remaining three locations.

4. Mate new pivot contact tips (2) to new contact supports (3). Secure the halves with screws and lockwashers making certain that the halves are centered on each other.

5. Ensure that support areas for wipe springs and pivot springs are free of all foreign particles.

6. Place a wipe spring (6) over each of the three small pins in one of the four contact pockets.

7. Place a pivot spring (5) over each of the three larger pins in the same contact pocket.

8. Attach a pivot spring cap (4) to the bottom of each of the three pivot contact assemblies by the spring tension of the two ears on spring cap. Bend ears inward if necessary to bind on support half.

9. Place one contact assembly with attached spring cap over wipe spring and pivot spring making certain that the spring cap is firmly seated over the top of pivot spring. Position the remaining two contact assemblies in the same manner.

10. Insert the pointed nose of top terminal (1) into cavity in back of the stationary contact assemblies, engaging the pivots of the mating parts.

11. Secure top terminal to base molding with screw and lockwasher. Be certain that the pivots remain engaged and that the rear end of the top terminal touches the base molding.

12. Check for freedom of motion at each stationary contact. A clearance of 0.020" to 0.045" shall be maintained behind the top edge of each pivot contact, Fig. 8-31.

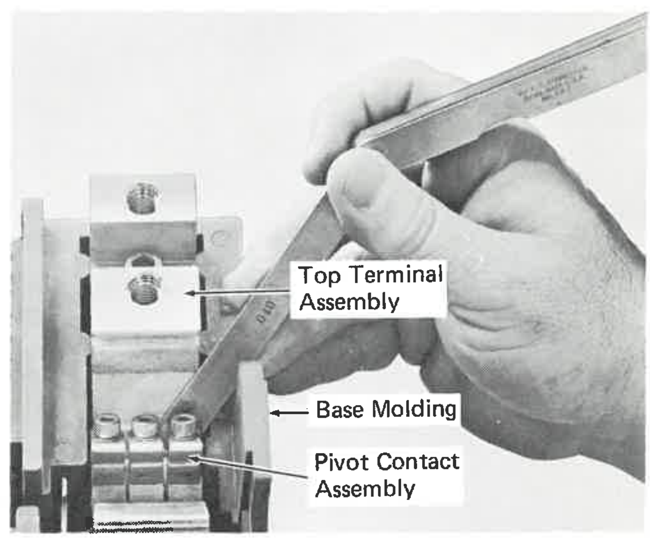

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Fig. 8-31 – Checking Stationary Contact Clearance

13. Install the remaining three sets of stationary contacts and top terminals using the same procedure.

REFERENCES

Power Contactors – 8416134 and 8458534	M.I. 5422
Braking Contactors -- 8461331, 8461332, and 8461333	M.I. 5424
Dynamic Brake Grid Shorting Contactors – 8416136, 8436326, and 8459697	M.I. 5406
Motor Operated Switch – Motor Module 8453176, Switch Module 8453175	M.I. 5421

ROUTINE MAINTENANCE PARTS

ALLIS CHALMERS –

POWER CONTACTOR 8458534

Movable Main Contact	8424739
Pivot Contact Tip	8424740
Interlock Assembly	8329110
Cover Assembly – Stationary Contacts A-B, E-F	8190090
G-H, C-D	8190092
Contact Bridges	8190094
Contact Carrier	8339411

MOTOR OPERATED SWITCH

Switch Module	8453174
Stationary Main Contact	8446420
Pivot Support	8436607
Movable Main Contact	8446413
Motor Module	8453176
Interlock Assembly	8465590
Movable Contact -- (Finger Assembly)	8446438
Stationary Contact -- (Finger Assembly)	8446437
40 Ohm, 55 Watt Resistor	8446446

BRAKING CONTACTOR 8461331

Movable Main Contact	8339390
Flexible Stationary Contact Kit	8441835
Contact Assembly	8441833
Contact Spacer	8441834
Pivot Springs -- (With Caps)	8441836
Wipe Springs	8379138
Stationary Arc Tip	8407131
Movable Arc Tip	8407132
Top Stationary Contact Assembly	8339355
Arc Chute Assembly	8399841
Interlock Assembly	8329110
Cover Assembly – Stationary Contacts A-B, E-F	8190090
G-H, C-D	8190092
Contact Bridges	8190094
Contact Carrier	8339411

CUTLER-HAMMER

DYNAMIC BRAKE GRID SHORTING CONTACTOR 8459697

Movable Main Contact (Non-Arcing Bridge)	8451522
Upper Stationary Main Contact	8451523
Lower Stationary Main Contact	8451530
Movable Arcing Contact	8451655
Stationary Arcing Contact	8451656
Interlock Assembly Contacts A-B, C-D	8332487
E-F, G-H	8332489
Arc Chute Assembly	8424706

SPECIFICATIONS

POWER CONTACTOR 8458534

MAIN CONTACTS

Contact Rating	74 V DC
Normally Open Contact	1200 amps at 1500 volts
Contact Wear Allowance (Total)	1/8"
Contact Opening (Nominal)	0.484"
With Coil De-energized	
Nominal gap between stationary contact and top terminal	0.035"
Gap between hold-on iron and armature	0.020"
With Coil Energized (74 V DC)	
With arc chute removed, interlock spring must keep main contacts separated	1/4" minimum
Initial contact pressure	15-25 lbs.

Measure at center of movable contact tip with armature blocked so that contacts do not touch.

INTERLOCK CONTACTS

Contacts A-B, C-D	Normally closed
E-F, G-H	Normally open
Contact Spring Pressure (at 3/32" deflection)	0.25 lbs.
Contact Opening	3/16"
Contact Lift	3/32"
Contact Wear Allowance (Total)	0.060"
With Coil De-energized	
Top of interlock movable contact carrier to top of interlock housing	within 0.030"
With Coil Energized (74 V DC)	
Horizontal clearance between operating lever and interlock operator	1/32"
Step on lower portion of interlock movable contact carrier to bottom of interlock housing	within 0.030"

MAGNET COIL

Resistance (at 20°C)	120 ohms (±10%)

OPERATION

Working Voltage (Continuous)	74 V DC
Pickup (at 20°C)	48 V DC
Dropout (at 20°C)	5-28 V DC

BRAKING CONTACTOR 8461331

MAIN CONTACTS

Contact Rating . . . . . 1000 amps
Contact Pressure (New Contacts) . . . . . 9-10 lbs.
Contact Wear Allowance (Each Contact) . . . . . 1/16"
Contact Opening (New Contact, Min.) . . . . . 15/32"
With Coil De-energized
  Nominal gap between flexible stationary contacts and top terminal . . . . . 0.045"
  Movable main contact centered in the top terminal molding . . . . . within 0.030"

INTERLOCK CONTACTS

Contacts A-B, C-D . . . . . Normally closed
  E-F, G-H . . . . . Normally open
Contact Lift, Short Wipe (at 3/32" deflection) . . . . . 0.25 lbs.
Contact Lift, Long Wipe (at 1/4" deflection) . . . . . 0.30 lbs.
Movable Contact Assembly Travel . . . . . 0.375"
Contact Wear Allowance (Total) . . . . . 0.060"
With Coil De-energized
  Top of interlock movable contact carrier to top of interlock housing . . . . . within 0.03"
With Coil Energized (74 V DC)
  Horizontal clearance between operating lever and interlock operator . . . . . 3/32"
  Step on lower portion of interlock movable contact carrier to bottom of interlock housing. . within 0.03"

MAGNET COIL

Resistance (at 20°C) . . . . . 120 ohms (±10%)

OPERATION

Working Voltage (Continuous) . . . . . 74 V DC
Pickup (at 20°C) . . . . . 48 V DC
Dropout (at 20°C) . . . . . 5-28 V DC

DYNAMIC BRAKE GRID SHORTING CONTACTOR 8459697

MAIN CONTACTS

Contact Rating . . . . . 74 V DC
Contact Wear Allowance Gap . . . . . 0.035"
Contact Replacement Gap Limit . . . . . 0.010"
Contact Spring Pressure . . . . . 6.25-6.5 lbs.

INTERLOCK CONTACTS

8332487 Contacts A-B, C-D. . . . . Normally open
8332489 Contacts E-F . . . . . Normally open
  G-H . . . . . Normally closed

ARCING CONTACTS

Contact Spring Pressure . . . . . 3.75-4.0 lbs.
Wear Limit . . . . . Silver insert eroded to copper base at lower edge of insert

MAGNET COIL

Resistance . . . . 123 ohms (± 10%)

OPERATION

Working Voltage (Continuous) . . . . 74 V DC
Pickup (From -40° to +100°C) . . . . 48 V DC
Dropout (From -40° to +100°C). . . . . 5-28 V DC

SWITCH MODULE 8453174

MAIN CONTACTS

Contact Rating (Continuous) . . . . 1200 amps
Interruption Rating . . . . 100 amps
Contact Wear Allowance (Total) . . . . 1/8"
With contact open, nominal gap between stationary contact and top terminal . . . . 0.035"
With motor cutout energized, main contact gap (after removing slack in movable contact). . . . . . 0.094"

MOTOR CUTOUT SWITCH 8453175

Coil Resistance (at 20°C) . . . . 190 ohms (± 10%)
Coil Pickup (at 20°C) . . . . 48 V DC
Coil Dropout (at 20°C) . . . . 5-28 V DC

MOTOR MODULE 8453176

INTERLOCK CONTACTS

Contact Rating . . . . 10 amps
Contact Gap. . . . . 0.172-0.187"

Contact Position

	Interlock Camshaft Pointer Position		
Contacts	1	0	2
Y-V	Open	Closed	Closed
X-W	Closed	Closed	Open
A-B	Open	Open	Closed
C-D	Open	Open	Closed
E-F	Closed	Open	Open
G-H	Closed	Open	Open
N-P	Open	Open	Closed
Q-R	Closed	Open	Open

LOAD TEST AND HORSEPOWER STANDARDIZATION

INTRODUCTION

This section contains procedures for load test and horsepower standardization. Accurate and standardized horsepower data can be used to evaluate performance of the engine and auxiliary equipment and to indicate possible malfunction or excessive horsepower output. Correction of malfunctions will improve engine performance, and operation at normal horsepower will minimize engine wear. Refer to grid load checks (GL) in the Section 11 Troubleshooting outlines for procedures to check various control components, using the locomotive dynamic braking resistor grids as a load.

The following information is provided in this section.

1. Preliminary preparation for load test.
2. Test setup for automatic load test on dynamic braking grids.
3. Test setup for load testing on dynamic braking grids.
4. Test setup for load testing on load box or external grid hatches.
5. Test setup for load testing on dynamic braking grids in parallel with a load box or external grid hatch.
6. Loading the unit.
7. Horsepower calculation and standardization.

The Service Data pages included at the end of this section provide the following information.

1. References to drawings and other publications relating to equipment and procedures covered in this section.
2. A list of routine maintenance parts and equipment recommended for use with the procedures provided in this section.
3. Specifications covering components and circuits.
4. Horsepower and loading resistance graphs, and horsepower correction factors.

PRELIMINARY PREPARATION FOR LOAD TEST

1. Stop the diesel engine and remove the starting fuse. Open the generator field circuit breaker.
2. Check that fuel tank contains sufficient fuel (minimum 250 gallons) for the period of the load test (about 90 minutes). Fuel should be in accordance with specifications listed in M.I. 1750.
3. Check oil level at:

    a. Engine oil pan.

    b. Air compressor.

    c. Governor.

    d. Engine air filter.
4. Check that coolant level is at the STOP/FULL mark on the water tank sight glass gauge.
5. Make an engine air box inspection. Check condition of piston rings and cylinder walls.
6. Make a generator air box inspection. Replace any blown fuses and shorted diodes.

NOTE: The inertial air filter compartment door is to remain closed during the testing.

7. Suspend a thermometer for measuring ambient air temperature. The thermometer may be hung at the radiator air inlet grill.

8. Remove the plug in the engine mounted fuel filter and install a dial thermometer to read fuel oil temperature.

9. A thermometer well is located in the water pump discharge elbow. Fill the well with oil, and in it place a glass thermometer for measuring engine water inlet temperature.

10. Suspend a caged glass thermometer below the oil level in the lube oil strainer housing. This will measure engine oil inlet temperature.

11. Disconnect the TR module by pulling it half way out.

TEST SETUP

The test setup for loading the locomotive is determined by the type of loading equipment that is available. The following paragraphs provide test setup procedures for the most common types of loading equipment.

SETUP FOR AUTOMATIC LOADING ON DYNAMIC BRAKING GRIDS (On Units So Equipped)

1. Connect a 0-75 or 0-50 millivolt meter, with 1/2 of 1 percent accuracy, to the load test jacks provided on the test panel located at the left of the control modules. This connects the meter to a 4000 ampere 50 millivolt shunt.

2. Connect a 0-1500 DC voltmeter at test panel MAIN GEN. VOLTS binding posts. Use leads with spade lube, clamping the lugs firmly at the binding posts.

3. Refer to procedures for loading the unit.

SETUP FOR LOADING ON DYNAMIC BRAKING GRIDS, Fig. 9-1 (Units Not Equipped For Automatic Loading)

1. Disconnect and remove the main generator bus located at lower left front of the electrical cabinet.

2. Using a minimum of two 1100/24 cables, connect a 2000 or 4000 ampere 50 millivolt meter shunt, with 1/2 of 1 percent accuracy, to the GP bus terminal.

3. Connect three lengths of 774/24 cable between the shunt and motor/brake transfer switch terminals as shown in Fig. 9-1.

4. Connect three lengths of 775/24 cable between motor/brake transfer switch terminals and the GN bus terminal as shown on Fig. 9-1.

NOTE: The above connections provide nominal loading resistance of 0.573 ohm with cold grids.

5. Connect a 0-75 or 0-50 millivolt meter, with 1/2 of 1 percent accuracy to the shunt.

6. Connect a 0-1500 DC voltmeter at test panel MAIN GEN. VOLTS binding posts. Use leads with spade lugs, clamping the lugs firmly at the binding posts.

7. Refer to procedures for loading the unit.

SETUP FOR LOADING ON LOAD BOX OR EXTERNAL GRID HATCH

1. Disconnect and remove the main generator bus located at lower left front of the electrical cabinet.

2. Using four 1100/24 cables or equivalent, connect a 4000 ampere 50 millivolt meter shunt, with 1/2 of 1 percent accuracy, to the GP bus terminal.

3. Connect a 0-75 or 0-50 millivolt meter, with 1/2 of 1 percent accuracy, to the shunt.

4. Connect a 0-1500 DC voltmeter at test panel MAIN GEN. VOLTS binding posts. Use leads with spade lugs, clamping the lugs firmly to the binding posts.

5. Connect loading cables between the shunt and load box or external grid hatches as shown in Fig. 9-2.

6. Connect loading cables, as shown in Fig. 9-2, between the load box or external grid hatches and the GN bus terminal.

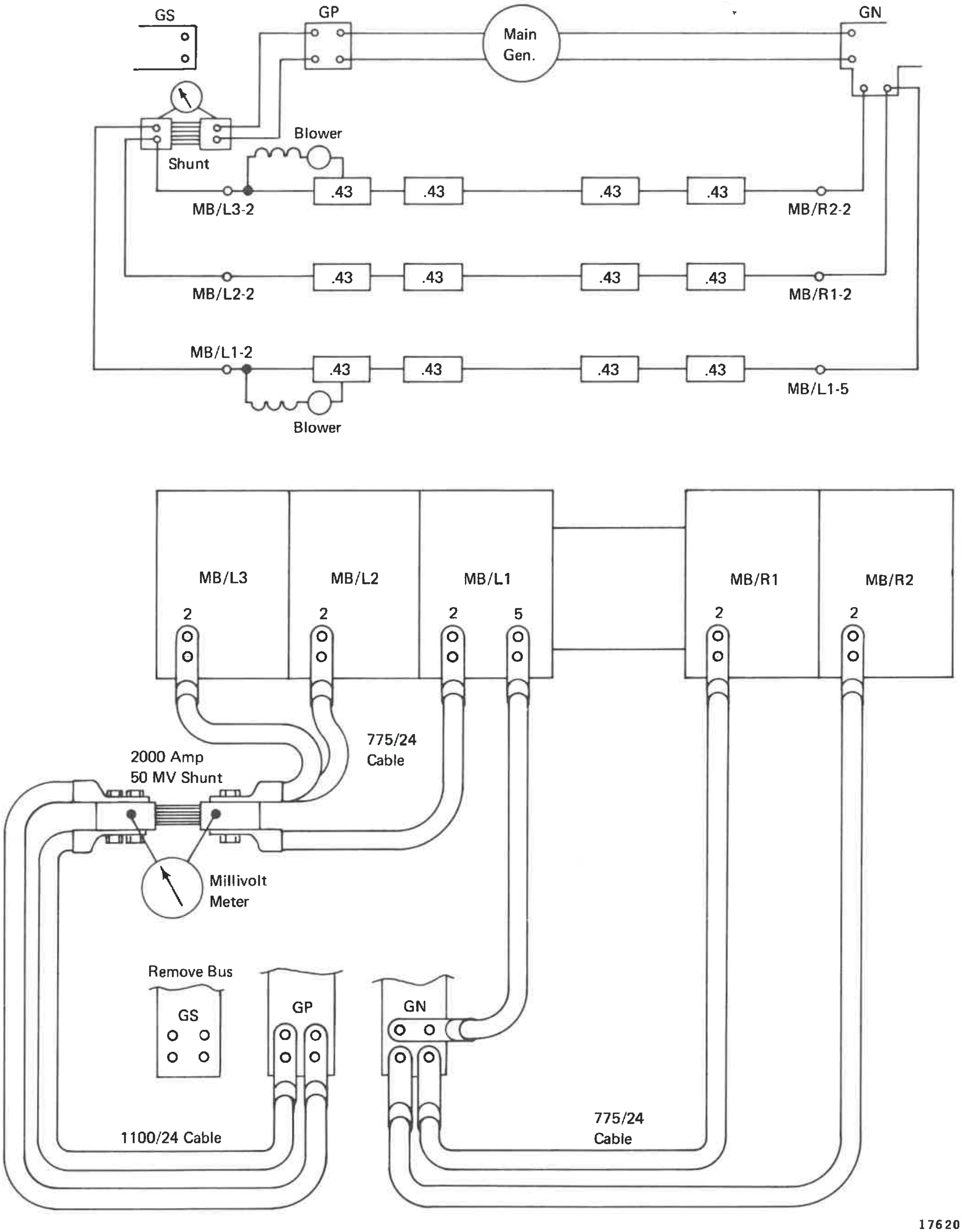


Fig. 9-1 -- Test Setup For Loading On Dynamic Braking Grids

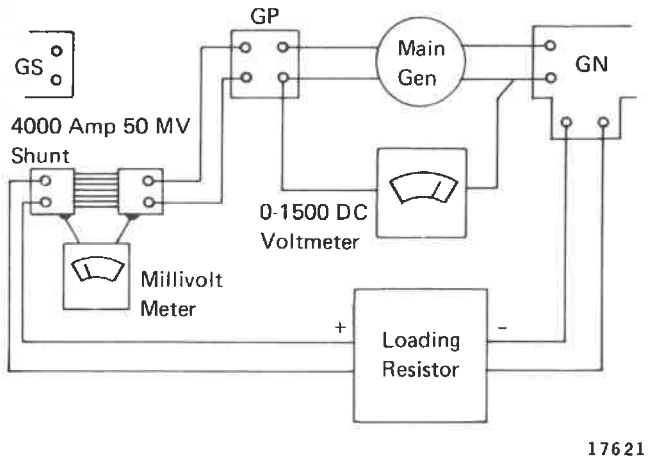


Fig. 9-2 – Test Setup For Loading Testing On Load Box Or External Grid Hatches

7. Refer to procedures for loading the unit.

TEST SETUP FOR LOADING ON DYNAMIC BRAKING GRIDS IN PARALLEL WITH A LOAD BOX OR EXTERNAL GRID HATCH

1. Perform the test setup for load testing on load box or external grid hatches, then connect dynamic braking grids into circuit by connecting the 775/24 cables as shown in Fig. 9-1.

NOTE: When paralleling braking grids with an external loading resistor, the connections at MB/L2 terminal 2 and MB/R1 terminal 2 generally need not be made. Use of two braking resistor paths will result in nominal grid resistance of 0.86 ohm in parallel with the external resistance and have both braking grid blowers operative.

If all three grid paths are paralleled with a loading resistance, be careful not to exceed the recommended maximum current of 4000 amperes.

2. Refer to procedures for loading the unit.

LOADING THE UNIT

When the load test setup is checked and in order, perform the load test as follows:

1. Replace the starting fuse, start the diesel engine, and allow the engine time to warm up.

CAUTION: Do not apply load until water temperature reaches at least 120° F. If the engine has been idling in extremely cold weather, applied load gradually to increase engine temperature.

2. Set the locomotive controls for operation under power, but allow the throttle to remain in IDLE position.

3. Center the reverser handle.

4. Place the load test switch in LOAD TEST position.

5. Close the generator field CB, and place the throttle in Run 1 position. Check the following:

   a. Engine oil pressure satisfactory.

   b. No fuel, oil, or water leaks.

   c. Load box or grid hatch fans and dynamic brake grid blower operating.

   d. Generator volts and amperes registering.

6. Advance throttle one step at a time to full engine speed and load. When at full speed and load, check radiator fan and shutter operation. A test button is located on each engine temperature switch.

7. With throttle in Run 8 position, check that the load regulator is at a balance point and is not at maximum field position.

8. Operate test switch on the TH module. Load regulator should move quickly to the minimum field position. After releasing the test switch the load regulator should return to a balance point.

9. Close all engine room doors and allow the engine to run at full load until conditions stabilize (about one half hour if horsepower only is being checked, and at least 60 minutes if the oil cooler performance is being checked). The shutters can be blocked off if closer control of temperature is needed for stability.

10. Check engine water temperature periodically until there is no difference between one temperature reading and another taken 15 minutes later.

NOTE: Opening the engine room doors to take temperature readings can affect the stability of conditions. Always allow time for conditions to stabilize before taking a second reading.

11. When the stability of conditions is verified, observe and record values and conditions as indicated on the form shown on the Service Data page. Take a second set of readings in 10 or 15 minutes, and a third set 10 or 15 minutes after the second.

CALCULATION AND HORSEPOWER STANDARDIZATION

1. From the observations, calculate the corrected brake horsepower, using the formulas, correction factors, and auxiliary horsepower values that appear in the Service Data.

2. If the total horsepower adjusted to standard conditions does not fall within the allowable limits listed on the Service Data page, the rack settings, injector timing, valve timing governor settings, injector calibration, air filter cleanliness, power assembly condition, and generator excitation, should be checked to find the reason for the horsepower discrepancy.

3. If the engine lube oil inlet temperature is higher than the maximum indicated by the lube oil cooler performance base line graph shown in the Service Data pages in Section 2 of this manual, the oil cooler should be cleaned.

CAUTION

On units not equipped for automatic self loading, the LOAD TEST position of the test panel rotary switch will open circuit the main generator unless an external load is applied.

Never return the test switch to the NORMAL position while operating under load.

LOAD TEST AND HORSEPOWER STANDARDIZATION

REFERENCES

Locomotive "Charts And Graphs" drawing, which includes setting values for systems and components, and the locomotive "Wiring Running List" which includes an electrical parts list, is referenced in the lower right corner of the locomotive wiring diagram.

645E Engine Maintenance Manual

Lube Oil Coolers . . . . M.I. 927

ROUTINE MAINTENANCE PARTS AND EQUIPMENT

2000 Ampere 50 Millivolt Meter Shunt 8309746
  Spacers (4 required with 8309746) 8309755
4000 Ampere 50 Millivolt Meter Shunt 8464090
  Spacers (6 required with 8464090) 8463875
Volt-Millivolt-Milliammeter (2 Required) 8218499
1100/0.0201 Cable (444,400 Circular Mills)
  Ethylene Propylene Diene With Hypalon Jacket 8421211
  Terminal Lugs For 1100/0.201 Cable 8118062
1325/24 Cable (535,000 Circular Mills)
  Ethylene Propylene Diene With Hypalon Jacket 8421212
  Terminal Lugs For 1325/24 Cable 8160274
775/24 Cable (313,000 Circular Mills)
  Ethylene Propylene Diene With Hypalon Jacket 8421210
  Terminal Lugs For 775/24 Cable 8118061
550/24 Cable (220,000 Circular Mills)
  Ethylene Propylene Diene With Hypalon Jacket 8421209
  Terminal Lugs For 550/24 Cable
  Drilled To Accept 3/8" Bolt Or Stud 8197509
  Blank 8118060

TABLE OF CABLE RECOMMENDATIONS* FOR LOAD TESTING DUTY

Size	Amperes	Size	Amperes
550/24	660	1325/24	1190
775/24	810	1600/24	1370
1100/24	1020	1925/24	1520

*Based on four conductors 1/2" spacing in open air to keep temperature within 120° C. rise.

THERMOMETERS REQUIRED

Dial indicating thermometer 0°-150° F. Equipped with 1/4" N.P.T. threaded stud.

Glass thermometer 0°-150° F.

Glass thermometer 100°-250° F. Bulb 1/4" maximum diameter.

Caged Glass thermometer 100°-250° F.

SPECIFICATIONS

Model SD40-2

Governor Rack	Engine RPM	Total Horsepower Adjusted To Standard Conditions
0.83	900-908	3195-3390

Formulas: Input To Generator = Generator Horsepower = $\frac{\text{Main Gen. Volts x Main Gen. Amps.}}{\text{Generator Efficiency Factor*}}$

*A factor of 715 is recommended

$$\text{Total Horsepower Adjusted To Standard Conditions} = \frac{\text{Gen. HP + Auxiliary HP}}{A \times B \times C \times D}$$

Where in the formula -

A - Is the correction factor for air temperature
(Standard is 60° F.)

B - Is the correction factor for altitude.
(Standard at sea level is 29.9 inches Hg.)

C - Is the correction factor for fuel density.
(Standard is 0.845 specific gravity.)

D - Is the correction factor for fuel temperature.
(Standard is 60° F.)

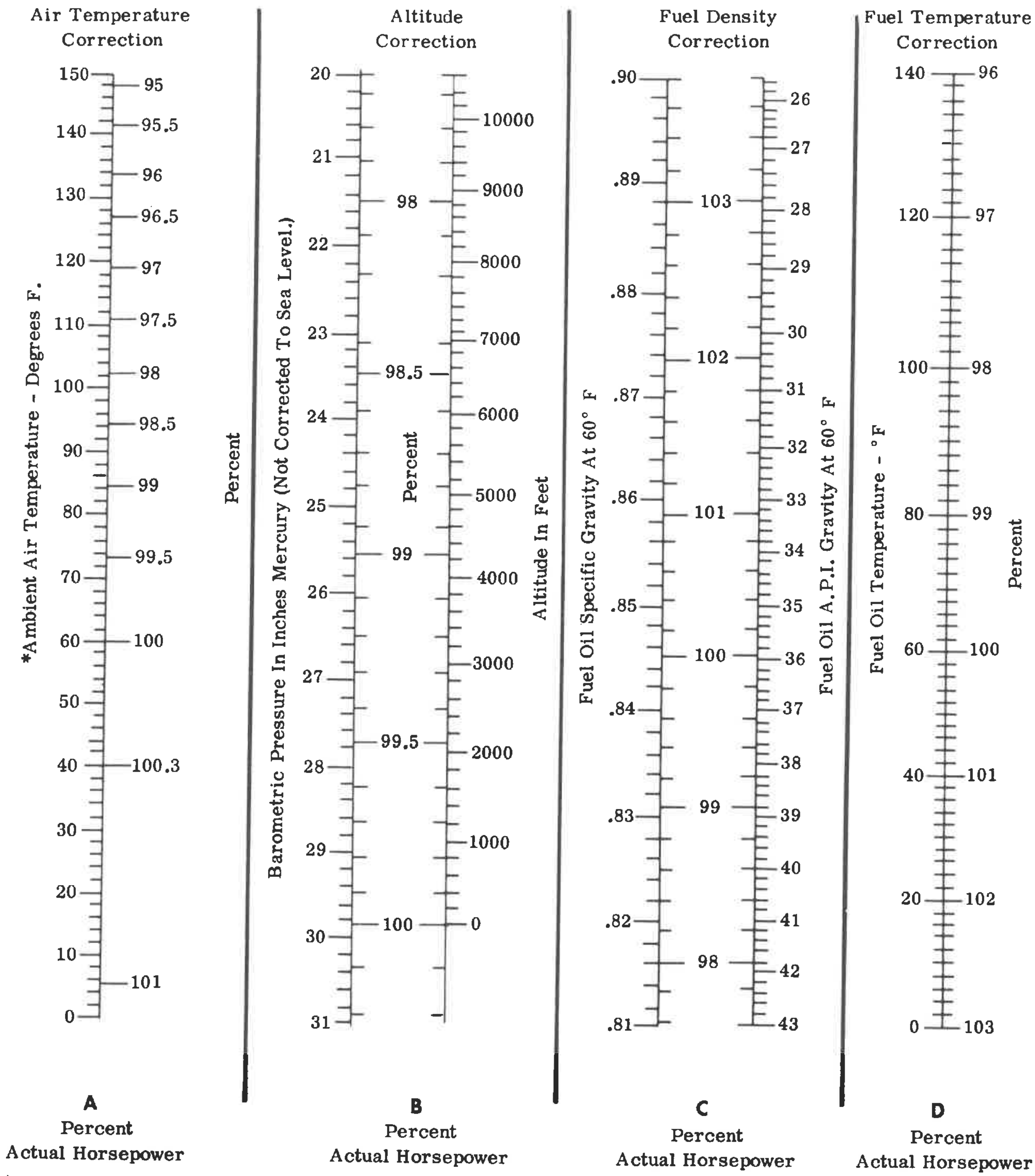
Reference the table of correction factors on the other side of this data sheet.

TABLE OF AUXILIARY HORSEPOWER - SD40-2	
Auxiliary Generator	4.0
Traction Motor Blower	122.0
3 Cooling Fans (48" - 8 Blade)	111.0*
Inertial Separator Blower	12.0
WBO Compressor - Unloaded	15.0
*Deduct 37 HP for each cooling fan not running.	264.0 TOTAL

EMD
SERVICE DEPARTMENT

SERVICE DATA (CONT'D)

HORSEPOWER CORRECTION FACTORS FOR
MODEL 16 - 645E3 DIESEL ENGINE

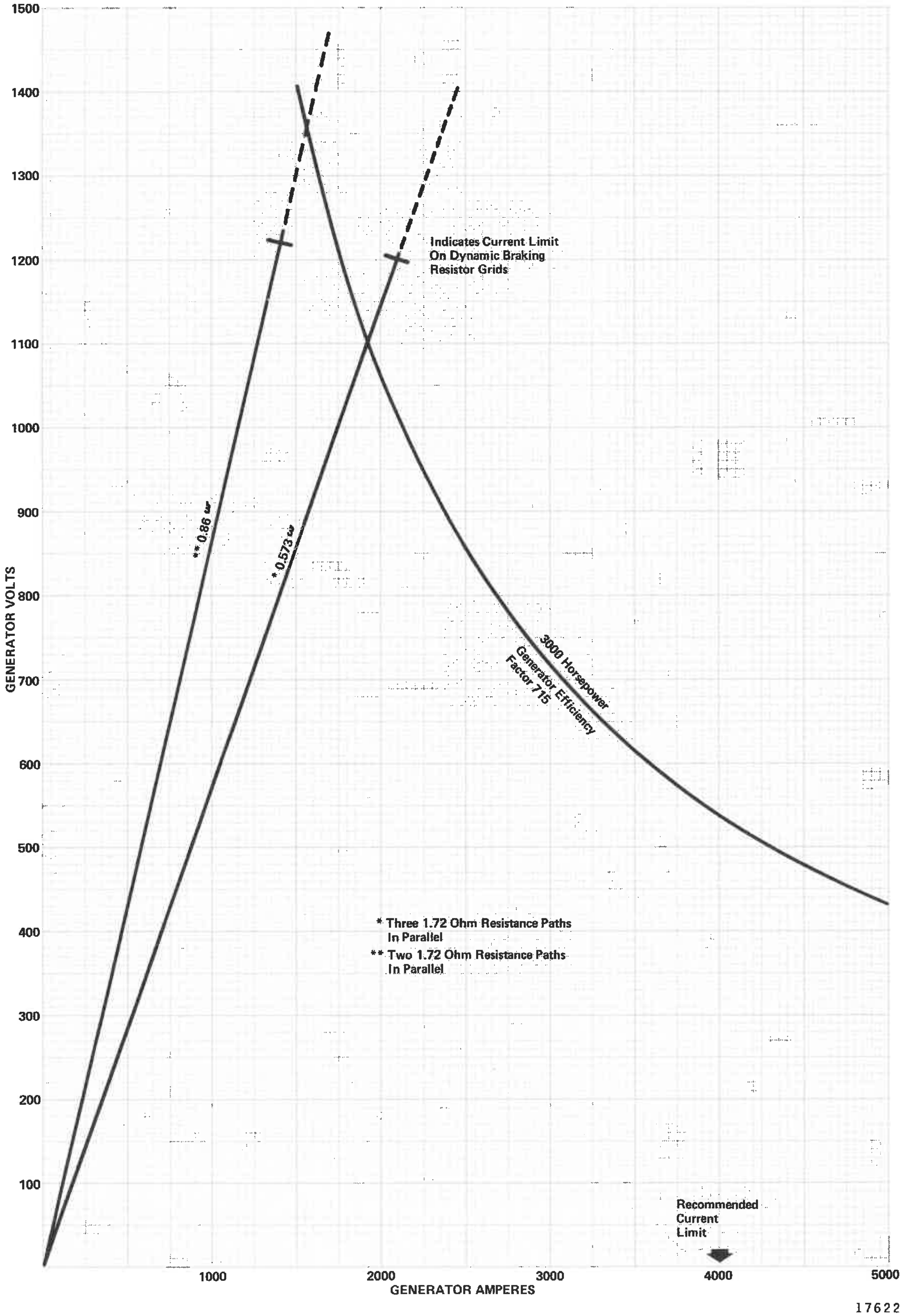


***There is no significant temperature rise across the locomotive inertial or the engine air filter.**

15244

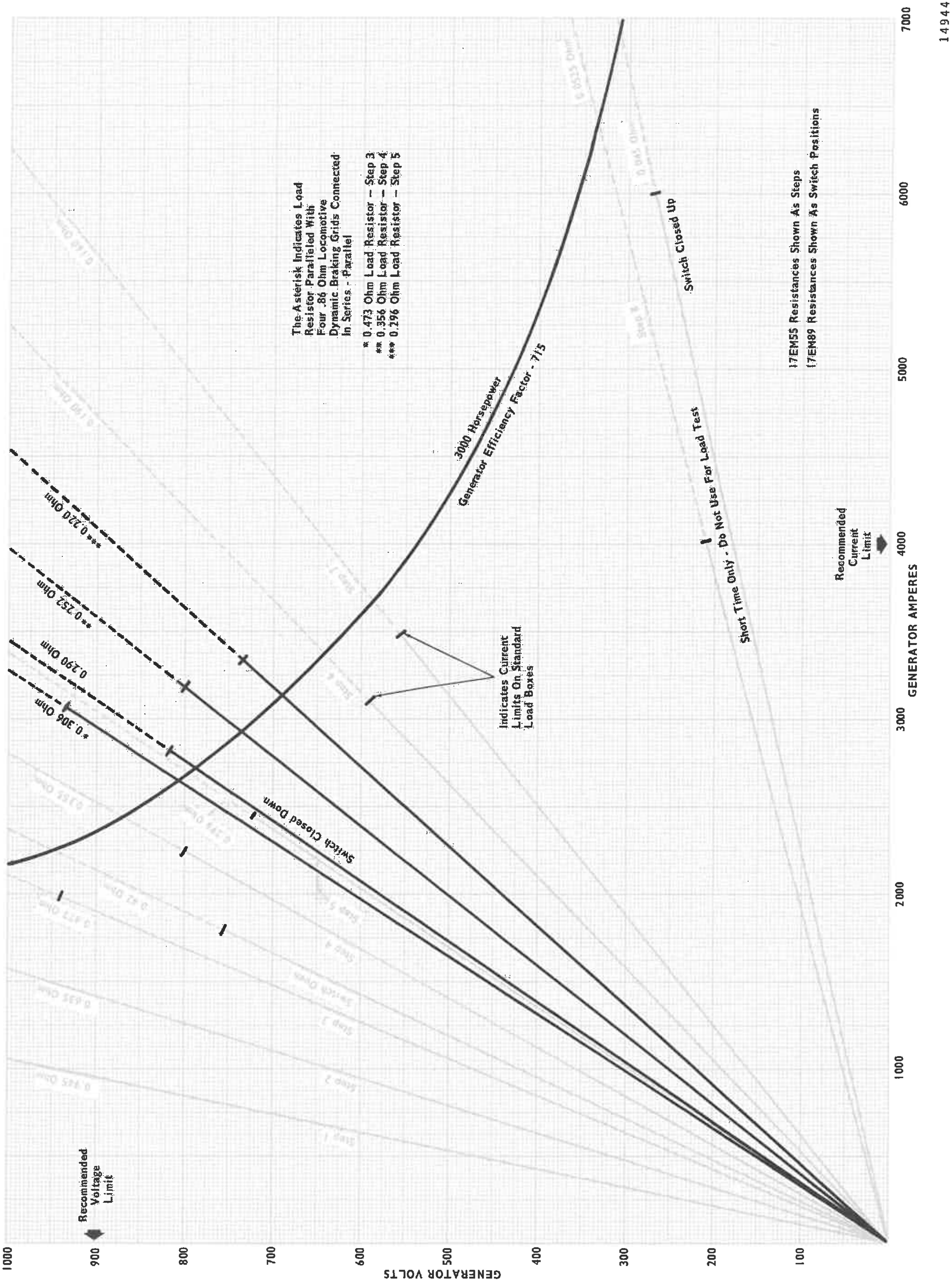
Horsepower Correction Factors

SERVICE DATA (CONT'D)



3000 HP Generator Loading Graph
(Dynamic Brake Grid Load)

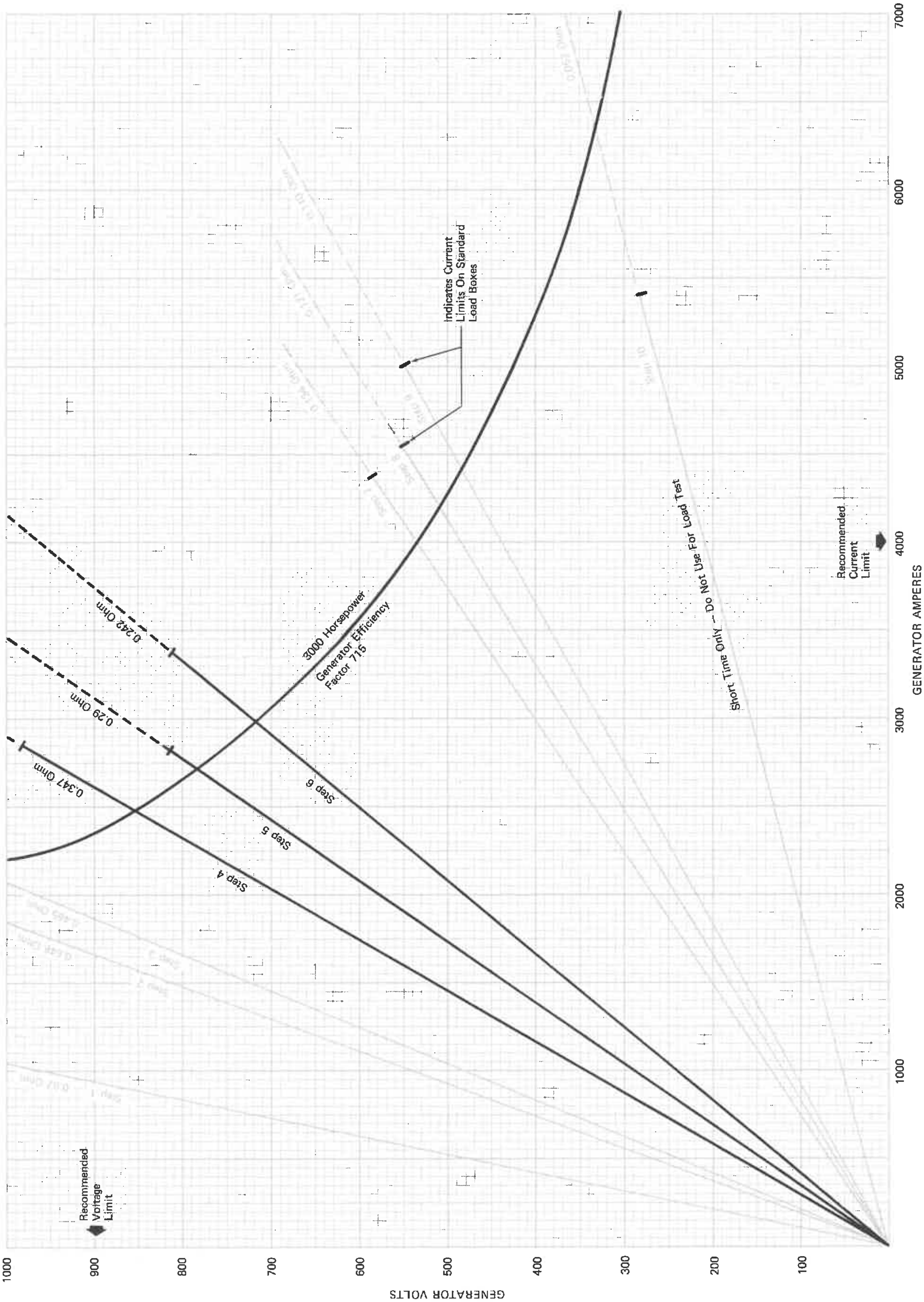
SERVICE DATA (CONT'D)



3000 HP Generator Loading Graph (17EM55 & 89 Loading Resistor Boxes)

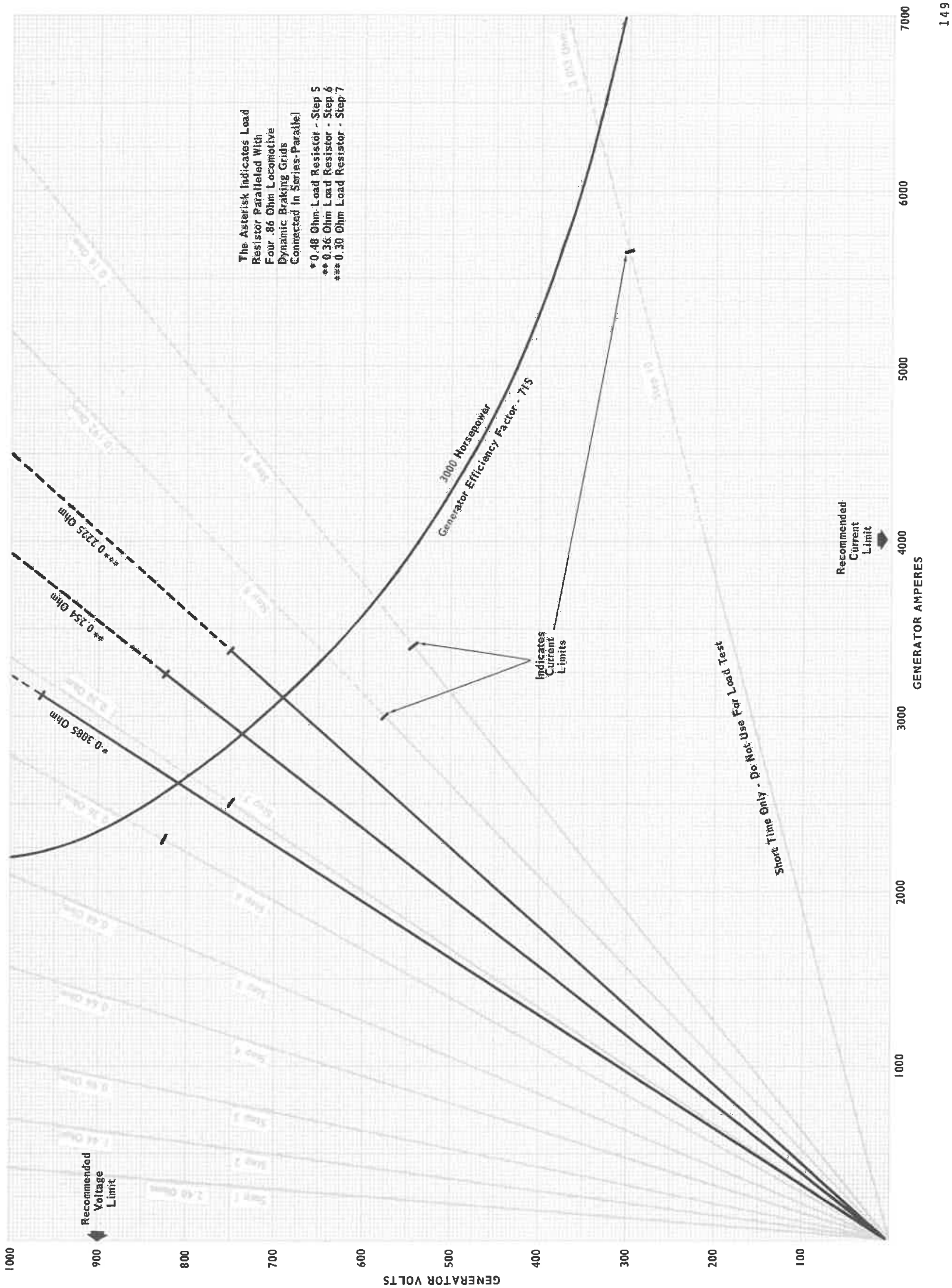
12S172

14945

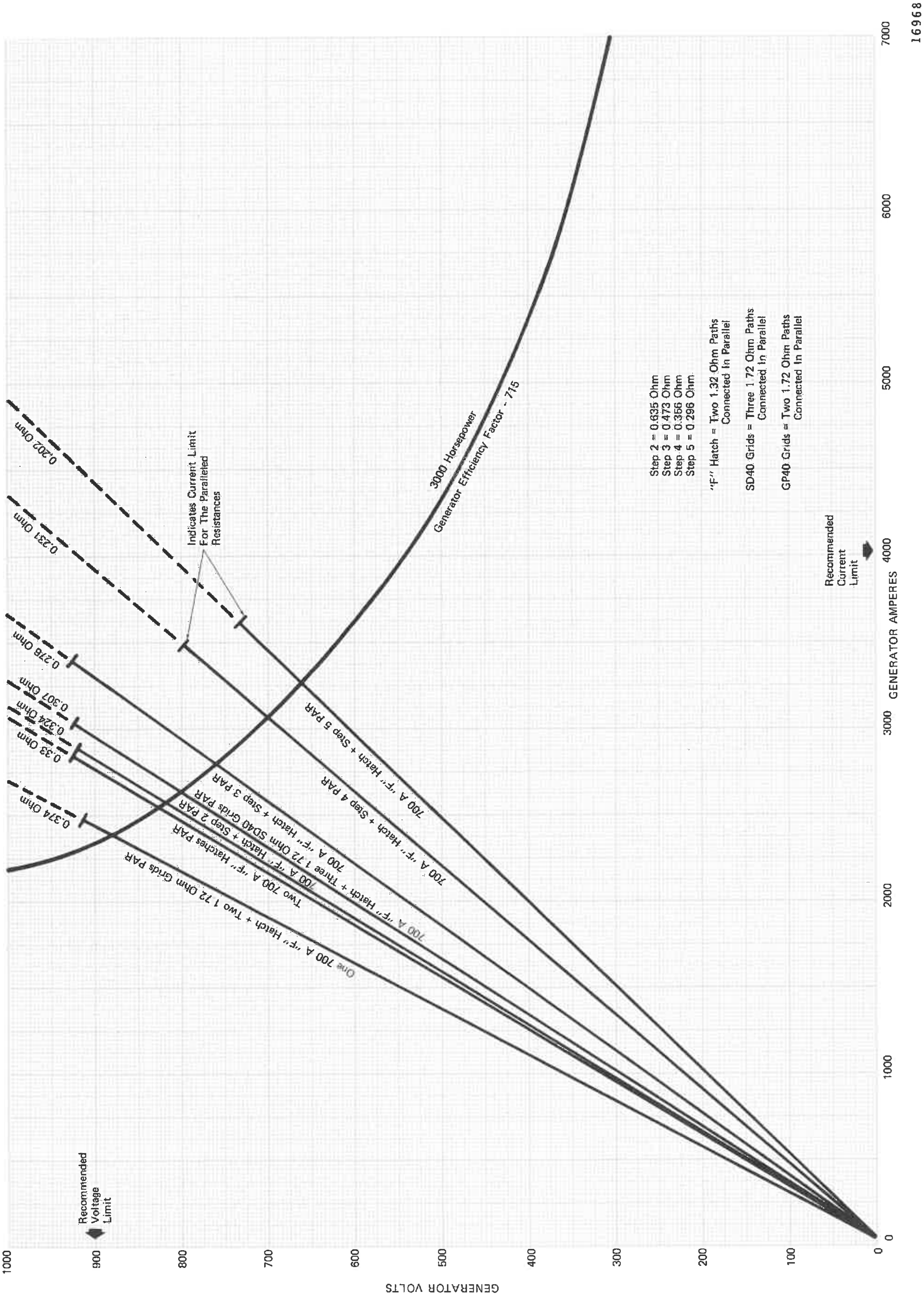


3000 HP Generator Loading Graph (17EM99 Loading Resistor Box)

14946



3000 HP Generator Loading Graph (Westinghouse 10 Step Load Box)



3000 HP Generator Loading Graph (F-Type Grid Hatches - 700 Ampere And 17EM55 Load Box)

HIGH POTENTIAL TESTS FOR LOCOMOTIVES IN SERVICE

INTRODUCTION

Locomotive electrical circuits and equipment are sufficiently well insulated to withstand potentials far in excess of those experienced in normal operation. This insulation dielectric strength should, however, be periodically checked to verify that this margin of safety remains in existence. High potential tests provide the means for making this check.

During high potential testing, wiring and equipment are subjected to voltage or potentials that are higher than normal. These potentials are applied for a specific period of time. For the circuit to qualify, there must be no breakdown of insulation to ground. The dielectric strength of the insulation is then considered satisfactory. On the other hand, a breakdown to ground indicates the need for improved insulation on the circuit or device tested.

This instruction provides a guide for high potential testing of locomotive wiring and equipment. The service Data page provided with this instruction indicates recommended procedures to prevent accidental destruction of circuit components that may be unable to withstand the test potential should a fault exist in the tested circuit.

TEST EQUIPMENT

It is of the utmost importance that a reliable high potential testing machine is used. The machine should be in verified good condition so that adequate tests can be made safely, without unnecessarily overstressing insulation during testing.

The machine to be used for high potential testing should have the following characteristics.

1. Wave Form

   The voltages specified for high potential testing are root-mean-square voltages, and the wave form should be such as to have a limit of 5% third harmonic. This limitation fixes the peak voltage for any RMS voltage. The wave form may be influenced by the capacity of the testing apparatus relative to the size of the equipment being tested.

2. Surges

   The means employed to change voltage on the primary must be such that harmful surges do not occur.

3. Regulation

   The secondary voltage drop should not exceed 20% under actual test conditions.

SAFETY PRECAUTIONS

1. Whenever possible, high potential tests should be performed by one man. All others should be kept off the locomotive and away from the test area.

2. A thorough knowledge of the circuits, equipment, and procedures involved is essential. Extreme care should be taken to make certain that tests are properly made. Before making any high potential tests, a 500 voltage megger test should be applied for one minute to determine the condition of the circuit. Circuits containing static electronic components such as transistors and silicon rectifiers must be disconnected or shorted during the tests.

3. To prevent dangerous overvoltage surges, test electrodes must be firmly connected to the circuit or item before the voltage is applied. Similarly, the voltage should be removed before the electrodes are removed.

4. After the tester has been removed from the item being tested, clear the item of possible residual voltage by discharging to ground with a suitable insulated conductor.

TESTS OF LOCOMOTIVES IN SERVICE

To comply with established regulations, it is necessary to perform high potential tests on locomotive high voltage (DC), and alternating current (AC) circuits. It is also good practice to megger the low voltage control circuits. Preparations for tests should be made as indicated on the service data page that follows this instruction.

1. High Voltage DC Circuits

   High voltage circuits include all equipment and wiring connected to the output of the main generator, plus the dynamic brake grid resistors and circuits (where used).

2. Alternating Current (AC) Circuits

   The alternating current circuits include the D14 alternator, cooling fans, inertial filter blower motor, various control circuit transductors and transformers, excitation equipment, and associated wiring.

3. Low Voltage (DC) Circuits

   The low voltage circuits include all control, equipment, and wiring connected to the locomotive auxiliary generator and storage battery. High potential tests are not required for low voltage circuits and equipment, however, it is good practice to check insulation resistance to ground. This may be done using a meghommeter (500 V DC maximum) after grounding the high voltage DC and AC circuits. A reading of one megohm or better indicates satisfactory insulation resistance to ground. Perform protective steps indicated on the service data page before performing the checks.

TEST PROCEDURE

The preferable time to perform high potential tests is right after a locomotive has completed a run. In such instances, the equipment is warm and dry, thus eliminating the possibility of moisture that might be present in units that have been shut down for an extended period of time.

Prior to making a high potential test, the circuit insulation resistance should be checked with a suitable megohmmeter. Readings of less than one megohm should be viewed with suspicion, as applying a high potential test in such instances may cause a breakdown of the insulation. To reduce the risk of this possibility, the cause of low meghommeter readings should be determined and corrected. This may be done by reducing the complete circuit concerned into individual circuits which are then isolated and checked separately. In this way, the circuit portion or equipment causing the low reading can be found. Correction may often be made by thorough cleaning and drying of the affected areas.

Refer to the service data page provided with this instruction for data regarding protective procedures before making high potential tests.

When preparations have been completed, apply the high potential test as follows:

1. Make certain that the tester is not connected to the power supply, the control knob is set at zero (0), and the control switch is off.
2. Place one electrode firmly in contact with the insulated conductor of the circuit being tested. Refer to wiring diagram for suitable points of connection.
3. Place the other electrode firmly in contact with ground, such as locomotive underframe.
4. Make certain that circuits other than the one being tested have been isolated and grounded.
5. Connect the high potential tester to a power supply and turn the control switch on.
6. Press ON button firmly down, and while holding in this position, slowly turn control knob to specified test voltage.
7. After applying specified voltage for the required period of time, and while still holding the ON button down, slowly turn the control knob back to zero (0).
8. Release ON button and place control switch OFF.
9. Discharge tested circuit to ground before removing electrodes.
10. Repeat the preceding tests for other circuits involved in the test.

HIGH POTENTIAL TESTS FOR LOCOMOTIVES IN SERVICE

High Voltage DC Circuits . . . . 1050 Volts RMS For 1 Minute
Maximum Output Current - 330 Milliamperes

Alternating Current AC Circuits . . . . 400 Volts RMS For 1 Minute

Low Voltage DC Circuits . . . . Megohmmeter Test Only
(500 Volt DC Maximum Megger)

PRELIMINARY MEGGER CHECK

Before making high potential checks of the high voltage DC and AC circuits, make a preliminary check of circuit condition with a 500 or 1000 volt megohmmeter. These megohmmeter readings should be recorded in a locomotive maintenance log. The readings are most useful when compared to previous readings. The low voltage control circuits may be checked at the same time, using a maximum 500 volt megohmmeter.

Before starting the checks, take the following protective measures.

1. Open main battery switch and ground relay cutout switch.
2. Jumper main battery switch blades from negative to positive.
3. Place all circuit breakers in the ON position.
4. Close all control switches.
5. Pull out all circuit modules half way to fully disconnect the circuit modules from locomotive circuitry.
6. Completely remove the PF module; at the rack, jumper pins 15 and 16 to pin 17.
7. Connect a jumper wire from positive terminal to negative terminal of CR17.
8. Jumper positive to negative at the battery charging rectifier CRBC.
9. Jumper from left-yellow to right-yellow on ground relay CRGR.
10. At the SCR assembly, jumper AC1 to AC2, AC2 to AC3, AC3 to negative bus, negative bus to positive bus, and positive bus to DC+.
11. At main generator output, jumper all positive and negative buses together.
12. Disconnect or jumper out any electronic equipment such as radio, train control, speed indicator, automatic reset devices, and fault counters.

13. High Voltage DC Circuits

    Ground the main battery switch blades, and ground the D14 alternator. Perform high potential tests on high voltage DC circuits and equipment. Reference locomotive schematic diagram. Do not perform high potential tests on cranking motors.

14. High Voltage AC Circuits

    Remove the ground from the D14 alternator, and connect the ground to the main generator output. Perform high potential tests on high voltage AC circuits and equipment.

15. Low Voltage DC Control Circuits

    Remove the ground from the main battery switch, and connect the ground to the D14 alternator. Perform megohmmeter check on low voltage DC circuits and equipment, including the engine cranking motors.

16. When the tests are completed, be certain to remove all shorting and grounding jumpers.

17. Return controls and switches to normal standby condition. Use procedure for applying jumpers as a check list to make sure that all jumpers have been removed.

TROUBLESHOOTING

The material in this publication is to be used as a guide in qualifying and troubleshooting the locomotive. It is presented in the following parts.

A. TROUBLESHOOTING GUIDE – POWER CONTROL SYSTEM

1. Qualification

This guide lists checks that can be performed when no specific trouble is reported or indicated. The checks can be performed to qualify a locomotive for service.

2. Troubleshooting

These guides are intended for only the most probable and easiest to locate types of electrical trouble. It should be understood that various types of trouble can occur that will require more thorough investigation than the procedures covered in this guide.

B. TROUBLESHOOTING OUTLINES

Text in outline form provides a guide to finding and correcting trouble reported of a specific nature. Letter symbols generally similar to an abbreviation of the word or words commonly used to describe a component or a trouble are provided to aid in locating the applicable text.

For example:

"CT" Indicates current transformer.

"FIL" Indicates filter.

"OL" Indicates overloading.

A column for publication references is provided on the right hand side of the troubleshooting guide outlines. The references are provided to identify publications that may be of help in identifying and correcting troubles.

Examples of the references follow:

M.I. 000 General Motors – EMD Maintenance Instruction.

LSM-9 Locomotive Service Manual – Section 9

EMM-6 Engine Maintenance Manual – Section 6

MODULAR ARRANGEMENT OF CIRCUITS

Most of the locomotive control and protective circuits are designed with solid state components and small relays that allow placement of essential circuit components and wiring on a standard size circuit board. The circuit boards are fitted with a handle and with a standard arrangement of terminal receptacles. When the circuit board is fitted into the appropriate guideway in the electrical cabinet of a locomotive and pressed into place, the receptacles on the board make contact with stationary pins that are fastened firmly in the electrical cabinet. Faston terminals connected to wires complete circuits to other pins or components.

A faceplate is also fastened to the terminal board. Receptacles that accept the standard 0.185" banana plug are located on the faceplate. These receptacles are connected to specific circuit points for test purposes. The receptacles are color coded to identify the type of voltage appearing at the test point.

Orange 72-76 V DC positive.

Blue Control circuits. Generally low DC voltage.

Yellow AC voltage, either from the D14 or from the main generator feedback transformers.

Red Main generator DC output, or dynamic brake motor armature output.

Black Control circuit 74 V DC negative.

Green Main Generator Field.

The module face plates may also contain switches and test lights.

WARNING: Never disconnect a module during locomotive operation. Do not operate test switches during locomotive operation without thorough familiarity with the circuits involved and a firm understanding of the results of such action.

Always consider the particular set of conditions the locomotive is operating under before performing tests on a moving locomotive.

When performing standstill tests, always disconnect control jumper cable between units. When extensive checking of control circuit voltages is to be done, it is recommended that the ER relay be disabled whenever possible during high-throttle no-load testing.

The Circuit Check and Load Test positions of the test panel rotary switch do not preclude excitation of the main generator. The load test position will open circuit the main generator on units not equipped for automatic self loading. Do not exceed Throttle No. 1 with main generator open circuit. Never return test switch to normal position while unit is being loaded.

TROUBLESHOOTING INSTRUMENTS

VOLTMETERS – OHMMETERS

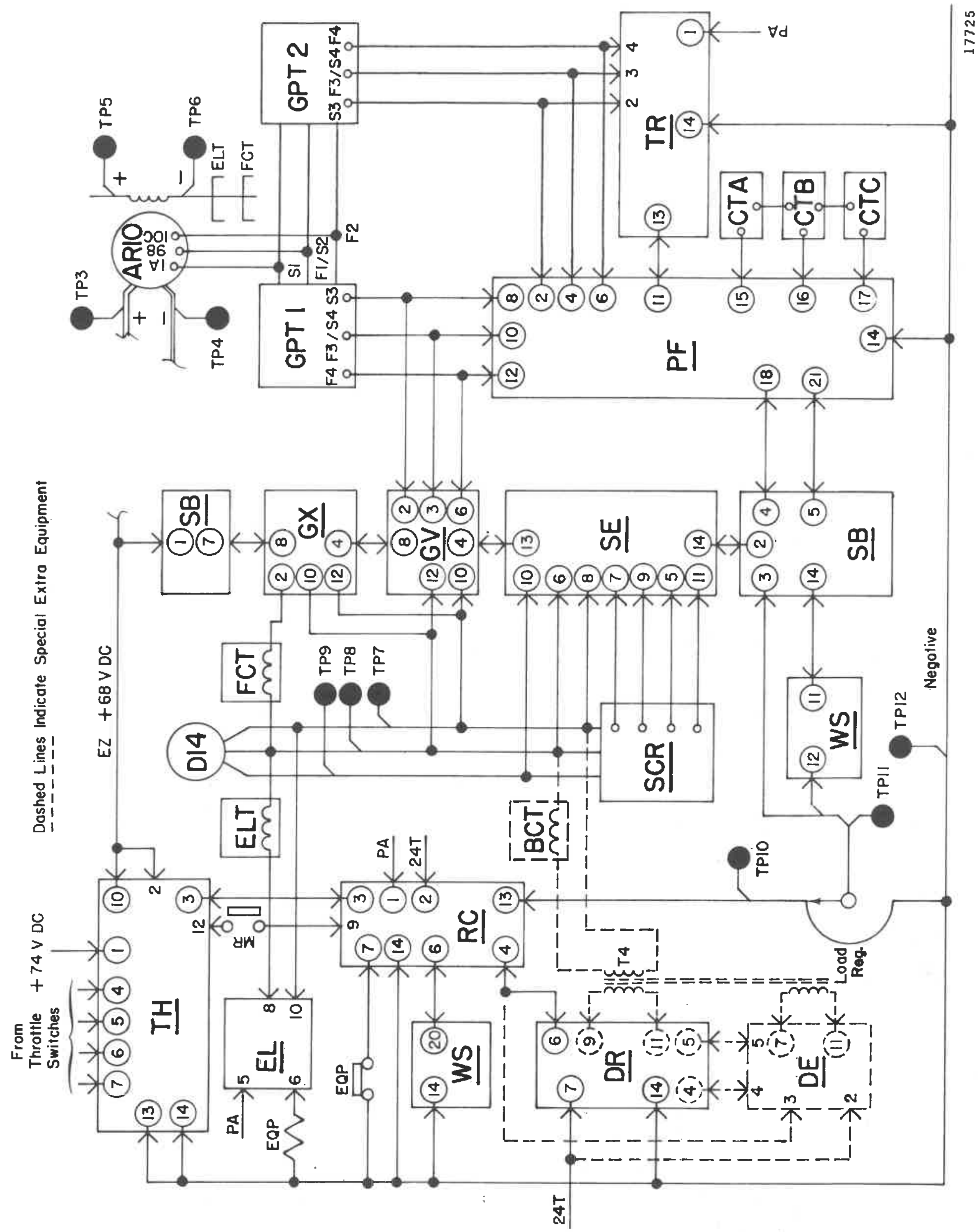
In general a voltmeter and an ohmmeter will be the only tools necessary for basic electrical troubleshooting. These meters and any shunts should be at least 0.5% accuracy, and all readings should be taken at the upper 1/3 of the meter scale.

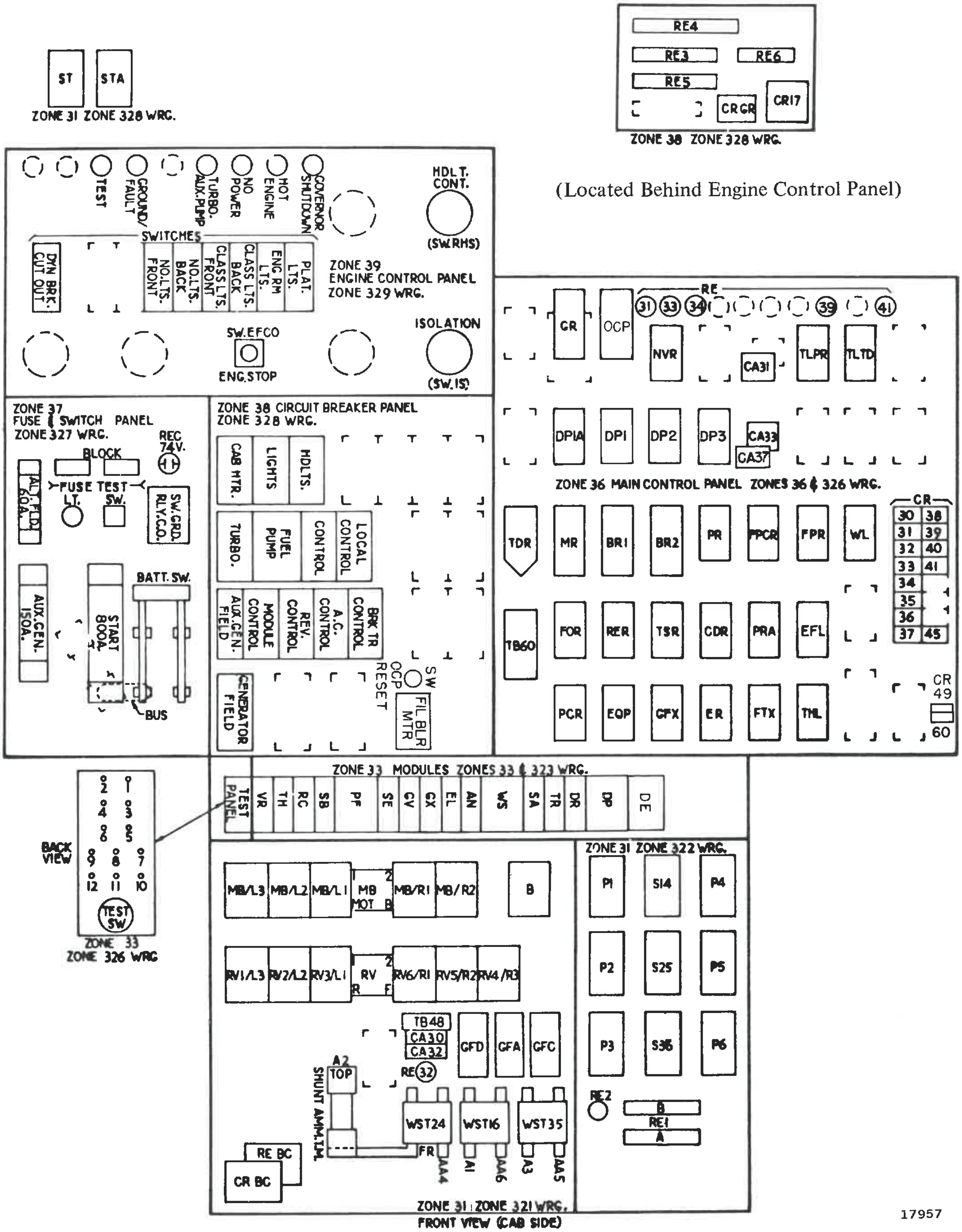
Sensitivity of the voltmeter should be a minimum of 20,000 ohms per volt. Verify accuracy of voltmeter 0-100 range by reading voltage from TH-TP10 to TH-TP14, with locomotive engine running. Voltmeter should indicate 68 ± 0.2 V DC.

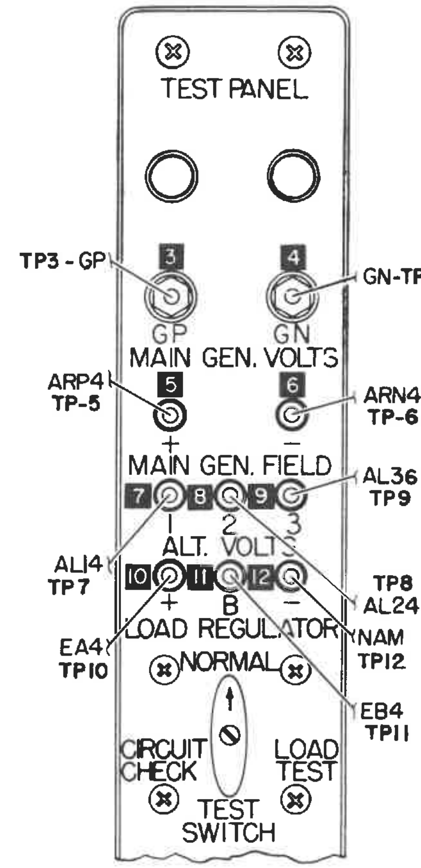
MANOMETER

A simple water manometer will be required to measure air pressure drops across various devices. Instructions for fabricating a simple vacuum metering device are included on page CP.

CAUTION: Never use a test lamp for troubleshooting locomotive control circuits. A lamp may overload the circuits and cause destruction of components.


Dashed Lines Indicate Special Extra Equipment
EZ +68 V DC
From Throttle Switches
+74 V DC
TH
EL
RC
WS
DR
DE
SB
GX
GV
SE
SCR
PF
TR
GPT 1
GPT 2
ARIO
CTA
CTB
CTC
D14
FCT
ELT
BCT
MR
EQP
PA
24T
T4
Load Reg.
Negative
TP1
TP3
TP4
TP5
TP6
TP7
TP8
TP9
TP10
TP11
TP12
17725


ST
STA
ZONE 31 ZONE 328 WRG.
RE4
RE3
RE6
RE5
CRGR
CR17
ZONE 38 ZONE 328 WRG.
(Located Behind Engine Control Panel)
TEST
GROUND/ FAULT
TURBO. AUX.PUMP
NO POWER
HOT ENGINE
GOVERNOR SHUTDOWN
HDLT. CONT.
(SW.RHS)
SWITCHES
DYN BRK. CUT OUT
NO.LTS. FRONT
NO.LTS. BACK
CLASS LTS. FRONT
CLASS LTS. BACK
ENG RM LTS.
PLAT. LTS.
ZONE 39
ENGINE CONTROL PANEL
ZONE 329 WRG.
SW.EFCO
ENG.STOP
ISOLATION
(SW.IS)
ZONE 37
FUSE & SWITCH PANEL
ZONE 327 WRG.
REC 74V.
BLOCK
ALT. FLD. 60A.
FUSE TEST
LT.
SW.
SW.GRD. RLY.C.O.
BATT. SW.
AUX.GEN. 150A.
START 800A.
BUS
ZONE 38 CIRCUIT BREAKER PANEL
ZONE 328 WRG.
CAB HTR.
LIGHTS
HDLTS.
TURBO.
FUEL PUMP
CONTROL
LOCAL CONTROL
AUX.GEN. FIELD
MODULE CONTROL
REV. CONTROL
A.C. CONTROL
BRK TR CONTROL
GENERATOR FIELD
OCP RESET
SW
FIL BLR MTR
RE
31 33 34 39 41
CR
OCP
NVR
CA31
TLPR
TLTD
DPIA
DPI
DP2
DP3
CA33
CA37
ZONE 36 MAIN CONTROL PANEL ZONES 36 & 326 WRG.
CR
30 38
31 39
32 40
33 41
34
35
36
37 45
TDR
MR
BR1
BR2
PR
PPCR
FPR
WL
TB60
FOR
RER
TSR
CDR
PRA
EFL
PCR
EOP
CFX
ER
FTX
THL
CR 49
60
ZONE 33 MODULES ZONES 33 & 323 WRG.
TEST PANEL
VR
TH
RC
SB
PF
SE
GV
GX
EL
AN
WS
SA
TR
DR
DP
DE
BACK VIEW
1 2 3 4 5 6 7 8 9 10 11 12
TEST SW
ZONE 33
ZONE 326 WRG
ZONE 31 ZONE 322 WRG.
MB/L3
MB/L2
MB/L1
MB MOT
MB/R1
MB/R2
B
P1
S14
P4
RV1/L3
RV2/L2
RV3/L1
RV
RV6/R1
RV5/R2
RV4/R3
P2
S25
P5
TB48
CA30
CA32
GFD
GFA
GFC
P3
S36
P6
A2
TOP
SHUNT AMM.I.M.
RE 32
RE2
B
RE1
A
WST24
WST16
WST35
FR
AA4
A1
AA6
A3
AA5
RE BC
CR BC
ZONE 31 ZONE 321 WRG.
FRONT VIEW (CAB SIDE)
17957



NOTE: Load Regulator Plus Is Not +74 VDC.

TEST SWITCH			
TERM.	CKT CHECK	NORM	LOAD TEST
1- 2			•
1- 3		•	
4- 5			•
4- 6		•	
7- 8	•		•
7- 9	•	•	
10- 11			•
10-13		•	
12-13	•		
14-15			•
14-17		•	
16-17	•		

WARNING: *Circuit check position does not prevent excitation of the main generator. On units NOT equipped for automatic self loading, load test position will open circuit the main generator. Do not exceed throttle No. 1 with AR10 open circuit.*

Do not return test switch to normal position while unit is under Load.

■ Refer back to the excitation system block diagram for location of test points in the system.

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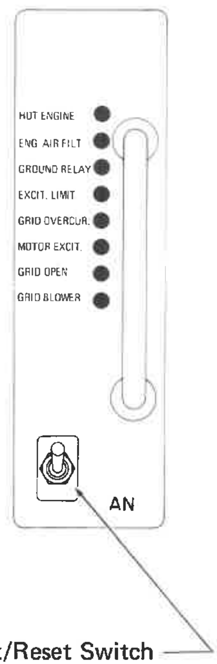
Test Panel

OPERATING FUNCTIONS AT TEST POINTS

AN The annunciator module receives signals from various fault detecting devices. When a fault signal has been received, the applicable fault light remains on until the reset switch is operated after the fault signal has ceased.

The basic AN module contains only the first four indications shown below. When the unit is equipped with dynamic brakes, the fifth and sixth lights are provided with a seventh light functional if the unit has extended range dynamic brakes. As a special extra, the eighth light is provided on units equipped with dynamic brakes.



Test/Reset Switch

In order from top to bottom, the annunciator indications are as follows:

HOT ENGINE — Temperature at engine coolant inlet over 215° F.

ENG. AIR FILT. — Plugged engine air filters.

GROUND RELAY — High voltage path to locomotive ground or a group of failed diodes in the main generator.

EXCIT. LIMIT — Excessive main generator field current.

GRID OVERCUR. — Excessive current in the dynamic braking resistor grids.

MOTOR EXCIT. — Excessive current in motor fields or excessive voltage across the motor fields during dynamic braking.

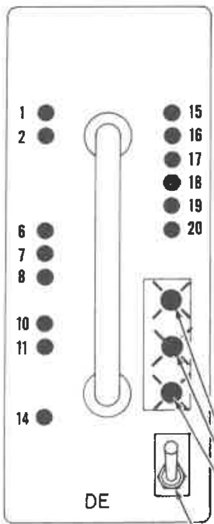
GRID OPEN — Open resistor grid on unit equipped with extended range dynamic brakes only.

GRID BLOWER — Current unbalance due to an open or short, or due to a stalled grid blower motor.

OPERATING FUNCTIONS AT TEST POINTS

DE Receives a signal from 24T and compares it to a signal proportional to brake current from BCT. When brake current drops below a given level because of low train speed, the module picks up the "D" contactor at the proper time. It also drops out the "D" contactors at the proper time as train speed increases. There is a built-in time delay between steps.

During extended range operation a signal proportional to grid current is compared in the DE circuitry with a signal from the dynamic braking rheostat, and grid current is limited at a level proportional to braking handle position. On special order, the grid current control function of the DE module is operative over the full range of dynamic braking.



1 - Control circuit DC pos; PA feed thru BR interlocks and IPS switch.

2 - Input from dynamic brake rheostat (24T).

6 - Main gen. current feedback signal input from performance control module PF.

7 } 11 } Armature current signal input from BCT and T4; AC voltage.

Test lamps DC1, DC2, DC3 - Indicate pickup of grid shorting contactors DC1, DC2, DC3 respectively.

Test Switch-Operate to sequence dropout of grid shorting contactors.

8 } 10 } AC power supply from D14.

14 - Control circuit DC negative; NA;

15 - Output to pick up pilot relay DP1 and grid shorting contactor DC1.

16 - Output to hold DP1 picked up.

17 - Output to pick up pilot relay DP2 and grid shorting contactor DC2.

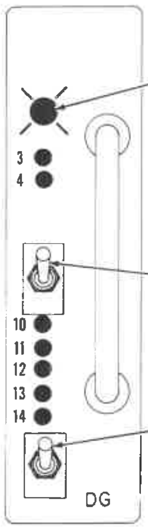
18 - Output to hold DP2 picked up.

19 - Output to pick up the pilot relay DP3 and grid shorting contactor DC3.

20 - Output to hold DP2 picked up.

OPERATING FUNCTIONS AT TEST POINTS

DG Receives signal from DGT, which is a transductor that compares grid blower current. Provides protection against a non-operating grid blower, since it will drop out the "B" contactor on either no blower motor current or excessive blower motor current.



Red test lamp - Indicates that a current unbalance has occurred between the dynamic brake grid blower motors, resulting in pickup of DG module. This usually means a failed motor.

Reset Switch - Must be pressed to reset the DG module and allow the "B" contactor to pick up. Releases either blower circuit.

Test switch - Applies control circuit current to a test winding on the DGT transductor to simulate current unbalance to obtain a signal from the transductor. The signal fires the DG circuit, the red test lamp comes on, the "B" power contactor drops out, and the GRID BLOWER light latches on.

3 - Output to annunciator to register DG module operation.

4 - Normally closed contacts of DGR pilot DGX relay to interrupt feed to "B" contactor coil.

10 - Voltage in DG circuit proportional to the instantaneous value of grid-motor unbalance.

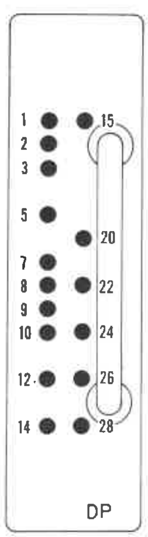
11, 12 - Voltage in DG module which monitors a time delay circuit.

13 - Zener reference voltage to which firing of the DG circuit is calibrated.

14 - Control circuit DC negative; NA.

DP First function receives voltage signal from braking grids and interrupts feed to EQP coil when limiting value is reached. Provides back-up protection against a DR or control circuit failure.

Second function receives voltage from generator during dynamic brake. Interrupts feed to EQP coil when limiting value is reached. Provides protection against hot motor fields, open field circuit, or control circuit failure.



1 - Control circuit DC positive input; feed to EQP relay operating coil thru protective interlocking.

2 - Same as TP3, but used on four-motor unit.

3 - Main gen DC pos during braking. Motor field protective circuit input, six-motor unit.

5, 7, 9 - Used only for standstill test as indicated in qualification section of this handbook.

8, 10 - D14 AC voltage power supply to BWR circuit.

12 - Main gen DC neg during braking. Motor field protective circuit input.

14 - Control circuit DC negative; NA.

15 - 74 V DC output to EQP coil. NC interlocks of MFP and BWR, under fault conditions, regulate the main generator output by dropping the gen. field and discharging the rate control capacitors.

22 - Pos input from traction motor armature and brake grids to brake warning circuit.

24 - Same as TP22.

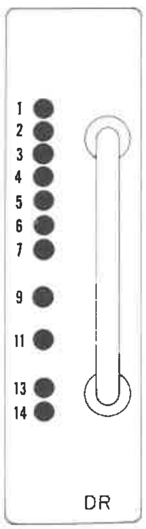
26 - Same as TP22.

28 - Negative input from traction motor armature and dynamic brake grids to the brake warning circuit.

DR The DR module receives a signal (from braking grids) proportional to braking current. Provides grid current limit by reducing RC module output (reference voltage) when grid signal indicates maximum permissible grid current.

On units with extended range dynamic brakes, the DE module receives a separate signal (from brake current transductor BCT) proportional to braking grid current and compares it to a signal (24T wire) established by braking handle position. A signal resulting from the comparison is directed to the DR module to provide grid current limit at a value established by braking handle position. The signal is basically applied to DR only during extended range braking; however, on special order the signal may be applied to DR during the entire braking range.

On special order units without the DE module may have the BCT signal compared to the braking handle position signal directly at the DR module to limit grid current to a value established by braking handle position.



1 - Provision only (when provided).

2 - Positive high voltage input from dynamic braking grids.

3 - Input from anticipation capacitor that functions to smooth out regulation and minimize overshoot.

4 - On units with extended range dynamic brakes, receives input from DE module for grid current control related to braking handle position. Not functional on units equipped for grid current trainline control, but not equipped for extended range dynamic braking. Not provided on basic DR.

5 - Same as 4.

6 - Output from DR which shunts the 24T signal at the base of the rate control transistor to NA negative when DR operates. This brings about discharge of the rate control capacitors at a predetermined rate not related to braking handle position.

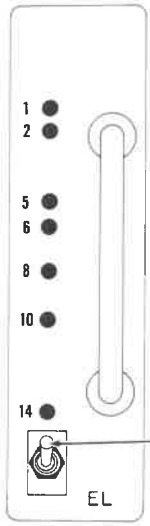
7 - Functional on units equipped for grid current trainline control and not equipped with extended range dynamic brakes. 24T input from brake rheostat. Signal is at a value related to braking handle position. It is matched with BCT signal (TP9-11 below).

9, 11 - Not used on units equipped for extended range dynamic brakes. On units equipped for grid current trainline control, AC signal from brake current transductor BCT is compared to signal from braking rheostat (see TP7) to regulate maximum braking current to a value related to braking handle position.

13 - Negative high voltage DC input from dynamic braking grids.

14 - Control circuit DC negative; NA.

OPERATING FUNCTIONS AT TEST POINTS



EL Receives an input signal from ELT at terminals 8 & 10 proportional to generator field current. If excessive field current is reached, EQP feed is interrupted.

Provides back-up protection against excitation control failure.

1 - Control circuit DC positive; PA feed to ELR and ELRA coils within the EL module.

2 - PA feed through test button to energize test coil of ELT transductor.

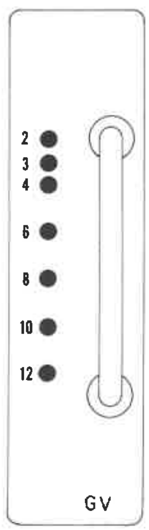
Simulates excessive generator excitation.

5 - Interlock in circuit to equipment protective relay EQP coil.

6 - Same as TP5.

8, 10 } Input, generator field current signal from ELT transductor; AC voltage.

14 - Control circuit DC negative; NA.



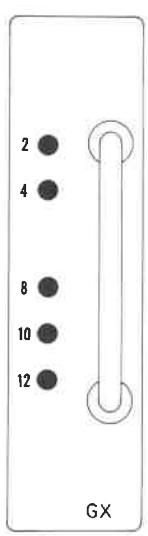
GV Provides a limit to the generator voltage by interrupting the current at the SE control winding. Receives a signal from the GPT (generator potential transformer) proportional to main generator voltage.

2, 3, 6 } Input, generator voltage signal from generator potential transformer GPT.

10, 12 } AC power supply from D14.

4 - Sensor current output to sensor control windings.

8 - Sensor current input from TH module thru SB and GX.



GX Provides a limit to the generator field current by interrupting the current to the SE control winding. Receives a signal proportional to field current from the FCT (field current transductor).

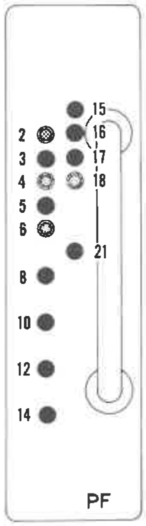
2, 12 } Input, generator field current signal from FCT transductor; AC voltage.

10, 12 } AC power supply from D14

4 - Sensor current output to sensor control windings by way of GV module.

8 - Sensor current input to GX module from current limiting resistor on SB module.

OPERATING FUNCTIONS AT TEST POINTS



Applied With Special Extra Performance Control

PF Receives signals proportional to generator voltage from GPT1 (and GPT2 on special extra) and generator current from CT's. The sum of these voltages at terminal 21 (or 18) is compared to the reference voltage by the SB.

3, 5 — On units equipped for traction motor lockout, these points are connected across a voltage dropping resistor in the reference voltage connection between TH and RC modules.

2, 4, 6 — AC feedback signal from generator potential transformer GPT2 on units equipped for special performance control.

8, 10, 12 — AC feedback signal from generator potential transformer GPT1.

14 - Control circuit DC negative; NA.

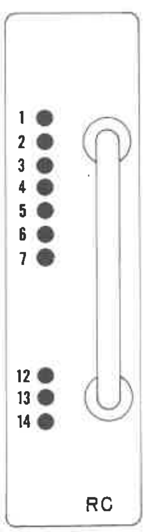
15, 16, 17 — AC feedback signal from AR10 current transformers CTA, CTB, CTC.

18 - AR10 current plus voltage feedback signal utilized above minimum continuous speed on units with special performance control extra.

21 - AR10 current plus voltage feedback signal. (Utilized below minimum continuous speed only on units with special performance control extra.)

RC Receives a step input voltage from the TH module or the brake rheostat. Provides a reference voltage to the load regulator with a time rate of build-up.

Shuts off the reference voltage when terminals 4 or 6 are connected to N or NA.



1 - Input, 74 V DC to pre bias the transistor before braking.

2 - Input, 24T variable DC from brake rheostat.

3 - Input, variable DC from TH module.

4 - Input, brake regulation by DR module.

5 - Provisional function only.

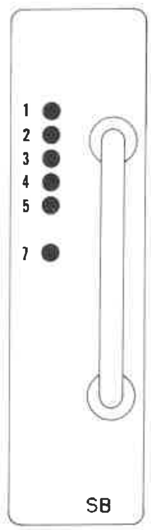
6 - Output, discharge of rate capacitor at wheel slip and when DC contactors operate.

7 - Rate capacitor discharge at EQP dropout.

13 - Output, reference voltage to load reg.

14 - Control circuit DC negative; NA.

OPERATING FUNCTIONS AT TEST POINTS



SB Controls the current to the SE control winding. Receives a reference voltage from the load regulator and a feedback voltage from the PF module and regulates the SE so that they are approximately equal.

1 - Input, 68 V DC.

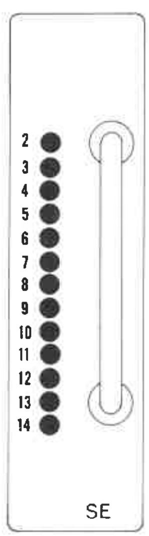
2 - Input signal from Sensor.

3 - Reference voltage input signal from load regulator.

4 - Not used on basic unit. On units equipped with special extra performance control receives input from PF (main generator current plus voltage feedback signal for power control above minimum continuous speed).

5 - Main generator current plus voltage feedback signal. On units with special extra performance control this signal is utilized below minimum continuous speed.

7 - Output to Sensor control windings thru GX and GV modules.



SE Provides gating pulses to the SCR at the proper time determined by the current in the control windings. Primary control windings are connected to terminals 13 & 14.

2 - Provisional function; control or bias.

3 - Input from AR10 positive during dynamic braking.

4 - Provisional function; control or bias.

5 - Output to gate of SCR1.

7 - Output to gate of SCR2.

9 - Output to gate of SCR3.

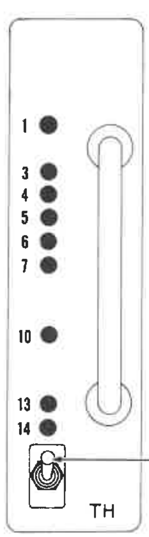
6, 8, 10 - AC power supply from D14.

11 - Common point for gate outputs; cathodes of SCR's.

12 - AR10 negative during dynamic braking.

13 - Input, excitation control windings.

14 - Input, excitation control windings.



TH Provides a closely regulated voltage (68 V DC) at terminal 10 for use as a reference.

TRP relays put a fixed resistance in series output so that output voltage increases to 68 V DC in Run 8.

1 - Input, 74 V DC to VRR.

3 - Output, variable DC from TRP.

4 - Input to TRP-A from THS 2, 4, 6, 8.

5 - Input to TRP-B from THS 5 thru 8.

Operate to drive load regulator toward minimum field position.

6 - Input to TRP-C from THS 3 thru 8.

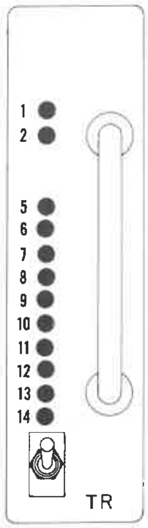
7 - Input to TRP-D from THS Stop, 5, 6.

10 - 68 V DC output from VRR.

13 - "N" negative - TRP relays.

14 - "NA" negative - VRR circuit.

OPERATING FUNCTIONS AT TEST POINTS



TR Receives PF module signal proportional to main generator current and voltage. TR output controls relays to initiate forward and backward transition sequence.

1 - Input, 74 V DC; supply to FTR and BTR operating circuits within the module.

2 - DC voltage proportional to AR10 voltage.

5, 6 } Normally open BTR interlock.

6, 7 } Normally open FTR interlock.

8, 10 } Single phase AC supply from D14.

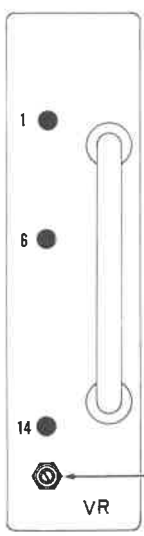
9 - 74 V DC input to recalibrate FTR during parallel motor connection.

11 - Timed 74 V DC input to recalibrate FTR and BTR for a delayed period to prevent cycling.

12 - Momentary 74 V DC signal holds FTR dropped out and BTR picked up.

13 - 0-50 V DC input signal from PF module. Signal is proportional to AR10 current.

14 - NA negative.



VR Regulates auxiliary generator voltage to 74 V DC by controlling the auxiliary generator field current.

1 - Aux. Gen. Positive.

6 - Output To Aux. Gen. Fld.

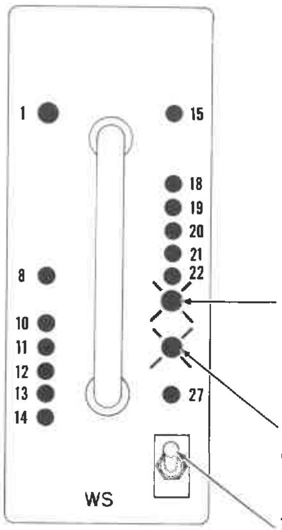
14 - Aux. Gen. Negative.

CAUTION: Do not install or remove VR module in locomotive unless engine is completely stopped.

Battery Charging Voltage Adjust.

OPERATING FUNCTIONS AT TEST POINTS

WS Receives signals from WST and from motor voltage bridge circuit. Provides various corrections to reference voltage; actuates sanding, wheel slip light, and ORS under some conditions.



1 - Control circuit DC positive; 13T feed.

8 - AC input from wheel slip transductors, and AC power supply from D14.

10 - AC power supply from D14.

11 - Output to base of SB transistor, neg. polarity.

Green test lamp indicates satisfactory WS module when it remains lit while test switch operated and held.

Red test light comes on to indicate faulty WS module when switch is operated.

Test switch. With throttle idle or unit isolated, switch actuates WS test circuits and test lamps.

12 - Output to base of SB transistor, pos. polarity.

13 - Control circuit DC negative; N.

14 - Control circuit DC negative; NM.

15 - Input upon pickup of parallel relay PR to energize "U" relay of WS and recalibrate the wheel slip control at moderate and high track speed.

18 - Output to wheel slip light relay WL operating coil.

19 - Output to sanding module and ORS.

20 - RC capacitor discharge by WS action.

21 - AC input from wheel slip transductors.

22 - 74 V DC input to test switch.

27 - Test point for zener breakdown voltage of 16 V AC.

12S172

SD40-2

GENERAL ELECTRICAL QUALIFICATION

AND

TROUBLESHOOTING GUIDE

GENERAL CHART
SD40-2/SD45-2 LOCOMOTIVES

Sect	Item No.	Device	Function	Test Conditions	Adjust At	Settings	Remarks
I MISC.	1.	SA	Sanding Control	SA Or WS Test SW	None	3-5 Sec	Delay On Drop-Out
	2.	VR	Aux. Gen. Volt. Reg.	Throttle 8	VR	74 ± 1/2V	Measure At VR Test Points 1 to 14
	3.	TLTD	Turb. Lube Pump Cont.		TLTD	35 ± 8 Min	Delay On Pick-Up
	4.	TDR	Transition Recal. Delay	TR Test Switch	TDR	60 ± 10 Sec	Delay On Drop-Out
II EXCITATION CONTROL	1.	TH14	First Throttle Current	Brakes Set Throttle 1	None	275 ± 75A	No. 2 Motor
	2.	TH14	Throttle Response	Throttle One Throttle Two Throttle Three Throttle Four Throttle Five Throttle Six Throttle Seven Throttle Eight	None None None None None None None None	9.2V 21.6V 28.6V 35.7V 43.3V 51.2V 61.4V 68.0V	Open Gen. Field Circuit Breaker & Remove SB Module During Test. Test Switch At Circuit Check. All Voltages ± IV. Measure Voltage From TH14 Test PT.3 to RC11 - Test PT.14
	3. 4.	RC11	Rate Control	8th Throttle Power 8th Throttle Brake	None	50 ± .5V 49.6 ± 1.5V	At RC-TP13
	5.	GV12	Voltage Limit Regulator	.8 to .9 Ohm Grid Load	None	1250 ± 25V	Run 8, 5 to9 Jumpered
	6.	GX2	Excitation Limit Regulator	AR10 Short CKT Measure Gen. Field Current	None	108 ± 2A	5 to 6 Jumpered
	7.	EL11	Excitation Limit Protection	Main Gen. Short CKT. Measure Gen. Field Current	None	114 ± 3A P.U.	
III DYNAMIC BRAKE	1.	DR10 Or DR13	Grid Current Limit	Operation Above 30 MPH	None	700 $^{+20}_{-30}$A	
	2.	DP12	Grid Current Protection	Operation Above 30 MPH With DR Pulled Out	None	729 ± 20A P.U.	628 ± 26A. Drop-Out
	3.	DP12	MTR. FLD. Current Protection	Main Gen Open Circuit In Dynamic Brake	None	76 ± 2V P.U.	30 ± 5V. Drop-Out
	4.	OCP	Open CKT. Protection		None	550 ± 50V P.U.	Reset At OCP Reset Button
	5.	IPS	Flat Wheel Protection		Device	15 psi	Drops Out DC Contactors

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GENERAL ELECTRICAL QUALIFICATION

AT STANDSTILL

PURPOSE OF CHECK	GENERAL QUALIFICATION TEST SETUP	ACTION	RESPONSE
Checking excitation system response to throttle.	Power setup; Engine running; Reverse Fwd; Air brake set.	Place throttle in Run 1.	Load current indicating meter rises slowly to between 200 and 350 and stops.
		Momentarily place throttle in Run 2 position.	No wheel slip indication should occur.
		Return throttle to idle, change reverser handle position, and repeat tests.	Same response as above.
Checking WS module response and wheel slip correction.		With throttle at idle, engine running, operate WS module test switch. NOTE: Control CB must be closed.	Red lamp flashes on and off. Green test lamp comes on and remains on while switch is held, and wheel slip light comes on and remains on while switch is held. SA module test light comes on. Continue to hold WS test switch; SA module test light goes out in 3 to 5 seconds. Sand is applied to rail in proper amount at proper location. Load regulator moves toward minimum field.
		Release WS test switch.	Wheel slip light and WS module test light go out. SA module test light comes on for 3 to 5 seconds.
		Change reverser position and repeat test.	Same response as above.

PURPOSE OF CHECK	GENERAL QUALIFICATION TEST SETUP	ACTION	RESPONSE
Checking power response to WS test.		Connect jumper from WS-TP1 to WS-TP22.	
		Throttle Run 1. Operate WS module test switch.	Load indicating meter needle dips slightly. Also same response as above.
		Release WS test switch and return throttle to idle. Remove jumper wire.	CAUTION: Do not exceed Run 1 with jumper in place.
Checking reference voltages, rate, and engine speed response to throttle.	Power setup; Engine running; Gen. field circuit breaker OFF; Test panel test switch in CIRCUIT CHECK position; Reverser Fwd.	Connect voltmeter positive to SB-TP1; negative to TH-TP14.	Meter must indicate 68 ± 1 V DC. If reading is incorrect, replace meter with a qualified meter.
		Connect voltmeter positive to VR-TP1; negative to TH-TP14. Throttle Run 8.	Meter should indicate between 71 and 77 V DC. (74 V DC is recommended minimum).
		Connect voltmeter positive to RC-TP3; Negative to TH-TP14. Open throttle in steps from idle to Run 8.	Voltage should increase in steps; Zero volts at idle, and above 65 volts in Run 8. Engine speed increases with each step 2 thru 8. (See setting chart for specific voltage checks.)
		Return throttle to idle.	
		Connect voltmeter positive to RC-TP13; negative to TH-TP14. Wipe throttle to Run 8.	Voltage should increase with rate. Zero volts at idle, and from 40 to 50 V DC in Run 8. (About 18 to 36 seconds build up time.)
		Return throttle to idle.	

WARNING

Do not close the traction generator field circuit breaker until the throttle is in idle position. The circuit check position of the test panel test switch does not prevent excitation of the main generator.

Checking load regulator response.	Power setup; Engine running; Generator field circuit breaker OFF; Test panel test switch in CIRCUIT CHECK position; Reverser Fwd.	Connect voltmeter positive to WS-TP12; negative to TH-TP14. Place throttle in Run 8.	Voltmeter indicates between 40 and 50 V DC.
		Operate test switch on TH module to energize ORS and drive the load regulator to minimum field position.	Voltage drops to zero.
		Release TH test switch.	Voltage increases slowly to above value.
		Return throttle to idle.	Voltage drops to zero.
EL module field current limit protection; Main generator current limit protection by GX module.	Pull out SB module. Engine running; Power setup; Air brake set; Throttle idle; Reverser Fwd; Ohmmeter positive at GX-TP8 negative at GX-TP4.	Operate and hold the EL module test switch.	EQP relay drops out. AN module EXCIT. LIMIT light comes on. Ohmmeter indication goes from low to high resistance.
		Release EL test switch.	Ohmmeter goes to low resistance; EQP picks up.
		Reset AN module.	EXCIT. LIMIT light goes out.
Checking GV module for high generator voltage protection.	Engine running; Power setup; Generator field circuit breaker OFF; Test panel test switch in CIRCUIT CHECK position; Reverser Fwd; Throttle idle.	Pull out to disconnect SB module.	
		Ohmeter on low resistance (R x 100) scale. Lead of positive polarity at GV-TP8; lead of negative polarity at GV-TP4.	Ohmmeter should show low resistance.
		Pull out to disconnect GV module. Disconnect ohmmeter. Reinstall GV and SB modules.	Ohmmeter indicates high resistance.

PURPOSE OF CHECK	GENERAL QUALIFICATION TEST SETUP	ACTION	RESPONSE
Checking ground relay protective circuit.	Power setup; Engine running; Gen. Field circuit breaker ON. Reverser centered; Test panel test switch in LOAD TEST. 0-500 DC voltmeter spade lugs tightly secured at test panel GP (3) and GN (4) terminals.	Connect 5 amp fused jumper wire from generator positive to locomotive ground.	
		Open throttle to Run 1.	Ground relay should pick up between 75 and 125 volts.
		Throttle idle; Move jumper from main generator positive to main generator negative; Repeat check.	Same pickup as above.
CAUTION: Main generator is open circuited. Do not exceed throttle position 1.		Throttle idle; Remove jumper and meter; Return test panel test switch to NORMAL position.	
Checking TR module, transition circuits, and wheel overspeed protection.	Generator field circuit breaker OFF; test switch in CIRCUIT CHECK position; controls and switches set up for power; Reverser Fwd. or Rev. Throttle 1.	Operate and hold the TR module test switch.	FTX and PR relays pick up; GFC drops out.
		Release TR test switch.	FTX drops out; "S" contactors drop out; "P" contactors pick up; TDR and PRA relays pick up; GFC contactor again picks up.
		Immediately after GFC pickup, again operate and hold the TR module test switch.	FTX picks up; EQP drops out; wheel slip light on.
		Release TR test switch.	EQP picks up and the wheel slip light goes out; after a time delay, PR drops out, and the transition circuits sequence back to series-parallel motor connection.
	Throttle idle; Return test switch to NORMAL; Close generator field circuit breaker.		

Checking DP module for motor excitation protection during dynamic braking.	Throttle idle; Engine running; Reverser Fwd. One RV switch module centered. (Reference procedure on page MFP-1.) Selector handle in "B" position.	Jumper DP-TP9 to DP-TP14 to discharge a capacitor. Connect a 0-100 DC voltmeter positive at DP-TP3; negative at DP-TP12.	
		Disconnect jumper and advance the throttle (dynamic braking handle).	MFP relay in the DP module picks up as generator voltage rises. MFP pickup and EQP dropout occur between 70 and 80 V DC. DP-TP3 to DP-TP12. EQP cycles in and out. MOTOR EXCIT. light on AN module may come on, after a number of cycles.
		Return throttle to idle and reset AN module. Operate reverser handle to Bkwd. and Fwd.	
Checking for grid overcurrent protection.	Engine running; Controls set up for dynamic braking; Selector handle in "B" position.	Momentarily connect a jumper from DP-TP7 to DP-TP14. This will discharge a capacitor in DP.	
		Remove the jumper and connect it from DP-TP14 to DP-TP5.	
		Apply another jumper from DP-TP1 to DP-TP20.	EQP relay will drop out after the BWR relay in the DP module picks up. After a time delay of between 1 and 2 seconds, the BWA relay in DP will pick up and the brake warning light will come on. GRID OVERCUR. light on the AN module may come on.
		Remove jumpers. Reset AN module.	

PURPOSE OF CHECK	GENERAL QUALIFICATION TEST SETUP	ACTION	RESPONSE
Checking main generator voltage during dynamic braking.	Engine running; Air brakes set; Controls and switches set up for dynamic braking; 0-100 DC voltmeter pos. at DP-TP3; neg. at DP-TP12.	Wipe braking handle to maximum.	Voltage DP-TP3 to DP-TP12 immediately surges, then decays to between 20 and 60 V DC in a few seconds.
Checking grid current control.	Above test setup remains.	Connect jumper from DR-TP4 to DR-TP5.	Voltage slowly drops to zero or near zero. NOTE: Refer to BCT, GL, DE, or DR pages of Troubleshooting Outlines for further checks.
Checking DE module for control of contactors for high braking current at low speeds.	Engine running: Controls and switches set for dynamic braking; independent air brakes released. Reverser Fwd.	Place throttle in Run 3.	Engine speed increases to Run 4 speed. DE module test lamps indicate in sequence DC1, DC2, DC3, with an interval between indications.
		Operate and hold the DE test switch.	DE test lamps go out in sequence DC3, DC2, DC1 with an interval between steps.
		Release test switch.	Sequence repeats; lamps on.
		Apply independent brake.	Test lamps go out all at once.
		Release independent brake.	Sequence repeats; lamps on.
		Return throttle to IDLE.	Engine goes to idle speed; lamps remain on.
		Move selector lever to OFF.	Test lamps go out all at once.

Checking extended range dynamic brake open circuit protection.	Engine running; Reverser centered. Test panel switch in LOAD TEST position. Dynamic brake cutout switch in Dynamic Brake position. <u>Units with automatic self loading</u>: 0-1000 DC voltmeter positive connected to "P" of OCP; meter neg at main gen. neg. Connect jumper from E2 of BR2 to main gen. neg. <u>Units without automatic self loading</u>: 0-1000 DC voltmeter connected at test panel GP to GN. Jumper from E1 to E2 of BR2. Jumper from OCP "P" to main gen. neg.	Open throttle to obtain required voltage. NOTE: If on units with auto self load, voltage is not high enough to pick up OCP, disconnect the BKD6 wire from "P" of OCP and jumper OCP-P to main generator positive to obtain higher voltage.	OCP should pick up and the GRID OPEN light on the AN module should come on at approximately 550 volts.
CAUTION: Do not allow main generator voltage to exceed 800.		Throttle idle. Disconnect jumpers and meter. Move selector lever to "B" position.	The "B" contactor will <u>not</u> pick up.
		Return test switch to NORMAL position. Reverser Fwd. Press OCP reset button.	The "B" contactor picks up when OCP resets.
		Reset the annunciator.	

PURPOSE OF CHECK	GENERAL QUALIFICATION TEST SETUP	ACTION	RESPONSE
Checking DG module protection against no grid cooling.	Engine running; controls and switches set up for dynamic braking.	With throttle at position 4, operate and hold the DG test switch in test position.	After 1 to 15 seconds, "B", GFC, and GFX contactors drop out. Annunciator GRID BLOWER light on; DG test lamp on.
		Release test switch.	
		Return throttle to idle. Operate DG module reset switch. Reset annunciator.	DG test lamp goes out. GRID BLOWER light goes out.

GENERAL TROUBLE GUIDE

OPERATING OR TEST CONDITION	ENGINE SPEED	HP $\frac{V \times A}{715}$	GOVERNOR RACK POSITION INDICATOR	LOAD REGULATOR POSITION	TYPE OF TROUBLE TO SUSPECT
Load test or road operation th 8 over 25 MPH.	Normal	LOW or NO LOAD	LONG	Max. Field	ELECTRICAL
Load test or road operation	Possibly Variable	Variable	HUNTING	HUNTING	ELECTRICAL OR MECHANICAL
Load test or road operation th 8	Normal	LOW	NORMAL	BALANCED	MECHANICAL
Load test or road operation th 8	Normal	LOW	LONG	Balanced, but toward min. fld.	MECHANICAL – Gov. ENGINE AIR
Load test or road operation th 8	Normal	LOW or HIGH	SHORT	BALANCED	MECHANICAL – Gov.
Load test or road operation th 8	LOW	LOW or HIGH	SHORT	MINIMUM	ELECTRICAL

TROUBLESHOOTING GUIDE

TROUBLE REPORT	POSSIBLE CAUSE	RECOMMENDED TEST OR CORRECTIVE ACTION
OVERLOADING	FAILED COMPONENT IN EXCITATION SYSTEM	NOTE: The following must be performed in sequence to be valid. THROTTLE 1 STALL CURRENT HIGHER THAN 350 AMPERES. If locomotive is at a safe test site, momentarily place throttle in Run 2 position to verify that wheel slip will not occur. Return throttle to idle. a. Remove SE module; Place throttle in Run 1. If load current is over 50 amperes, replace SCR with a qualified SCR and Retest. b. Return throttle to idle. Remove SB module and reinstall SE. Throttle Run 1. If load current is over 50 amperes, replace SE module with a qualified SE and retest. c. Return throttle to idle. Remove WS module and reinstall SB module. Throttle Run 1. If load current is over 50 amperes, replace SB module with a qualified SB and retest. d. Return throttle to idle. Reinstall WS module. Throttle Run 1. With stall current over 350 amperes, read voltage from SB-TP3 to SB-TP5 (and from SB-TP3 to SB-TP4 on units with GPT2). If either reading is over 5 volts, check AC voltage balance between PF-TP15 to PF-TP16; TP16 to TP17; TP17 to TP15. If all readings are not within 5 V AC, check wiring to AR10 current transformers CTA, CTB, CTC. If readings are in balance replace PF module with a qualified PF and retest. e. With throttle in Run 1, operate and hold the test switch on the TH module. Load current should go to zero in about 6 to 8 seconds as the load regulator goes to minimum position. If load current remains over 50 amperes, check for load regulator open on the negative side. f. If Steps a thru e above indicated no failure, and throttle 1 stall current is still over 350 amperes, replace TH module with a qualified TH and retest.
	ENGINE OR GOVERNOR PROBLEMS	An incorrectly adjusted governor or engine can cause overloading.

TROUBLE REPORT	POSSIBLE CAUSE	RECOMMENDED TEST OR CORRECTIVE ACTION
UNDERLOADING OR NOT LOADING	COMPONENT FAILED IN EXCITATION SYSTEM	NOTE: The following must be performed in sequence to be valid. PART 1 OF 3 PARTS Engine running; Controls and switches set up for power operation; Test panel test switch in CIRCUIT CHECK position; Generator field circuit breaker open. 0-75 DC voltmeter positive at WS-TP12; negative at PF-TP14. Place throttle in Run 8. a. About 46 V DC; Momentarily pull out SB module. If voltage rises perform Part 2 of 3 parts. If voltage does not rise perform G of Part 2. b. Zero or much less than 46 V DC; Perform Part 3 of 3 parts. PART 2 OF 3 PARTS Air brakes set; Control and switches set up for power operation. Test panel test switch in CIRCUIT CHECK position; Generator field circuit breaker open. Throttle Run 8. Obtain voltages test point to test point. The first test point is positive. If the voltages obtained indicate failure, replace the affected module with a qualified module and test. a. SB-TP1 to PF-TP14 should be 68 V DC. If less than 65 V DC; Failed TH module. b. SB-TP1 to SB-TP7 – If more than 35 V DC; Failed SB. c. GX-TP8 to GX-TP4 GV-TP8 to GV-TP4 – If more than 5 V DC; Failed GX or GV. d. SE-TP13 to SE-TP14 – If more than 5 V DC; Failed SE. e. SB-TP2 to SB-TP4 -- If more than 35 V DC; Failed SB. f. SB-TP2 to SB-TP5 – If more than 35 V DC; Failed SB.

g. PF-TP21 to PF-TP14 –
PF-TP18 to PF-TP14 – (If so equipped.)
Voltages less than 10 V DC. If voltage is 50 V DC; Failed PF. If voltage is more than 50 V DC; Failed SB. If there is no voltage; Failed WS or SB.

h. Check for equal voltages (approximately 75 V AC with engine at idle speed) SE-TP6 to SE-TP8; SE-TP8 to SE-TP10; SE-TP10 to SE-TP6. If voltages do balance; Failed SE.

WARNING: Do not place generator field circuit breaker in the ON position until the throttle is in IDLE position. The CIRCUIT CHECK position of the test panel test switch does not prevent excitation of the main generator.

PART 3 OF 3 PARTS – Zero or much less than 46 V DC; WS-TP12 to PF-TP14.

Controls and switches set up for power operation; Test panel test switch in CIRCUIT CHECK position. Generator field circuit breaker open. Throttle Run 8.

a. TH-TP1 to TH-TP14 – If not 74 V DC, check wiring to TH-TP1.

b. TH-TP10 to TH-TP14 – If less than 65 V DC, failed TH.

c. TH-TP3 to TH-TP14 – If less than 65 V DC, failed TH, or wiring error TH-TP10 to TH-TP2.

d. RC-TP3 to TH-TP14 – If less than 65 V DC, check wiring between TH and RC.

e. RC-TP13 to RC-TP14 – If less than 40 V DC, remove WS. If voltage increases to more than 65 V DC, go to Step f. If voltage does not increase, make certain that RC-TP6, TP4, TP7, and TP8 to negative are open. If they are open, RC is failed.

f. Replace WS. Check WS-TP12 to RC-TP14 – If less than 40 V DC, failed WS or shorted load regulator, bad load regulator brushes, jammed load regulator.

g. Check voltage RC-TP6 to RC-TP14 – If less than 40 V DC, failed WS.

h. Non-dynamic unit -- WS-TP12 to WS-TP11
Dynamic Unit -- SB-TP3 to WS-TP11
- If more than 15 volts, failed WS.

TROUBLE REPORT	POSSIBLE CAUSE	RECOMMENDED TEST OR CORRECTIVE ACTION
NO DYNAMIC BRAKING	FAILED DP MODULE	Engine running; Controls set up for dynamic braking; Dynamic brake handle in maximum brake position. Main generator volts GP to GN should be 20 to 60 V DC. If no voltage is obtained, pull out DR module. If no voltage is obtained, do Brake Warning checks. If no voltage is obtained, check for pickup of EQP. If EQP is not picked up, connect a jumper from C1 to C2 of MR. If EQP picks up and voltage is obtained when jumper is applied, replace DP module with a qualified DP and repeat test.
LOSS OF POWER REPORTED UNDER SEVERE TRACK AND GRADE CONDITIONS	NORMAL CORRECTIVE ACTION BY WHEEL SLIP CONTROL SYSTEM	No action required. The wheel slip control system responds under severe conditions to maintain power at an optimum level for adhesion conditions. The lowering of the power level under severe conditions should not be misinterpreted as a fault.
LACK OF ADHESION AND WHEEL SLIP CORRECTION REPORTED	WS MODULE FAILURE	Refer to General Qualification procedures to verify SA and WS module function. Refer to Troubleshooting Outlines for WST and WS qualification.
H. V. GROUND/ FAULT	MOISTURE GROUND	Dry out wet area.
	GROUNDED CABLE OR DEVICE	Repair or replace.
	TRACTION MOTOR FLASH-OVER	Inspect, clean, and repair flashed motor if required. Refer to General Qualification procedures to verify GV module action. Refer to General Qualification procedures to verify WS module action; Troubleshooting Outlines for WS and WST function.
	MAIN GENERATOR FAULT	Inspect main generator for blown fuses and shorted diodes. Inspect for bad capacitors and resistors. M.I. 3317-2. Qualify GV module in the event of multiple diode failure. Refer to Grid Load Checks in Troubleshooting Outlines.

BRAKE WARNING LIGHT AND BUZZER	FAILURE IN EXCITATION SYSTEM	Perform checks listed under OVERLOADING.
	DR MODULE FAILURE	Engine running; Controls set up for dynamic braking; Dynamic brake handle in maximum braking position; Voltage DR-TR8 to DR-TP10 should be 115 to 150 V AC. Measure voltage RC-TP13 to RC-TP14, then connect a jumper from DR-TP4 to DR-TP5. Voltage should decrease very slowly to near zero. If voltage does not decrease, check BR2 relay and wiring. If wiring seems intact and BR2 picks up, replace DR with a qualified DR and retest.
EXCESSIVE BRAKING AT LOWER DYNAMIC BRAKE HANDLE POSITIONS	DR MODULE FAILURE	Engine running; Controls set up for dynamic braking; Dynamic brake handle at maximum position. Measure voltage RC-TP13 to RC-TP14. Connect jumper from DR-TP4 to DR-TP5. Voltage should decrease slowly to zero or near zero. If voltage does not decrease, check BR2 relay. If wiring is intact and BR2 picks up, replace DR with a qualified module and recheck. NOTE: On units with DE modules and units with grid current trainline control (i.e. units that can not use a DR10 module), refer to GL, BCT, DE, or DR pages of troubleshooting outlines for grid current control functional check.

TROUBLESHOOTING OUTLINES

ISSUE RECORD

The following listed pages comprise the latest issue for Section 11 Part B of the SD40-2 Locomotive Service Manual.

Page	Code
11B-1	12S472
11B-2	14S272
BATT-1	12S172
BCT-1	12S172
CB-1	12S172
CP-1	14S272
CP-2	13S172
CT-1	12S172
DE-1	12S172
DE-2	12S172
DP-1	12S172
DR-1	12S172
DR-2	12S172
DR-3	12S172
EL-1	12S172
FZ-1 -- FZ-2	12S172
GL-1	12S172
GL-1A	12S172
GL-2	12S172
GL-3	12S172
GL-4	12S172
GL-5	12S172
GL-6	16S372
GL-7	12S172
GOV-1	12S172
GPT-1	12S172
GPT-2	12S172
GR-1	12S172
GR-2	12S172
GR-3	12S172
GV-1	12S172
HDL-1	12S172
HOT-1	12S172
HOT-2	12S172
LO-1	12S172
LR-1	13S172
MFP-1	14S272
NVR-1	12S172
PF-1	12S172
PF-2	12S472
PF-3	12S472
RC-1	14S272
SB-1	12S172
SCR-1	12S172
SE-1	14S272
SE-2	12S172
TEM-1	12S172
TH-1	14S272
TR-1	12S172
UL-1	12S172
UL-2	12S172
UL-D-1	12S172
VR-1	12S172
WS-1	12S172
WST-1	12S172
WST-2	14S272
WST-3	12S172
WST-4	15S372
WST-5	14S272
WST-6	14S272
WST-7	14S272
WST-8	14S272
WST-9	14S272
WST-10	14S272

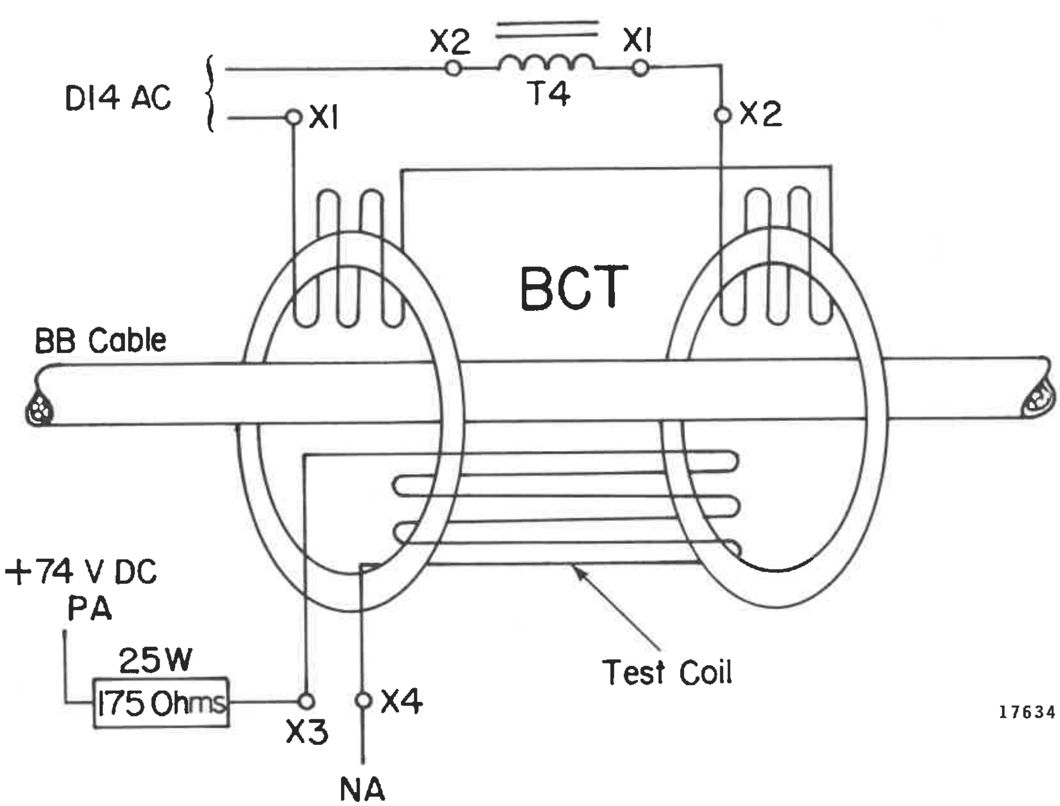
LEGEND OF REFERENCE SYMBOLS

The reference symbols used in this troubleshooting guide consist of one or more letters generally similar to the common words describing a component or trouble.

BATT	Battery
BCT	Brake Current Transductor
CB	Circuit Breaker
CP	Crankcase (Oilpan) Pressure
CT	Current Transformer
DP	Dynamic Brake Protection
DR	Dynamic Brake Regulation
EL	Main Generator Field Excitation Limit
EMM	Engine Maintenance Manual
FZ	Fuse
GL	Grid Load Test
GOV	Governor
GPT	Generator Potential Transformer
GR	Ground Relay
GV	Generator Voltage Module
HDL	Headlights
HOT	Hot Engine
LO	Low Oil Pressure
LR	Load Regulator
MFP	Motor Field Protection
NVR	No Voltage Relay (Aux. Gen; Aux. Alt.)
PF	Performance Control
RC	Rate Control
SB	Sensor Bypass (Comparison)
SCR	Main Gen. Excitation Controlled Rectifier
SE	Sensor
TEM	Temperature Switches
TH	Throttle Response (And Reference Voltage Regulator)
UL	Underloading-Unloading
UL-D	Unloading – Dynamic Brakes
VR	Voltage Regulator
WS	Wheel Slip
WST	Wheel Slip Transductor

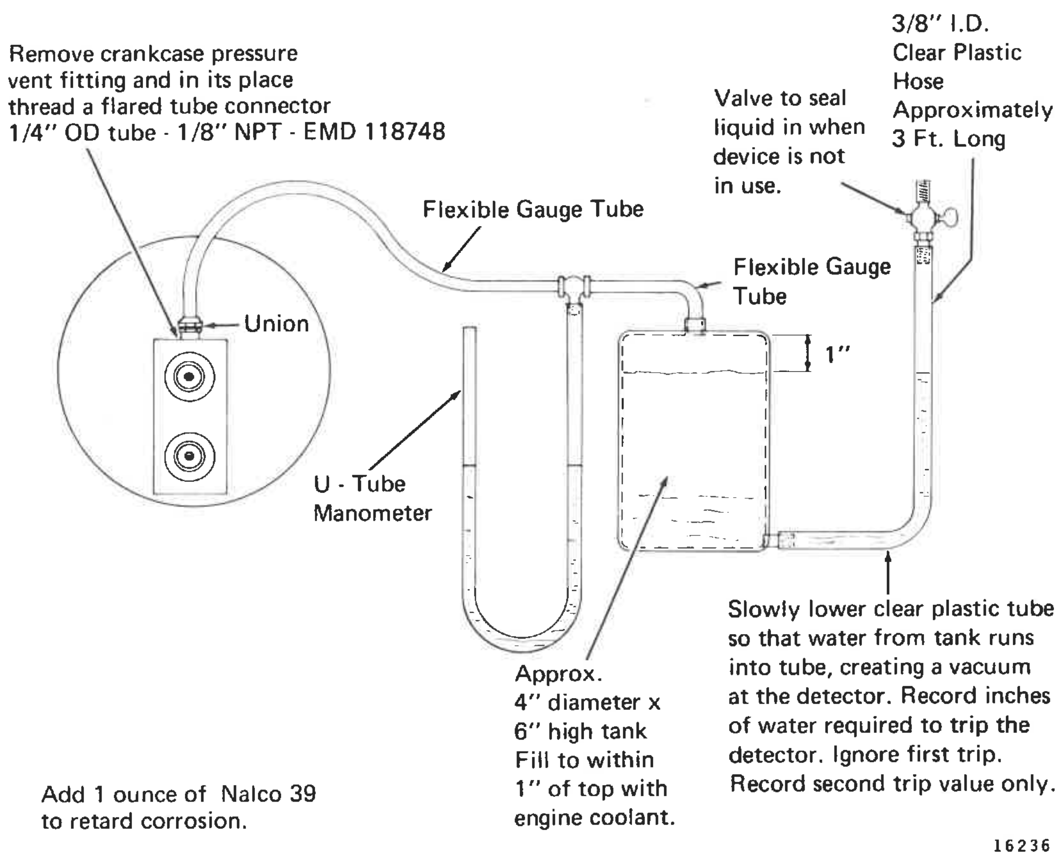
Reference Symbol	TROUBLE – POSSIBLE CAUSE AND SYMPTOM Test Procedure Normal Indication For Test Setup Or Operating Condition *Fault Indication And Corrective Step* *Asterisk Indicates Most Probable Fault —**	Instruction Reference
BATT	EXCESSIVE USE OF BATTERY WATER –	
	Check voltage at auxiliary generator fuse clip and right side of main battery switch.	
	Between 71 and 78 V DC.	
	If voltage is higher than allowed range, manipulate adjustment screw on face of VR module to obtain voltage within tolerance. If voltage cannot be brought within tolerance, replace VR module with a qualified module and retest.	*VR*
	Reset new regulator to the voltage required by the railroad for battery charging characteristics desired.	
	CAUTION: *Auxiliary generator voltage of less than 74 V may result in marginal excitation of the D14 auxiliary alternator, and the desired fast speed pickup of cooling fan motors may not be obtained.*	
BATT	BATTERY CHARGE LOW Battery charging indicator indicates high charging rate.	
	Check specific gravity. (See battery manufacturers manual.) Check voltage at auxiliary generator fuse clip and right side of main battery switch.	
	Between 71 and 78 V DC.	
	With adjustment on face of VR module, adjust charging voltage as required to obtain a satisfactory charging rate.	
	CAUTION: *Do not remove or install VR module unless the diesel engine is completely stopped.*	

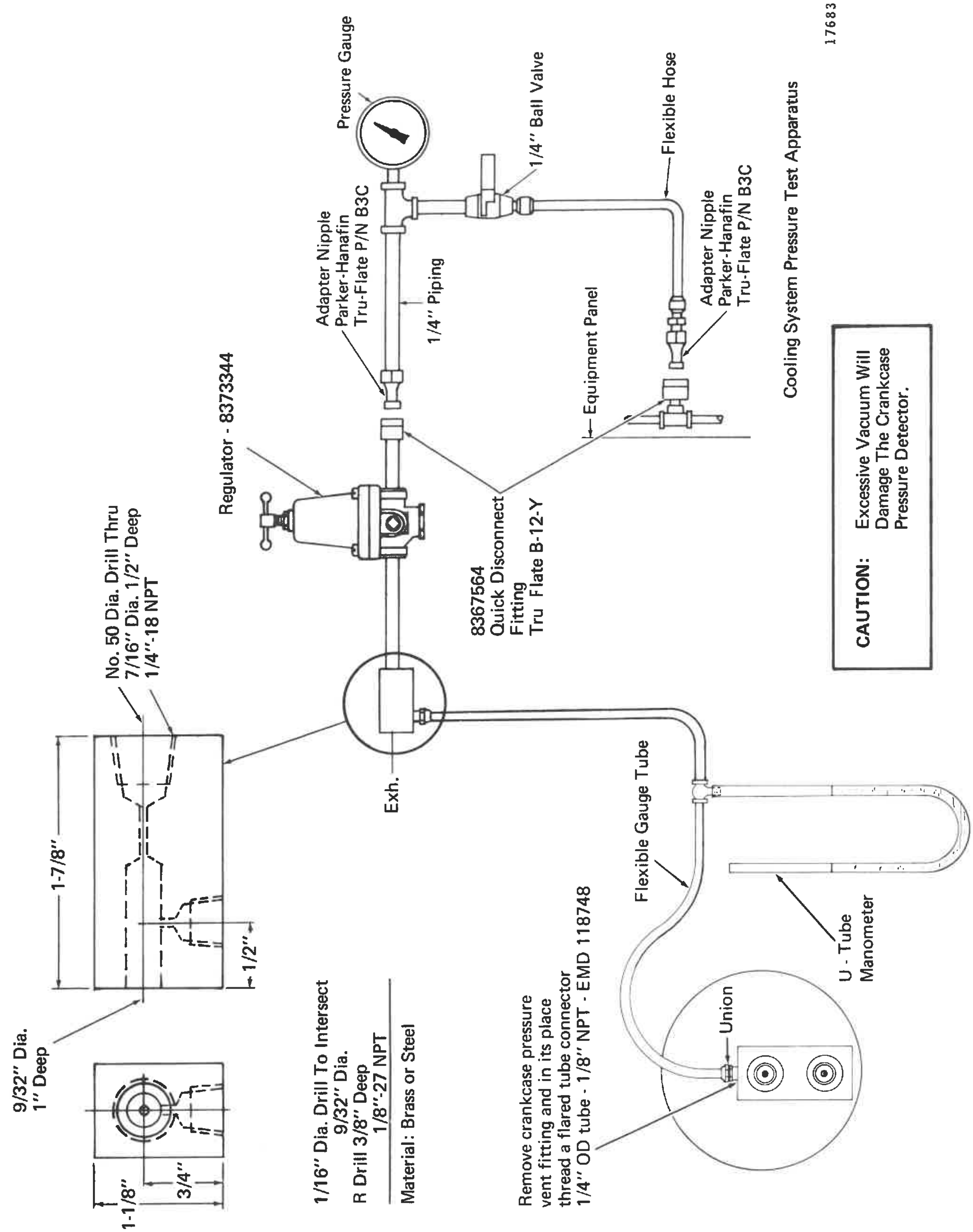
Reference Symbol	TROUBLE – POSSIBLE CAUSE AND SYMPTOM Test Procedure Normal Indication For Test Setup Or Operating Condition *Fault Indication And Corrective Step* *Asterisk Indicates Most Probable Fault —**	Instruction Reference
BCT	BCT SUSPECTED FAULTY -- (Units with grid current trainline control, without extended range dynamic brakes.)	GL
	Engine running; Controls and switches set up for dynamic brake operation; Brake handle at maximum position. Measure voltage RC-TP13 to TP-14 or GP to GN. Connect BCT test coil terminal X3 in series with a 175 ohm 25 watt resistor to 74 V DC (PA). Connect BCT terminal X4 to negative (NA).	
	Voltage RC-TP13 to TP14 or GP to GN should fall to zero or nearly zero.	
	If improper indication is obtained, and DR checks are satisfactory, replace BCT with a qualified BCT and retest.	DR



Reference Symbol	TROUBLE – POSSIBLE CAUSE AND SYMPTOM Test Procedure Normal Indication For Test Setup Or Operating Condition *Fault Indication And Corrective Step* *Asterisk Indicates Most Probable Fault —**	Instruction Reference
CB	AUX. GEN. FIELD BREAKER TRIPPED	
	→ Engine shut down and isolated. Pull out the VR module and open the auxiliary generator fuse. Check the auxiliary generator for shorts and grounds.	
	→ Possible causes of a tripped breaker are an auxiliary generator ground or short. →	*
	→ *If the auxiliary generator tests good, replace the voltage regulator VR with a qualified module and retest.* →	*VR*
	Also check the Aux. Gen. fuse. →	*FZ*
	CAUTION: *Engine must be completely stopped when removing or installing the VR module.*	
CB	GEN. FIELD CIRCUIT BREAKER TRIPPED Check for the following defects:	
	a. Defective SCR assembly. →	SCR*
	b. Defective sensor SE.	SE
	c. Defective excitation limit circuit EL.	EL
	d. Defective voltage regulator GV.	GV
	Refer to specific instructions for the component.	
CB	ALTERNATOR (D14) FIELD CIRCUIT BREAKER TRIPPED (Units so equipped)	
	→ Check for shorted CR17 and for shorted or grounded alternator field or wiring.	
	→ *Replace faulty component and retest.*	

Reference Symbol	TROUBLE — POSSIBLE CAUSE AND SYMPTOM Test Procedure Normal Indication For Test Setup Or Operating Condition *Fault Indication And Corrective Step* *Asterisk Indicates Most Probable Fault —**	Instruction Reference
CP	CRANKCASE PRESSURE DETECTOR SUSPECTED DEFECTIVE — Any time a true crankcase pressure trip has occurred, or is suspected to have occurred.	
	→ Check crankcase (oilpan) pressure detector trip value, using locally fabricated metering device comparable to that illustrated below.	
	→ Shut engine down. Operate the device to trip the detector, then reset the detector. Ignore the first trip value. Slowly operate the vacuum metering device again. Crankcase pressure detector trip button should pop out at a maximum of 2.5″ water with increasing vacuum at the vent opening. Minimum of 0.8″ water.	
	→ *If the detector does not trip when maximum value is reached, replace the detector with a qualified detector. The detector may be qualified with bench apparatus.*	*M.I. 259*



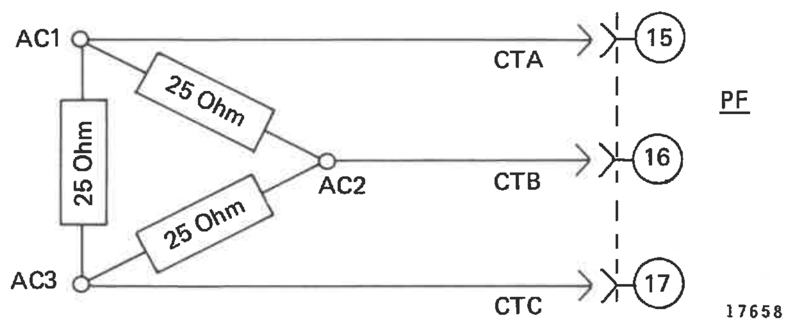


Cooling System Pressure Test Apparatus

CAUTION: Excessive Vacuum Will Damage The Crankcase Pressure Detector.

Reference Symbol	TROUBLE — POSSIBLE CAUSE AND SYMPTOM Test Procedure Normal Indication For Test Setup Or Operating Condition *Fault Indication And Corrective Step* *Asterisk Indicates Most Probable Fault —**	Instruction Reference
CT	CTA, CTB, CTC, CURRENT TRANSFORMERS SUSPECTED DEFECTIVE — Underloading	UL

Grid Load or Short circuit; Connect three 25 ohm resistors in delta fashion to CTA, CTB, and CTC, at PF-TP15, 16, and 17.



Close traction generator field circuit breakers and place throttle in Run 1. Check voltage drops across the resistors. They should be within 2 volts.

If the voltages are out of balance, replace PF module with a qualified module, and test. If voltages are still out of balance; At terminal board 39 at back of the electrical cabinet, connect three 25 ohm resistors in delta fashion and connect the CTA, CTB, and CTC wires to the delta. → *PF*

If voltage readings are out of balance; Open traction Gen Fld CB. Verify that the CTA, CTB, CTC wires in the main generator airbox are connected to the X1 terminals of the current transformers, and the X2 terminals are connected common by jumpers AB and BC.

If connections are in order, determine which current transformer CT is defective, and replace it with a qualified transformer. (Resistance CTA to CTB, CTB to CTC, CTC to CTA 22±2.2 ohms. Greater variation indicates shorted turns or open windings.)

CAUTION: *Do not excite the main generator with wires CTA, CTB, and CTC disconnected. Extremely high and damaging voltage will result.*

If current transformers are not defective, verify that there is no fault in generator wiring.

Reference Symbol	TROUBLE – POSSIBLE CAUSE AND SYMPTOM	Instruction Reference
	Test Procedure – – – Normal Indication For Test Setup Or Operating Condition *Fault Indication And Corrective Step* *Asterisk Indicates Most Probable Fault —**	
DE	**DE MODULE SUSPECTED FAULTY** Checking generator excitation and DE sequence function. → Engine running; Controls and switches set up for dynamic braking; Reverser forward; Independent air brake released; 0-75 DC voltmeter connected at test panel GP and GN terminals. → Advance dynamic braking handle to maximum braking position. – – → Engine speed increases to Run 4 speed. DE module test lamps indicate in sequence DC1, DC2, DC3 with an interval between indications. After sequence, voltmeter settles between 20 and 60 V DC. → Operate and hold the DE test switch. – – → Test lamp sequence repeats in reverse order. → Release test switch. – – → Sequence repeats; lamps on. → Apply independent brake fully to open IPS switch. – – → Test lamps go out all at once. → Release independent brakes. – – → Sequence repeats; lamps on. → Return braking handle to idle. – – → Engine goes to idle speed; lamps remain on. → Move selector lever to OFF position. – – → Test lamps go out all at once. → *If indications are incorrect, replace DE module with a qualified module and repeat tests. If indications are still incorrect, check circuitry at DP relays and DC contactors.* *If independent brake application does not cause sequencing, check IPS switch.* (Continued)	

Reference Symbol	TROUBLE – POSSIBLE CAUSE AND SYMPTOM Test Procedure Normal Indication For Test Setup Or Operating Condition *Fault Indication And Corrective Step* *Asterisk Indicates Most Probable Fault —**	Instruction Reference
	(DE checks continued from preceding page.)	
	Checking DE module grid current control function.	
	Apply independent brake.	
	Return selector handle to "B" position, and dynamic braking handle to maximum position. After the meter reading stabilizes, connect jumper from PA to terminal 3 NO of DP3 relay.	
	Voltmeter indication drops quickly to near zero.	
	Remove jumper from DP3 relay.	
	Voltage returns to between 20 and 60 V DC.	
	Connect a jumper wire from 1C to 1 NO of relay DP1A on units so equipped.	
	Turn headlights off. Connect jumper wire from No. 5 terminal of headlight control switch at the back of the engine control panel. Connect other end of jumper to DE-TP7.	
	With selector at DIM, turn on front headlight.	
	Reduce dynamic brake handle one number at a time, allowing voltage to settle at each position.	
	Voltage will settle at a lower value for each handle position, until at some lower position, voltage will continue falling to zero.	
	This response checks the grid current control function of the DE module operating through the DR module.	
	If faulty response is obtained, check DR function.	*DR*
	If DR is satisfactory, replace DE module with a qualified DE module and retest.	

Reference Symbol	TROUBLE – POSSIBLE CAUSE AND SYMPTOM	Instruction Reference
	Test Procedure Normal Indication For Test Setup Or Operating Condition *Fault Indication And Corrective Step* *Asterisk Indicates Most Probable Fault —**	
DP	DP MODULE SUSPECTED FAULTY	
	At the back of the electrical cabinet, disconnect the BB13 wire from terminal 22 of the DP terminal strip. In the cab, connect a 0-100 DC voltmeter to test panel GP and GN terminals. Using a motor generator set, connect DC positive at DP-TP22; negative at DP-TP28.	
	Engine running; Controls and switches set up for dynamic braking; Move dynamic braking handle to maximum braking position. Voltmeter at GP-GN will jump, then settle to a lower value within a few seconds.	
	Slowly apply and increase MG set voltage.	
	The DP module should regulate and main generator voltage drop off when MG set voltage is between 270 and 330 volts, with cold grids. (Nominally 315 volts when grids are hot.)	
	If correct regulation does not occur, replace the DP module and repeat the test.	*GL*
	If retest fails, qualify the RC module.	*RC*
DP	DP MODULE SUSPECTED FAULTY	
	Check motor field protection.	MFP
	NOTE: *The above instructions for checking only. Settings are to be made only with bench test equipment.*	

Reference Symbol	TROUBLE – POSSIBLE CAUSE AND SYMPTOM Test Procedure Normal Indication For Test Setup Or Operating Condition *Fault Indication And Corrective Step* *Asterisk Indicates Most Probable Fault —**	Instruction Reference
DR	DR MODULE SUSPECTED FAULTY	GL
	Engine running; Independent brake fully set (to open IPS switch when applicable); Controls and switches set up for dynamic brake operation; Brake handle at maximum position. Measure the voltage RC-TP13 to TP14, then connect a jumper from DR-TP4 to TP5.	
	Voltage should decrease very slowly to less than 1 V DC.	
	If voltage RC-TP13 to TP14 does NOT decrease, replace the DR module with a qualified DR module and retest. If retest fails, qualify the RC module.	*RC*
	NOTE: *A satisfactory indication on the above test does not by itself qualify the DR module. Various portions of the DR circuits are not tested by the above test. Refer to the other tests.*	*DR-2* *DE* *GL*

GENERAL TROUBLESHOOTING OUTLINE

Reference Symbol	TROUBLE — POSSIBLE CAUSE AND SYMPTOM Test Procedure Normal Indication For Test Setup Or Operating Condition *Fault Indication And Corrective Step* *Asterisk Indicates Most Probable Fault —**	Instruction Reference
DR	DR MODULE SUSPECTED FAULTY	
	→ At the back of the electrical cabinet, disconnect the wires from DR terminal No. 2. In the cab, connect a 0-100 DC voltmeter at test panel GP and GN terminals. Using a motor generator set, connect DC positive at DR-TP2; negative at DR-TP13.	
	→ Engine running; Controls and switches set up for dynamic braking; Move the dynamic braking lever to maximum braking position. Voltmeter at GP-GN will jump, then settle at a lower value within a few seconds.	
	→ Slowly apply MG set voltage.	
	- - → The DR module should regulate and main generator voltage should drop off when MG set voltage is between 295 and 310 volts.	
	→ Return MG set voltage to zero.	
	- - → Main generator volts will return to the former value.	
	On units equipped for "Grid Current Trainline Control" of dynamic brakes or with extended range dynamic brakes, reference DR and DE pages covering grid current control checks. →	DR DE
	→ *If correct indications do not occur, replace DR module with a qualified module and repeat the tests. If retest fails, qualify the RC module.* →	*RC* *GL*
	NOTE: *The above instructions are for checking only. Settings are to be made only with bench test equipment.*	

Reference Symbol	TROUBLE – POSSIBLE CAUSE AND SYMPTOM	Instruction Reference
	Test Procedure – – – Normal Indication For Test Setup Or Operating Condition *Fault Indication And Corrective Step* *Asterisk Indicates Most Probable Fault —**	
DR	**DR MODULE SUSPECTED FAULTY** Checking grid current control function on units equipped for grid current trainline control and not equipped with DE module. Excessive braking reported at low braking handle positions. **NOTE:** Units which can accept a DR10 module and are not fitted with extended range dynamic brake DE module are <u>not</u> equipped for grid current trainline control. Units with DE module and with relay DP1A are not equipped for full range grid current control. → Engine running; Controls and switches set up for dynamic braking; Reverser forward; 0-75 DC voltmeter connected at test panel GP and GN terminals. → Advance dynamic braking handle to maximum. – – → Voltmeter indication surges, then settles between 20 and 60 V DC. → Turn headlights off. Connect jumper from No. 5 terminal of headlight control switch at the back of the engine control panel; Connect other end of jumper to DR13-TP9. → With selector switch at <u>DIM</u>, turn on front headlight. → Reduce dynamic braking handle one number at a time allowing voltage to settle at each step. – – → Voltage will settle at a lower value for each handle position, until at some lower position, voltage will continue falling to zero. → *If voltage indications are not correct, replace DR module with a qualified module and retest.* – – → If indications are correct and grid current control function is still suspected faulty, perform BCT or GL checks. →	BCT GL

Reference Symbol	TROUBLE – POSSIBLE CAUSE AND SYMPTOM — Test Procedure - - - Normal Indication For Test Setup Or Operating Condition — *Fault Indication And Corrective Step* *Asterisk Indicates Most Probable Fault —**	Instruction Reference
EL	EL MODULE SUSPECTED FAULTY –	
	→ With selector handle indexed to neutral, and throttle at idle, press EL test button.	
	- - → EXCIT. LIMIT light on AN module comes on. The EQP relay drops out.	
	→ *EQP relay fails to drop out; Annunciator light fails to come on. Replace EL with a qualified module and retest. If replacement module fails to respond to test button, qualify excitation limit transductor ELT.* → (see EL MODULE OR ELT TRANSDUCTOR SUSPECTED FAULTY)	
	Reset AN module.	
EL	EL MODULE OR ELT TRANSDUCTOR SUSPECTED FAULTY	
	→ Remove the generator bus at the base of the electrical cabinet, and short circuit the main generator. Disconnect the ARY or ARP1 wire from the front negative terminal GFD and bolt one side of a 300 ampere 75 millivolt shunt to the terminal. Bolt the ARP1 or ARY wire to the other side of the shunt. Connect a 0-75 millivolt meter to the shunt. Connect jumper from GX-TP8 to GX-TP4. With the engine running and controls set up for power operation, advance throttle as required.	
	- - → The ELR relay in the EL module should pick up to drop out EQP and GFC when main generator field current is at EL pickup value indicated on the general Charts and Graphs drawing. Field current will rise and fall as EL picks up and drops out. (Peak at nominally 114 amperes.)	
	→ Pull out the GX-TP8 to TP4 jumper.	
	- - → Current will hold steady at a lower value. (Nominally 108 amperes.)	
	→ *If improper regulation is obtained, replace the EL module with a qualified EL module and retest.* *If retest fails, replace the ELT transductor with a qualified transductor and retest.*	
	Reset AN module.	

Reference Symbol	TROUBLE – POSSIBLE CAUSE AND SYMPTOM Test Procedure Normal Indication For Test Setup Or Operating Condition *Fault Indication And Corrective Step* *Asterisk Indicates Most Probable Fault —**	Instruction Reference
FZ	AUXILIARY GENERATOR FUSE BLOWN No power alarm reported; Engine shut down.	
	As a precaution, first measure voltage from the upper auxiliary generator fuse clip to the negative (right) side of the main battery switch.	
	Voltage zero or very nearly zero.	
	Voltage at or near 64 V DC indicates a shorted battery charging rectifier.	
	If voltage is zero or nearly zero, remove the auxiliary generator fuse and verify that it is blown. Disconnect the VR module.	
	CAUTION: *Engine must be completely stopped whenever removing or installing the VR module.*	
	Open the BN string by disconnecting BN1 wire from CR17, and check circuit for shorts and grounds. If circuit is satisfactory, the VR module is probably defective. Replace VR module with a qualified module and renew the auxiliary generator fuse. Start the engine and check for proper operation.	*VR**
	Check headlights, which may have burned out from high voltage prior to fuse blow.	
FZ	AR10 RECTIFIER FUSES BLOWN Check for the following defects:	
	a. Defective GV module.	GV
	b. Defective SCR assembly.	SCR
	c. Bad commutation resistors or capacitors.	M.I. 3317-2*
	Refer to specific instructions for the component.	

Reference Symbol	TROUBLE – POSSIBLE CAUSE AND SYMPTOM Test Procedure Normal Indication For Test Setup Or Operating Condition *Fault Indication And Corrective Step* *Asterisk Indicates Most Probable Fault —**	Instruction Reference
FZ	RADIATOR FAN MOTOR FUSE BLOWN Indicating pin protrudes. → Replace BOTH fuses in the fan motor circuit with qualified fuses. With engine running, operate the applicable temperature switch test button to verify fan contactor operation and fan motor operation. **NOTE:** If inspection reveals a single blown fuse in a fan motor circuit, always replace BOTH fuses. This is required because the second fuse would have been in the process of opening when the locomotive unit was shut down for some other reason. Such a fuse will open the next time the fan motor is called upon to start. If for some reason good fuses are removed from a unit, they should be removed in pairs from the individual motor circuit so that each motor involved becomes completely isolated.	

Reference Symbol	TROUBLE – POSSIBLE CAUSE AND SYMPTOM Test Procedure Normal Indication For Test Setup Or Operating Condition *Fault Indication And Corrective Step* *Asterisk Indicates Most Probable Fault —**	Instruction Reference
GL	GRID LOAD CHECK OF MODULAR CIRCUITS	

NOTE: The following instructions are for checking only. Settings are to be made only with bench test equipment. The procedures are intended for use only in exceptional circumstances and are not to be considered a part of routine troubleshooting.

TR Function
GV Regulation
DR Regulation
Grid Current Control
DP BWR Regulation

→ Stop the diesel engine.

If the unit under test is equipped for automatic self loading, perform the following:

At the grid hatch, disconnect and insulate the following cable connectors:
BKC from terminal 3 of RE-GRID D.
BB20 from terminal 1 of RE-GRID D.
Grid D is the center grid at the left side of the locomotive. Terminals 1 and 3 are at the left (forward) end of that grid.

If the unit is <u>not</u> equipped for automatic self loading, perform the following:

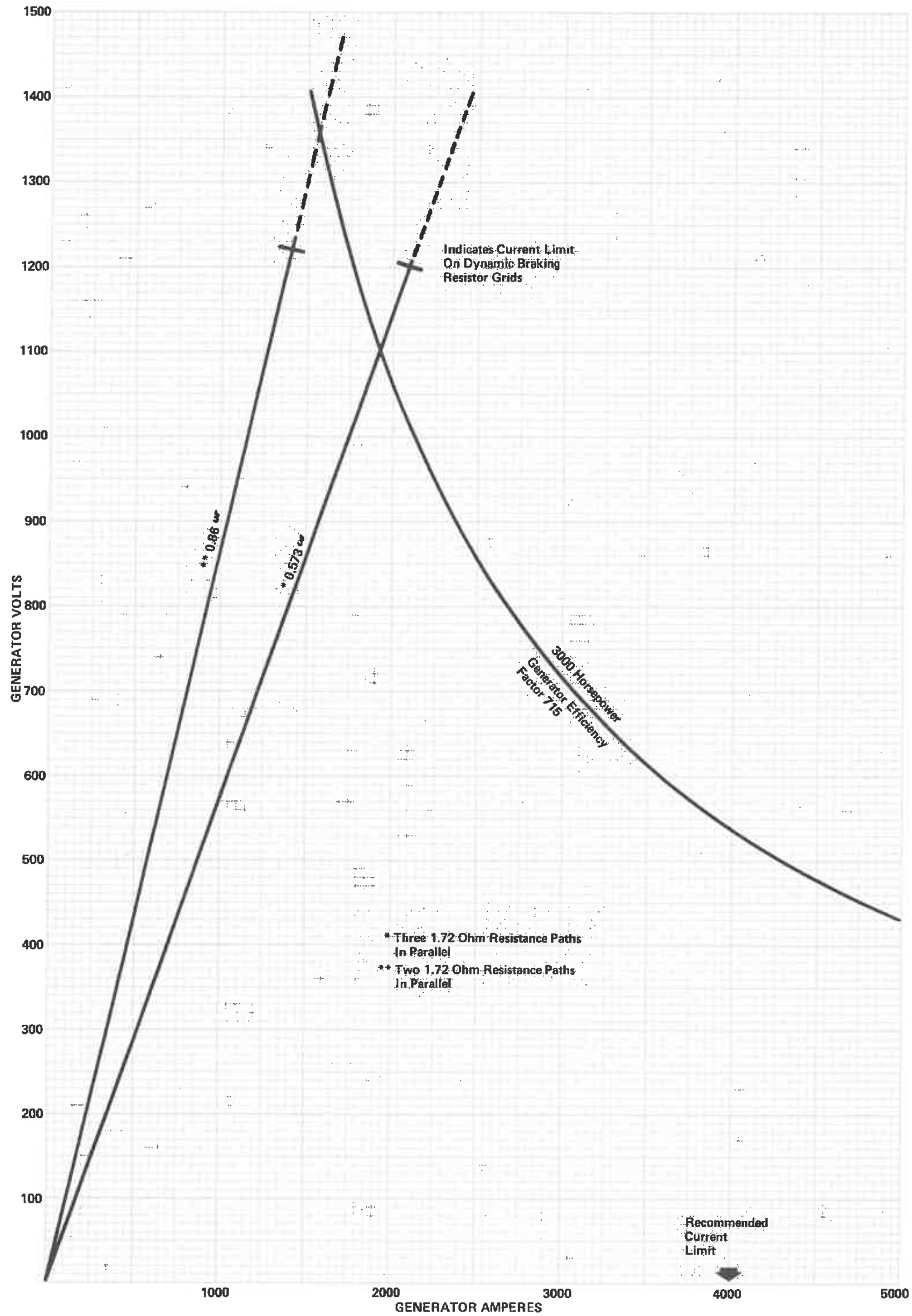
a. Remove the main generator GP to GS bus, and connect two lengths of 1100/24 cable to the GP bus. Connect the cables to a 2000 ampere 50 millivolt meter shunt.

b. Using four lengths of minimum 550/24 cable, make the following connections to brake transfer switch MB:
Meter shunt to MB/L3-2 (at BB1 cable).
Meter shunt to MB/L1-2 (at BB3 cable).
GN to MB/R2-2 (at BR4 cable).
GN to MB/L1-2 (at BR6 cable).

CAUTION: Either of the above loading setups provide grid resistance of 0.86 ohm with cold grids. Generator voltage at full load would be higher than acceptable for this unit.

(Continued)

Reference Symbol	TROUBLE — POSSIBLE CAUSE AND SYMPTOM Test Procedure Normal Indication For Test Setup Or Operating Condition *Fault Indication And Corrective Step* *Asterisk Indicates Most Probable Fault —**	Instruction Reference



Reference Symbol	TROUBLE — POSSIBLE CAUSE AND SYMPTOM	Instruction Reference
	Test Procedure Normal Indication For Test Setup Or Operating Condition *Fault Indication And Corrective Step* *Asterisk Indicates Most Probable Fault —**	

(Grid load checks continued from preceding page.)

Connect a 0-50 millivolt meter either to the LOAD TEST SHUNT terminals on the test panel, or to the externally connected meter shunt as applicable.

Connect a 0-1500 DC voltmeter at the test panel MAIN GEN. VOLTS terminals.

On units equipped with DE module, or on units equipped for grid current trainline control, connect one end of a 100 ohm 100 watt potentiometer to a convenient No. 6 wire terminal; Connect the other end to NA. Connect the center tap as follows:

Units with DE module: — To DE-TP2.

Units with no DE, but grid current control (equipped with BCT and T4): — To DR13-TP7.

Place potentiometer brush arm at No. 6 wire end of potentiometer.

Place the test panel rotary test switch in LOAD TEST position. Start the diesel engine, and set up control for power operation with reverser centered.

NOTE: Units which can accept a DR10 module and are not fitted with extended range dynamic brake module DE are not equipped for grid current control.

Units with DE module and with relay DP1A are not equipped for full range grid current control. However, on such units a jumper applied between 1C and 1 NO of DP1A will activate full range grid current control.

(Continued)

Reference Symbol	TROUBLE – POSSIBLE CAUSE AND SYMPTOM	Instruction Reference
	Test Procedure Normal Indication For Test Setup Or Operating Condition *Fault Indication And Corrective Step* *Asterisk Indicates Most Probable Fault —**	
	(Grid load checks continued from preceding page.)	
	CHECKING TR FUNCTION	
	Open throttle one step at a time. Verify that grid blowers are operating properly. Immediately stop loading if hot spots appear on the grids.	
	FTX relay will pick up between 800 and 1200 main generator volts. This broad range is applicable under the specific test conditions and should not be construed as checking the normal TR module operating value.	
	FTX relay fails to pick up during the given range. Qualify the TR module and transition circuitry.	*TR*

(Continued)

Reference Symbol

TROUBLE – POSSIBLE CAUSE AND SYMPTOM
Test Procedure
Normal Indication For Test Setup Or Operating Condition
Fault Indication And Corrective Step

*Asterisk Indicates Most Probable Fault —**

Instruction Reference

(Grid load checks continued from preceding page.)

CHECKING GV REGULATION

Open throttle one step at a time. Verify that grid blowers are operating properly. Immediately stop loading if hot spots appear on the grids.

Units with PF17 module. Load regulator will remain at or near maximum field position at all throttle positions.

Nominal Values With Cold Grids

Throttle	Volts	Amperes
1	200	225
2	500	500
3	600	700
4	875	875
5	900	1050
6	1075	1225
7	1250*	1460
8	1250*	1460

*GV regulates. Voltage appears across GV-TP8 to TP4.

Units with PF18 module.

Nominal Values With Cold Grids

Throttle	Volts	Amperes
1	230	275
2	490	560
3	650	730
4	775	900
5	925	1090
6	1075	1225
7	1250*	1460
8	1250*	1460

*GV regulates. Voltage appears across GV-TP8 to TP4.

If regulation is incorrect, replace GV module with a qualified GV and retest.

WARNING: *If main generator voltage exceeds 1250 V DC, immediately return throttle to idle.*

(Continued)

Reference Symbol	TROUBLE – POSSIBLE CAUSE AND SYMPTOM Test Procedure Normal Indication For Test Setup Or Operating Condition *Fault Indication And Corrective Step* *Asterisk Indicates Most Probable Fault —**	Instruction Reference
	(Grid load checks continued from preceding page.)	
	CHECKING DR REGULATION	
	Connect a jumper from G1 to G2 of BR2 relay, and from H1 to H2 of BR2 (when used).	
	Open throttle to Run 7 and Run 8. Generator volts and amperes should hold as DR regulates.	
	Approximately 1400 amperes — 1200 volts.	
	If regulation is incorrect, replace DR module with a qualified DR and retest.	
	NOTE: *The ripple inherent in AR10 output as compared to output from the traction motors during dynamic braking, causes regulation at a lower value than during normal dynamic brake operation.*	
	(Continued)	

Reference Symbol	TROUBLE — POSSIBLE CAUSE AND SYMPTOM	Instruction Reference
	Test Procedure Normal Indication For Test Setup Or Operating Condition *Fault Indication And Corrective Step* *Asterisk Indicates Most Probable Fault —**	
	(Grid load checks continued from preceding page.)	
	CHECKING GRID CURRENT TRAINLINE CONTROL (Units with no DE module.)	
	→ With throttle at Run 8 and DR regulating generator current at about 1400 amperes, operate the test potentiometer to reduce voltage at DR13-TP7.	
	- - → Generator volts and amperes follow potentiometer movement down to zero.	
	→ *If regulation is incorrect, replace DR module with a qualified module and retest. If indications are still incorrect, check wiring to braking current transductor BCT and transformer T4.*	*BCT*
	CHECKING EXTENDED RANGE DYNAMIC BRAKE GRID CURRENT CONTROL (Units with DE module)	
	→ Connect jumper from 1C to 1 NO of relay DP1A on units so equipped. Also jumper from RC-TP4 to RC-TP6.	
	→ With throttle at Run 8; DR module regulating at approximately 1400 amperes; operate the test potentiometer to reduce voltage at DE-TP2.	
	- - → Generator volts and amperes follow potentiometer movement down to zero.	
	→ *If regulation is incorrect, replace DE module with a qualified module and retest. If indications are still incorrect, check wiring to brake current transductor BCT and transformer T4.*	*BCT*
	(Continued)	

Reference Symbol	TROUBLE – POSSIBLE CAUSE AND SYMPTOM	Instruction Reference
	Test Procedure Normal Indication For Test Setup Or Operating Condition *Fault Indication And Corrective Step* *Asterisk Indicates Most Probable Fault —**	

(Grid load checks continued from preceding page.)

CHECKING DP MODULE BWR FUNCTION

NOTE: Reference MFP check page for motor field protection function of DP module. MFP

Remove jumper(s) from BR2 relay. Disconnect the PPG6 wire from C2 of MR relay.

Open throttle to Run 6. When current settles at about 1250 amperes, manipulate the test switch on the TH module to prevent current rise while advancing the throttle to Run 8. Release the TH test button while closely observing generator current reading.

Generator current will rise to a value slightly higher than the DR regulating value previously observed. At this point EQP and GFC will drop out. Volts and amperes will decline and EQP and GFC will again pick up. Meter readings will rise and fall as relay pickup and dropout repeat.

If voltage rises to 1250 and current holds steady before EQP drops out, the GV module is regulating before the DP module BWR relay operates. Return throttle to idle, and at the back of the electrical cabinet, disconnect the jumper from GV terminal strip pin 4 or 5. GV will then regulate at 1300 V DC.

Repeat the DP check. If EQP dropout does not occur at a current value slightly higher than the DR regulating value noted earlier, replace the DP module with a qualified DP and retest.

NOTE: *The GRID OVERCUR. light on the AN module will come on, but the brake warning light on the control stand is not operative during this check.*

Return throttle to idle and reset the AN module. If the jumper at GV terminal strip pins 4 and 5 was disconnected, reconnect it. Reconnect the PPG6 wire to C2 of MR. Open throttle to Run 8 to verify that GV regulates at 1250 volts.

Return throttle to idle, stop the diesel engine, and remove all test equipment. Return all circuits to normal operating condition.

Reference Symbol	TROUBLE — POSSIBLE CAUSE AND SYMPTOM	Instruction Reference
	Test Procedure Normal Indication For Test Setup Or Operating Condition *Fault Indication And Corrective Step* *Asterisk Indicates Most Probable Fault —**	
GOV	LOAD REGULATOR TIMING SUSPECTED FAULTY —	
	→ Engine running and warm; Generator field circuit breaker open. Throttle 3. Load regulator in Max. position; Governor cover removed. Press and release TH module several times to obtain warm oil in lines. Insert and twist screwdriver blade to lift pilot valve and uncover unloading ports fully, but do not uncover the overriding solenoid dump slots. (Pilot valve pointer just at the top of the letter "T" of the word "START.")	
	- - → Load regulator travels from maximum to minimum position in 2 to 5 seconds.	
	→ Quickly release the screwdriver and withdraw. **CAUTION:** Make certain that the pilot valve scale pointer operator does not slip under the washer on the pilot valve operator.	
	- - → Load regulator travels from minimum to maximum in 16 to 25 seconds.	
	→ *Governor timing incorrect. Replace governor with a qualified governor and retest.*	

Reference Symbol	TROUBLE — POSSIBLE CAUSE AND SYMPTOM Test Procedure Normal Indication For Test Setup Or Operating Condition *Fault Indication And Corrective Step* *Asterisk Indicates Most Probable Fault —**	Instruction Reference
GPT	GENERATOR POTENTIAL TRANSFORMER(S) SUSPECTED DEFECTIVE	

→ Place the test panel rotary test switch in LOAD TEST position and center the reverser. Engine running and controls set up for power operation; Place throttle in Run 1 on basic units, and to Run 3 or 4 on units equipped for automatic self loading.

CAUTION: Do not exceed Run 1 on units not equipped for automatic self loading.

→ Measure AC voltage with a 0-300 AC voltmeter; PF-TP8 to TP10; TP8 to TP12; TP10 to TP12. The three readings should balance within 10% of each other.

→ On units equipped with GPT2, also read from PF-TP2 to TP4; TP2 to TP6; TP4 to TP6.

- - → Readings balance within 10%.

→ *Voltage readings differ by more than 10%; Verify accuracy of connections to GPT. Check continuity of GPT and wiring.*

Isolate various GPT inputs to circuit modules and repeat voltage balance checks. →

CHECKING FOR FAULT IN GV

→ Pull out the GV module; Connect a jumper form GX-TP4 to SE-TP13. Open throttle as required.

Check voltage balance; PF-TP8 to TP10; TP8 to TP12; TP10 to TP12.

→ *If voltage readings balance when GV is isolated, replace GV with a qualified GV and retest.*

→ *If voltage readings are still unbalanced, allow test setup to remain, and perform TR checks.*

(Continued)

Reference Symbol	TROUBLE – POSSIBLE CAUSE AND SYMPTOM Test Procedure Normal Indication For Test Setup Or Operating Condition *Fault Indication And Corrective Step* *Asterisk Indicates Most Probable Fault —**	Instruction Reference

(GPT checks continued from preceding page.)

CHECKING FOR FAULT IN TR

Pull out the TR module. Open throttle as required. Check voltage balance; PF-TP8 to TP10; TP8 to TP12; TP10 to TP12.

If voltage readings balance when TR is isolated, replace TR with a qualified TR and retest.

If voltage readings are still unbalanced, allow test setup to remain, and perform PF checks.

CHECKING FOR FAULT IN PF

Pull out the PF module. Connect jumpers at PF receptacle pins 15 to 16 and 16 to 17 to short out the current transformers.

CAUTION: Make certain that the connections are secure.

Connect a 1000 ohm resistor from SB-TP5 to load regulator negative at the test panel.

Open throttle as required; Measure voltage balance at PF receptacle pins 8 to 10; 8 to 12; 10 to 12.

On units with GPT2 also from 2 to 4; 4 to 6; 2 to 6.

If voltages balance when PF is isolated, replace PF with a qualified PF and retest.

Reference Symbol	TROUBLE — POSSIBLE CAUSE AND SYMPTOM Test Procedure Normal Indication For Test Setup Or Operating Condition *Fault Indication And Corrective Step* *Asterisk Indicates Most Probable Fault —* *	Instruction Reference
GR	HV GRD FAULT LIGHT — Traction motor flashover; Moisture ground; Insulation breakdown; Loose component; Multiple AR10 diode failure; leaking capacitor.	*
	→ Inspect motors for flashover indication or damage.	
	- - → No heavy carbon tracks on motor commutator or riser; Brush "pigtail" leads intact; Brushes in acceptable condition.	
	→ *If flashover indication is observed, repair flashover damage and clean motor as required.*	
	→ Visually inspect switchgear for burns, cuts, evidence of moisture.	
	→ *Repair defects as required.*	
	→ Visually inspect for multiple blown fuses in AR10 rectifier assembly. Visually inspect for burned commutation resistors and damaged capacitors.	M.I. 3317-2
	- - → No pins protrude from fuse indicators; Capacitors not bulged; Resistors not burned; Wires not burned or broken.	
	→ *Test fuses and diodes for shorts and opens wherever blown fuses are indicated. Renew all faulty diodes and fuses. Check for defective GV, SE or PF modules. Check SCR.*	*M.I. 3317-2*
	→ *Check for grounded or shorted suppression capacitors and open or shorted resistors.*	*M.I. 3317-2*

Reference Symbol	TROUBLE – POSSIBLE CAUSE AND SYMPTOM	Instruction Reference
	Test Procedure Normal Indication For Test Setup Or Operating Condition *Fault Indication And Corrective Step* *Asterisk Indicates Most Probable Fault —**	
GR	HV GRD FAULT LIGHT – Insulation breakdown suspected. → Isolate and stop the unit under test. Remove jumper cables between units. Perform megger or high potential tests for insulation failure and electrical ground. a. Open main battery switch and ground relay switch. b. Connect a jumper from AR10 negative to AR10 positive. c. Connect jumpers to short out AR10 and D14 slip rings. d. Refer to schematic wiring diagram wiring strings and isolate circuits as desired. e. With a minimum of 3 inches movement of each module, displace (but do not withdraw completely) all modules to disconnect module receptacles from cabinet mounted contact pins. f. Disconnect or jumper out electronic equipment. → Test suspected circuits and components with a 500 volt megohmmeter for one minute to determine condition of circuits before making high potential tests. – – → Normal megohmmeter indication is 1 megohm or more. → *Under 1 megohm the circuit is suspected.* → Test suspected circuits (except control circuits and cranking motors) and components with high potential tester. 1050 volts for 1 minute. – – → Less than 1/3 ampere leakage. → *1/3 ampere leakage or more.* **WARNING:** *Observe personal safety precautions when working with high voltage. Do not subject static electronic components to megohmmeter or high potential tests.*	

Reference Symbol	TROUBLE — POSSIBLE CAUSE AND SYMPTOM Test Procedure Normal Indication For Test Setup Or Operating Condition *Fault Indication And Corrective Step* *Asterisk Indicates Most Probable Fault —**	Instruction Reference
GR	HV GRD FAULT LIGHT FAILS TO COME ON HV GRD FAULT LIGHT COMES ON UNECESSARILY Locomotive controls set up for power operation; Air brakes set; Engine running; Reverse lever centered; Test panel test switch in LOAD TEST POSITION. **WARNING:** The AR10 will be open circuited on units not equipped for automatic self loading. Do not exceed Run 1 and do not allow main generator volts to exceed 800 V DC with the main generator open circuited. If the main generator contains a ground, hazardous conditions can exist if the test ground is made by an unfused heavy connector. Connect a 5 ampere fused jumper from generator positive to locomotive ground. Connect a 0-500 V DC voltmeter from GP to GN. Press the test button on the TH module for five seconds to drive the load regulator to minimum field position, then open the throttle to Run 1 and release the TH test button. Return throttle to idle, move the grounding jumper from generator positive to generator negative, and repeat the test. The ground relay should pick up between 75 and 125 volts DC across the main generator. *If ground relay action is faulty, check out ground relay resistors, rectifiers, and coil. Replace faulty components as required.* *If ground relay fails to pick up during the test, shut the engine down and perform the following checks.* *a. If the test fuse has blown, disconnect the 021 and 011 wires from the terminal board 39 at the back of the electrical cabinet, and check for a ground in wiring leading to the generator and in the generator itself.* *b. If the fuse did not blow, disconnect the 021 and the 011 wires from terminal board 39 at the back of the electrical cabinet. Insulate or fold back the wire ends, and open the ground relay cutout switch. Apply 74 V DC across TB39L4 and TB39R4. If the relay fails to pick up, some ground relay circuit component is faulty.*	

Reference Symbol	TROUBLE – POSSIBLE CAUSE AND SYMPTOM Test Procedure Normal Indication For Test Setup Or Operating Condition *Fault Indication And Corrective Step* *Asterisk Indicates Most Probable Fault —**	Instruction Reference
GV	GV MODULE SUSPECTED FAULTY	GL
	Unit not loading.	GPT
	AR10 diodes failing.	
	→ Power setup; Air brakes set; Throttle 1; Motors stalled.	
	- - → Normally zero or very low voltage appears between GV-TP8 and GV-TP4.	
	→ *If above normal voltage (over 10 V DC) appears at GV-TP8 to GV-TP4, a fault may exist in the GV, SB, or PF modules.*	
	→ SB module pulled out; Engine running; throttle idle. Ohmmeter at low resistance scale. Positive at GV-TP8; negative at GV-TP4.	
	- - → Ohmmeter should show very low resistance. Pull out the GV module. Ohmmeter should show very high resistance.	
	→ *If resistance remains low when the GV module is pulled out, a shorted GV is indicated. Replace with a qualified GV and retest.*	
	→ Throttle idle; Disconnect ohmmeter; Reinstall SB and GV; Open the AC control circuit breaker to isolate D14 from transductor coils; Bell rings, no power light ON. Power setup; Air brakes set; Throttle 1.	
	- - → With throttle in Run 1, full 68 V DC appears between GV-TP8 and TP4. No load current.	
	→ *Low voltage (less than 10 V DC) between GV-TP8 and TP4 indicates shorted GV. Replace GV with qualified GV and retest.*	

Reference Symbol	TROUBLE — POSSIBLE CAUSE AND SYMPTOM Test Procedure Normal Indication For Test Setup Or Operating Condition *Fault Indication And Corrective Step* *Asterisk Indicates Most Probable Fault —**	Instruction Reference
HDL	HEADLIGHTS FLARE BRIGHT, THEN OUT	
	→ If engine continues to run, check auxiliary generator output voltage from top of auxiliary generator fuse to right side of main battery switch.	
	- - → 72 to 77 V DC.	
	→ *Voltage above 80 V DC. Stop engine and replace VR module with a qualified VR. Check battery water level.*	→ *VR**
	→ If engine stops, check auxiliary generator fuse.	
	→ *If fuse is blown, replace fuse and replace VR module with a qualified VR and test.*	

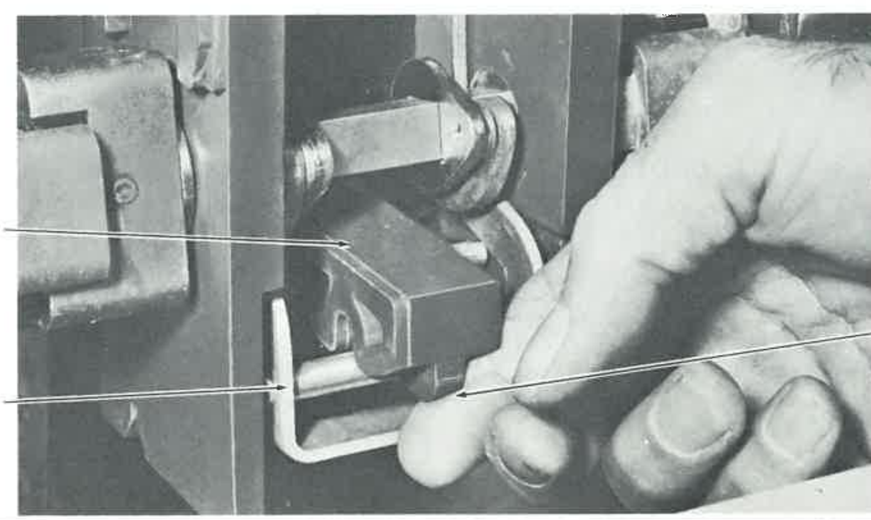
Reference Symbol	TROUBLE — POSSIBLE CAUSE AND SYMPTOM	Instruction Reference
	Test Procedure Normal Indication For Test Setup Or Operating Condition *Fault Indication And Corrective Step* *Asterisk Indicates Most Probable Fault —**	
HOT	HOT ENGINE TEMPERATURE	
	→ Check water level on tank sight glass.	
	→ Water level satisfactory. No evidence of water loss.	
	→ *If water is low, inspect for leaks or overheating.* *a. Check oil level.* *b. Press test buttons on temperature switches to verify fan operation.* *c. Visually inspect piping, pumps, and radiators for leaks.* *d. Visually inspect engine top deck and air box for evidence of water leaks.* *e. Visually inspect exhaust stack for evidence of chromate in the exhaust system.* *f. Test oil for presence of water.* *If standard checks fail to reveal source of repeated water loss, extended engine loading, system pressurization, and engine teardown may be required to reveal the source of the leak.* **WARNING:** *Do not subject the water tank to pressure greater than 50 psi. If pressure in excess of 50 psi is required to test the engine, isolate the engine by using blanking plates at water pump connections and at the discharge "Y." As an added safety precaution, maintain the greatest volume of water and the smallest volume of air practicable in the system or engine during testing.*	
	→ *If water level is low, verify operation of engine low water detector, and low oil shutdown plunger operation on engine governor.*	

Reference Symbol	TROUBLE – POSSIBLE CAUSE AND SYMPTOM Test Procedure Normal Indication For Test Setup Or Operating Condition *Fault Indication And Corrective Step* *Asterisk Indicates Most Probable Fault —**	Instruction Reference
HOT	HOT OIL DETECTOR QUALIFICATION TEST Remove detector from engine and test as follows: 1. Connect air lines to and from valve. 2. Immerse valve in heated thoroughly agitated liquid bath. Temperature increase not to exceed 1° F. per minute over 240° F. 3. Apply 50 psi air pressure, and observe for leaks. None acceptable. 4. At 250° F., maximum air passage to be 10 standard cubic feet of air per hour. 5. Turn off air to avoid chilling. 6. Raise temperature to 258° F. 7. Turn on air. Minimum air passage to be 10 standard cubic feet of air per hour.	

Reference Symbol	TROUBLE — POSSIBLE CAUSE AND SYMPTOM	Instruction Reference
	Test Procedure Normal Indication For Test Setup Or Operating Condition *Fault Indication And Corrective Step* *Asterisk Indicates Most Probable Fault —**	
LO	GOVERNOR SHUTDOWN Light On.	
	Low Oil	
	Plugged Oil Filters	*
	Hot Oil	HOT
	Check oil level. If level is satisfactory, check oil pressure at plug in lube oil filter assembly door. Engine speed at Run 8, no load, and water temperature at least 130° F.	
	If proper water temperature cannot be obtained before engine shutdown, change out the turbocharger lube oil filter and make the check.	
	Less than 30 psi.	
	Pressure at lube oil filter tank is 30 psi or more, indicates that main lube oil filters are plugged and are bypassing unfiltered oil which is plugging the turbocharger lube oil filter element. *Since engine oil pressure at the gauge and governor is sensed after the turbocharger filter element, a plugged element will result in engine shutdown.*	

Reference Symbol	TROUBLE — POSSIBLE CAUSE AND SYMPTOM	Instruction Reference
	Test Procedure - - - Normal Indication For Test Setup Or Operating Condition *Fault Indication And Corrective Step* *Asterisk Indicates Most Probable Fault* —*	
LR	**LOAD REGULATOR SUSPECTED DEFECTIVE** → With engine running and controls and switches set up for power operation, but with Gen. Field circuit breaker open and test panel test switch in CIRCUIT CHECK position, place throttle in Run 8. Connect a 0-75 V DC voltmeter positive at test panel Load Reg. B; negative at Loading Reg. —. - - → Voltage at test panel should be between 40 and 50 V DC. → *Voltage less than 40 V DC. Check for –* *a. Open load regulator connections.* *b. Bad load regulator brush.* *c. Jammed load regulator.* → Return throttle to idle; Pull out to disconnect the SB, RC, and WS modules. Connect a jumper from test panel Load Reg. + to a convenient 74 V DC source. Press the test button on the TH module. Meter needle falls to zero in about 5 seconds. While observing meter closely, release the TH test button. - - → Meter indication will increase slowly from zero to 74 V DC. → *Momentary meter needle deflection toward zero at any time after the TH module test button is released indicates an open load regulator rheostat contact button. Replace load regulator rheostat with a qualified rheostat.* → *A sudden jump in the meter reading from zero to 74 V DC at any time after the TH test button has been released indicates an open load regulator rheostat.* **CAUTION:** *Remove the 74 V DC source before reinstalling the RC, SB, and WS modules.*	

Reference Symbol	TROUBLE — POSSIBLE CAUSE AND SYMPTOM	Instruction Reference
	Test Procedure Normal Indication For Test Setup Or Operating Condition *Fault Indication And Corrective Step* *Asterisk Indicates Most Probable Fault —**	
MFP	MOTOR FIELD PROTECTION SUSPECTED FAULTY → Engine running; Throttle idle; Selector in PWR; Reverser in reverse position. → Apply upward pressure on the tip of transfer switch RV1/L3 contact carrier, Fig. MFP-1, and operate the reverser handle to forward position. The contact carrier will disengage from the main lever assembly as the transfer switch operates. The movable contact assembly of that switch module is left in a centered position. Other RV switch modules complete their travel. → Place selector in "B" position. Open engine run switch to prevent engine speed increase. → Connect a jumper from DP-TP9 to DP-TP14 to discharge a capacitor. Connect a 0-150 DC voltmeter positive at DP-TP3; negative at DP-TP12. Remove jumper, then advance dynamic braking handle slowly as required. → MFP relay in the DP module picks up as generator voltage rises. MFP pickup along with EQP dropout should occur between 73 and 79 V DC. EQP cycles in and out. **CAUTION:** Immediately wipe throttle to idle if meter goes to full scale. → *If pickup is incorrect, replace DP module with a qualified DP and retest.* After the test operate the reverser to re-engage the contact carrier and the main lever assembly. Open the dynamic braking handle to verify that voltage then settles at a smaller value.	



Reference Symbol	TROUBLE — POSSIBLE CAUSE AND SYMPTOM	Instruction Reference
	Test Procedure - - - Normal Indication For Test Setup Or Operating Condition *Fault Indication And Corrective Step* *Asterisk Indicates Most Probable Fault —**	
NVR	**NO AC VOLTAGE RELAY NVR DROPPED OUT** Alarm sounds; No Power light on; Engine running.	
	→ Check for tripped Generator Field CB. If tripped, turn test panel test switch to CIRCUIT CHECK position.	
	- - → NVR picks up; D14 output is satisfactory.	
	→ *Check for shorted SCR.*	*SCR**
	→ Check for tripped AC Control CB.	
	→ *AC Control Breaker tripped. Pull out circuit modules SE, DR, TR, GV, EL, DP, GX, and WS and visually inspect for evidence of fault.* *Disconnect AX30 wire from No. 10 pin of GX terminal strip. Close the AC Control CB. If NVR picks up and the breaker trips again, check for faulty wiring to transductors WST, BCT, ELT, FCT.*	
NVR	**NO AC VOLTAGE RELAY DROPOUT REPORTED** Alarm sounds; No power light on; Engine running. Hot engine.	HOT
	→ Check for locked or binding fan motor rotor causing low D14 voltage.	
	→ Check for tripped D14 Alternator Field CB.	
	→ *If breaker is tripped, check for shorted CR17 or grounded field.*	
NVR	**NO AC VOLTAGE RELAY DROPPED OUT** Alarm sounds; No Power light on; Engine stopped.	
	→ Check for tripped Aux. Gen. Field CB.	
	→ Check for blown Aux. Gen Fuse. If fuse is blown, check for burned out headlights and for shorted CR-BC.	
	→ *If CR-BC is not shorted, replace VR with a qualified VR and check auxiliary generator voltage.*	*VR*
	CAUTION: *Make certain that the engine is completely stopped before removing or inserting a VR module.*	

Reference Symbol	TROUBLE — POSSIBLE CAUSE AND SYMPTOM Test Procedure Normal Indication For Test Setup Or Operating Condition *Fault Indication And Corrective Step* *Asterisk Indicates Most Probable Fault —**	Instruction Reference
PF	PF MODULE SUSPECTED FAULTY — Abnormal current feedback signal.	
	→ Power setup; Air brake set; Throttle 1; Motors stalled.	
	- - → Measure AC voltage between test points PF-TP15 to TP16; TP16 to TP17; TP17 to TP15. The three voltage readings should be within 15% of each other.	
	→ *Voltage readings TP15 to TP16; TP16 to TP17; TP17 to TP15 out of balance 15% or more. Replace PF module with a qualified PF and retest.*	*PF-2,3*
	Qualify current transformers CTA, CTB, CTC. Verify accuracy of connections to CT's. Qualify CT's.	*CT*
	CAUTION: *Extremely high and damaging voltage will result if CT's are open circuited with the main generator excited.*	
PF	PF MODULE SUSPECTED FAULTY — Abnormal voltage feedback signal.	
	→ Place the test panel rotary switch in LOAD TEST position and center the reverser. Engine running and controls set up for power operation; place throttle in Run 1 on basic units, and to Run 3 or 4 on units equipped for automatic self load test.	
	CAUTION: Do not exceed Run 1 on units not equipped for automatic self loading.	
	→ Measure AC voltage with a 0-150 AC voltmeter at the following points to read GPT-1 output. PF-TP8 to TP10, TP10 to TP12; TP12 to TP8.	
	→ On units equipped with GPT-2 also measure at: PF-TP2 to TP4; TP4 to TP6; TP6 to TP4.	
	- - → The three readings from a single GPT should be within 10% of each other.	GPT
	→ *Voltage readings differ by more than 10%, use an ohmmeter to check the PF module. Verify accuracy of connections to GPT. Qualify GPT.*	*PF-2,3* *GPT*

Reference Symbol	TROUBLE – POSSIBLE CAUSE AND SYMPTOM	Instruction Reference
	Test Procedure Normal Indication For Test Setup Or Operating Condition *Fault Indication And Corrective Step* *Asterisk Indicates Most Probable Fault —**	

PF17

PF17 MODULE SUSPECTED FAULTY

Faulty feedback signal causes overloading or underloading.

→ Pull out PF module and test with an ohmmeter.

→ *Low reading indicates shorted component.*

→ *Infinite reading indicates open component.*

NOTE: *Verify polarity of ohmmeter leads.*

+ Indicates that uncertain forward resistance of diodes must be added to the reading. Diode forward resistance will vary with the meter scale used and with the individual diode.

On straight resistance readings allow 5 to 10% meter tolerance.

Ohmmeter Polarity		Nominal Reading
Pos	Neg	
5	3	300
21	19	290
19	23	490
19	11	53
19	13	88
19	14	491
8	19	1000+
10	19	1000+
12	19	1000+
21	8	290+
21	10	290+
21	12	290+
15	14	490+
16	14	490+
17	14	490+
23	15	980+
23	16	980+
23	17	980+

Reference Symbol	TROUBLE – POSSIBLE CAUSE AND SYMPTOM	Instruction Reference
	Test Procedure; Normal Indication For Test Setup Or Operating Condition; *Fault Indication And Corrective Step*; *Asterisk Indicates Most Probable Fault —**	

PF18

PF18 MODULE SUSPECTED FAULTY

Faulty feedback signal causes overloading or underloading.

→ Pull out PF module and test with an ohmmeter.

→ *Low reading indicates shorted component.*

→ *Infinite reading indicates open component.*

NOTE: *Verify polarity of ohmmeter leads.*

+Indicates that uncertain forward resistance of diodes must be added to the reading. Diode forward resistance will vary with the meter scale used and with the individual diode.

On straight resistance readings allow 5 to 10% meter tolerance.

Ohmmeter Polarity		Nominal Reading
Pos	Neg	
5	3	295
28	20	410
28	21	710
28	27	1000
28	19	1410
18	23	675
18	19	265
18	11	315
18	13	350
18	14	763
8	19	1410+
10	19	1410+
12	19	1410+
20	8	1000+
20	10	1000+
20	12	1000+

Ohmmeter Polarity		Nominal Reading
Pos	Neg	
2	18	810+
4	18	810+
6	18	810+
18	2	200+
18	4	200+
18	6	200+
15	13	150+
16	13	150+
17	13	150+
19	15	500+
19	16	500+
19	17	500+

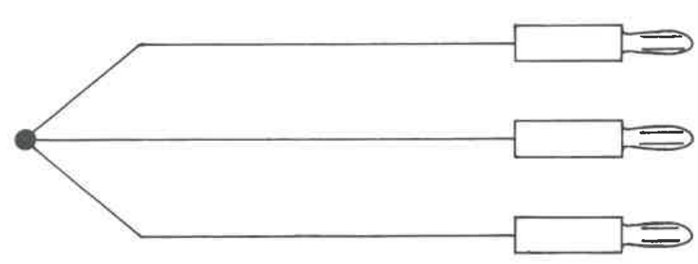
Reference Symbol	TROUBLE – POSSIBLE CAUSE AND SYMPTOM	Instruction Reference
	Test Procedure – – – Normal Indication For Test Setup Or Operating Condition *Fault Indication And Corrective Step* *Asterisk Indicates Most Probable Fault —**	
RC	RC MODULE SUSPECTED DEFECTIVE Rate Control function suspected defective. → Engine running and warm; Throttle idle; Controls and switches set up for power operation; Generator field circuit breaker open; Test panel test switch in CIRCUIT CHECK position. Pull out the SB module. → Wipe throttle to Run 8 position. – – → Voltage RC-TP13 to RC-TP14 should increase from zero to about 50 V DC in from 18 to 36 seconds time. → When voltage is up, connect jumpers to check the discharge rate. After a jumper is connected and the discharge rate observed, remove the jumper and allow voltage to return to full value. → Jumper from RC-TP4 to RC-TP14. – – → Voltage decays very slowly to zero (1 to 4 minutes). Remove jumper and allow voltage to become stable. → Jumper from RC-TP7 to RC-TP14. – – → Voltage decays at a rapid rate to 3 to 7 V DC. Remove jumper and allow voltage to become stable. → Jumper from RC-TP6 to RC-TP14. – – → Voltage decays at a rapid rate to near zero. → Return throttle to idle and remove jumper. Place selector handle in brake "B" position. Wipe throttle handle to Run 8 position. – – → Voltage RC-TP13 to RC-TP14 increases from zero to about 49 V DC within 4 to 11 seconds on basic units, and within 12 to 33 seconds on units equipped for full range grid current trainline control. **NOTE:** Refer to note on page DR-3 for identification of units with grid current trainline control. → *If incorrect indications are obtained, replace RC module with a qualified RC and retest.*	

Reference Symbol	TROUBLE – POSSIBLE CAUSE AND SYMPTOM	Instruction Reference
	Test Procedure Normal Indication For Test Setup Or Operating Condition *Fault Indication And Corrective Step* *Asterisk Indicates Most Probable Fault —**	
SB	SB MODULE SUSPECTED DEFECTIVE – High starting current. → Power setup; Air brake set; Throttle 1; Motors stalled. → Load indicating meter indicates between 200 and 350 amperes. Advance throttle to Run 2 position to verify that wheel slip light does not come on, then return throttle to idle. If wheel slip is indicated in Run 2, check wheel slip and motor circuits. →	WS
	→ *If excessive amperes (350 plus) show on the indicating meter with throttle in Run 1, remove the RC module. Full 68 V DC should appear across SB-TP2 to TP4. If it does not, replace SB with a qualified module and retest.*	

Reference Symbol	TROUBLE – POSSIBLE CAUSE AND SYMPTOM Test Procedure Normal Indication For Test Setup Or Operating Condition *Fault Indication And Corrective Step* *Asterisk Indicates Most Probable Fault —**	Instruction Reference
SCR	MAIN GENERATOR EXCITATION RECTIFIER SCR SUSPECTED FAULTY	
	NOTE: Most SCR failures result in a shorted SCR. This will be seen as a tripped Generator Field Circuit Breaker, or will be seen as a lack of power control.	
	If doubt about the condition of the SCR exists, perform SE checks. ⟶	SE-2

Reference Symbol	TROUBLE – POSSIBLE CAUSE AND SYMPTOM Test Procedure Normal Indication For Test Setup Or Operating Condition *Fault Indication And Corrective Step* *Asterisk Indicates Most Probable Fault —**	Instruction Reference
SE	SE MODULE SUSPECTED DEFECTIVE	
	AC failure.	UL
	Engine running; Throttle idle or unit isolated.	
	SE voltage TP6 to TP8, TP8 to TP10, TP10 to TP6 balanced at a value between 65 and 80 V AC.	
	Voltage incorrect or out of balance.	
	a. AC control or Gen Field CB open.	
	b. Open wiring or defective connection.	

Reference Symbol	TROUBLE – POSSIBLE CAUSE AND SYMPTOM Test Procedure Normal Indication For Test Setup Or Operating Condition *Fault Indication And Corrective Step* *Asterisk Indicates Most Probable Fault —**	Instruction Reference
SE	SE MODULE SUSPECTED DEFECTIVE – Unbalanced output. → Engine running; Air brakes set; Control and switches set up for power operation. Using a three terminal jumper with banana plugs, perform the following at the SE module. → a. Jumper TP9 to TP7 to TP11 in order to check output to SCR G1. Place throttle in Run 1; Record current; Return throttle to idle and remove jumpers. → b. Jumper TP9 to TP5 to TP11 to check output SCR G2. Place throttle in Run 1; Record current; Return throttle to idle and remove jumpers. → c. Jumper TP7 to TP5 to TP11 to check output to SCR G3. Place throttle in Run 1; Record current; return throttle to idle and remove jumpers. – – → AR10 current as seen on the load indicating meter should be nominally equal in each of the three tests above. → *If AR10 current is significantly unequal, replace defective SE with qualified SE module and retest. If retest fails, replace SCR.*	



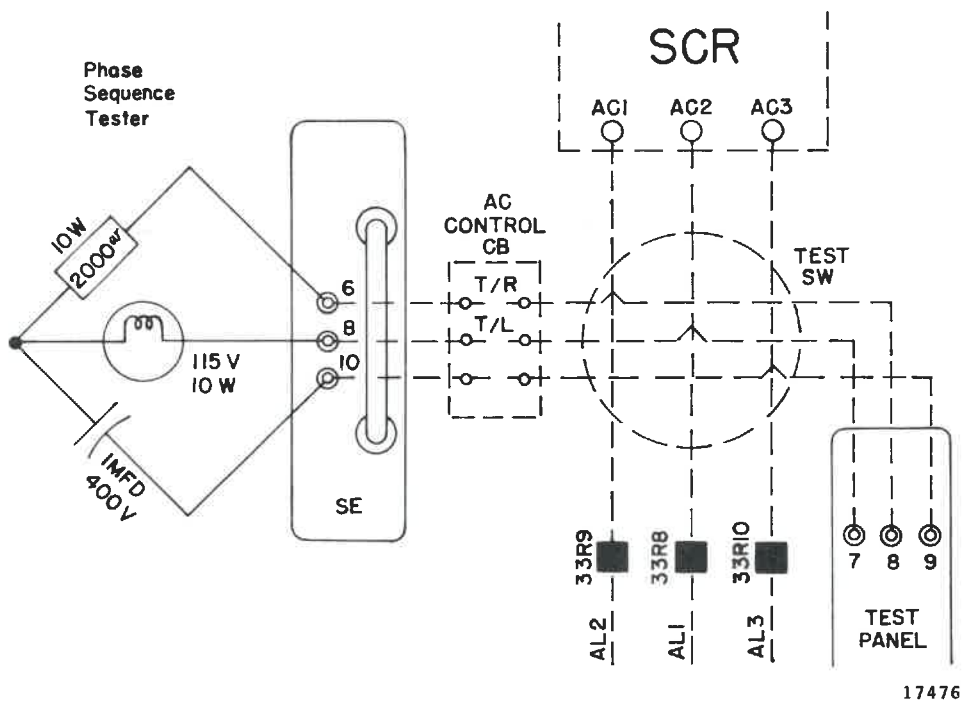
Reference Symbol	TROUBLE — POSSIBLE CAUSE AND SYMPTOM Test Procedure Normal Indication For Test Setup Or Operating Condition *Fault Indication And Corrective Step* *Asterisk Indicates Most Probable Fault —**	Instruction Reference
TEM	COOLING SYSTEM TEMPERATURE SWITCHES SUSPECTED DEFECTIVE Hot engine alarm.	HOT
	Large movement of governor rack scale pointer as fans come in. D14 failure.	
	→ Place thermometer in well of temperature switch manifold. Road or loading grid operation under full power.	
	→ Temperature switches operate fan contactors in sequence. TA — FC1 — 174° F. TB — FC2 — 182° F. TC — FC3 — 190° F. ETS — THL — 215° F. } Verify temp indicated on switch nameplate.	
	→ Fans comes up to full speed within 15 seconds.	
	→ *Two fan contactors pick up within a few seconds of each other. Shut the unit down immediately. Inspect and megger the D14, the fan motors, and fan cables. Check temperature switch part numbers. Replace any switch suspected defective.*	*HOT*
	→ *Third fan fails to come up to speed within 15 seconds. Verify that voltage from alternator field fuse to BN is minimum 72 V DC.*	

Reference Symbol	TROUBLE – POSSIBLE CAUSE AND SYMPTOM	Instruction Reference
	Test Procedure – – – Normal Indication For Test Setup Or Operating Condition *Fault Indication And Corrective Step* *Asterisk Indicates Most Probable Fault —**	
TH	TH MODULE THROTTLE RESPONSE OR REFERENCE VOLTAGE REGULATION SUSPECTED FAULTY	
	→ Engine running and warm; Open the Generator Field circuit breaker; Place test panel rotary switch in CIRCUIT CHECK position; Pull out SB module; Set up controls for power operation; Throttle Run 1.	
	– – → Voltage TH-TP2 to TP14; 67.8 to 68.2 V DC. Voltage TH-TP3 to TP14; Approx. 9 V DC. Advance throttle to Run 8. Voltage TH-TP3 to TP14 increases in steps to 67.8 to 68.2 V DC.	
	→ *Voltage out of tolerance; Qualify VR module.* →	*VR*
	If voltage TH-TP1 to TP14 is satisfactory (71 to 77 V DC) but voltage TH-TP3 to TP14 is out of tolerance, replace TH module with a qualified module and retest.	
	→ Throttle Run 8; Press the TH test button.	
	– – → Voltage – load regulator "B" to minus at the test panel terminals drops to zero as load regulator goes to minimum field position in from 4 to 10 seconds.	
	→ *Incorrect timing or voltage, qualify the load regulator, governor, or rate control module RC.* →	*LR* *RC* *GOV*

Reference Symbol	TROUBLE – POSSIBLE CAUSE AND SYMPTOM — Test Procedure - - - Normal Indication For Test Setup Or Operating Condition — *Fault Indication And Corrective Step* *Asterisk Indicates Most Probable Fault —**	Instruction Reference
TR	TR MODULE SUSPECTED FAULTY → Engine running; Generator field circuit breaker OFF; Test switch in CIRCUIT TEST position; Controls and switches set up for power operation; Reverser forward or reverse; Throttle 1. → Operate and hold the TR module test switch. - - → FTX and PR relays pick up; GFC drops out. → Release TR test switch. - - → FTX drops out; "S" contactors drop out; "P" contactors pick up; TDR and PRA relays pick up; GFC contactor again picks up. → Immediately after GFC picks up again, operate and hold the TR module test switch. - - → After a time delay, FTX picks up; EQP drops out; Wheel slip light on. → Release TR test switch. - - → EQP picks up, and wheel slip light goes out; PR drops out, and the transition circuits sequence back to series-parallel motor connection. → *If indications are incorrect, replace TR module with a qualified module and retest.*	

Reference Symbol	TROUBLE — POSSIBLE CAUSE AND SYMPTOM Test Procedure Normal Indication For Test Setup Or Operating Condition *Fault Indication And Corrective Step* *Asterisk Indicates Most Probable Fault —**	Instruction Reference
UL	UNDERLOADING No AR10 Output Or Output Lower Than Normal	
	1. Check GFC, GFD, EQP contactor pickup, and generator field circuit breaker closed.	
	2. Check output voltage at TH and RC at all throttle positions. Reference the general Charts And Graphs drawing.	
	3. Check position of load regulator. Should be — a. Units with PF17 module. At a balance point with AR10 current between 1800 and 4200 amperes, Run 8, 62:15 Gearing. b. Units with PF18 module. At a balance point with AR10 current between 1800 and 2900 amperes, Run 8, 62:15 Gearing. At a maximum field position with AR10 current higher than 3000 amperes, Run 8, 62:15 Gearing.	
	NOTE: These are nominal values for checking purposes only.	
	4. Resistance of load regulator should be 1500±0.25% ohms. Check continuity of all contact buttons. →	LR
	5. Check wiring to all terminal boards.	
	6. Check for proper AC supply to all modules.	
	7. Check AR10 and D14 slip ring brushes.	
	8. Check for correct engine speed and for correct governor power piston balance point. →	EMM-11
	9. Check for plugged fuel filters. →	LSM-1
	10. Perform NOT LOADING OR UNLOADING checks in troubleshooting guide.	

Reference Symbol	TROUBLE — POSSIBLE CAUSE AND SYMPTOM Test Procedure Normal Indication For Test Setup Or Operating Condition *Fault Indication And Corrective Step* *Asterisk Indicates Most Probable Fault —**	Instruction Reference
UL	UNDERLOADING	
	Difficult to obtain High Current Readings (such as when using low resistance position on a loading resistor grid or when checking settings under short circuit conditions).	LSM-9
	1. Check current thru terminal 13 to 14 at the SE module. This current should not exceed 1.4 milliamperes at 4000 amperes in Run 8.	
	2. If current 13 to 14 at SE is high, check phase rotation with the engine at idle speed using the following test setup. The lamp must be bright. If the light is dim or not lit, there are faulty wiring connections.	
	3. Check phase rotation at SCR and terminals boards.	
	4. Check SCR assembly.	SCR



Reference Symbol	TROUBLE — POSSIBLE CAUSE AND SYMPTOM — Test Procedure - - - Normal Indication For Test Setup Or Operating Condition — *Fault Indication And Corrective Step* *Asterisk Indicates Most Probable Fault —**	Instruction Reference
UL-D	UNLOADING Unit reported not loading or unstable in dynamic brake.	
	→ Engine running; Controls and switches set up for dynamic brake operation; Brake handle in maximum dynamic braking position. Voltage RC-TP2 to TP14 verified. →	RC
	- - → Voltage RC-TP13 to TP14, 42 to 52 V DC. If this voltage is correct, the DR module is satisfactory. The excitation system should be checked.	
	→ *Voltage RC-TP13 to TP14 lower than 42 V DC or at zero.* *Withdraw to disconnect the DR module. If voltage increases to the correct value, perform the following:* *1. Replace the defective DR. Voltage should decrease slowly. If voltage dumps immediately, replace the RC module with a qualified RC before replacing DR with a qualified module.* *2. Replace the defective DR module with a qualified module and retest.* →	*DR*
	If disconnecting the DR module did not correct the RC-TP13 to TP14 voltage, the excitation system should be checked.	

Reference Symbol	TROUBLE – POSSIBLE CAUSE AND SYMPTOM Test Procedure Normal Indication For Test Setup Or Operating Condition *Fault Indication And Corrective Step* *Asterisk Indicates Most Probable Fault —**	Instruction Reference
VR	VOLTAGE REGULATOR VR SUSPECTED DEFECTIVE – **NOTE:** The VR module does not provide reference voltage for the excitation system. The reference voltage regulator is part of another module. → Gen. Field CB open; Power setup; Air brake set; 0-100 DC voltmeter positive connected at auxiliary generator fuse; negative at main battery switch. → With engine running, read voltage at Run 1 speed and Run 8 speed. - - → Voltage at Run 8, at value within the 71 - 77 V DC range desired by the railroad for battery charging purposes. Voltage at Run 1 within 1 volt of Run 8 voltage. → *Voltage at any throttle position not within 1 volt of selected value within 71 - 77 volt range. Replace VR module with a qualified module if adjustment cannot be made.* **WARNING:** *Do not close the Gen. Field CB until the throttle is in idle position. Do not remove or install VR module until engine is completely stopped.*	
VR	VOLTAGE REGULATOR VR SUSPECTED DEFECTIVE → Locomotive idling or in service. - - → Voltage measured from positive at auxiliary generator fuse; negative at main battery switch; 71 - 77 V DC. → *Replace VR with qualified module if any of the following conditions are observed.* *Voltage fluctuates between 20 and 40 V DC.* *No regulation. Auxiliary generator fuse blows.* *No voltage.* *Voltage oscillates between 80 and 85 volts.* *Low voltage can not be brought up by adjusting screw.*	

Reference Symbol	TROUBLE – POSSIBLE CAUSE AND SYMPTOM	Instruction Reference
	Test Procedure Normal Indication For Test Setup Or Operating Condition *Fault Indication And Corrective Step* *Asterisk Indicates Most Probable Fault —**	

WS **EXCESSIVE WHEEL SLIP ACTION REPORTED**

Check for fault in motor circuits.

Position the unit under test against other locomotive units, against a bumping post, or against some other restraining arrangement. Set air brake on all units.

Engine running and warm; Controls and switches set up for power operation; Advance throttle one step at a time to Run 3. As soon as current stabilizes in Run 3, return throttle to idle.

No wheel slip action will occur if motor circuits are in balance.

If wheel slip action occurs, the motor circuits are out of balance. Open the AC Control circuit breaker, and disconnect the following:

AXD1 from TB48B1
AXD2 from TB48B2
AXD4 from TB48B3

Insulate wire ends.

Reconnect one of the above wires independently to its proper TB48 terminal. Close the AC Control CB, and repeat the stall current checks. Perform the checks for each transductor independently connected. Wheel slip response with a given transductor connected will narrow the fault down to one of the motor circuits. Inspect motors, contactors, cables.

Reference Symbol	TROUBLE – POSSIBLE CAUSE AND SYMPTOM Test Procedure Normal Indication For Test Setup Or Operating Condition *Fault Indication And Corrective Step* *Asterisk Indicates Most Probable Fault —**	Instruction Reference
WST	WHEEL SLIP TRANSDUCTOR SUSPECTED FAULTY	

WHEEL SLIP TRANSDUCTOR SUSPECTED FAULTY

CAUTION: Use the following recommended method for obtaining differential current at the transductors.

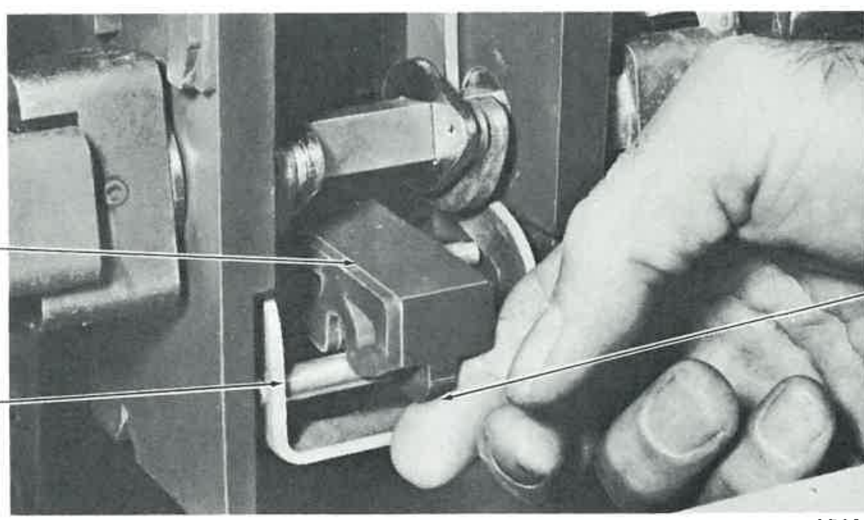
Do not place insulating material between power contactor or transfer switch main contact tips. The presence of foreign material at contact tips will lead to failure of the device.

Procedure for centering individual transfer switch modules to open a motor circuit.

Engine running; Controls and switches set up for power operation; Reverser handle in reverse position.

Apply upward pressure on the tip of one transfer switch module contact carrier, Fig. WST-1, and operate the reverser to forward position. The contact carrier will disengage from the main lever assembly as the transfer switch operates. The movable contact assembly of that switch module is left in a centered position. Other switch modules in the same assembly will complete their travel.

Proceed with WST transductor checks.



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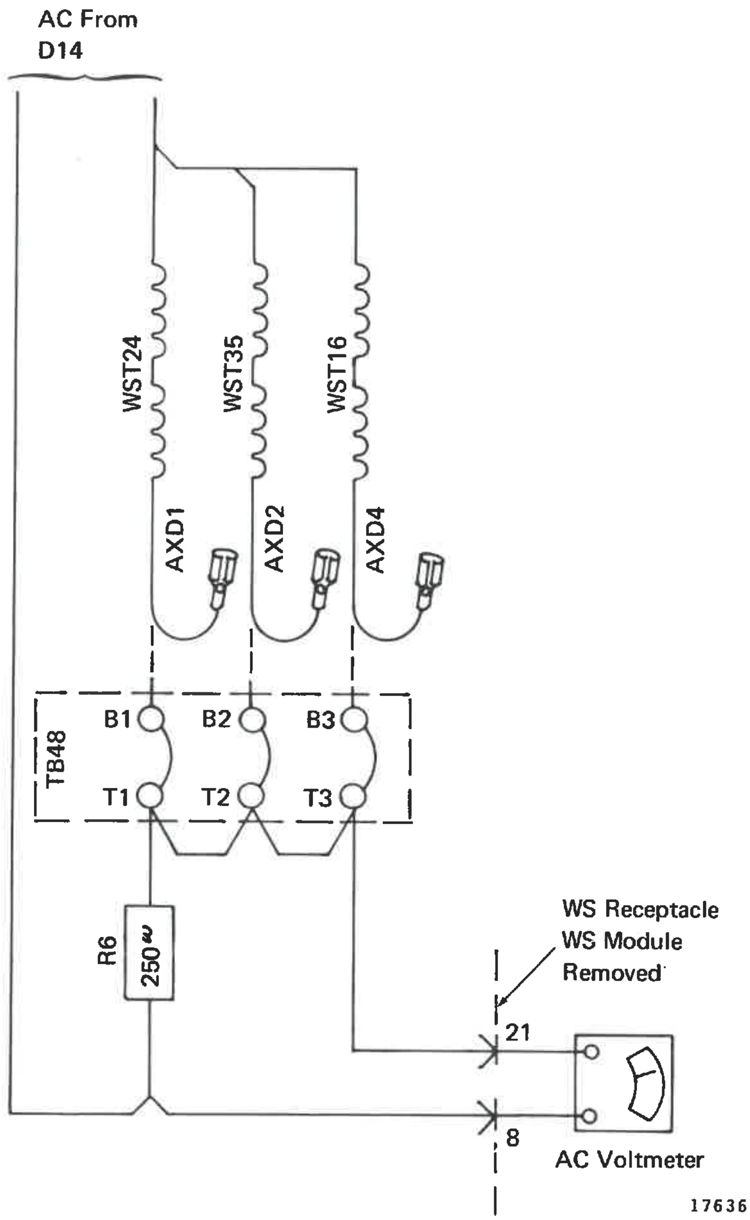
Reference Symbol	TROUBLE – POSSIBLE CAUSE AND SYMPTOM — Test Procedure – – – Normal Indication For Test Setup Or Operating Condition ▬ *Fault Indication And Corrective Step* *Asterisk Indicates Most Probable Fault —**	Instruction Reference
	(WST checks continued)	
	→ Engine running; Locomotive controls and switches set up for power operation; Air brakes set; Throttle idle. Open the AC Control CB and disconnect the following wires: AXD1 from TB48B1 AXD2 from TB48B2 AXD4 from TB48B3 Insulate wire ends.	
	<u>WST24 CHECK</u>	
	→ Reconnect wire AXD1 to TB48B1. Using the procedure given on page WST-1, center switch module RV1/L3. Close the AC Control CB. Place throttle in Run 1.	
	– – → Current rises to a level.	
	Throttle Run 2.	
	– – → Load current rises to a level, then falls off as wheel slip control system operates. Current then rises again and cycling continues.	
	Throttle Run 3.	
	– – → Same response as for Run 2.	
	→ Throttle idle. Return reverser handle to reverse position. Center RV2/L2. Repeat above throttle 1, 2, and 3 checks.	
	→ *If response is incorrect, check cabling thru transductors, and qualify the transductors.*	*WST-4* *WST-6*
	(Continued)	

Reference Symbol	TROUBLE – POSSIBLE CAUSE AND SYMPTOM Test Procedure Normal Indication For Test Setup Or Operating Condition *Fault Indication And Corrective Step* *Asterisk Indicates Most Probable Fault —**	Instruction Reference
	(Continued from WST24 check)	
	WST35 CHECK	
	Throttle idle; Open the AC Control CB. Disconnect the AXD1 wire from TB48B1. Insulate the end. Reconnect the AXD2 wire to TB48B2. Close the AC Control CB.	
	Open throttle to Run 1, 2, 3.	
	Same response as for WST24 check.	
	Throttle idle. Move reverser handle to reverse position. Center RV3/L1. Move throttle to Run 1, 2, 3.	
	If response is incorrect, check cabling thru transductors, and qualify the transductors.	*WST-4* *WST-6*
	WST16 CHECK	
	Throttle idle; AC Control CB open. Disconnect the AXD2 wire from TB48B2. Insulate the wire end. Reconnect the AXD4 wire to TB48B3. RV3/L1 remains centered. Close the AC Control CB.	
	Open throttle to Run 1, 2, 3.	
	Same response as for WST35 check.	
	Throttle idle. Return reverser handle to reverse position. Center RV1/L3. Repeat throttle Run 1, 2, 3 checks.	
	If response is incorrect, check cabling thru transductors, and qualify the transductors.	*WST-4* *WST-6*
	Return circuits to normal operating condition.	

Reference Symbol	TROUBLE – POSSIBLE CAUSE AND SYMPTOM Test Procedure Normal Indication For Test Setup Or Operating Condition *Fault Indication And Corrective Step* *Asterisk Indicates Most Probable Fault —**	Instruction Reference
WST	WST QUALIFICATION CHECK	
	→ Engine running; throttle idle; air brakes set; controls and switches set up for power operation; AC Control breaker OFF. Pull out the WS module and connect an AC voltmeter to WS receptacle pins 21 and 8. Meter should have a scale to accept 100 volts and a scale to accurately measure low voltage. Disconnect wires AXD1, AXD2, and AXD4 wires from TB48 terminals B1, 2, and 3. Insulate wire ends.	
	WST16 CHECK	
	→ Reconnect AXD4 wire to TB48B3 and close the AC control CB. Voltmeter on high scale. → Place throttle in Run 2 position. - - → Voltmeter should indicate between 1 and 5 V AC. → *More than 80 volts indicates open RE6 or shorted WST. Zero volts indicate open circuit. If result is not conclusive, retest at Run 8. Return throttle to idle.*	
	WST35, WST24 CHECKS	
	→ Reference the drawing on the reverse side of this sheet and perform checks for each transductor with other transductors isolated. Return controls and circuits to normal standby condition after tests are completed. Reference WST — for further transductor qualification checks. →	WST-6
	(Continued)	

Reference Symbol	TROUBLE – POSSIBLE CAUSE AND SYMPTOM Test Procedure Normal Indication For Test Setup Or Operating Condition *Fault Indication And Corrective Step* *Asterisk Indicates Most Probable Fault —**	Instruction Reference
	(WST qualification check continued)	



Reference Symbol	TROUBLE – POSSIBLE CAUSE AND SYMPTOM — Test Procedure - - - Normal Indication For Test Setup Or Operating Condition — *Fault Indication And Corrective Step* *Asterisk Indicates Most Probable Fault —**	Instruction Reference
WST	TRANSDUCTOR CHARACTERISTICS CHECKS CHECK 1 → Engine running; Generator field circuit breaker open; Test panel rotary test switch in CIRCUIT CHECK position. Place throttle in Run 3, Measure and compare AC voltage from X1 to C and from X2 to C at each transductor under test. - - → A sizeable voltage difference can exist between measurements taken on a good transductor. If the voltage difference appears significant, perform further checks indicated below. → *If the voltage drop across one coil is three times greater than the voltage drop across the second coil, replace the transductor with a qualified transductor and retest.*	

(Continued)

Reference Symbol	TROUBLE — POSSIBLE CAUSE AND SYMPTOM	Instruction Reference
	Test Procedure Normal Indication For Test Setup Or Operating Condition *Fault Indication And Corrective Step* *Asterisk Indicates Most Probable Fault —**	

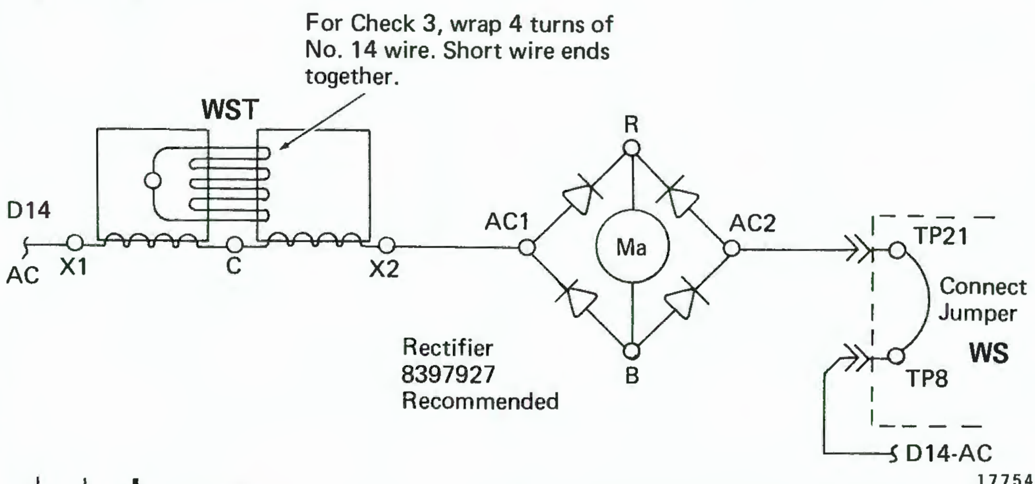
(WST characteristics checks continued)

CHECK 2

Throttle idle; Engine run switch off; Open the AC Control circuit breaker, and disconnect wires AXD1, AXD2, and AXD4 from TB48B1 thru B3. Insulate wire ends.

Connect a jumper from WS-TP21 to WS-TP8 to short out the WS module and RE6.

Connect a small rectifier bridge and a DC milliammeter in series with the transductor under test as indicated in the illustration below.



Close engine run switch, and AC Control circuit breaker. Place throttle in Run 3.

If milliammeter reading is less than 0.020 ampere, proceed to Check 3.

If milliammeter reading is 0.020 or more, replace the transductor under test with a qualified transductor.

Check 4 may be performed to verify transductor condition before replacement is undertaken.

(Continued)

Reference Symbol	TROUBLE – POSSIBLE CAUSE AND SYMPTOM Test Procedure Normal Indication For Test Setup Or Operating Condition *Fault Indication And Corrective Step* *Asterisk Indicates Most Probable Fault —**	Instruction Reference
	(WST characteristics checks continued) CHECK 3 Throttle idle; Open engine run switch and AC Control circuit breaker. Wrap four turns of No. 14 wire around both transductor cores. This is done to compensate for meter tolerances and test conditions. Close engine run switch and AC Control circuit breaker; Place throttle in Run 3. Milliammeter reading should be less than 0.020 ampere. *If milliammeter reading is 0.020 or more, replace the transductor under test with a qualified transductor and retest.* *Check 4 may be performed to verify transductor condition before replacement is undertaken.*	

(Continued)

Reference Symbol	TROUBLE – POSSIBLE CAUSE AND SYMPTOM — Test Procedure - - - Normal Indication For Test Setup Or Operating Condition — *Fault Indication And Corrective Step* *Asterisk Indicates Most Probable Fault —**	Instruction Reference
	(WST characteristics checks continued)	
	CHECK 4	
	→ Throttle idle; Engine run switch off; Open the AC Control circuit breaker; Close the generator field circuit breaker, and return test panel rotary test switch to NORMAL position; Air brakes set.	
	If four turns of No. 14 wire were wrapped at the transductor, disconnect the wire ends.	
	Connect a millivolt meter of 0.5% accuracy to the 1000 ampere 50 millivolt load indicating meter shunt to indicate current in the No. 2 traction motor circuit.	
	NOTE: Stall current is essentially equal in all motor circuits.	
	WST24 CHECK	
	→ Using the procedure outlined on page WST-1, center transfer switch module RV1/L3 while operating the reverser handle from reverse to forward position.	
	Connect wire AXD1 to TB48B1. Disconnect wires AXD2 and AXD4 from TB48. Insulate wire ends.	
	Close the AC Control circuit breaker and the engine run switch; Open throttle to Run 1 position. Compare current readings with the wheel slip transductor qualification graph. Return throttle to idle.	→ WST-12
	CAUTION: Allow high levels of stall current only long enough to obtain meter readings.	
	- - → Milliammeter readings should fall within the tolerance band indicated on the transductor qualification graph.	
	→ *If readings are out of tolerance, replace the transductor with a qualified transductor and retest.*	
	(Continued)	

Reference Symbol	TROUBLE – POSSIBLE CAUSE AND SYMPTOM	Instruction Reference
	Test Procedure Normal Indication For Test Setup Or Operating Condition *Fault Indication And Corrective Step* *Asterisk Indicates Most Probable Fault —**	
	(WST characteristics checks continued)	
	WST35 CHECK	
	Throttle idle; Open the AC Control circuit breaker and the engine run switch.	
	Using the procedure outlined on page WST-1, center transfer switch module RV3/L1 while operating the reverser handle from reverse to forward position.	
	Connect AXD2 wire to TB48B2. Disconnect wires AXD1 and AXD4 from TB48. Insulate wire ends.	
	Close the AC Control circuit breaker and the engine run switch. Open throttle to Run 1 position. Compare current readings with the wheel slip transductor qualification graph. Immediately return throttle to idle.	WST-12
	Milliammeter readings should fall within the tolerance band indicated on the transductor qualification graph.	
	If readings are out of tolerance, replace transductor with a qualified transductor and retest.	

(Continued)

Reference Symbol	TROUBLE – POSSIBLE CAUSE AND SYMPTOM Test Procedure Normal Indication For Test Setup Or Operating Condition *Fault Indication And Corrective Step* *Asterisk Indicates Most Probable Fault —**	Instruction Reference
	(WST characteristics checks continued)	
	WST16 CHECK	
	→ Throttle idle; Open the AC Control circuit breaker and the engine run switch.	
	Using the procedure outlined on page WST-1, center transfer switch module RV3/L1 while operating the reverser handle from reverse to forward position.	
	Connect the AXD4 wire to TB48B3. Disconnect AXD1 and AXD2 wires if they were connected. Insulate wire ends.	
	Close the AC Control circuit breaker and the engine run switch. Open throttle to Run 1 position. Compare current readings with the wheel slip transductor qualification graph. Immediately return throttle to idle.	→ WST-12
	Operate reverser handle to reverse position, then while returning it to forward position, center transfer switch module RV1/L3. Open throttle to Run 1 position and compare current readings with previous check.	
	→ Milliampere readings should fall within the tolerance band indicated on the transductor qualification graph.	
	→ *If readings are out of tolerance, replace transductor with a qualified transductor and retest.*	
	→ Disconnect all test equipment, and return all circuits to normal standby condition.	

(WST characteristics checks continued)